ORIGINAL ARTICLE

Prediction of anemia with thoracic computed tomography findings

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ABSTRACT

BACKGROUND: This study explored the potential of non-contrast thoracic computed tomography (CT) to predict anemia by correlating CT parameters with hemoglobin (Hb) levels in patients who underwent non-contrast thoracic CT for various indications.

METHODS: This retrospective study included 150 patients who underwent non-contrast thoracic CT scans and complete blood counts within 24 hours at our center between January and June 2023. Exclusion criteria included acute bleeding, iron accumulation disorders, recent transfusions, pregnancy, and certain thoracic CT artifacts. Hounsfield Unit (HU) measurements were obtained from the ascending aorta, left ventricular cavity, and descending aorta, and compared with Hb and hematocrit (Htc) values. Anemia indicators such as the "Aortic Ring Sign (ARS)" and the "Hyperdense Septum Sign (HSS)" were also evaluated.

RESULTS: Anemic patients (48%) exhibited significantly lower HU measurements at all three CT scan locations and higher instances of ARS and HSS compared to non-anemic patients. Notably, the presence of HSS and ARS was strongly associated with anemia. Thresholds for HU measurements corresponding to anemia were determined using receiver operating characteristic curve analysis, which also revealed strong positive correlations between HU measurements and Hb/Htc levels.

CONCLUSION: The study concludes that non-contrast thoracic CT parameters, particularly HU measurements and the presence of ARS and HSS, are significantly associated with anemia. These CT indicators could serve as reliable, non-invasive markers for predicting anemia in patients, potentially aiding in the early diagnosis and management of the condition.

Keywords: Anemia; computed tomograph; hemoglobin; hounsfield unit.

INTRODUCTION

Anemia, characterized by a deficiency of red blood cells or hemoglobin in the blood, is a global health issue affecting many individuals. According to the World Health Organization (WHO), it is projected that anemia impacts approximately 500 million women aged 15-49 years and about 269 million children between the ages of 6 and 59 months worldwide. In 2019, it was estimated that 30% (539 million) of non-pregnant women and 37% (32 million) of pregnant women within the age bracket of 15-49 years suffered from anemia.[1]

Traditionally, the diagnosis of anemia is confirmed by a complete blood count (CBC), including hemoglobin (Hb). Hb levels less than 13 grams per deciliter (g/dL) in men and 12 g/dL in women are generally considered anemic.[2] Although CBC is the primary tool for diagnosing anemia, it can also serve as an alternative method providing additional information about the patient, such as the severity of anemia, in cases where non-contrast chest CT is performed in the emergency department for any indication. Regarding this, several investigators have explored whether non-contrast thorax computed tomography (CT) can guide the diagnosis of anemia.[3] The presence of

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anemia could affect treatment decisions, so having an indicator of anemia from CT scan results could be beneficial.

Although there is a clear rationale and several studies on measuring blood pool density in anemic and non-anemic patients,[4-6] there are issues related to sex-specific anemia definitions. Therefore, we aimed to investigate whether non-contrast thorax CT can play a role in suspecting anemia by directly comparing CT parameters with hemoglobin values in cases who underwent non-contrast thorax CT for various reasons in our center.

MATERIALS AND METHODS

Patients Selection

This study included all consecutive patients aged 18 years and older who were admitted to our center between January 2023 and June 2023. These patients underwent non-contrast thorax CT and had a CBC performed within 24 hours for various indications. Demographic data, Hb, and hematocrit (Htc) values were documented for all cases included in the study. Patients with acute bleeding, iron accumulation, glycogen storage disease, a history of transfusion in the last seven days, pregnancy, and thorax CT examinations with contrast were excluded from the study. Images with pacing lead artifacts extending into cardiac chambers, aortic calcifications, metallic valve replacements, and respiration abnormalities that may affect the measurements were also excluded. The study was approved by the local institutional review boards (26.07.2023/1137).

Quantitative Measurements

Non-contrast CT images of the thorax were acquired using a 128-detector spiral CT scanner (GE Optima CT660, USA). Hounsfield Unit (HU) measurements were made on the reconstructed axial images with a section thickness of 3 mm and soft-tissue window settings (window, 400 H; level, 30 H) on a commercial Picture Archiving and Communication System PACS-based workstation. An average of 1.5 cm^2 diameter region of interest was placed in the ascending aorta (AA), left ventricular cavity (LV), and descending aorta (DA) (Fig. 1). Three measurements were taken from each point to obtain a consistent value, and their average was recorded.

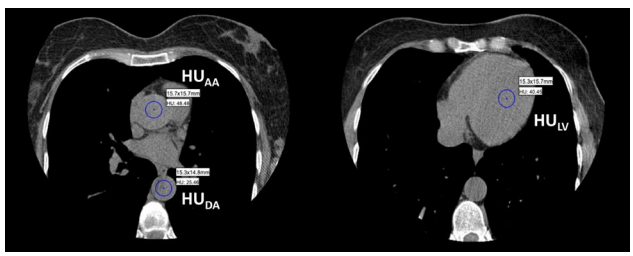

Figure 1. Quantitative image analysis: The region of interest (ROI) with a minimum of 1 cm was placed in the ascending aorta (Hounsfield Unit Ascending Aorta - HUAA), descending aorta (HUDA), and left ventricle (HULV).

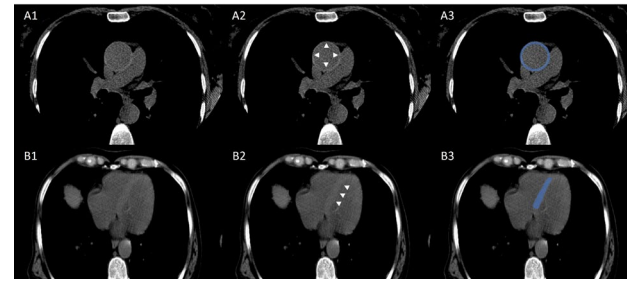

Figure 2. (A1-3) Aortic ring sign. (B1-3) Hyperdense interventricular septum sign in a 65-year-old anemic patient.

HU measurements were performed by a radiologist who was blinded to the hemoglobin levels.

Definition of Categorical Variables

According to current guidelines, anemia was defined as Hb levels below 13 g/dL in men and below 12 g/dL in women.[2] The "Aortic Ring Sign (ARS)" and the "Hyperdense Septum Sign (HSS)" were defined consistent with literature descriptions. The myocardium or interventricular septum appears more attenuated than the comparatively low-density left ventricle cavity, termed the "HSS sign." Similarly, a more attenuated aortic wall relative to the less dense aortic blood pool is termed the "ARS" (Fig. 2).[7] Two independent readers assessed and documented these subjective findings without knowledge of the Hb levels. Cases with unequivocal reports were ultimately excluded from the study.

Statistical Analysis

The data analysis was performed using IBM SPSS version 20.0 software for Windows (IBM Corp., Armonk, NY, USA). Continuous variables were depicted as mean ± standard deviation (with minimum-maximum values) or median values (25th-75th percentiles). Categorical variables were shown as counts and percentages. To evaluate significant differences in continuous variables across specific patient groups, we utilized either the independent samples t-test or the Mann-Whitney U test. The chi-square test was employed for comparing categorical data. Relationships between continuous variables, such as CT values at particular points and levels of Hb and Htc, were assessed using either Pearson's or Spearman's correlation tests, depending on suitability. Receiver operating characteristic (ROC) curve analysis was used to set thresholds for CT value measurements from specific regions and Hb thresholds for certain categorical variables. To identify independent predictors of defined thresholds, multivariable logistic regression analysis was performed with parameters showing a value less than 0.05 in univariate analysis. The diagnostic effectiveness of these thresholds was evaluated through measures like sensitivity, specificity, and area under the curve (AUC), complemented by their confidence intervals (CI). A p-value below 0.05 was deemed statistically significant.

RESULTS

This study comprised 150 patients, nearly half of whom were anemic (48.0%, n=72). The patients' ages ranged from 22 to 93 years, with a mean age of 60 years. The anemic group was significantly older than the non-anemic group (67±14 vs. 53±12 years, p<0.001). The gender distribution among both groups was roughly equal, with no significant difference observed.

The comparison of hemogram and CT values of anemic and non-anemic patients is provided in Table 1. The median Hb level for the entire cohort was 12.6 g/dL. As expected, anemic patients had significantly lower Hb than the non-anemic group (9.2 vs. 14.1 g/dL, p<0.001). Similarly, the mean Htc level was lower in the anemic group compared to the non-anemic group (30.3% vs. 43.2%, p<0.001). The density of blood, measured by Hounsfield Units (HU), at different areas, including the AA (HUAA), DA (HUDA), and LV (HULV), was also significantly lower in anemic patients (p<0.001 for HUAA and HULV; p=0.034 for HUDA). Furthermore, the incidence of HSS and ARS was markedly higher in the anemic group (51.4% vs. 1.3%, p<0.001; 58.3% vs. 6.4%, p<0.001, respectively).

Table 2 provides a comparison between the presence and absence of ARS and HSS in relation to anemia, Hb levels, Htc levels, and CT measurements. The presence of HSS was observed in 38 patients (25.3%). The median Hb level was significantly lower in patients with HSS than in those without it (9.0 vs. 13.1 g/dL, p<0.001). Similarly, the mean Htc level was lower in patients with HSS than in those without (28.3% vs. 40.0%, p<0.001). Anemia was more prevalent in patients with HSS (97.4% vs. 31.3%, p<0.001). The HUAA, HUDA, and HULV were also significantly lower in patients with HSS. ARS was present in 47 patients (31.3%). Similar to the findings with HSS, patients with ARS had lower median Hb levels, lower mean Hct levels, and a higher prevalence of anemia. CT value measurements (HUAA, HUDA, and HULV) were also lower in patients with ARS. It is also interesting to note the strong co-occurrence of HSS and ARS. In the presence of ARS, HSS was also present in 66.0% of cases, and vice versa; in the presence of HSS, ARS was found in 86.1% of cases. These findings reinforce the potential of these signs as indicators of anemia.

A correlation analysis was conducted between various CT value measurements (HUAA, HUDA, and HULV), and both Hb and Htc levels (Table and correlation plots are provided in Supplementary Files S1 and S2). There is a significant positive correlation between HUAA and both Hb [correlation coefficient (CC) = 0.508, p<0.001] and Hct [Pearson correlation (PC) = 0.479, p<0.001]. Similarly, there was a significant positive correlation between HUDA and both Hb (CC=0.299, p<0.001) and Hct (PC=0.337, p<0.001). The strongest correlation was observed between HULV and Hb (CC=0.596, p<0.001) and Hct (PC=0.570, p<0.001), indicating that HULV has a substantial positive relationship with these hematological parameters. In addition, significant positive correlations were found between the different CT value measurements.

By ROC analysis, we have identified threshold levels of hemoglobin that could be used to detect the presence of both ARS and HSS (Supplementary File 3). For ARS, the threshold level of hemoglobin has been determined to be ≤10.4 g/dL. This threshold shows a sensitivity of 80.8% and a specificity of 83.5%. Similarly, for HSS, the threshold level of hemoglobin has been found to be ≤10.0 g/dL. This threshold exhibits a sensitivity of 89.4% and a specificity of 83.9%.

Table 1. Comparison of hemogram and CT values between anemic and non-anemic patients

	All patients (N=150)	Anemic (n=72; 48.0%)	Non-anemic (n=78; 52.0%)	p
Age (years) Mean±SD [min-max]	60±14 (22-93)	67±14 (31-93)	53±12 (22-76)	<0.001*
Sex (M:F)	89:61	41:31	48:30	0.567†
Hb (g/dL) Median [25th-75th percentile]	12.6 (9.8-14.1)	9.2 (8.0-10.4)	14.1 (13.0-15.0)	<0.001‡
Hct (percent) Mean±SD [min-max]	37.0±7.7 (19.0-56.2)	30.3±4.6 (19.0-42.6)	43.2±3.7 (37.5-56.2)	<0.001*
HUAA Mean±SD [min-max]	37±7 (12-56)	35±8 (12-56)	39±6 (20-56)	<0.001*
HUDA Mean±SD [min-max]	35±7 (19-68)	34±7 (20-52)	37±7 (19-68)	0.034*
HULV Mean±SD [min-max]	39±7 (18-61)	36±7 (18-61)	43±5 (26-55)	<0.001*
Presence of HSS	38 (25.3)	37 (51.4)	1 (1.3)	<0.001†
Presence of ARS	47 (31.3)	42 (58.3)	5 (6.4)	<0.001†

Anemia: Defined as hemoglobin levels less than 12 g/dL for women and less than 13.0 g/dL for men. ARS: Aortic Ring Sign; Hb: Hemoglobin; Hct: Hematocrit; HSS: Hyperdense Septum Sign; HUAA: Measured radiodensity of blood at the level of the ascending aorta; HUDA: Measured radiodensity of blood at the level of the descending aorta; HULV: Measured radiodensity of blood in the left ventricular cavity. *Independent samples T-test. †Pearson's Chi-square test/Fisher's Exact Test. ‡Mann-Whitney U test.

Table 2. Comparison between the presence and absence of the ARS and HSS in relation to anemia, Hb levels, Htc levels, and CT measurements

	Hyperdense Septum Sign		Aortic Ring Sign		p HSS/p ARS
	Present 38 (25.3)	Absent 112 (74.7)	Present 47 (31.3)	Absent 103 (68.7)	
Hb (g/dL, Median [25th-75th percentile]	9.0 (8.0-10.0)	13.1 (11.2-14.7)	9.0 (8.0-10.0)	13.6 (12.0-14.8)	<0.001†/<0.001‡
Hct (percentage) Mean±SD [min-max]	28.3±4.0 (19.0-37.7)	40.0±6.3 (24.0-56.2)	29.9±5.3 (19.0-44.7)	40.3±6.2 (25.0-56.2)	<0.001*/<0.001*
Anemia (n [%])	37 (97.4)	35 (31.3)	42 (89.4)	41 (38.3)	<0.001†/<0.001†
Presence of HSS	-	-	31 (66.0)	7 (6.8)	-/<0.001†
Presence of ARS	31 (86.1)	16 (14.3)	-	-	<0.001†/-
HUAA (Mean±SD [min-max])	32±6 (12-47)	39±6 (20-56)	32±7 (12-47)	39±6 (20-56)	<0.001*/<0.001*
HUDA (Mean±SD [min-max])	31±6 (20-48)	37±7 (19-68)	32±6 (20-51)	37±7 (19-68)	<0.001*/0.002*
HULV (Mean±SD [min-max])	33±6 (18-44)	42±6 (26-61)	34±7 (18-48)	42±6 (26-61)	<0.001*/<0.001*

Anemia: <12g/dL for women and <13.0 g/dL for men; ARS: Aortic Ring Sign; Hb: Hemoglobin; Hct: Hematocrit; HSS: Hyperdense Septum Sign; HUAA: Measured radiodensity of blood at the level of the ascending aorta; HUDA: Measured radiodensity of blood at the level of the descending aorta; HULV: Measured radiodensity of blood at the left ventricular cavity. *Independent samples T-test. †Pearson's Chi-square test/Fisher's Exact test. ‡Mann-Whitney U test.

Table 3. Comparison of various CT parameters against defined Hb thresholds

	All patients (N=150)	Hb<10g/dL (n=37; 24.7%)	Hb≥10g/dL (n=113; 75.3%)	p*
HUAA ≤37	73 (48.7)	32 (86.5)	41 (36.3)	<0.001
HUDA ≤33	57 (38.0)	34 (47.2)	23 (29.5)	0.001
HULV ≤38	60 (40.0)	30 (81.1)	30 (26.5)	<0.001
Presence of HSS	38 (25.3)	26 (70.3)	12 (10.6)	<0.001
Presence of ARS	47 (31.3)	28 (75.7)	19 (16.8)	<0.001

Hb: Hemoglobin; HUAA: Measured radiodensity of blood at the level of the ascending aorta; HUDA: Measured radiodensity of blood at the level of the descending aorta; HULV: Measured radiodensity of blood in the left ventricular cavity. *Pearson's Chi-square test/Fisher's Exact Test.

As these results suggest that the presence of ARS and HSS could be indicated by a universal hemoglobin threshold of <10.0 g/dL, we investigated possible corresponding cut-off values for HUAA, HUDA, and HULV (Supplementary File S4). For HUAA, a cut-off value of ≤37 was identified, offering a sensitivity of 86.5% and a specificity of 63.7%. For HUDA, a cut-off value of ≤33 was established, with a sensitivity of 62.2% and a specificity of 69.9%. Lastly, for HULV, a cut-off value of ≤38 was determined, yielding a sensitivity of 81.1% and a specificity of 73.5%. When comparing the curves, HUAA and HULV outperformed HUDA with significantly higher AUC values. The comparison between HUAA and HUDA revealed a significant difference of 0.141 (p=0.004). However, when comparing HUAA and HULV, the difference in AUC was minimal, suggesting no significant difference in the performance of these two measures. Finally, the comparison between HUDA and HULV showed a significant difference (p=0.005). The analysis was concluded in Table 3. When looking at the presence of HSS, 70.3% of the patients in the Hb<10g/dL group had this sign, compared to only 10.6% in the Hb≥10g/dL group (p<0.001). In the final analysis, the presence of ARS was observed in 75.7% of patients in the Hb<10g/dL group and 16.8% in the Hb≥10g/dL group (p<0.001).

After adjusting for potential confounders, multivariable logistic regression analysis showed that the presence of HSS [adjusted odds ratio (OR) 3.143, 95% CI 2.489-6.712, p<0.001] and ARS (OR 2.654, 95% CI 2.002-5.985, p=0.001) was independently associated with an Hb level ≤10.0 g/dL. In addition, lower HULV values (below 38) were found to be a strong predictor (OR 2.137, 95% CI 1.889-5.102, p=0.003) for an Hb level ≤10.0 g/dl. The validity of an Hb level ≤10.0 g/dL was assessed if ≥1, ≥2, or all three of the criteria (presence of ARS, presence of HSS, and HULV≤38) were found together. The best performance was achieved when at least two criteria were positive: sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were found to be 81.1%, 85.8%, 65.2%, 93.3%, and 84.6%, respectively (Supplementary File S5). These findings show that the coexistence of certain CT value measurements and certain indicators (HSS and ARS) is highly correlated, especially when the Hb level falls below 10 g/dL.

DISCUSSION

In the field of anemia prediction using radiological techniques, numerous studies have been conducted, each contributing to a rich body of literature. However, variability in research methodologies and different definitions in these studies result in a complex, multifaceted understanding of the correlation between hemoglobin levels and HU measurements.

Mahmoudi et al. assessed the potential of radiomic features to non-invasively predict moderate-to-severe anemia using non-contrast enhanced CT scans.[3] The results showed that a median HU value ≤36.5 indicated moderate-to-severe anemia, and first-order radiomic features correlate with hemoglobin levels and may be feasible for predicting moderate-to-severe anemia. Another article by Abbasi et al. aimed to evaluate the diagnostic accuracy of subjective and objective criteria for diagnosing anemia using unenhanced thoracic CT scans.[8] The findings indicated that a threshold value for aortic arch of 20 HU provided the best diagnostic performance for detecting severe anemia (defined as <8 g/dL). The subjective analysis revealed that the aortic ring sign was more sensitive in detecting anemia than the interventricular septum sign, but the latter was more specific. The study by Kamel et al. involved a sample of 50 patients with proven anemia and 50 non-anemic individuals.[9] The aortic ring sign was more sensitive than the interventricular septum sign for detecting anemia (84% vs. 72%). However, the latter sign was more specific (100% vs. 92%). When a threshold of ≤35 HU was used for diagnosing anemia, the sensitivity and specificity of the aortic CT attenuation value were 84% and 94% respectively, which was the largest area under the curve (0.89) among all diagnostic criteria. Lan et al. aimed to determine the most suitable computed tomography (CT) attenuation parameter for predicting the presence or severity of anemia.[10] They found that the best quantitative method for diagnosing anemia was the difference in CT attenuation between the left ventricle and interventricular septum. Title et al. classified patients as definitely anemic, probably anemic, indeterminate, probably not anemic, or definitely not anemic using a 5-point scale and recorded the HU measurements of the blood in the left ventricle.[11] The results indicated that HU measurements significantly outperformed subjective analyses by reviewers in distinguishing anemic from non-anemic states. Using a CT density threshold of 35 Hounsfield units, the sensitivity for diagnosing anemia was 76% with a specificity of 81%. In contrast, the sensitivity of the three reviewers ranged from 40-72%, with a specificity of 60-83%. In another study, researchers investigated the correlation between serum hemoglobin levels and attenuation values measured in the abdominal aorta and inferior vena cava (IVC) using routine abdominal unenhanced CT examinations.[12] They observed a stronger association between the aortic density and Hb levels in women than in men. However, this pattern was statistically significant only among non-anemic patients, while it was not the same in anemic patients. Linear regression analysis also revealed that the density of the IVC detected anemia more accurately than that of the abdominal aorta. Zhou et al. found a strong correlation between the hemoglobin concentration and CT attenuation of the difference between the interventricular septum (IVS) and left ventricle cavity (IVS-LV) (the determination coefficient was 0.818; $p<0.001$).[13] According to their study, the diagnostic value of IVS-LV HU value in diagnosing mild anemia was limited, while it was high for diagnosing moderate and severe anemia. Once the HU value was more than 13.5 HU, the sensitivity and specificity for diagnosing severe anemia in all genders were significantly good (94.7% and 83.6% in males; 82.4% and 84.6% in females). The paper by Zopfs et al. analyzed 522 patients who underwent contrast-enhanced Multidetector Computed Tomography (MDCT) of the chest and had Hb values.[14] The area under the curve (AUC) for differentiating healthy individuals from those with any type of anemia was 0.857 for men and 0.833 for women. The optimal thresholds for this distinction were 39.2 HU for men and 37.6 HU for women, with sensitivities of 0.72 and 0.77, and specificities of 0.85 and 0.81, respectively. To differentiate severe anemia from other conditions, the AUC was 0.879 for men and 0.932 for women. The optimal thresholds for this were lower, at 33.6 HU for men and 32.7 HU for women, with sensitivities of 0.78 and 1.00, and specificities of 0.87 and 0.79, respectively. The study found a significant linear relationship between Hb and CT attenuation on Virtual Non-Contrast (VNC) images. The equation to estimate Hb based on these measurements is $-0.875+0.329 \times HU$, indicating that for each unit increase in attenuation, the hemoglobin increases by 0.329 g/dL.

All these data converge on the significant correlation between hemoglobin levels and HU measurements. However, an essential point of discussion arises from the prevalent mischaracterization of anemia as a categorical variable in literature. Such categorization can lead to discrepancies, such as classifying a hemoglobin level of 12.5 g/dL as normal for women but as anemic for men. To address this discrepancy and align with our initial research objectives, we sought a more universal hemoglobin threshold to meaningfully assess CT images and established a clinically relevant threshold of 10 g/dL. Finally, HSS, ARS, and lower HULV values (especially below 38) on non-contrast thorax CT are strong predictors for Hb<10 g/dL. This threshold has significant clinical implications, given its potential to reflect patient morbidity and guide management strategies, especially before emergency care and emergent surgical procedures.

Our research does have certain limitations. Firstly, while our sample size was acceptable, a larger cohort would provide a more robust dataset and potentially yield more nuanced insights. Secondly, the findings do not provide data on the anemic and non-anemic episodes of the same patient. Despite these limitations, our findings offer a valuable reference point for predicting anemia severity in patients and provide a basis for future investigations.

CONCLUSION

The present study demonstrated a definite correlation between Hb levels and HU measurements on non-contrast thorax CT. Combined with two or more criteria (presence of ARS, presence of HSS, and HULV≤38), which is a significant indicator of a lower Hb value, it may have important clinical implications in emergency care settings. The recommendation to emergency medicine clinicians in this direction will further facilitate the recognition of anemic patients.

Ethics Committee Approval: This study was approved by the Izmir Bakircay University Ethics Committee (Date: 26.07.202, Decision No: 1137).

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Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Toraks BT bulguları ile aneminin öngörülmesi

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AMAÇ: Bu çalışmada, çeşitli endikasyonlarla kontrastsız toraks BT çekilen hastalarda BT parametreleri ile hemoglobin (Hb) düzeyleri ilişkilendirilerek kontrastsız toraks bilgisayarlı tomografisinin (BT) anemiyi öngörme potansiyeli araştırıldı.

GEREÇ VE YÖNTEM: Retrospektif çalışma, Ocak-Haziran 2023 tarihleri arasında merkezimizde 24 saat içinde kontrastsız toraks BT taraması ve tam kan sayımı yapılan 150 hastayı kapsamaktadır. Dışlama kriterleri arasında akut kanama, demir birikimi bozuklukları, yakın zamanda transfüzyon, gebelik ve bazı toraks BT artefaktları yer aldı. Hounsfield Ünitesi (HU) ölçümleri çıkan aort, sol ventrikül boşluğu ve inen aorttan elde edilmiş ve Hb ve hematokrit (Htc) değerleriyle karşılaştırıldı. "Aortik Halka İşareti (ARS)" ve "Hiperdens Septum İşareti (HSS)" gibi anemi göstergeleri değerlendirildi.

BULGULAR: Anemik hastalar (%48), anemik olmayan hastalara kıyasla her üç yerden BT ölçümümde de anlamlı derecede daha düşük HU ölçümleri gösterdi. Özellikle HSS ve ARS varlığı anemi ile güçlü bir şekilde ilişkiliydi. Anemiye karşılık gelen HU ölçümleri için eşik değerler ROC analizi ile elde olunmuş olup, HU ölçümleri ile Hb/Htc seviyeleri arasında güçlü pozitif korelasyonlar ortaya koyuldu.

SONUÇ: Bu çalışma, kontrastsız toraks BT parametrelerinin, özellikle de HU ölçümleri ile ARS ve HSS varlığının anemi ile anlamlı bir ilişkisi olduğu sonucuna varmıştır. Bu BT göstergeleri, hastalarda anemiden şüphelenmek için güvenilir, invazif olmayan belirteçler olarak kullanılabilir ve durumun erken teşhisine ve yönetimine yardımcı olabilir.

Anahtar sözcükler: Anemi; bilgisayarlı tomografi; hemoglobin; hounsfield ünitesi.

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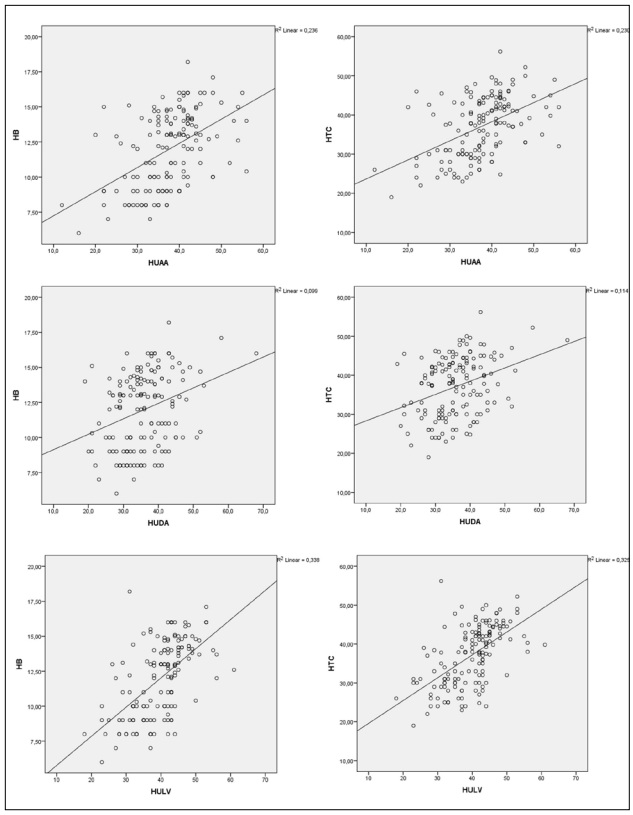
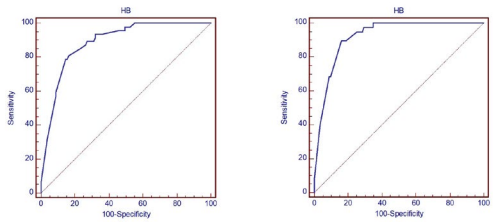


Supplementary Figure S2. Correlation plots.



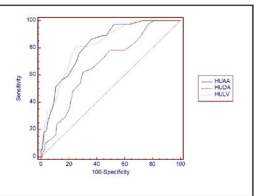
	ARS				HSS			
	Cut-off	AUC	Sensitivity	95% CI	Specificity	95% CI	+LR	-LR
Presence of ARS	≤10,4	0,888	80,8	66,7 - 90,8	83,5	74,9 - 90,1	4,90	0,23
Presence of HSS	≤10	0,921	89,4	75,2 - 97,0	83,9	75,8 - 90,2	5,57	0,13

ARS: aortic ring sign; AUC: area under curve; CI: confidence interval; Hb: hemoglobin; HSS: hyperdense septum sign; LR: likelihood ratio

Supplementary Figure S3. Receiver operating characteristic (ROC) analysis of hemoglobin (Hb) levels to diagnose the presence of subjective variables.

	Cut-off	Sensitivity	Specificity	AUC	95% CI
HU_{AA}	≤37	86,5	63,7	0,819	0,748 - 0,877
HU_{DA}	≤33	62,2	69,9	0,678	0,597 - 0,752
HU_{LV}	≤38	81,1	73,5	0,821	0,750 - 0,879

AUC: area under curve; CI: confidence interval; Hb: hemoglobin;
HU_{AA}: measured radiodensity of blood at the level of ascending aorta;
HU_{DA}: measured radiodensity of blood at the level of descending aorta;
HU_{LV}: measured radiodensity of blood at left ventricular cavity



Supplementary Figure S4. ROC analysis of HU measurements to diagnose Hb<10g/dL.