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Detection of Anemia on Non-Contrast Chest CT: A Prospective Cross-Sectional Study from Nepal

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ABSTRACT

Introduction: Anemia affects 24.8% of the global population. Complete blood count remains the diagnostic gold standard, but laboratory access is limited in rural Nepal. Blood attenuation on non-contrast computed tomography (NCCT) correlates directly with hemoglobin concentration. The study aims to evaluate diagnostic accuracy of subjective signs and objective Hounsfield unit (HU) measurements for detecting anemia on non-contrast chest CT in a Nepalese population.

Methods: In this prospective cross-sectional study (May–December 2024), 329 adults undergoing non-contrast chest CT with hemoglobin assay within 7 days were enrolled. Anemia was defined as hemoglobin <10 g/dL. Two blinded radiologists assessed aortic rim and interventricular septum signs. Mean HU values were measured in the left ventricle, right ventricle, pulmonary trunk, inferior vena cava, and ascending aorta. Diagnostic performance and area under the receiver operating characteristic curve (AUC) were calculated.

Results: Of 329 participants (mean age 58.0±14.2 years; 58% male), 101 (30.7%) were anemic. Aortic rim sign showed sensitivity 88.1% and specificity 75.9% (χ^2 $p<0.001$). The interventricular septum sign had a sensitivity 91.1% but a specificity 70.6%. HU measurements correlated significantly with hemoglobin across all sites (all $p<0.001$), strongest for the left ventricle (r=0.625) and aorta (r=0.555). Left ventricle yielded the highest AUC (0.814), followed by right ventricle (0.808) and aorta (0.790). At a 35 HU cutoff in the left ventricle, sensitivity was 80.2% and specificity 73.7%.

Conclusions: Quantitative HU measurements, particularly in the left ventricle and aorta, demonstrate good diagnostic accuracy for anemia detection on non-contrast chest CT. In resource-limited settings like Nepal, opportunistic anemia screening during routine CT interpretation could prompt timely confirmatory testing and management.

Keywords: *Blood Cell Count; Heart Ventricles; Radiologists*

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INTRODUCTION

Anemia affects 24.8% of the global population. In Nepal, national surveys report a prevalence of 34% in women and 28% in men. Untreated anemia contributes to reduced work capacity, impaired cognition, maternal mortality, and increased perioperative risk.[1,2,3]

Complete blood count remains the diagnostic gold standard, but laboratory access is limited in rural Nepal. Non-contrast chest computed tomography (NCCT) is increasingly performed for pulmonary, cardiac, and oncologic indications without prior knowledge of hematologic status. Blood attenuation on NCCT, expressed in Hounsfield units (HU), correlates directly with hemoglobin concentration because hemoglobin is the primary determinant of X-ray attenuation in whole blood.[4,5]

Qualitative signs described in anemic patients include the "aortic rim sign" (hyperattenuating aortic wall relative to hypoattenuating intraluminal blood) and "interventricular septum sign" (increased septal conspicuity against hypodense left ventricular cavity)[6]. Quantitative HU thresholds in central vessels have also been proposed. However, most data derive from high-income countries with different anemia etiologies. Validation in the Nepalese population, where nutritional, infectious, and genetic causes predominate, is lacking.[7,8]

This study aimed to: (1) evaluate the diagnostic performance of subjective CT signs; (2) correlate hemoglobin with HU measurements at five anatomical sites; (3) determine optimal HU cutoffs using ROC analysis; and (4) assess the feasibility of opportunistic anemia detection during routine CT interpretation in Nepal.

METHODS

This prospective cross-sectional study was conducted at Patan Academy of Health Sciences (May–December 2024) after Institutional Review Committee approval (Ref. No. PAHS-2023-RES-015). Written informed consent was obtained. Adults aged 18–80 years undergoing NCCT with hemoglobin assay within 7 days were enrolled. Exclusion criteria: known anemia, recent transfusion, pregnancy, or contrast-enhanced CT. Sample size of 329 provided >90% power (α=0.05) based on anticipated sensitivity 73% and specificity 89%.[7]

All scans were performed on a 128-slice Philips Ingenuity CT scanner with standardized acquisition parameters (120 kVp, automatic tube current modulation, slice thickness 1 mm). No intravenous contrast was administered. Images were viewed on a PACS workstation (Philips IntelliSpace v7.0) using soft-tissue windows (window width 400 HU, level 40 HU).

Two radiologists with 5 and 8 years of experience, blinded to Hb values, independently assessed. Aortic rim sign was present if the aortic wall appeared denser than intraluminal blood. The IVS sign was present if the interventricular septum was clearly visible without contrast

For quantitative analysis, a circular region of interest (0.5-1.0 cm²) was placed in the lumen of the left ventricle, right ventricle, pulmonary trunk, inferior vena cava, and ascending aorta. Mean HU values were recorded. Interobserver agreement was excellent (κ=0.87); discrepancies were resolved by consensus.

Venous hemoglobin was measured via an automated hematology analyzer (Sysmex XN-1000). Anemia was defined as hemoglobin <10 g/dL (pragmatic threshold for moderate-severe anemia in Nepalese clinical practice).

Data were analyzed using R v4.2.2. Continuous variables expressed as mean±SD; categorical as frequencies (%). Pearson correlation assessed relationships between hemoglobin and HU. Diagnostic accuracy (sensitivity, specificity, PPV, NPV) was calculated. ROC curves determined AUC and Youden-index-based optimal cutoffs. Chi-square tests evaluated associations. P<0.05 is considered significant.

RESULTS

Demographics

Of 329 enrolled patients, 101 (30.7%) were anemic. Mean age 58.0 ± 14.2 years; 191 (58%) male. Mean hemoglobin 11.1 ± 2.5 g/dL (range 5.3-17.8) (Table 1).

Table 1: Participant Demographics and Characteristics (n=329)

Variable	Overall (n=329)	Non-anemic (n=228)	Anemic (n=101)	p-value
Age (years), mean ± SD	58.0 ± 14.2	57.2 ± 14.0	59.8 ± 14.6	0.142
Male sex, n (%)	191 (58.1)	133 (58.3)	58 (57.4)	0.887
Hemoglobin (g/dL), mean ± SD	11.1 ± 2.5	12.7 ± 1.3	7.5 ± 1.4	<0.001

Performance of subjective signs

Aortic rim sign showed sensitivity 88.1%, specificity 75.9%, PPV 61.8%, NPV 93.5% (χ^2 p<0.001). Interventricular septum sign had a sensitivity 91.1%, specificity 70.6%, PPV 57.9%, and NPV 94.7% (χ^2 p<0.001) (Table 2).

Table 2: Performance of Subjective CT Signs for Anemia Detection

Sign	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	χ^2 p-value
Aortic rim	88.1	75.9	61.8	93.5	<0.001
IVS	91.1	70.6	57.9	94.7	<0.001

Detailed crosstabulations showed that among 101 truly anemic patients (Hb <10 g/dL), 89 had a positive aortic rim sign, while only 12 anemic patients were missed by this sign. Similarly, 92 of 101 anemic patients demonstrated a positive IVS sign (Table 3).

Table 3: Crosstabulation of CT Signs vs. True Anemia (Hb <10 g/dL)

Aortic Rim Sign	Not Anemic (n=228)	Anemic (n=101)	Total
Negative	173 (75.9%)	12 (11.9%)	185
Positive	55 (24.1%)	89 (88.1%)	144
Total	228	101	329

IVS Sign	Not Anemic (n=228)	Anemic (n=101)	Total
Negative	161 (70.6%)	9 (8.9%)	170
Positive	67 (29.4%)	92 (91.1%)	159
Total	228	101	329

Correlation between hemoglobin and HU

All sites showed significant positive correlations between hemoglobin and HU (all p<0.001). Strongest correlations: left ventricle (r=0.625) and aorta (r=0.555); weakest: inferior vena cava (r=0.420) (Table 3).

Table 4: Pearson Correlation Coefficients (r) Between Hb and HU Measurements

Site	Correlation Coefficient (r)	p-value
Left Ventricle	0.625	<0.001
Aorta	0.555	<0.001
Right Ventricle	0.510	<0.001
Pulmonary Trunk	0.475	<0.001
Inferior Vena Cava	0.420	<0.001

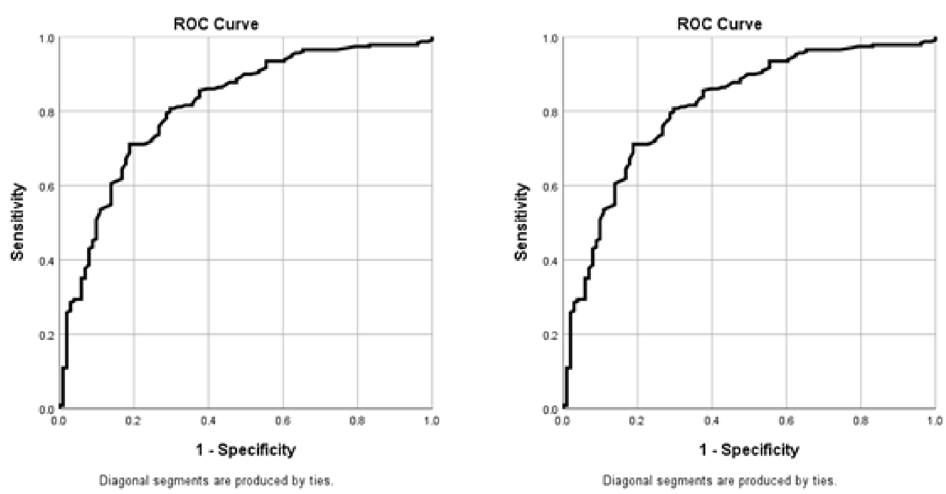
ROC Analysis and Optimal Thresholds

ROC analysis demonstrated the highest diagnostic accuracy for LV HU measurements (AUC=0.814), followed by RV (AUC=0.808), aorta (AUC=0.790), IVC (AUC=0.749), and PT (AUC=0.736) (Figure 1).

Table 5: ROC Analysis of HU Measurements for Anemia Detection

Site	AUC (95% CI)	Optimal Cutoff (HU)	Sensitivity (%)	Specificity (%)	Youden Index
Left Ventricle	0.814 (0.771-0.857)	35	80.2	73.7	0.539
Right Ventricle	0.808 (0.764-0.852)	34	78.2	75.9	0.541
Aorta	0.790 (0.744-0.836)	35	80.2	70.6	0.508
Inferior Vena Cava	0.749 (0.699-0.799)	33	74.3	68.4	0.427
Pulmonary Trunk	0.736 (0.685-0.787)	32	71.3	68.4	0.397

At the optimal cutoff of 35 HU for the aorta, sensitivity was 80.2% and specificity was 70.6%. For the LV at the same cutoff (35 HU), sensitivity was 80.2% with specificity of 73.7%.



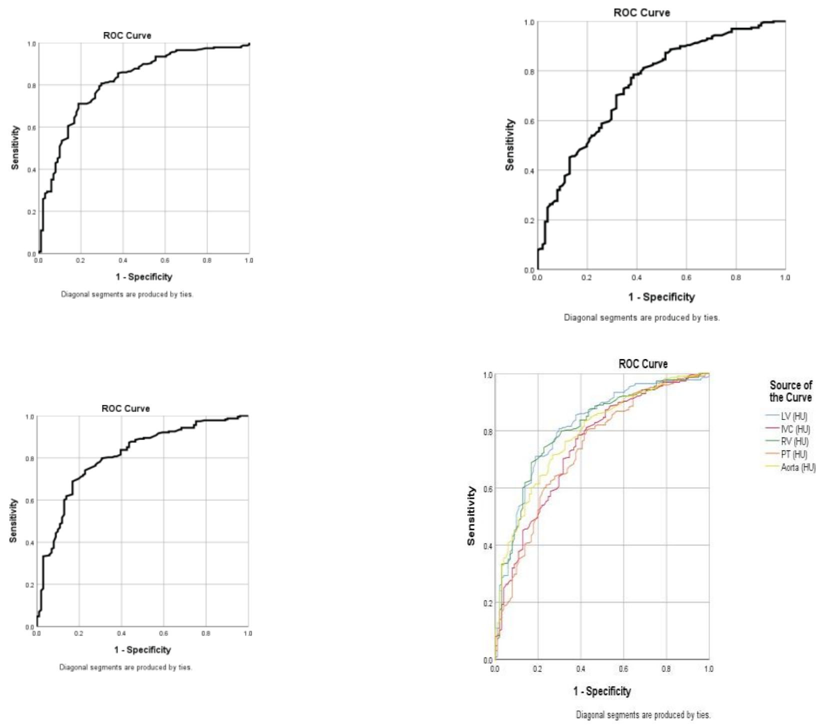


Figure 1: ROC curves for HU measurements at five anatomical sites for detection of anemia (Hb <10 g/dL). Left ventricle (LV); B. Inferior Vena Cava (IVC); C. Right Ventricle (RV); D. Pulmonary Trunk (PT) E. Aorta

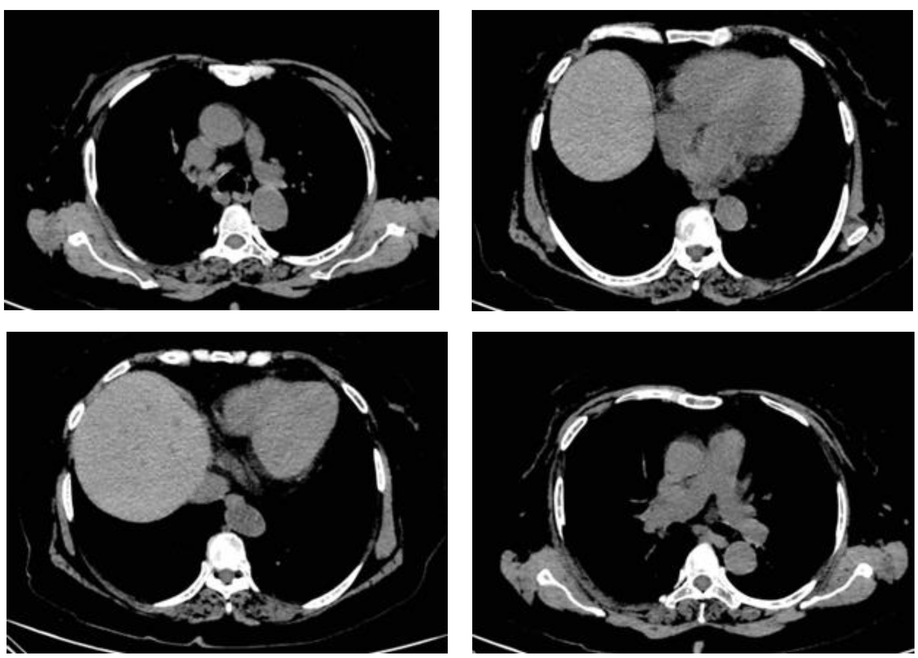


Figure 2: Composite NCCT Findings of Severe Anemia ($Hb = 6.3 g/dL) in a 60-Year-Old Female. This figure demonstrates the opportunistic diagnostic signs of anemia across multiple anatomical sites: the Aortic Rim sign (A), where the hyperdense vessel wall contrasts against hypodense blood; the Interventricular Septum (IVS) sign (B), showing increased septal conspicuity; and quantitative attenuation measurements within the Pulmonary Artery (C) and Inferior Vena Cava (D). All regions show Hounsfield Units (HU) significantly below the study's established threshold of 35 HU, illustrating a strong positive correlation (r = 0.475) between intravascular CT density and hemoglobin concentration as detailed in the manuscript's results

DISCUSSION

Our study demonstrates that both qualitative signs and quantitative HU measurements on NCCT reliably detect anemia in Nepalese patients. The aortic rim sign showed high sensitivity (88.1%) and moderate specificity (75.9%), consistent with prior literature. The interventricular septum sign had even higher sensitivity (91.1%) but lower specificity (70.6%), suggesting utility as a screening rather than confirmatory tool.[6,7,9]

Quantitative HU measurements outperformed subjective signs. Left ventricle yielded highest AUC (0.814), with 35 HU cutoff providing 80.2% sensitivity and 73.7% specificity. Our correlation coefficients (LV: r=0.625) align with biophysical principles that blood attenuation directly correlates with hemoglobin concentration.[5,11]

Our optimal cutoff (35 HU) aligns closely with Abbasi et al. (34–36 HU for aorta)[7] and Ghanem et al. (35 HU). Minor variations may reflect differences in scanner technology, population characteristics, or anemia etiologies. Notably, our cohort had higher prevalence of nutritional anemias (iron deficiency) compared to Western cohorts where anemia often stems from chronic disease.[12,13]

Clinical implications are significant for Nepal's resource-limited health system. Where laboratory services are unavailable or delayed, radiologists can leverage routine chest CT to identify probable anemia. A simple HU measurement in the aorta or left ventricle could trigger confirmatory testing.[14]

Limitations include: (1) pragmatic hemoglobin cutoff (<10 g/dL) rather than WHO criteria (<13/<12 g/dL); (2) single-center design limiting generalizability; (3) exclusion of pregnant women and transfused patients; (4) lack of anemia etiology assessment, which may influence HU-hemoglobin relationships.

Future multicenter studies should validate these thresholds using WHO definitions, evaluate the cost-effectiveness of CT-based screening in routine reporting, and investigate relationships between specific anemia etiologies (iron deficiency, vitamin B12 deficiency, hemoglobinopathies) and HU measurements.

CONCLUSION

Non-contrast chest CT provides quantifiable indicators of anemia in the Nepalese population. The aortic rim sign demonstrates good sensitivity, while quantitative HU measurements—particularly in the left ventricle-show excellent diagnostic accuracy. At a 35 HU cutoff, the left ventricle achieves 80.2% sensitivity and 73.7% specificity for detecting anemia. Integrating these findings into routine radiology practice could enhance opportunistic anemia detection in high-burden settings like Nepal, prompting timely confirmatory testing and appropriate management.

CONFLICT OF INTEREST

None

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None

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