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Sarcopenia defined by a computed tomography estimate of the psoas muscle area does not predict frailty in geriatric trauma patients

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ABSTRACT

Introduction: The aim of our study was to assess the correlation between frailty & sarcopenia and impact of each condition on outcomes in geriatric trauma patients.
Methods: We performed a four-year (2013–2016) secondary analysis of our prospectively maintained frailty database and included all trauma patients age ≥65 y who had CT-abdomen. Trauma-Specific-Frailty-Index (TSFI) was used to calculate frailty. Patients were classified as non-frail or frail. Sarcopenia was defined as the lowest sex-specific-quartile of total-psoas-index (TPI). Outcome measures included in-hospital complications, mortality and adverse disposition.
Results: 325 patients were included in the study, 36% (n = 117) were frail and 24.9% (n = 81) had sarcopenia. There was a weak correlation between frailty and sarcopenia ($R^2 = 0.04$). The overall rate of complications and mortality was 19.4% and 7.7% respectively. On regression analysis, after controlling for possible confounding variables and frailty status, sarcopenia was associated with adverse disposition (OR:1.41,$p = 0.01$). However, it was not associated with in-hospital complications (OR:1.21,$p = 0.54$) or in-hospital mortality (OR:1.12,$p = 0.73$).
Conclusion: Sarcopenia as an individual marker might not be an effective screening tool for risk assessment in geriatric-trauma patients. Frailty assessment should be a part of risk assessment and prognostication.

Introduction

Every day, more than 12,000 Americans surpass the age of 65. In 2015, geriatric patients made up 14.5% of the United States population. This figure is expected to rise to 23.5% by 2060.[1] As more and more elderly patients present to trauma centers, the need for tools to assess outcomes in geriatric patients grows as well. Clinical decision-making is challenging in this population, in part due to variability in the physiologic reserve of different individuals.[2]

Frailty is a biological syndrome which is defined as decreased reserve and resistance to stressors due to cumulative declines across multiple physiological systems that cause vulnerability to adverse outcomes. Frailty is used to assess various aspects of a patient's medical condition, including screening for functional decline as well as postoperative morbidity and mortality.[3–5] In elderly trauma patients, frailty has been studied in relation to in-hospital outcomes, discharge disposition, and 1-year mortality.[6–8] In our previous studies, we demonstrated that the 50-variable Canadian Study of Health and Aging Frailty Index can be applied to trauma patients.[9] However, because of its time-intensiveness, we developed the 15-variables Trauma Specific Frailty Index (TSFI) that can be easily implemented in an acute trauma setting.[6] Albeit, a subjective assessment of frailty may be difficult to complete in demented or critically ill trauma patients.

Consequently, the medical community also needs a more

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objective tool to predict outcomes effectively in the surgical population and to intervene and halt the progression of frailty. Sarcopenia, defined as a decline in muscle mass and strength, has been proposed as a surrogate for frailty.[10] It has predicted adverse outcomes for elderly surgery patients.[11–14] While sarcopenia is a component of the biological basis of frailty, it should not be the only measure in a risk assessment. Therefore, concerning elderly trauma patients, we sought to assess the correlation between frailty (via the TSFI) and sarcopenia (as measured by the total psoas muscle index). We also aimed to investigate the effects of frailty and sarcopenia as both individual and combined markers of morbidity and mortality after trauma in geriatric patients. We hypothesized that sarcopenia is associated with higher rates of morbidity and mortality, regardless of the frailty status.

Methods

Study setting and population

We performed a 4-year (2013–2016) secondary analysis of our prospectively maintained frailty database, which contains all geriatric patients presented at our Level-1 trauma center. It has data on frailty status (based on the TSFI), demographics, vital and injury parameters, complications, disposition, and mortality. The Institutional Review Board (IRB) of the University of Arizona approved this study.

Inclusion and exclusion criteria

We included all geriatric (age $\geq$65 years) trauma patients admitted to our Level-1 trauma center. We excluded patients who did not undergo computed tomography (CT) scans of the abdomen/pelvis, did not have a recorded weight or height, and/or had an abnormal psoas muscle (psoas hematoma).

Data points and definitions

After enrollment in the study, data were collected prospectively by trained researchers for each subject, including patient demographics (age, gender, race, and ethnicity), injury characteristics (type and mechanism), vital signs on presentation (Glasgow Coma Scale score, systolic blood pressure, heart rate, and body temperature), body mass index (BMI), comorbidities, need for operative intervention, in-hospital complications, hospital and intensive care unit (ICU) length of stay (LOS), mortality, and discharge disposition. The trauma registry was queried for the injury severity score (ISS) and the abbreviated injury scale (AIS) score.

Every morning during trauma sign-out rounds, elderly trauma patients who fulfilled the enrollment criteria were identified. After approaching eligible patients and securing written informed consent, investigators administered the TSFI questionnaire (Appendix 1). We explained the TSFI variables, with an emphasis on how they relate to pre-injury conditions. The patients' responses were recorded on an allocated frailty index form. For those who were intubated or unresponsive, we approached the closest family member to complete the questionnaire, if possible. We excluded patients who could not reply and did not have an available family historian. In all, 85% of the patients replied for themselves, and a close family historian was the proxy respondent for the rest of them (15%).

We calculated TSFI scores based on responses to the TSFI questionnaire. It includes the following domains: patient demographics (age, comorbidities, and medication history), social activity, activities of daily living, nutritional status, and general attitude. The presence of a deficit equals to one point. Most of the variables in the TSFI are dichotomized, and some have multiple categories. The TSFI is calculated as the total score of deficits present in a patient divided by the total number of possible responses ($n = 15$) in the TSFI questionnaire. The TSFI score ranged from 0 (representing a non-frail status) to 1 (representing a severely frail status). Patients were then stratified into two groups based on the established cutoffs for frailty measured by TSFI: Non-frail (TSFI$\leq$0.27) and frail (TSFI >0.27).

Sarcopenia calculation

We identified all of the geriatric patients in the frailty database who underwent CT scans of the abdomen/pelvis. In order to preclude any observer bias, the CT scans were reviewed and analyzed by only one researcher. We used the Philips IntelliSpace Picture Archiving and Communications System (PACS) imaging software. Psoas muscles were manually outlined at the level of the third lumbar (L3) vertebra on the first axial slice at the most superior aspect of the L3 vertebral body.[15] The total psoas area (TPA) was measured on both the right and left side and then averaged. All measurements were done using a density threshold of −30 and 110 Hounsfield unit (HU) to exclude vasculatures and fatty infiltration areas from the calculation. The average TPA was then adjusted for height to calculate the total psoas index (TPI) ($TPI = TPA/height^2$ [cm^2/m^2].[15] Sarcopenia was defined as the lowest sex-specific quartile (males: <3.51 cm^2/m^2 and females: <2.42 cm^2/m^2).[16,17]

Outcome measures

Our primary outcome measures were in-hospital complications and in-hospital mortality. In-hospital complications were defined as respiratory (acute respiratory distress syndrome and pneumonia), cardiovascular (myocardial infarction), infectious (sepsis and urinary tract infection), hematological (deep venous thrombosis), and renal (acute renal failure). Secondary outcome measures were unfavorable discharge disposition (discharge to rehab/skilled nursing facility [SNF]) as well as hospital and intensive care unit (ICU) length of stay (LOS).

Statistical analysis

Data are presented as mean ± SD for continuous variables, as medians [interquartile range] for ordinal variables, and as proportions for categorical variables. We used the Student *t*-test to assess the difference between parametric variables and the Mann-Whitney *U* test to assess the difference between non-parametric variables. A chi-square test was used to assess the difference between categorical variables. A univariate analysis was performed for the association between variables and outcomes. Variables with a significant ($p < 0.20$) association on univariate analysis were used in the multivariate logistic regression model. For the multivariate logistic regression analysis, a p-value of <0.05 was considered significant. All statistical analyses were performed using software for social sciences (SPSS, Version 24; IBM, Inc., Chicago, Illinois).

Results

After reviewing the records of 651 elderly trauma patients, 325 were included in the analysis (Fig. 1). Of those, 36% (117/325) were frail and 24.9% (81/325) had sarcopenia. The mean age of the population was 76 ± 7 years, 64% were male, and 74% were white. The median ISS was 11 [9–17], the median head-AIS score was 2 [0–3], the median GCS was 15 [15-15], and the mean TSFI was 0.22 ± 0.17. The most common mechanism of injury was a ground-level fall (59%), followed by a motor vehicle collision (36%).

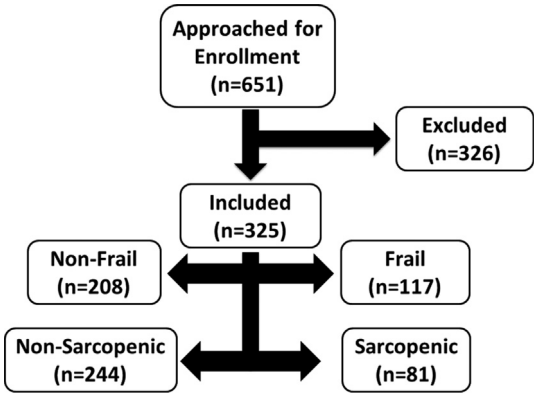

Fig. 1. Flow diagram of the study population.

Patients who were frail were more likely to have a higher frailty index ($p < 0.001$), lower systolic blood pressure on admission ($p = 0.014$), a higher ISS ($p = 0.039$), and a higher head-AIS ($p = 0.045$). Frail patients were also more likely to present after a fall compared to non-frail patients ($p < 0.001$). However, there was no difference in age ($p = 0.58$), gender ($p = 0.54$), race ($p = 0.18$), admission heart rate ($p = 0.16$) and GCS ($p = 0.25$) between the two groups. The comparative demographics between both groups are shown in Table 1. Additionally, frail patients were more likely to have sarcopenia than non-frail patients (32.4% vs. 20.6%, $p = 0.02$). In correlation analysis, there was a weak correlation between the frailty index and the TPI ($R = 0.220$, $R^2 = 0.04$, $p < 0.001$).

Overall, 19.4% (63) of the patient population developed in-hospital complications. The most common complications were infectious (9.8%), followed by respiratory (7%). Frail patients were more likely to develop in-hospital complications compared to non-frail patients (11% vs. 34%, $p < 0.001$). Frail patients also had higher infectious ($p = 0.012$), respiratory ($p < 0.001$), and hematological complications ($p = 0.03$) than non-frail patients. The details of our primary and secondary outcomes among frail and non-frail patients are in Table 2. The overall mortality rate was 7.7% (25), while 26% (80) had an adverse discharge disposition. Frail patients had a higher mortality rate (5% vs. 12.8%, $p = 0.01$) and were more likely to be discharged to Rehab/SNF than non-frail patients (18% vs 36.8%, $p < 0.001$). However, there was no difference in the hospital ($p = 0.45$) and ICU ($p = 0.67$) LOS between the two groups. Similarly, sarcopenic patients were more likely to develop in-hospital complications compared to non-sarcopenic patients (17% vs. 27%, $p = 0.03$). Sarcopenic patients also had higher respiratory ($p = 0.01$) and hematological complications ($p = 0.04$) than non-sarcopenic patients. The details of our primary and secondary outcomes among sarcopenic and non-sarcopenic patients are in Table 3. Additionally, sarcopenic patients were more likely to be discharged to Rehab/SNF than non-frail patients (39.5% vs 19.6%, $p = 0.01$). However, there was no significant difference in mortality rate ($p = 0.36$), and hospital ($p = 0.45$) and ICU ($p = 0.67$) LOS between the two groups.

Table 1
Demographics and injury parameters for the pre-matched data.

Characteristics	Non-Frail (n = 208)	Frail (n = 117)	P-value
Demographics			
Age, mean ± SD	76.5 ± 5.1	77.5 ± 8.4	0.58
65-74, n (%)	110 (53%)	57 (49%)	0.48
75-84, n (%)	64 (31%)	37 (32%)	
≥85, n (%)	34 (16%)	23 (19%)	
Male gender, n (%)	131 (63%)	78 (67%)	0.54
White race, n (%)	160 (77%)	82 (71%)	0.18
Frailty Index, mean ± SD	0.09 ± 0.07	0.38 ± 0.09	<0.001
Admission Vitals			
SBP, mean ± SD	140 ± 34	131 ± 27	0.014
Heart rate, mean ± SD	83 ± 19	86 ± 18	0.16
GCS, median [IQR]	15 [15-15]	15 [14–15]	0.25
Injury Parameters			
Mechanism of injury			
Fall, n (%)	108 (52%)	83 (71%)	<0.001
MVC, n (%)	89 (43%)	27 (23%)	
ISS, median [IQR]	10 [9–15]	12 [9–19]	0.039
Head AIS, median [IQR]	0 [0–3]	1 [1–3]	0.045
Sarcopenic, % (n)	20.6% (43)	32.4% (38)	0.02

GCS = Glasgow Coma Scale, ED = Emergency Department, SBP = Systolic Blood Pressure, HR = Heart rate, ISS = Injury Severity Score, AIS = Abbreviated Injury Scale, MVC = Motor Vehicle Collision.

Table 2
In-hospital and Discharge Outcomes in Non-Frail and Frail patients.

Characteristics	Non-Frail (n = 208)	Frail (n = 117)	P-value
In-hospital complications:	11% (23)	34.1% (40)	<0.001
Respiratory, n (%)	4% (8)	13% (15)	<0.001
Cardiovascular, n (%)	0.5% (1)	1% (1)	0.95
Infectious, n (%)	6.7% (14)	15.3% (18)	0.012
Hematological, n (%)	2% (4)	7% (8)	0.03
Renal, n (%)	1% (2)	3% (3)	0.87
Discharge Disposition:			
Home, n (%)	77% (161)	50.4 (59)	<0.001
Rehab/SNF, n (%)	18% (37)	36.8% (43)	
In-hospital mortality, n (%)	5% (10)	12.8% (15)	0.01
Hospital LOS, median [IQR]	3 [1–7]	4 [1–7]	0.45
ICU LOS, median [IQR]	1 [1–4]	1 [1–4]	0.67

SNF=Skilled Nursing Facility, LOS = Length of Stay, IQR=Interquartile Range, ICU-=Intensive Care Unit.

On multivariate regression analysis (after controlling for demographics, admission vitals, injury parameters, and comorbidities), sarcopenia was an independent predictor of in-hospital complications (OR: 1.52 [1.19–2.13]) and an unfavorable discharge disposition (1.61 [1.23–1.98]). However, sarcopenia was not associated with in-hospital mortality (OR: 1.23 [0.71–1.62]).

On regression analysis (after controlling for demographics, admission vitals, injury parameters, comorbidities, and frailty status), sarcopenia was not associated with in-hospital complications (OR: 1.21, $p = 0.54$), in-hospital mortality (OR: 1.12, $p = 0.73$), or an unfavorable discharge disposition (OR: 1.19, $p = 0.66$). However, frailty was independently associated with in-hospital complications (OR: 2.1, $p < 0.001$), mortality (OR: 1.72, $p < 0.001$), and an unfavorable discharge disposition (OR: 2.62, $p < 0.001$) after controlling for demographics, admission vitals, injury parameters, comorbidities, and sarcopenia. On further analysis, frailty and sarcopenia together were associated with higher odds of complications (OR: 2.03, p=0.01), mortality (OR: 1.67, $p = 0.03$), and discharge disposition (OR: 2.48, $p < 0.001$). The multivariate regression analysis for outcomes is in Table 4.

Discussion

In our single-center secondary analysis of a prospectively maintained database, sarcopenia was weakly correlated with the frailty index. Moreover, sarcopenia was associated with in-hospital complications and adverse discharge disposition. When adjusted for frail status, sarcopenia was associated with adverse disposition only. However, a frail status was independently associated with morbidity, mortality, and an adverse disposition regardless of sarcopenia.

The recognition and assessment of frailty is an integral component in the evaluation and treatment of geriatric trauma

Table 3
In-hospital and discharge outcomes in non-sarcopenic and sarcopenic patients.

Characteristics	Non-Sarcopenic (n = 244)	Sarcopenic (n = 81)	P-value
In-hospital complications:	17% (41)	27% (22)	0.03
Respiratory, n (%)	5.3% (13)	12.3% (10)	0.01
Cardiovascular, n (%)	0.4% (1)	1.2% (1)	0.95
Infectious, n (%)	8.6% (21)	13.5% (11)	0.22
Hematological, n (%)	2% (5)	8.6% (7)	0.04
Renal, n (%)	0.8% (2)	3.7% (3)	0.67
Discharge Disposition:			
Home, n (%)	73.7% (180)	49.4% (40)	0.01
Rehab/SNF, n (%)	19.6% (48)	39.5% (32)	
In-hospital mortality, n (%)	6.7% (16)	11.1% (9)	0.36
Hospital LOS, median [IQR]	3 [1–7]	3 [1–7]	0.85
ICU LOS, median [IQR]	1 [1–4]	1 [1–4]	0.76

SNF=Skilled Nursing Facility, LOS = Length of Stay, IQR=Interquartile Range, ICU=Intensive Care Unit.

patients. Acknowledging they have a diminished reserve and resistance to stressors will help guide therapy as well as identify additional needs. Although, a frailty assessment can be time-consuming or difficult in the demented or critically ill patient. Previously, both sarcopenia and frailty have been studied in parallel, and while sarcopenia has been a point of interest in basic science, frailty can be utilized in a clinical setting.[18] There is still controversy about whether sarcopenia is a clinical manifestation of frailty or an actual cause of frailty. Recently, in the medical and surgical literature, sarcopenia has been proposed as a surrogate for frailty.[10] In our analysis of geriatric trauma patients, we demonstrated that sarcopenia measured by a total psoas index is weakly correlated with frailty. This might be because it does not reflect the overall state of frailty and is just a component or clinical manifestation of frailty. Some studies have shown that sarcopenia and frailty are individual entities that might share some characteristics, hence, the weak correlation.[19] Others have defined it as "two sides of the same coin".[20]

Studies have measured sarcopenia using magnetic resonance imaging, CT scans, creatinine excretion, dual-energy x-ray absorptiometry, and ultrasonography.[21] In the literature, the psoas muscle has been extensively used as a marker for sarcopenia. In our analysis, we have used the total psoas index to normalize the psoas muscle area for height, and sarcopenia was defined based on the lowest sex-specific quartiles. This method has been utilized previously.[15] In our analysis, without accounting for frailty status, sarcopenia was associated with in-hospital complications and an adverse discharge disposition. However, it was not associated with in-hospital mortality. When we controlled for a frail status, sarcopenia was not associated with in-hospital complications or mortality. Kaplan et al. also analyzed sarcopenia in geriatric trauma patients.[8] They demonstrated that sarcopenia was not associated with short-term outcomes, including in-hospital complications and 30-day mortality. Moreover, when they analyzed 1-year mortality, they reported a higher 1-year mortality rate in patients with sarcopenia. However, they did not adjust for the frailty status or report the cause of mortality. In our analysis, sarcopenia was only associated with an adverse discharge disposition after adjusting for frailty status. This finding was similar to reports published by Fairchild et al. in their analysis of geriatric trauma patients.[14] They reported that an incremental increase of every 1 cm^2 increase in the psoas muscle cross-sectional area resulted in a 20% decrease in the degree of living dependency.

Table 4
Multivariate regression analysis for outcomes.

Outcomes	OR	95% CI
In-hospital Complications		
Sarcopenia	1.21	0.91–1.50
Frailty	2.13	1.82–2.50
Frailty and Sarcopenia	2.03	1.12–2.83
In-hospital Mortality		
Sarcopenia	1.12	0.87–1.35
Frailty	1.72	1.53–1.96
Frailty and Sarcopenia	1.67	1.09–2.02
Unfavorable discharge disposition		
Sarcopenia	1.41	1.04–1.87
Frailty	2.62	2.50–2.71
Frailty and Sarcopenia	2.48	1.79–2.97

As our geriatric population continues to grow, more physicians and multi-specialty teams are aware of frailty and its impact on outcomes in this specific patient population. Several studies have demonstrated an association between frailty and adverse outcomes in geriatric patients undergoing elective or emergency surgical procedures. We have previously shown that the frailty index can be utilized in the geriatric trauma population and that a higher TSFI was an independent predictor of an unfavorable discharge disposition in such patients.[5,6] In our analysis, we have demonstrated that frailty was associated with morbidity, mortality, and an adverse hospital disposition, regardless of sarcopenia. To the best of our knowledge, this is the first study to evaluate the role of frailty with sarcopenia in an acute care setting. With the increasing number of geriatric patients, it is encouraging that the frailty syndrome is being recognized as an important predictor of outcomes in these patients. Undertaken in many specialty areas, frailty research highlights the importance of a variety of factors, including nutrition, physical activity, mental health, and comorbidities with associated inflammatory states. Therefore, the assessment of frailty in elective surgical, emergency surgical procedures, and trauma scenarios is vital. Sarcopenia is an attractive alternative to frailty assessments, but our research does not support it as an individual marker for frailty. However, we recognize recent research in which sarcopenia is combined with a frailty index in order to improve predicting outcomes in gastrointestinal surgery rather than with either sarcopenia or frailty index alone.[13] This may reflect that sarcopenia is not just a quantitative loss of muscle, but a qualitative one as well.[22] The radiographic determination of sarcopenia with CT or ultrasound only identifies one component of sarcopenia, and the frailty assessment may help to quantify qualitative muscle loss. Therefore, more research should be designed to investigate this further.

Our study has several limitations. First, our results were obtained from a single academic institution and, therefore, might not be generalizable. We have a small sample size for evaluating sarcopenia and frailty. Moreover, we did not analyze the impact of sarcopenia or frailty on long-term outcomes. Lastly, we also only included patients who had abdominopelvic CT scans. This excludes patients who were either too severely injured or unstable to undergo a CT scan as well as those who did not have a CT scan because

they were deemed to be less severely injured. Despite these limitations, to the best of our knowledge, this is the first study to compare sarcopenia and frailty in terms of their impact on outcomes in an acute care setting.

Conclusion

Psoas muscle sarcopenia as an individual marker might not be an effective screening tool for risk assessment in geriatric-trauma patients. A frailty assessment provides a brief overview of a patient's physiological reserve, and it should be a part of risk assessment and discussion regarding prognosis. Further studies are required to delineate whether sarcopenia is a clinical manifestation or a cause of frailty.

Authors contributions

B.J, A.M, M.K, M.H, T.O, M.Z, J.S, A.T, and N.K designed this study.
B.J, A.M, M.K, M.H, T.O, M.Z, H.H, and N.K searched the literature.
B.J, A.M, M.K, F.J, M.Z, T.O, A.T, and N.K collected the data.
B.J, A.M, M.K, F.J, H.H, T.O, M.Z, J.S, M.H, and N.K analyzed the data.
All authors participated in data interpretation, manuscript preparation and approval.

Conflicts of interest

There are no identifiable conflicts of interests to report.

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The authors have no financial or proprietary interest in the subject matter or materials discussed in the manuscript.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.amjsurg.2018.07.024.

References

1. Ortman JM, Velkoff VA, Hogan H. *An Aging Nation: The Older Population in the United States: United States Census Bureau, Economics and Statistics Administration*. US Department of Commerce; 2014.
2. Cooper Z, Maxwell CA, Fakhry SM, et al. A position paper: the convergence of aging and injury and the need for a Geriatric Trauma Coalition (GeriTraC). *J Trauma Acute Care Surgery*. 2017;82(2), 419–22.
3. Revenig LM, Canter DJ, Kim S, et al. Report of a simplified frailty score predictive of short-term postoperative morbidity and mortality. *J Am Coll Surg*. 2015;220(5), 904–11. e1.
4. Sirois M-J, Griffith L, Perry J, et al. Measuring frailty can help emergency departments identify independent seniors at risk of functional decline after minor injuries. *J Gerontol A Biol Sci Med Sci*. 2015;72(1):68–74.
5. Khan M, Joseph B. Frailty in trauma patients: an emerging geriatric syndrome. *Curr Surg Rep*. 2017;5(11), 30.
6. Joseph B, Pandit V, Zangbar B, et al. Validating trauma-specific frailty index for geriatric trauma patients: a prospective analysis. *J Am Coll Surg*. 2014;219(1):10–17. e1.
7. Romanowski KS, Barsun A, Pamlieri TL, Greenhalgh DG, Sen S. Frailty score on admission predicts outcomes in elderly burn injury. *J Burn Care Res*. 2015;36(1):1–6.
8. Kaplan SJ, Pham TN, Arbabi S, et al. Association of radiologic indicators of frailty with 1-year mortality in older trauma patients: opportunistic screening for sarcopenia and osteopenia. *JAMA surgery*. 2017;152(2). e164604-e.
9. Joseph B, Pandit V, Zangbar B, et al. Superiority of frailty over age in predicting outcomes among geriatric trauma patients: a prospective analysis. *JAMA surgery*. 2014;149(8):766–772.
10. Calvani R, Marini F, Cesari M, et al. Biomarkers for physical frailty and sarcopenia: state of the science and future developments. *J Cachexia Sarcopenia Muscle*. 2015;6(4):278–286.
11. Dirks RC, Edwards BL, Tong E, et al. Sarcopenia in emergency abdominal surgery. *J Surg Res*. 2017;207:13–21.
12. Paknikar R, Friedman J, Cron D, et al. Psoas muscle size as a frailty measure for open and transcatheter aortic valve replacement. *J Thorac Cardiovasc Surg*. 2016;151(3):745–751.
13. Buettner S, Wagner D, Kim Y, et al. Inclusion of sarcopenia outperforms the modified frailty index in predicting 1-year mortality among 1,326 patients undergoing gastrointestinal surgery for a malignant indication. *J Am Coll Surg*. 2016;222(4):397–407. e2.
14. Fairchild B, Webb TP, Xiang Q, Tarima S, Brasel KJ. Sarcopenia and frailty in elderly trauma patients. *World J Surg*. 2015;39(2):373–379.
15. Rangel EL, Rios-Diaz AJ, Uyeda JW, et al. Sarcopenia increases risk of long-term mortality in elderly patients undergoing emergency abdominal surgery. *J Trauma Acute Care Surgery*. 2017;83(6):1179–1186.
16. Englesbe MJ, Patel SP, He K, et al. Sarcopenia and mortality after liver transplantation. *J Am Coll Surg*. 2010;211(2):271–278.
17. Amini N, Spolverato G, Gupta R, et al. Impact total psoas volume on short-and long-term outcomes in patients undergoing curative resection for pancreatic adenocarcinoma: a new tool to assess sarcopenia. *J Gastrointest Surg*. 2015;19(9):1593–1602.
18. Bauer J, Sieber C. Sarcopenia and frailty: a clinician's controversial point of view. *Exp Gerontol*. 2008;43(7):674–678.
19. Mijnarends DM, Schols JM, Meijers JM, et al. Instruments to assess sarcopenia and physical frailty in older people living in a community (care) setting: similarities and discrepancies. *J Am Med Dir Assoc*. 2015;16(4):301–308.
20. Cesari M, Landi F, Vellas B, Bernabei R, Marzetti E. Sarcopenia and physical frailty: two sides of the same coin. *Front Aging Neurosci*. 2014;6:192.
21. Pahor M, Manini T, Cesari M. Sarcopenia: clinical evaluation, biological markers and other evaluation tools. *J Nutr Health Aging*. 2009;13(8):724–728.
22. Marzetti E, Calvani R, Tosato M, et al. Sarcopenia: an overview. *Aging Clin Exp Res*. 2017:1–7.