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Original Article
Role of pleural fluid attenuation values on CT for hemothorax diagnosis in trauma patients

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Abstract: Background and aim: Hemothorax is a critical issue in patients with chest trauma. It should be diagnosed quickly and accurately. The study's aim was to define the potential role of pleural fluid (PF) attenuation value determined on computerized tomography (CT) for the diagnosis of traumatic hemothorax. Methods: From 01.07.2011 to 01.07.2016, patients with PF detected on CT with tube thoracostomy were reviewed. On CT sections, PF attenuation values taken from levels where pleural fluid had the most intense appearance were measured as Hounsfield Units (HU). The relationship between HU values and chest traumatic findings, macroscopic discharge diagnosis, peripheral blood Hb and Htc levels and CT protocol were investigated. Results: Thirty-eight cases were reviewed in the study group. All PF HU values were determined to be more than 20.0 HU. PF attenuation values were more than 35 HU in 71.1% (n:27) of the cases and between 20.0 and 34.9 for 28.9% (n:11). In the subgroup with hemorrhagic fluid drained from the thoracic cavity, HU values were often higher than 35. For the sub-groups with and without coexisting traumatic findings, there was no statistically significant difference in terms of PF density being below or above 35 HU. No statistically significant correlation was detected between PF HU values and age, peripheral blood Hb and Htc values. Conclusion: For thorax trauma cases, PF attenuation values were between 20.0 to 34.9 HU, and more than 35 HU. Patients with acute trauma who have PF with attenuation value below 35 HU should be considered as hemothorax primarily, even with no coexisting traumatic findings on CT scans.

Keywords: Pleural fluid, Hounsfield unit, computerized tomography

Introduction

Described as blood accumulation in the pleural space, hemothorax [1] is a consequence of blunt trauma in 90% of cases [2]. Hemothorax manifests itself in 30 to 50% of chest trauma cases [3-5]. In such cases, bleeding might be caused by damage to the pulmonary parenchyma or intercostal arteries, associated with or without rib fractures, and other chest wall tissue injuries including parietal pleura or other thoracic structures [2, 4-8].

While other pleural effusion types may also manifest [5], such as chylothorax, pleural fluid should be accepted as blood in the case of trauma, unless it is proven not to be in the case of acute chest trauma [4, 5, 9-11]. Pleural fluid hematocrit level which is 50% above peripheral blood hematocrit is diagnosed as hemothorax [11-14], while diagnostic thoracentesis is not usually used in cases of acute trauma and is rarely used for sub-acute stages [2]. Hence, CT scan can be an important diagnostic tool to identify the characteristics of pleural fluid and can distinguish hemothorax from any other type of effusion [1, 7, 15, 16]. Spiral CT helps to detect even small hemothorax [2, 11] and allows for more advanced characterization of pleural fluid by means of scaling Hounsfield units [1, 9, 15]. Under standard temperature and pressure the density of water is accepted as 0 (zero) for X-ray attenuation, known as the Hounsfield unit (HU) scale, extending from + 1000 reflecting compact bone to - 1000 reflecting air [17-19]. In the literature, the reported HU values for blood vary. According to Sridhar [1], Sangster [3], Mirvis [5], Mirka [6], Oikonomu [7], and Cummings [10], blood density values in the pleural space are 30 HU and above (HU range: 30-45, 30-50 or 30-70), while Meyer [2], Miller [4], Kaewlavi [16], Hao [20] and Wells [21]

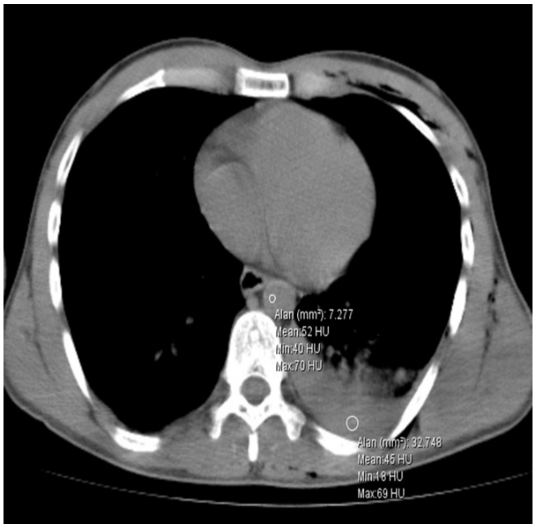

Figure 1. Noncontrast axial CT; Subcutaneous amphysema in left hemithoracis. Density values were measured from pleural space and aorta, at the level of densities from the more hyperdens seen with ROI.

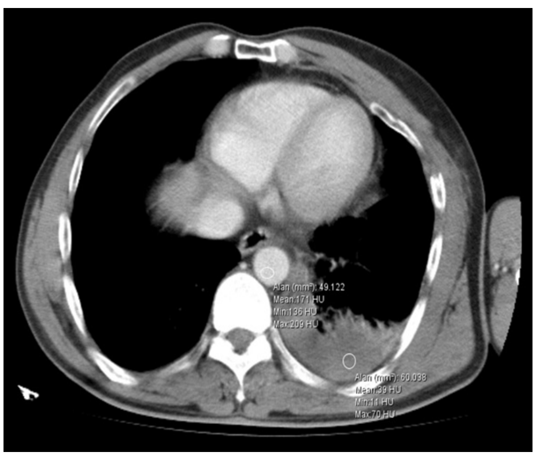

Figure 2. On axial CT scan with intravenous iodinated contrast media; measurement of left pleural fluid and aorta density.

argue that blood attenuation values in the pleural space are 35 HU and above (HU range: 35-70). Such variations in the basal HU values were generally small, in the range 0-5 HU. The density of hemorrhagic fluids detected on CT scan may vary according to the hematocrit level of the fluid, mixture of other types of fluids and coagulation processes [5]. In addition, some studies about the comparison of soft tissues, body fluids and non-organic materials suggest that the differences in attenuation values depend on the brand of the device and different types of beam energy [17, 19, 22, 23].

Any patient admitted to the emergency service following chest trauma should be suspected of hemothorax [11]. Since hemothorax is a potentially life-threatening injury, it should be diagnosed quickly and accurately in patients with chest trauma. Even if not life threatening, the presence of hemothorax affects trauma management. Therefore, in this present study, we aimed to assess PF and aorta CT attenuation values, coexisting traumatic findings, macroscopic discharge diagnosis, peripheral blood hemoglobin and hematocrit levels and to determine the possible diagnostic role of pleural fluid HU values in the differentiation of hemothorax on CT in trauma patients.

Materials and methods

Study design and patient selection

This was a retrospective descriptive study conducted in our third-degree hospital, where approximately 44,000 patients were admitted to the emergency department and 4962 patients were hospitalized in the year 2016, for example. In this study, all the electronically-archived documents of the patients were reviewed between the dates of July 1st 2011 and July 1st 2016. Throughout the study period, PF was detected in the CT scans of 307 cases in total, while 146 of them were analyzed with cytological examination or surgically drained. Inclusion criteria were: age above 18, trauma history, CT scan within the first 24 hours after trauma, blood cell count within the first 48 hours of trauma, administration of tube thoracostomy or thoracentesis. Those with no images in PACS (Picture Archiving and Communication Systems) and incomplete electronic records were excluded. A total of 38 cases who met the criteria were examined in terms of demographic data (sex, age), medical history, trauma mechanism, hemogram results, coexisting chest traumatic CT findings, macroscopic drainage diagnosis, PF and aorta attenuation values. The ethics committee of the university granted permission to conduct this study.

CT protocol and measurement of HU attenuation values

A 4-detector Toshiba Asteion (Toshiba America Medical Systems, Tustin, CA, USA) CT device was used in our radiology department. Thoracic CT was performed at 5 mm slice thickness,

Table 1. Descriptive properties of study group, discharge diagnosis and CT attenuation values

Characteristic	Evaluated population	
	N	(%)
Sex		
Female/Male	9/29	23.7/76.3
Mechanism of trauma		
Blounttrauma	32	84.2
Penetrantrauma	6	15.8
HbRanges		
Severe anemia: < 8 g/dL	1	2.6
Moderate anemia: 8.0-9.9 g/dL	4	10.5
Mild anemia: 10 g/dL and higher	33	86.9
CT procedure		
No contrast media	25	65.8
With contrast media	13	34.2
PF HU Ranges		
15-34.9	11	28.9
35 HU and higher	27	71.1
Surgical macroscopic discharge diagnosis (Drained substances from pleural space)		
Hemorrhagic fluid	16	42.1
Hemorrhagic fluid and Air	13	34.2
Air	9	23.7
	Mean ± sd	Median (min-max)
Age	59.4±17.6	60.5 (22.0-90.0)
Periferic blood Hb and Htc levels		
Hemoglobin	12.0±1.7	12.2 (7.9-15.7)
Hematocrit	36.2±4.9	37.3 (24.3-46.3)
CT attenuation values		
PF HU	40.2±14.3	40.0 (20.0-93.0)
PF HU with contrast media	38.0±10.7	40.0 (20.0-51.0)
PF HU no contrast media	41.5±16.0	40.0 (21.0-93.0)
Aorta HU with contrast media	205.7±125.9	171.0 (62.0-591.0)
Aorta HU no contrast media	49.2±13.7	50.0 (13.0-68.0)
PF/Aorta HU with contrast media	0.2±0.2	0.2 (0.03-0.8)
PF/Aorta HU no contrast media	0.9±0.6	0.7 (0.3-3.1)

Hb: Periferic blood hemoglobin, Htc: Periferic blood hemotocrit, PF HU: Pleural fluid hounsfield unite, %: Percentage from evaluation of 38 subjects.

100-120 keV and 100-150 mAs. Intravenous contrast media was applied to the patients with 100 ml nonionic iodinated contrast agent. Contrast agent was not used in patients with contraindications such as chronic renal failure, high risk of contrast nephropathy or known allergy history. The analysis of CT images and HU value measurements were performed by a radiologist with 12 years experience. Region of interest (ROI) was created on CT axial sections where the pleural fluid was observed to be most intense, and the density values of the pleural fluid and of the aorta were quantitatively measured in the same section (**Figures 1** and **2**). Since the ROI diameter did not affect the density values [23], the measurement was performed with different ROI diameters. The values were defined as HU.

Radiologic images and data analysis

The radiologist evaluated the following coexisting traumatic findings: pneumothorax, rib fractures, pulmonary contusion, subcutaneous emphysema, pneumomediastinum, thoracic vertebrae, scapula, sternum or clavicle fractures. The relation between the accompanying traumatic findings and PF HU and aortic blood HU values were examined. We also examined peripheral blood hb and htc levels on the day of CT scan or within two days after trauma. For the groups and sub-groups, the correlation between PF HU and aortic blood HU values and peripheral blood hb and htc values were reviewed. PF to aortic blood HU attenuation values (P/A) ratios were also calculated.

Statistical analysis

The data were analyzed with Statistical Product and Service Solutions (SPSS) (version 20.0; SPSS/IBM Inc., Chicago, IL, USA). The numbers, percentages, mean, standard deviation, median, minimum and maximum values were calculated for the presentation of descriptive data.

Table 2. Periferic blood Hb, Htclevels according to discharge diagnosis, comparison with CT attenuation values

	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	Mean ± SD	Median (min-max)	
Hb	12.5±0.9	12.4 (10.9-13.9)	11.8±1.6	11.8 (8.9-14.9)	11.9±2.2	11.9 (7.9-15.7)	0.442
Htc	37.9±2.4	37.7 (33.9-41.4)	35.5±4.7	36.6 (27.5-46.3)	35.7±6.2	35.9 (24.3-45.1)	0.297
PF HU	34.3±9.9	33.0 (22.0-49.0)	40.5±14.5	39.5 (20.0-74.0)	44.2±16.3	40.0 (21.0-93.0)	0.418
Aorta HU	101.3±79.9	52.0 (40.0-244.0)	107.4±138.6	54.5 (23.0-591.0)	98.0±73.3	67.0 (13.0-262.0)	0.467
PF/A HU	0.5±0.3	0.5 (0.2-0.9)	0.8±0.5	0.8 (0.03-1.7)	0.8±0.8	0.6 (0.2-3.1)	0.418
PF/A with CM	0.2±0.01	0.2 (0.2-0.2)	0.3±0.3	0.2 (0.03-0.8)	0.2±0.1	0.2 (0.2-0.3)	0.641
PF/A no CM	0.7±0.2	0.6 (0.4-0.9)	1.1±0.3	1.0 (0.7-1.7)	1.0±0.9	0.6 (0.5-3.1)	0.051
	Air		Hemorrhagic fluid		Hemorrhagic fluid and Air		p*
PF HU	n (%)		n (%)		n (%)		0.040
HU < 35	5 (55.6)		5 (31.2)		1 (7.7)		
HU ≥ 35	4 (44.4)		11 (68.8)		12 (92.3)		

Hb: Perifericblood hemoglobin, Htc: Periferic blood hemotocrit, PF HU: Plerural fluide hounsfield unit, A HU: Aorta hounsfield unite, PF/A HU: Pleural fluid/Aorta, PF/A with CM: Pleural fluid/Aorta HU with contrast media, PF/A no CM: Pleura lfluid/Aorta HU no contrast media, p: Kruskal Wallis Test, p*: Chisquare.

Chi-Square test was performed for the analysis of categorical data. Variables were compared using means with the Mann Whitney U test and Kruskal Wallis test. Correlation among the variables was analyzed using the Spearman correlation. Statistical significance was accepted as $p < 0.05$.

Results

In this study, a total of 38 cases diagnosed with pleural fluid as a result of CT following a chest trauma and with surgical drainage administered were examined. 5.2% of the cases (n = 3) were administered thoracentesis, while 94.7% of them underwent tube thoracostomy (one case had both thoracentesis and tube thoracostomy). The descriptive characteristics and HU values are summarized in **Table 1**. All of the PF densities were measured to be more than 20.0 HU, while mean PF HU value was 40.2±14.3. PF attenuation values were above 35 HU for 71.1% of the cases (n = 27), while it was between 20.0 and 34.9 for 28.9% (n = 11) (**Table 1**). There was no statistically significant difference between sex, age, peripheral blood Hb and Htc variables with PF HU below or above 35 HU ($p > 0.05$).

The samples drained from the pleural space were macroscopically defined as hemorrhagic fluid for 42.1% (n = 16), hemorrhagic fluid and air for 34.2% (n = 13) and air for 23.7% (n = 9). According to the macroscopic discharge diagnosis, no statistically significant difference was detected among the sub-groups in terms of peripheral blood Hb and Htc, PF HU, Aorta HU and the mean P/A ratio ($p > 0.05$, **Table 2**). In the sub-group with air drainage, for 55.6% of the subjects (n = 5) the PF density was below 35 HU, while it was 35 HU and above for 44.4% of the subjects (n = 4). In the sub-group with hemorrhagic fluid drainage, the PF density was below 35 HU for 31.2% of the cases (n = 5), while it was 35 HU and above for 68.8% of the cases (n = 11). In the sub-group with hemorrhagic fluid and air drainage the PF density was below 35 HU for 7.7% of the subjects (n = 1), while it was 35 HU and above for 92.3% of the subjects (n = 12). Because of these findings, there was a statistically significant difference among the sub-groups in terms of the PF density of 35 HU and above ($p = 0.040$, **Table 2**).

Coexisting traumatic findings detected on CT scans, macroscopic discharge diagnosis, PF HU values and aorta HU values are shown in **Table 3**. CT scans indicated pulmonary contusion for 65.8% (n = 25) of the cases, pneumothorax (Px) for 65.8% (n = 25) and rib fractures for 78.9% (n = 30). There was a statistically significant difference between the groups with and without pneumothorax in terms of macroscopic discharge diagnosis ($p = 0.001$). There was a statistically significant difference among the groups in with a number of rib fractures in terms of macroscopic discharge diagnosis ($p = 0.023$, **Table 3**). No statistically significant difference was detected among the groups with and without traumatic changes in terms of the pleural density below and above 35 HU ($p > 0.05$). However, the contrast media CT scans suggested that those with less than 3 rib fractures had 220.8±40.6 HU as the mean aorta

Table 3. Coexisting traumatic findings on CT and comparison of discharge diagnosis and CT attenuation values

	Hemorrhagic	Air	Hemorrhagic and Air		HU < 35	HU ≥ 35		With contrast media		No contrast media	
	n (%*)	n (%*)	n (%*)	p	n (%)	n (%)	p	mean ± SD	p*	mean ± SD	p*
Pneumothoracis				0.001			0.714		0.153		0.606
No	10 (76.9)	0 (0.0)	3 (23.1)		3 (23.1)	10 (76.9)		211.5±190.2		46.7±15.1	
Yes	6 (24.0)	9 (36.0)	10 (40.0)		8 (32.0)	17 (68.0)		200.7±39.3		50.2±13.4	
Ribfracture				0.023			0.637		0.017		0.206
< 3	0 (0.0)	3 (50.0)	3 (50.0)		1 (16.7)	5 (83.3)		220.8±40.6		41.5±2.1	
≥ 3	12 (50.0)	4 (16.7)	8 (33.3)		8 (33.3)	16 (66.7)		150.0±40.3		48.8±15.4	
Subcutaneous ampysema				0.080			1.000		1.000		0.493
No	10 (62.5)	3 (18.8)	3 (18.8)		5 (31.2)	11 (68.8)		249.6±193.1		47.8±13.6	
Yes	6 (27.3)	6 (27.3)	10 (45.5)		6 (27.3)	16 (72.7)		178.3±60.6		50.3±14.1	
Pulmonary contusion				0.116			1.000		0.008		0.600
No	8 (61.5)	1 (7.7)	4 (30.8)		4 (30.8)	9 (69.2)		134.6±44.0		47.9±14.3	
Yes	8 (32.0)	8 (32.0)	9 (36.0)		7 (28.0)	18 (72.0)		250.1±142.3		49.8±13.8	
Pneumomediastineum				0.511			1.000		0.324		0.873
No	13 (43.3)	8 (26.7)	9 (30.0)		9 (30.0)	21 (70.0)		220.7±129.2		49.0±14.9	
Yes	3 (37.5)	1 (12.5)	4 (50.0)		2 (25.0)	6 (75.0)		123.0±86.3		49.8±9.9	
Clavicle fracture				0.622			1.000		0.612		0.616
No	14 (42.4)	7 (21.2)	12 (36.4)		10 (30.3)	23 (69.7)		208.4±143.9		49.6±13.8	
Yes	2 (40.0)	2 (40.0)	1 (20.0)		1 (20.0)	4 (80.0)		196.7±42.4		44.5±16.3	
Vertebral fracture				0.672			0.395		0.236		0.633
No	12 (40.0)	8 (26.7)	10 (33.3)		10 (33.3)	20 (66.7)		203.9±137.4		50.1±13.5	
Yes	4 (50.0)	1 (12.5)	3 (37.5)		1 (12.5)	7 (87.5)		215.5±40.3		46.5±15.1	
Scapular fracture				0.955			0.395		0.758		0.393
No	13 (43.3)	7 (23.3)	10 (33.3)		10 (33.3)	20 (66.7)		215.7±142.6		50.4±13.5	
Yes	3 (37.5)	2 (25.0)	3 (37.5)		1 (12.5)	7 (87.5)		183.3±91.2		43.0±14.8	
Sternal fracture				0.062			1.000		-		0,094
No	13 (37.1)	9 (25.7)	13 (37.1)		10 (28.6)	25 (71.4)		205.7±125.9		50.6±13.9	
Yes	3 (100.0)	0 (0.0)	0 (0.0)		1 (33.3)	2 (66.7)		-		39.3±7.1	

%*: Percentage column, %: Percentage of line, SD: Standard deviation, p: Chi-Square Test, p*: Mann Whitney U test.

HU, while those with more than 3 rib fractures had 150.0±40.3 HU as the mean aorta HU, and this difference was statistically significant (p = 0.017). In addition, in the cases of CT scan with contrast media, those with pulmonary contusion had 250.1±142.3 HU as the mean aorta HU, while those with no pulmonary contusion had 134.6±44.0 HU as the mean aorta HU, and this difference was statistically significant (p = 0.008, **Table 3**).

Between the groups with and without contrast media, there was no statistically significant difference in terms of mean PF HU (p > 0.05). Mean aorta HU was 205.7±125.9 HU in the group with contrast media, while it was 49.2± 13.7 HU for the non-contrast CT group (**Table 1**), and there was a statistically significant difference in term of mean aorta HU (p < 0.001). For the cases with non-contrast CT scans, mean PF/A was 0.9±0.6 while without contrast media mean PF/A was 0.2±0.2 (**Table 1**), and there was a statistically significant difference in terms of mean PF/A values (p < 0.001).

No statistically significant correlation was detected between PF HU values and age, peripheral blood Hb and Htc values (r = -0.049, p = 0.769; r = -0.102, p = 0.543; r = -0.184, p = 0.617, respectively). There was a negative and moderately significant correlation between the aorta HU values and age, while there was a positive and moderately significant correlation between the aorta HU values and Hb (r = -0.386, p = 0.017; r = 0.362, p = 0.025, respectively). No significant correlation was detected between the aorta HU values and Htc (p > 0.05). There was, however, a negative and moderately significant correlation between PF/A values with Hb and Htc (r = -0.413, p = 0.010; r =

-0.356, $p = 0.028$, respectively). No significant correlation was detected between PF/A and age ($p > 0.05$).

For the group with non-contrast CT scans, there was no significant correlation between PF HU values with age, Hb, Htc and aorta HU values ($r = -0.176$, $p = 0.400$; $r = -0.154$, $p = 0.462$; $r = -0.144$, $p = 0.493$; $r = 0.093$, $p = 0.659$, respectively). No significant correlation was detected between the aorta HU values with age, Hb and Htc ($r = -0.204$, $p = 0.327$; $r = 0.166$, $p = 0.429$; $r = 0.116$, $p = 0.581$, respectively). There was no statistically significant correlation between PF/A ratio with age, Hb and Htc (age $r = 0.003$, $p = 0.988$; hb $r = -0.284$, $p = 0.169$; htc $r = -0.216$, $p = 0.299$). For the group with contrast media CT scans, no significant correlation was detected between PF HU values with age, Hb, Htc and aorta HU values ($r = 0.209$, $p = 0.494$; $r = 0.003$, $p = 0.993$; $r = 0.036$, $p = 0.908$; $r = 0.041$, $p = 0.893$, respectively). For the group with contrast media, a strong negative correlation was detected between the aorta HU values and age ($r = -0.672$, $p = 0.012$) with no significant correlation between the aorta HU values and Hb and Htc ($p > 0.05$). For the group with contrast media, no statistically significant correlation was detected between the PF/A ratio with age, Hb, Htc (age $r = 0.408$, $p = 0.167$; hb $r = -0.308$, $p = 0.306$; htc $r = -0.324$, $p = 0.280$).

Discussion

In the present study we found that PF attenuation values on CT scans of trauma patients were all more than 20 HU, while it was above 35 HU for 71% of the cases and below 35 HU for 29%. No statistically significant difference was found between the coexisting thoracic traumatic CT findings and PF HU values. However, there was statistically significant difference in terms of the mean aorta HU for the group with contrast media CT scans in the cases with rib fracture and pulmonary contusion coexistence or not. No statistically significant correlation was detected between PF HU values with age, peripheral blood Hb and Htc levels.

For patients with trauma, while the fluid in the pleural space is considered to be blood until it is proven not to be, it does not always have the characteristics of hemothorax [9]. Therefore, distinguishing hemothorax from pleural fluid is clinically important. According to previous researchers, the measurement of pleural fluid attenuation values was recommended for differentiation of blood from simple pleural fluid [1-7, 10, 11, 20, 21]. In the literature, it is reported that any attenuation value for pleural fluid between 35 and 70 HU is typically [16] hemothorax [2, 4, 21]. However, Liu *et al.* reported that the optimal cut-off value is ≥ 15.6 HU to distinguish traumatic hemothorax from pleural effusion (sensitivity: 86.8%; specificity: 97.4%) and ≥ 30.0% P/A ratios (sensitivity: 94.7%; specificity: 83.3%) [9]. Their study suggested that any attenuation value for pleural fluid above 15 HU should be considered as hemothorax [9]. In our study, we found that in the sub-groups with "hemorrhagic fluid" and "hemorrhagic fluid with air" drained from the thorax cavity, PF HU values were more than 35 HU, which was statistically significant. However, these sub-groups also included some cases with the PF HU value below 35 (20.7%, $n = 6$). In the subgroup with air drained from the thorax cavity, more than half of the cases had PF attenuation values detected below 35 HU (55.6%, $n = 5$). While the attenuation values are typically between 35 and 70 HU for hemothorax, our study revealed that acute hemothorax might have low attenuation values, too.

In the literature, PF macroscopic appearance is likely to provide useful information about the differential diagnosis of pleural effusions [12, 14, 24], PF Htc level must be known to distinguish gross hemorrhagic pleural fluid from hemothorax [11-13, 24] and PF hematocrit value must be at least 50% of peripheral blood hematocrit [11-14]. Even though the PF Htc is 5%, it looks like blood macroscopically [11] and only 1 mL blood can cause bloody pleural fluid for moderate-size pleural effusion [12]. However, the evaluation of density increase in the pleural space should be made in consideration of underlying diseases like chronic renal failure that might cause residual contrast media involvement in some anatomical structures [15], malignancy, trauma, pulmonary embolism, post-cardiac injury syndrome, and pulmonary infarction [12, 13]. Since our study offers no data about the Htc and Hb levels of the pleural fluid or the number of erythrocytes, it could not be confirmed whether or not the fluid is hemothorax or bloody pleural fluid in the cases with PF HU values below 35. However, the fact that the sub-group with PF attenuation below 35 HU had a trauma history and reddish drainage fluid made us think that such density values might be due to liquid blood because of delays in the coagulation process.

While spiral CT prevents tissue superposition with thin slice thickness imaging, pleural and paranchymal pathologies and posttraumatic processes can be differentiated, and in some patients, intravenous contrast media can be used to distinguish vascular structures and mass-occupying or inflammatory lesions. In this study, there was no statistically significant difference in terms of PF HU values between the groups with and without co-existing traumatic CT findings. However, the presence of more or less than 3 rib fractures and pulmonary contusion affected mean aorta HU in the group with CT scan using contrast media. Nandalur analyzed the accuracy of CT attenuation values in PF characterization, with CT imaging of patients with no hemothorax in the study group, and advised non-contrast scans in order to decrease partial volume effects of neighboring high attenuation structures and the accuracy of CT numbers [25]. Liu also reported that ROI should not include any bone, pleura, pulmonary parenchyma or air to reduce the partial volume effect [9]. In our study, we concluded that the contrast media did not have any effect on PF HU values, while it affected mean aorta HU and the P/A ratios. Based on these results, we can say that the effect of coexisting traumatic chest findings and using IV contrast media on the aorta HU values is methodologically important (**Figures 1** and **2**).

In the literature, to our knowledge, there is only one study by Liu *et al.* in which the correlation of pleural fluid density on CT images was evaluated with peripheral blood Hb and Htc levels in patients with trauma [9]. In their study, they found a less obvious correlation between the hemothorax HU values and the Hb levels, and no correlation between the hemothorax HU values and the peripheral blood Hct levels [9]. In our study, there was no correlation between PF HU values and age, peripheral blood Hb and Hct levels. Since there was only one (2.6%) patient with severe anemia and only four (10.5%) patients with moderate anemia in our group of patients, the findings are similar to the study by Liu *et al.* [9] in terms of patient groups and the lack of correlation between the hemothorax HU values and the peripheral blood Hct levels. Future studies must contain anemia subgroups to determine the effect of peripheral blood Hb and Htc levels on hemothorax attenuation values.

This study has some limitations. First of all, this was a retrospective descriptive single center study, and included a relatively small patient group. Secondly, the HU values were measured by one single radiologist from a single point where the pleural fluid was most intense, so intra observer bias in ROI measurement could play a role in the CT evaluation. Thirdly, we applied two different CT scanning procedures. And finally, in this retrospective study, the fact that we do not have any data about Htc levels of PF prevented us from being able to confirm the biochemical diagnosis of hemothorax.

In thoracic trauma cases, PF attenuation values may range between 20 and 34.99 HU and are mostly above 35 HU. Such high attenuation values should be considered as hemothorax for initial diagnosis. Even though there may be no presence of co-existing traumatic findings in patients with acute trauma, when pleural fluid attenuation value was measured below 35 HU hemothorax should also be considered at first. However, the biochemical verification of hemothorax requires the data of PF Htc level. In conclusion, prospective research will be useful with larger trauma groups, in which Htc and Hb levels of PF are studied for the clinical use of HU values to distinguish hemorrhagic pleural fluid from hemothorax.

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Disclosure of conflict of interest

None.

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