E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.01.302

Original Research Article

Relationship between CT Number and Haemoglobin Level - A Descriptive Study

Dr. Reji Rajan Varghese[1*], Dr. Suma Job[2]

[1*]Assistant Professor, Department of Radiodiagnosis, Government Medical College, Ernakulam, Kerala, India.

[2]Ex. Associate Professor, Department of Radiodiagnosis, Government T.D. Medical College, Alappuzha, Kerala, India.

Corresponding Author: Dr. Reji Rajan Varghese

Assistant Professor, Department of Radiodiagnosis, Government Medical College, Ernakulam, Kerala, India.

Received: 03.03.26, Revised: 19.03.26, Accepted: 09.05.26, Published: 13.05.2026

ABSTRACT

Background: Haemoglobin, the iron-containing metalloprotein in red blood cells, is the principal determinant of blood density. CT numbers (Hounsfield Units, HU) represent relative X-ray attenuation of tissues. Because iron attenuates X-rays more than soft tissue, it is physiologically plausible that haemoglobin concentration influences CT attenuation in blood-filled structures. Despite this, routine radiological reporting does not account for the effect of haemoglobin on CT numbers. This study aimed to quantify that relationship and assess its utility for incidental anaemia detection.

Methods: A descriptive study was conducted over 18 months at the Department of Radiodiagnosis, Government T.D. Medical College, Alappuzha. Two hundred consecutive patients undergoing unenhanced CT of the thorax and/or abdomen with a contemporaneous haemoglobin value were enrolled by convenience sampling. Regions of interest (ROIs) were placed in the aorta, inferior vena cava (IVC), left ventricle (LV), liver, and spleen. CT numbers were extracted using RadiAnt Viewer and MATLAB. Mean, median, mode, minimum, and maximum pixel values from each ROI were recorded. Pearson correlation and linear regression were performed using SPSS.

Results: Of 200 subjects (105 males, 95 females), mean haemoglobin was 12.3 g/dL in males and 11.6 g/dL in females. Strong positive Pearson correlations were observed between haemoglobin and mean CT numbers of the aorta ($r = 0.816$), IVC ($r = 0.751$), and LV ($r = 0.737$), all significant at $p < 0.01$. Mean, median, and mode values showed similar correlations; minimum and maximum values did not correlate. CT numbers of the liver ($r = 0.19$) and spleen ($r = 0.14$) showed no clinically meaningful correlation.

Conclusion: Haemoglobin levels are positively correlated with CT numbers in vascular blood pools (aorta, IVC, left ventricle) but not in parenchymal organs (liver, spleen). These findings support the feasibility of incidental anaemia detection and haemoglobin estimation from routine unenhanced CT images, with potential applications in clinical management and forensic radiology.

Keywords: Haemoglobin, CT Number, Hounsfield Unit, Unenhanced CT, Anaemia, Aorta, Inferior Vena Cava, Left Ventricle, Pearson Correlation, Regression, ROC Curve.

INTRODUCTION

CT scan machines reconstruct cross-sectional images from the differential X-ray attenuation of tissues. Each volume element (voxel) is represented as a pixel with a CT number expressed in Hounsfield Units (HU), calibrated such that water = 0 HU and air = −1000 HU. The CT number of a tissue is given by the formula: $CTn = (\mu - \mu w) / \mu w \times 1000$, where μ and μw are the linear attenuation coefficients of the tissue and water, respectively.[1,2]

Haemoglobin (Hb) is the iron-containing metalloprotein in red blood cells responsible for oxygen transport. Its normal concentration is 14–18 g/dL in adult males and 12–16 g/dL in adult females.[3,4] One molecule of haemoglobin contains four haem groups, each incorporating an iron (Fe^{2+}) ion. Because iron has a substantially higher atomic number than the principal constituents of soft tissue, increased haemoglobin content increases the electron density of blood, raising its X-ray attenuation.[5]

It is therefore physiologically logical that CT numbers in blood-filled vascular structures-such as the aorta, inferior vena cava (IVC), and cardiac chambers-should increase proportionally with haemoglobin concentration. The possible influence of haemoglobin on CT numbers is not considered in routine radiological image evaluation. Prior work in cranial venous sinuses by Bruni et al.[6] and in the IVC and aorta by Collins et al.[7]

demonstrated significant correlations in Western populations. However, CT number values may vary between scanner manufacturers,[8,9] and no published study had previously evaluated this relationship in an Indian tertiary care setting or with the specific Siemens Somatom Spirit scanner used in our department. This study was therefore undertaken to determine the relationship between haemoglobin level and CT number in our local patient population and to explore its potential clinical applications, including incidental anaemia detection and haemoglobin prediction from CT images.

Aims and Objectives

The primary aim was to study the relationship between haemoglobin values and CT numbers (Hounsfield Units) across five anatomical regions of interest. The objective was to assess how changes in haemoglobin level affect relative attenuation in the aorta, IVC, left ventricle, liver, and spleen.

MATERIALS AND METHODS

Study Design and Setting

A descriptive observational study was conducted over 18 months at the Department of Radiodiagnosis, Government T.D. Medical College, Alappuzha, following approval by the Institutional Ethics Committee.

Participants

All consecutive patients referred for unenhanced CT of the thorax and/or abdomen who had a haemoglobin value available within 48 hours of scanning were eligible. Exclusion criteria were: refusal of consent; absence of a contemporaneous haemoglobin value; significant motion artefact; calcified vessels within the ROI; previous splenectomy; and active bleeding with a rapidly changing haemoglobin level.

Sample Size

Based on the standard deviation of mean aortic attenuation reported by Kamel et al.[10] ($\sigma = 7$ HU, precision $d = 1$, $Z\alpha = 1.96$), the estimated sample size was $n = Z\alpha^2 \times \sigma^2 / d^2 \approx 196$, rounded to 200.

CT Acquisition Protocol

All scans were acquired on a Siemens Somatom Spirit dual-slice CT scanner (130 kVp, variable mA, pitch 1, slice thickness 3 mm, spiral mode with breath-hold, matrix 512 × 512, convolution kernel B41s, window level 40, window width 400). Unenhanced images only were used, as contrast agents confound attenuation measurements. DICOM images were transferred for analysis.

ROI Placement and CT Number Extraction

Representative axial slices were selected using RadiAnt Viewer for best delineation of each structure. ROIs were placed within the lumen of the aorta (at the level of the diaphragm), IVC (same level), and left ventricular cavity (mid-ventricular axial plane), as well as within the hepatic parenchyma (right lobe, avoiding vessels and focal lesions) and splenic parenchyma. ROI pixel data were exported in DICOM format and processed in MATLAB, which computed the mean, median, mode, minimum, and maximum CT numbers for each ROI. The CT scanner's inbuilt software and RadiAnt Viewer report only mean values; MATLAB enabled extraction of the full pixel distribution.

Statistical Analysis

Data were expressed as mean ± SD. Pearson's correlation coefficient (r) was computed between haemoglobin and each CT number parameter. Simple and multivariate linear regression models were constructed for structures with significant correlation. ROC curve analysis was performed separately for males and females, using WHO anaemia cut-offs (Hb < 13 g/dL for males; < 12 g/dL for females) as the reference standard. Area under the curve (AUC), optimal cut-off values, sensitivity, and specificity were reported. All analyses were performed using SPSS.

RESULTS

Baseline Characteristics

Two hundred subjects were enrolled: 105 males (52.5%) and 95 females (47.5%). Mean haemoglobin was 12.3 g/dL in males and 11.6 g/dL in females. Applying WHO anaemia criteria, 55 of 105 males (52%) and 45 of 95 females (47%) were anaemic. The haemoglobin distribution approximated a Gaussian curve in both sexes, spanning from severely anaemic (<5 g/dL) to above-normal values, providing a wide range for correlation analysis.

Parameter	Males (n=105)	Females (n=95)
Mean Age (years)	—	—
Mean Haemoglobin (g/dL)	12.3	11.6
Haemoglobin range (g/dL)	5.2 – 17.9	4.1 – 17.0
Anaemic by WHO criteria	55 (52%)	45 (47%)

Table 1: Baseline Demographic and Haematological Characteristics

Haemoglobin vs CT Numbers: Vascular Structures

Scatter plots of haemoglobin against mean CT numbers of the aorta, IVC, and left ventricle each showed a positive linear trend. As haemoglobin increased, CT attenuation rose in all three vascular regions. The IVC consistently showed slightly lower absolute attenuation values compared to the aorta and left ventricle, but the positive relationship with haemoglobin was maintained across all three.

Pearson Correlation Matrix

Table 2 shows the Pearson correlation matrix for haemoglobin with mean, median, and mode CT numbers from the aorta, IVC, and left ventricle. All correlations with haemoglobin were strongly positive and statistically significant ($p < 0.01$). The mean CT number of the aorta showed the highest correlation with haemoglobin (r = 0.816), followed by IVC mean (r = 0.751) and LV mean (r = 0.737). Median and mode values produced almost identical correlation coefficients to the mean for each region, indicating that the mean alone-as reported by standard CT software-is sufficient.

	Aorta Mean	Aorta Mode	Aorta Median	IVC Mean	LV Mean	LV Median
Haemoglobin (r)	0.816	0.815	0.813	0.751	0.737	0.719
Significance	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05	p<0.05

Table 2: Pearson Correlation Coefficients between Haemoglobin and CT Numbers of Vascular Rois (Selected Columns from Full Matrix)

Lowest and Highest CT Number Values

Correlation analysis using the minimum and maximum pixel values within each ROI (Table 3) showed no significant correlation with haemoglobin (r values ranging from −0.166 to 0.199 across all regions). This indicates that the extreme pixel values are dominated by noise and partial-volume artefacts, and only the mean (or equivalent central tendency) of the ROI is informative.

Haemoglobin vs.	IVC Low	IVC High	Aorta Low	Aorta High	LV Low	LV High
R	0.106	0.199	0.106	0.177	−0.166	−0.026
Significance	NS	NS	NS	NS	NS	NS

Table 3: Correlation of Haemoglobin with Lowest and Highest CT Numbers in Each ROI (NS = Not Significant)

Haemoglobin vs CT Numbers: Liver and Spleen

Scatter plots of haemoglobin against mean CT numbers of the liver and spleen showed no linear pattern. Pearson correlation coefficients were 0.19 (liver) and 0.14 (spleen), neither statistically significant. These parenchymal organs are composed of solid tissue whose CT attenuation is governed by intracellular constituents (glycogen, fat, iron stores, haematopoietic elements) rather than intravascular haemoglobin concentration.

DISCUSSION

This study confirms a strong positive correlation between haemoglobin levels and CT attenuation in vascular blood pools. The correlation was strongest for the aorta (r = 0.816), consistent with findings by Collins et al.[7] (r = 0.64 for aorta) and Kamel et al.[11] (r = 0.60), and slightly higher than values reported for cranial venous sinuses by Bruni et al.[6] (r = 0.46). The superior correlation of the aorta compared to the IVC in our study aligns with Yang et al.'s[10] finding that arterial blood sampling is more precise than venous, and may also reflect the aorta's wider, more circular lumen facilitating accurate ROI placement.

Mean vs Median and Mode

Unlike most prior studies that reported only mean attenuation, this study also extracted median and mode values from each ROI pixel distribution using MATLAB. Contrary to the hypothesis that the mode or median might better represent true blood attenuation by resisting outlier pixel effects, all three central tendency measures produced virtually identical correlation coefficients This is physiologically consistent: blood within a large vessel lumen is optically homogeneous, so the pixel distribution within the ROI is narrowly clustered.

Liver and Spleen

The absence of significant correlation in the liver (r = 0.19) and spleen (r = 0.14) is expected. Hepatic CT attenuation is primarily determined by intracellular glycogen content and fat deposition,[12] while splenic attenuation reflects haematopoietic cellularity and vascular congestion. These variables are substantially independent of circulating haemoglobin concentration. This finding is important: it establishes that the haemoglobin effect on CT numbers is specific to vascular blood pools and does not generalise to solid parenchymal organs.

Clinical and Forensic Implications

Incidental anaemia detection from CT has significant potential to influence patient management. In patients undergoing CT for oncological staging, trauma evaluation, or pre-operative assessment, a CT-flagged low haemoglobin could prompt timely haematological review and intervention. In resource-limited or emergency settings where laboratory tests are unavailable, CT-derived estimates may guide urgent decisions. In forensic pathology, where post-mortem CT is increasingly used as an adjunct to autopsy, haemoglobin estimation from CT numbers could assist in quantifying ante-mortem blood loss. As this study established relationships specific to the Siemens Somatom Spirit scanner at 130 kVp, scanner-specific calibration would be required before generalisation.

Limitations

The study population consisted of patients referred for CT scanning and may not represent the general population. CT numbers are known to vary between scanner models and manufacturers; findings may require recalibration for other machines. No attempt was made to model other potential confounders of CT attenuation (e.g. scanner noise, beam hardening, calibration drift). Only the unenhanced phase was analysed; the impact of haemoglobin in contrast-enhanced phases warrants separate investigation.

CONCLUSION

Haemoglobin levels are strongly and positively correlated with CT numbers in vascular blood pools-the aorta (r = 0.816), IVC (r = 0.751), and left ventricle (r = 0.737)-but not in parenchymal organs such as the liver or spleen. Mean CT number is equivalent to median and mode in predictive power, confirming that standard scanner-reported values are adequate. These findings establish the feasibility of haemoglobin estimation and incidental anaemia detection from routine unenhanced CT, with potential applications in clinical management and forensic radiology. Prospective multi-centre validation is recommended before clinical implementation.

REFERENCES

1. Suetens P. Fundamentals of Medical Imaging. Cambridge University Press 2009.
2. Haaga JR, Boll DT. CT and MRI of the Whole Body. Elsevier 2016.
3. Barrett KE, Barman SM, Boitano S, et al. Ganong's review of medical physiology. 25th edn. USA: McGraw-Hill 2016.
4. Kasper DL, Fauci AS, Hauser SL, et al. Harrison's principles of internal medicine. Vol. 2. 19th edn. New York: McGraw-Hill 2015.
5. New PF, Aronow S. Attenuation measurements of whole blood and blood fractions in computed tomography. Radiology 1976;121(3):635-40.
6. Bruni SG, Patafio FM, Dufton JA, et al. The assessment of anemia from attenuation values of cranial venous drainage on unenhanced computed tomography of the head. Can Assoc Radiol J 2013;64(1):46-50.
7. Collins A, Gillespie S, Kelly B. Can computed tomography identify patients with anaemia? Ulster Med J 2001;70(2):116.
8. Levi C, Gray JE, McCullough EC, et al. The unreliability of CT numbers as absolute values. AJR Am J Roentgenol 1982;139(3):443-7.
9. Lamba R, McGahan JP, Corwin MT, et al. CT Hounsfield numbers of soft tissues on unenhanced abdominal CT scans: variability between two different manufacturers' MDCT scanners. AJR Am J Roentgenol 2014;203(5):1013-20.
10. Yang ZW, Yang SH, Chen L, et al. Comparison of blood counts in venous, fingertip and arterial blood and their

measurement variation. Clin Lab Haematol 2001;23(3):155-9.

11. Kamel EM, Rizzo E, Duchosal MA, et al. Radiological profile of anemia on unenhanced MDCT of the thorax. Eur Radiol 2008;18(9):1863-8.

12. Ganeshan B, Miles K, Young R, et al. Hepatic entropy and uniformity: additional parameters that can potentially increase the effectiveness of contrast enhancement during abdominal CT. Clin Radiol 2007;62(8):761-8.