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Diaphragm thickness is associated with overall survival in elderly thoracic trauma patients

Debljina dijafragme je povezana sa preživljavanjem kod starijih pacijenata sa povredom grudnog koša

Zeynep Nilufer Tekin*, Zeynep Bilgi†

Istanbul Medeniyet University, *Goztepe Prof. Dr. Suleyman Yalcin City Hospital, Department of Radiology, †Faculty of Medicine, Department of Thoracic Surgery, Istanbul, Turkey

Abstract

Background/Aim. Diaphragm thickness (DT) has been associated with advanced age and adverse outcomes, especially in severe conditions such as prolonged intubation. The aim of this study was to assess the prognosis of elderly patients with thoracic trauma (TT) and to investigate DT and psoas muscle thickness as potential prognostic indicators. **Methods.** A retrospective study included TT related consultations, taken from hospital records, performed between November 2015 and January 2021. Demographic data, injury characteristics, trauma mechanisms, overall survival, etc., were documented. Radiological imaging was re-evaluated to measure DT and psoas muscle thickness. **Results.** Among 394 patients, 129 were classified as elderly (> 65 years old). The most common mechanism of trauma was falls (n = 71), followed by pedestrian traffic accidents (n = 16). The overall survival of all patients was 43.9 ± 3.6 months, with an 82% two-year survival rate for elderly patients. DT was significantly higher in elderly survivors compared to deceased patients (4.0 ± 1.19 mm vs. 3.57 ± 1.0 mm; *p* = 0.015). **Conclusion.** Decreased DT is associated with an increased mortality risk in the elderly population. Elderly patients with TT and reduced DT may benefit from screening programs for early intervention targeting potential contributing factors such as frailty, trauma recidivism, and missed cancer screening. Furthermore, DT may serve as a potential indicator within a scoring system for risk assessment.

Key words:
aged; biomarkers; diaphragm; frailty; injuries; thorax; tomography, x-ray computed.

Apstrakt

Uvod/Cilj. Debljina dijafragme (DD) povezana je sa starijim životnim dobom i neželjenim ishodima, posebno u teškim stanjima kao što je prolongirana intubacija. Cilj rada bio je da se proceni prognoza kod starijih pacijenata sa povredom grudnog koša (PGK) i da se ispitaju DD i debljina mišića psoasa kao potencijalni prognostički pokazatelji. **Metode.** Retrospektivna studija je uključivala konsultacije u vezi sa PGK, preuzete iz bolničkih kartona, obavljene između novembra 2015. i januara 2021. godine. Dokumentovani su demografski podaci, karakteristike povreda, mehanizmi povreda, ukupno preživljavanje, itd. Radiološki snimci su ponovo procenjivani u cilju merenja DD i debljine mišića psoasa. **Rezultati.** Od ukupno 394 pacijenata, 129 je svrstano u populaciju starijih osoba (> 65 godina). Najčešći mehanizam povrede bili su padovi (n = 71), a sledili su ih saobraćajne nesreće pešaka (n = 16). Ukupno preživljavanje svih pacijenata iznosilo je 43,9 ± 3,6 meseci, sa stopom dvogodišnjeg preživljavanja od 82% za starije pacijente. DD je bila značajno veća kod starijih preživelih nego kod preminulih pacijenata (4,0 ± 1,19 mm vs. 3,57 ± 1,0 mm; *p* = 0,015). **Zaključak.** Smanjena DD povezana je sa povišenim rizikom od mortaliteta u populaciji starijih osoba. Starije osobe sa PKG i smanjenom DD mogu imati koristi od programa skrininga ranih intervencija usmerenih prema potencijalno doprinosećim faktorima kao što su slabost, recidivi povreda i propušteni skrining na karcinome. Osim toga, DD može služiti kao potencijalni pokazatelj u sklopu sistema bodovanja u proceni rizika.

Ključne reči:
stare osobe; biomarkeri; dijafragma; krhkost; povrede; toraks; tomografija, kompjuterizovana, rendgenska.

Correspondence to: Zeynep Nilüfer Tekin, Istanbul Medeniyet University Goztepe Prof. Dr. Suleyman Yalcin City Hospital, Department of Radiology, Dr. Erkin Street, 34 722 Istanbul, Turkey. E-mail: drnilufer@gmail.com

Introduction

The elderly population is rapidly growing in many parts of the world, including developing nations. Correspondingly, their representation in various medical conditions is also on the rise [1]. In cases of trauma, elderly patients (EPs) are overrepresented, and these numbers are expected to rise further. This highlights the need for updates in guidelines to ensure effective triage and specialized care [2].

Age is recognized as a crucial prognostic factor in trauma patients, along with trauma severity and comorbidities; however, age dichotomies have been found to be unreliable at times. This indicates the need for additional, easily obtainable markers to facilitate a more comprehensive assessment of impaired physiological reserve or frailty [1, 2].

Frailty has emerged as a more comprehensive assessment of functional reserves than age stratification alone. Notably, up to one-third of adults over 85 years old were found to be non-frail despite their advanced age. On the other hand, increased frailty is consistently associated with adverse outcomes following various stressor events such as cancer diagnosis, surgery, infection, and trauma [1]. However, the measurement of frailty is a relatively complex process involving the use of several scoring modalities and specialized equipment for assessments such as grip strength [3].

Sarcopenia, characterized by the progressive loss of skeletal muscle mass, strength, and power, is a key component of frailty [1, 3]. It overlaps with frailty scores and clinical outcomes. Various methods can be used to assess sarcopenia, but currently, there is no consensus on a gold standard method. Proposed methods include measuring psoas muscle (PM) thickness – PMT, PM index, and skeletal muscle mass at different thoracic and lumbar vertebral levels, all showing strong correlations with different outcomes [4–6]. Additionally, diaphragm thickness (DT) has been associated with advanced age and adverse outcomes, such as prolonged intubation, both clinically and in experimental settings [7]. While some sarcopenia measurements require specialized software, the measurement of DT *via* computerized tomography (CT) scans has been shown to be reproducible and clinically relevant [8].

Thoracic trauma (TT) in the elderly is expected to become a significant public health burden, both as isolated cases and as part of multi-trauma situations. TT places additional stress on the physiologic reserve of patients due to impaired respiratory dynamics, clearance of secretions, pain, and restricted mobility. Therefore, EPs with TT may represent a particularly vulnerable population for worse outcomes.

The aim of this study was to assess DT and PMT and evaluate their association with clinical outcomes and overall mortality in patients presenting to the emergency room (ER) with TT.

Methods

All thoracic surgery consultations from the ER between November 2015 and January 2021 were collected from hospital electronic medical records (EMR). Trauma-related consultations were identified using both the contents of consultation requests and the International Classification of Diseases (ICD) coding information. Cases were confirmed through clinical and radiological data from the EMR before inclusion. Patients under active cancer treatment and those with injuries directly affecting the measurement area (e.g., retroperitoneal hematoma) were excluded. Mortality data were obtained from the central health ministry death registry, which is also integrated into the hospital EMR. EPs were defined as those aged > 65 years.

The study design is non-interventional and, it was conducted with the approval of the Ethics Committee of the Istanbul Medeniyet University Goztepe Education and Research Hospital (No. 2021/0051, from January 27, 2021). All patients consented to using their anonymized data for scientific purposes.

Demographic information, disposition type (admission, admitting department, discharge from the ER), length of hospital stay, type of thoracic injury, surgical procedures, overall mortality, and survival after the ER presentation were recorded.

All multi-slice thoracic and abdominal CT examinations were conducted using a 64-detector CT scanner (GE Optima CT660 GE Healthcare, Milwaukee, WI) with or without intravenous contrast medium, employing a trauma protocol. The CT image data were collected using a GE system equipped with a 512 × 512 matrix detector.

Helical scanning was performed in the supine position without gantry angulation, covering the region from the lung apices to the symphysis. Images were acquired with a 24 × 1.2 mm acquisition, slice collimation of 1.2 mm, slice width of 2.5 mm, pitch of 0.98, 120 kV, and 75 mAs. Axial imaging data were post-processed using a GE workstation (GE Healthcare, Milwaukee, Wisconsin, USA), and 1.25 mm coronal and sagittal reconstructions were generated. Chest and abdominal CT scans were retrospectively re-evaluated, and measurement data were obtained by a radiologist (board-certified with 15 years of experience) who was blinded to the clinical data.

PMT was defined as the largest transverse diameter of PM perpendicular to the longest diameter (anterior-posterior oblique) of PM at the level of the transverse process of the third lumbar vertebra. Maximum DT at the level of the origin of the celiac artery, identified as the most reliable single measurement point on axial CT images, was performed (Figure 1). PMT and DT were measured bilaterally using the Radx PACS system (Simplex Radx 3D).

The data were analyzed using SPSS 23.0 software. Mean, standard deviation, and median values were calculated as appropriate. The distribution of variables was assessed using the Shapiro-Wilk test. The Mann-Whitney *U* test was employed for non-parametric testing. The Chi-Square test was utilized for quantitative assessment when conditions were met; otherwise, Fisher's exact test was performed. A *p*-value < 0.05 was considered statistically significant. Cox regression analysis was conducted to ascertain the relationship between different variables and survival.

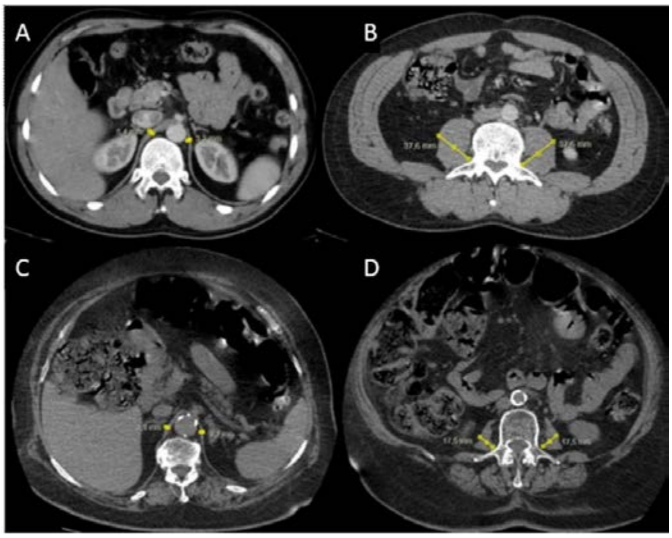

Fig. 1 – Axial contrast-enhanced computed tomography images of 34-year-old male (A, B) and 74-year-old female (C, D) patients showing measurements of maximum diaphragm thickness (A, C) at the celiac artery origin level and psoas muscle diameter (B, D) at the level of L3 vertebra (marked by yellow arrows).

Results

A total of 394 thoracic surgery consultations were identified in the ER due to trauma between November 2015 and January 2021. Of these cases, 129 involved EPs aged 65 years or older. Patient characteristics are shown in Table 1. There was a statistically significant difference between the appearance of pneumothorax and pulmonary contusion. However, the distribution of hemothorax, sternal fracture, and overall multi-trauma rates were comparable between EPs and non-EPs. EPs were less likely to be admitted to in-patient wards, but the need for intensive care was similar. The distribution of types of in-patient wards and length of hospital stay in case of admission are summarized in Table 1.

Table 1

Characteristics of patients with thoracic trauma

Characteristic	Patients total (n=394)	Patients elderly (n=129)	Patients non-elderly (n=265)	*p*-value
Age (years)	51.6 ± 21.8	77.6 ± 8.1	38.9 ± 13.7	n/a
Gender (m/f)	280/114	67/62	213/52	0.000
Multitrauma (y/n)	107/287	29/100	78/187	0.14
Inpatient admission (y/n)	228/165	53/75	175/90	< 0.001
Intensive care unit stay (y/n)	45/349	14/115	31/234	0.80
Length of hospital stay (days)	7.7 ± 7.9	6.9 ± 5.7	7.9 ± 8.5	0.69
Admission				
orthopedics (y/n)	35/359	7/122	28/237	0.09
neurosurgery (y/n)	27/369	9/120	18/247	0.94
general surgery (y/n)	22/372	0/129	22/246	0.001
Pneumothorax (y/n)	97/297	15/114	82/183	0.001
Hemothorax (y/n)	87/307	27/102	60/205	0.70
Sternum facture (y/n)	16/378	6/123	10/255	0.67
Pulmonary contusion (y/n)	59/335	8/121	51/214	0.001
Thoracic procedure (y/n)	64/330	9/120	55/210	0.001
Non-thoracic procedure (y/n)	18/376	5/124	13/252	0.64
Overall mortality (y/n)	76/318	57/72	19/246	< 0.001
Overall survival (estimate, month)	61.1 ± 1.3	43.9 ± 2.84	69.0 ± 1.1	< 0.001
Diaphragm thickness (mm)	4.3 ± 1.3	3.8 ± 1.14	4.5 ± 1.3	< 0.001
Psoas muscle thickness* (mm)	28.4 ± 7.7	21.9 ± 6.6	30.6 ± 6.7	< 0.001

n/a – not applicable; n – number; m/f – male/female; y/n – yes/no.
Values are given as numbers or mean ± standard deviation.
***59 elderly and 59 non-elderly patients did not have psoas muscle thickness data as they did not undergo an abdominal computed tomography scan during the emergency room care.**

EPs were less likely to undergo a thoracic procedure (such as tube thoracostomy or rib fixation) compared to their non-elderly counterparts. However, the rate of non-thoracic procedures (such as orthopedic or general surgery) was comparable between the two groups. While DT was comparable between EPs with and without thoracic procedures, PMT was significantly lower in those who underwent thoracic procedures (3.7 ± 0.9 mm vs. 3.8 ± 1.1 mm, $p = 0.82$ for DT; 4.2 ± 8.3 mm vs. 12.4 ± 12.0 mm, $p = 0.048$ for PMT).

For EPs, both DT and PMT were higher in those who had undergone non-thoracic operations compared to those who had not (5.3 ± 0.81 mm vs. 3.7 ± 1.11 mm, $p = 0.003$ for DT; 25.5 ± 11.2 mm vs. 11.3 ± 11.7 mm, $p = 0.026$ for PMT).

Overall survival was significantly worse in the EP population compared to non-EPs (43.9 vs. 69.0 months, $p = 0.00$) (Figure 2). Further analysis revealed that ICU admission, orthopedic admission, rib fractures, hemothorax, and gender were related to overall survival among the entire study population (log-rank test). However, after age stratification, none of these factors were found to be significantly associated with survival in the EP group (Table 2).

The mean PMT and DT were found to be lower in EPs than in non-EPs (3.8 ± 1.14 mm vs. 4.5 ± 1.3 mm, $p < 0.001$ for PMT; 21.9 ± 6.6 mm vs. 30.6 ± 6.7 mm, $p < 0.001$ for DT). Both PMT and DT were found to be related to overall survival among the whole study population and the elderly age group. However, the same relationship was not observed for the younger cohort (Table 3). DT and PMT according to subgroups (survival in relation to age) are shown in Table 4. Within EPs, the average PMT had moderate sensitivity and specificity for predicting death compared to the average DT (area under the curve – AUC = 0.603, $p = 0.045$ for PMT vs. AUC = 0.455, $p = 0.379$ for DT) (Figure 3).

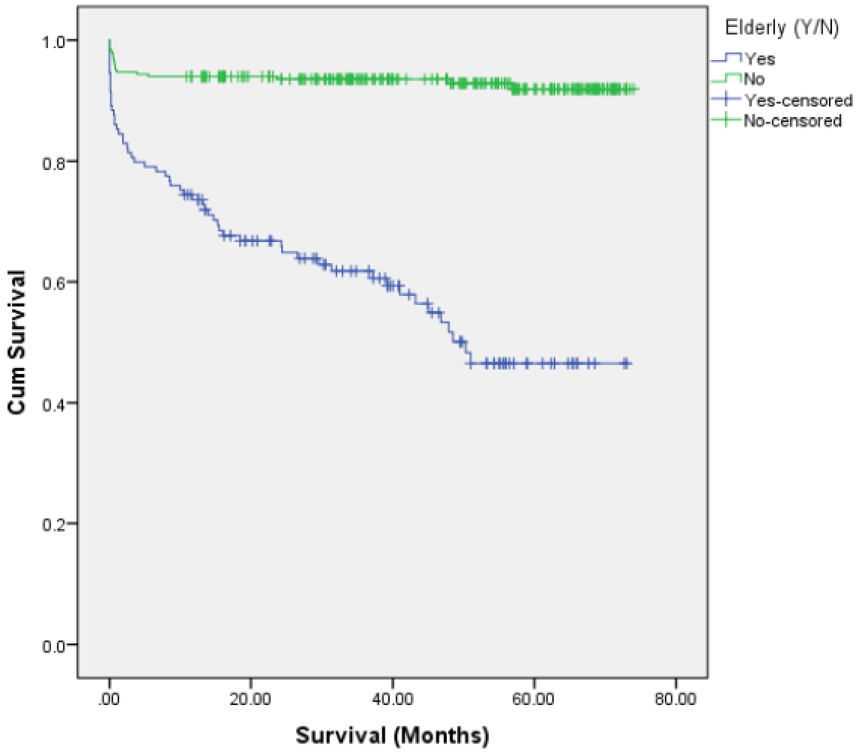

Fig. 2. – Kaplan-Meier plots for overall survival in patient population according to age group. y/n – yes/no.

Table 2

Kaplan-Meier survival analysis for elderly patients

Parameter	Survival estimate error	95% CI	*p*-value
Gender (m/f)	42.8 ± 3.6/43.7 ± 4.1	35.0–49.1/35.6–51.9	0.98
Multitrauma (y/n)	39.3 ± 5.8/44.6 ± 3.1	27.9–50.7/38.3–50.8	0.67
Intensive care unit stay (y/n)	28.8 ± 7.8/45.7 ± 2.9	13.4–44.1/39.8–51.5	0.059
Inpatient admission (y/n)	41.9 ± 4.5/45.8 ± 3.6	33.0–50.8/38.7–52.9	0.53
Neurosurgery admission (y/n)	44.9 ± 9.0/43.9 ± 2.9	27.2–62.7/38.1–49.7	0.93
Pneumothorax (y/n)	37.4 ± 8.9/44.6 ± 2.9	19.9–55.0/38.8–50.5	0.42
Hemothorax (y/n)	38.0 ± 4.8/44.1 ± 3.2	28.4–47.6/37.8–50.4	0.86
Rib fracture (y/n)	45.5 ± 3.0/30.8 ± 7.0	39.6–51.4/17.1–44.6	0.15
Pulmonary contusion (y/n)	25.4 ± 8.5/44.8 ± 2.9	8.7–42.1/39.1–50.5	0.19
Thoracic procedure (y/n)	33.4 ± 9.8/44.4 ± 2.9	14.0–52.8/33.6–50.1	0.58

CI – confidence interval. Values are given as mean ± standard deviation.

Table 3

Kaplan-Meier survival analysis for non-elderly patients

Parameter	Survival estimate error	95% CI	*p*-value
Gender (m/f)	68.4 ± 1.3/69.5 ± 1.7	65.8–70.9/66.1–72.9	0.29
Multitrauma (y/n)	61.1 ± 2.6/70.7 ± 1.0	58.9–69.2/68.6–72.8	0.019
Inpatient admission (y/n)	62.7 ± 1.4/70.7 ± 1.5	64.4–70.0/67.6–73	0.22
Intensive care unit stay (y/n)	61.4 ± 4.9/70.0 ± 1.0	52.7–70.2/67.9–72.1	0.006
Neurosurgery admission (y/n)	69.4 ± 1.4/68.8 ± 1.1	66.5–72.3/66.5–71.1	0.75
Pneumothorax (y/n)	68.0 ± 1.9/69.0 ± 1.3	64.1–71.8/66.4–71.6	0.91
Hemothorax (y/n)	61.4 ± 3.4/70.7 ± 0.9	54.6–68.2/68.9–72.6	< 0.001
Rib fracture (y/n)	67.3 ± 1.5/70.8 ± 1.2	64.1–70.4/68.3–73.2	0.038
Pulmonary contusion (y/n)	67.3 ± 2.7/69.1 ± 1.2	61.9–72.6/66.8–71.5	0.86
Thoracic procedure (y/n)	62.8 ± 2.7/69.6 ± 1.1	57.5–68.1/67.3–71.9	0.20

CI – confidence interval. Values are given as mean ± standard deviation.

Table 4

Diaphragm and psoas muscle thickness according to subgroups

Parameter	Alive	Exitus
Diaphragm thickness (mm)		
elderly	4.0 ± 1.19**	3.57 ± 1.0**
non-elderly	4.5 ± 1.3***	4.6 ± 1.4***
Psoas muscle thickness* (mm)		
elderly	10.9 ± 11.9	13.1 ± 12.1
non-elderly	23.6 ± 14.3	26.7 ± 10.7

Values are given as mean ± standard deviation.

***59 elderly and 59 non-elderly patients did not have psoas muscle thickness data as they did not undergo an abdominal computed tomography scan during the emergency room care; ** Cox regression analysis *p*-value was 0.015 (Exp(B) = 0.72, 95% CI = 0.56–0.93); *** Cox regression analysis *p*-value was 0.07 (Exp(B) = 1.04, 95% CI = 0.76–1.43).**

Exp(B) – odds ratio.

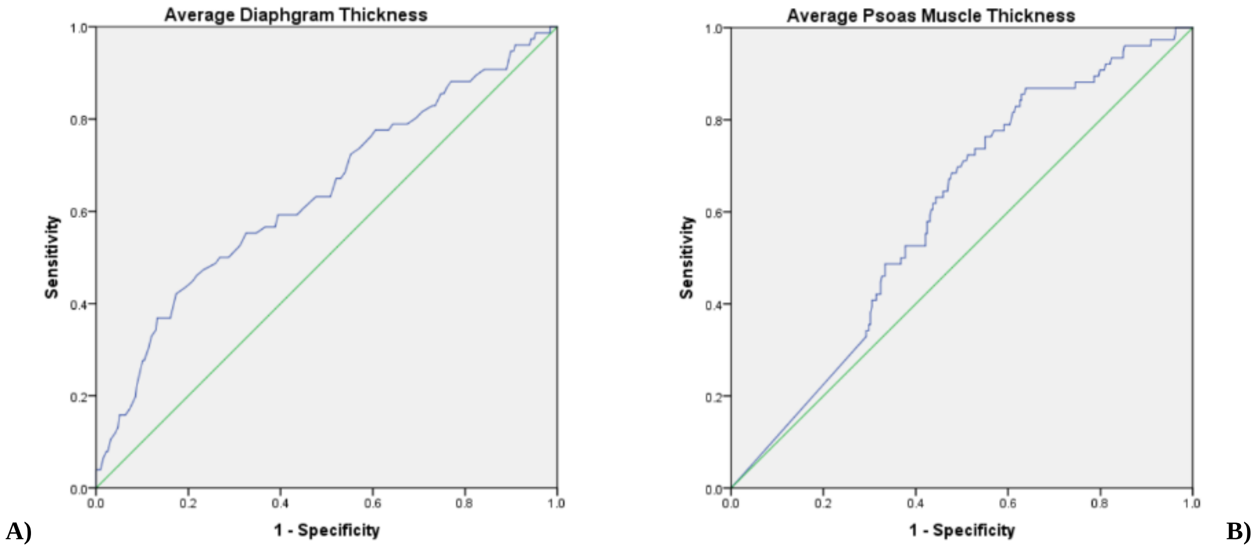

Fig. 3 – Receiver operating characteristic curves for average diaphragm thickness (A) and psoas muscle thickness (B) in relation to overall mortality.

Discussion

TT poses a significant public health challenge, especially in the elderly population. As life expectancy and the proportion of elderly individuals steadily increase, the incidence of trauma among the elderly is expected to rise accordingly. This trend is not exclusive to trauma cases; the unique needs of EPs have been acknowledged across various medical specialties and interventions. Discussions on this topic emphasize that while age is an important factor, it must be evaluated within the broader context of general frailty [1].

Frailty itself can be challenging for universal screening especially in non-acute outpatient settings [9]. Parameters like grip strength require specialized equipment, while others, like the assessment of walking speed, may be difficult to accommodate in the ER or inpatient settings [10]. On the other hand, sarcopenia has been found to correlate with the presence and severity of frailty and has been discussed as a negative prognostic risk factor in various contexts [4, 11–13]. For instance, sarcopenia, as measured by the lumbar (L)3-total psoas area (TPA)/vertebral body area (VBA) – L3-TPA/VBA technique on CT, was found to be a worse prognostic indicator for spinal surgery performed for metastatic lesions, whereas frailty assessment failed to predict adverse outcomes in this patient population [4]. Additionally, sarcopenia defined using PM area as a surrogate marker was a stronger predictive factor for suboptimal outcomes after spinal metastasis surgery compared to other well-known scoring systems such as the Karnofsky score [5].

Age bias in patient selection for surgery has been a topic of discussion, particularly in oncologic cases. EPs undergoing lung resection often face higher mortality and morbidity rates and lower survival benefits [14]. However, this issue could potentially be addressed by establishing high-volume centers equipped with multidisciplinary care and offering minimally invasive surgical techniques [15, 16]. In both oncologic and non-oncologic contexts, EPs have been observed to receive less aggressive treatment, such as forgoing surgery for neoplastic and non-neoplastic indications or adjuvant chemotherapy, leading to suboptimal outcomes. Despite evidence suggesting that factors beyond age alone influence these outcomes, there is still a tendency towards age-based classification rather than a more holistic approach [17–21]. In our study, we found that EPs undergoing non-thoracic post-traumatic operations tended to have preserved muscle mass, possibly indicating a surgical selection bias favoring less frail patients, which could lead to better short-term outcomes. However, this pattern was not observed for thoracic procedures, which mainly included tube thoracostomy and video-assisted thoracic surgery for hemostasis and lung expansion. These procedures are often more time-sensitive than the non-thoracic operations captured in our database, such as long bone fixation or vertebral instrumentation.

Life expectancy steadily increased in both developed and developing countries. For instance, the average life expectancy for individuals above 65 years is currently estimated to be 20–30 years longer in the United Kingdom [20]. However, our observations in this article indicate that EPs with TT continue to face an increased risk of mortality compared to the crude death rate for their demographic group [21–23]. This increased risk persists even though these patients were initially well enough to be discharged from the ER after observation or an inpatient stay. The overall two-year survival rate for EPs was 82%, despite our study excluding patients receiving treatment for malignancy.

Decreased DT has been identified as a useful marker for predicting difficulty in weaning from invasive mechanical ventilation [24, 25]. It has also been weakly associated with peripheral muscle wasting in the acute term [24]. In chronic diseases such as autoimmune conditions [26], chronic renal failure [27], muscular degeneration [28], and chronic obstructive pulmonary disease - COPD [29], changes in DT and morphology have been documented and linked to functional impairment, mortality, and morbidity. Similar relationships have been observed for PM measurements. Therefore, in this study, we focused on DT and PMT measured during post-trauma diagnostic work-up CT scans of these patients to gather additional information.

CT evaluation of these parameters has been shown to be reliable and reproducible in the literature [30, 31], requiring no additional resources beyond those already needed for the standard of care. Our findings suggest that although EPs, on average, have thinner diaphragms, subgroup analysis within the elderly population still revealed significant associations with mortality risk. Thus, DT can serve as a useful surrogate marker for frailty/sarcopenia. Further studies on larger populations are warranted to assess its full prognostic potential, as this measurement is straightforward to obtain and requires minimal additional effort, resources, or testing beyond the current clinical work-up protocols.

The limitations of this study include a relatively small number of cases and the fact that it was conducted at a single center. Although mortality data is automated and updated in real-time across the universal single-payer social security system, accurate determination of mortality cause was challenging in a retrospective setting. Additionally, PMT was not evaluated in all patients since there was no intervention beyond the standard of care assessment.

Conclusion

Elderly patients presenting to the emergency room with thoracic trauma face a higher risk of adverse long-term prognosis compared to the average population. This subgroup may benefit from screening for probable causes of mortality. Defining this subgroup could be enhanced by incorporating surrogate sarcopenia markers, such as diaphragm thickness or psoas muscle thickness, which can be easily obtained without additional testing beyond standard care in a trauma setting. Further studies with larger case numbers are needed to determine optimal cutoff points or develop scoring systems to identify vulnerable patients for referral to rehabilitation, social services for mobility issues, medical optimization, or cancer screening.

Conflict of interest

The authors declare no conflict of interest.

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