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Carotid Flow Time and Inferior Vena Cava Collapsibility Index for Prediction of Active Bleeding in Upper Gastrointestinal Haemorrhage: A Prospective Emergency Department Study

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Research Article

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Abstract

Background

Upper gastrointestinal bleeding (UGIB) is a frequent and potentially life-threatening emergency in which early identification of active bleeding critically influences clinical decision-making. Conventional risk stratification tools rely predominantly on static variables and may not capture dynamic haemodynamic changes. This study evaluated the diagnostic performance of two point-of-care ultrasonography (POCUS)-derived parameters—carotid flow time (CFT) and inferior vena cava collapsibility index (IVC-CI)—for predicting endoscopically confirmed active or high-risk bleeding in patients presenting to the emergency department (ED) with UGIB.

Methods

A prospective, cross-sectional, single-centre observational study was conducted at a tertiary-care ED (1 September 2022–1 September 2023). Of 248 screened patients, 78 consecutive adults (≥ 18 years) met eligibility criteria. Bedside POCUS assessment of CFT and IVC-CI was performed prior to endoscopy. Active/high-risk bleeding was defined as Forrest Ia–IIc. Diagnostic performance was evaluated by receiver operating characteristic (ROC) analysis; pairwise AUC comparisons used the DeLong method. Univariate logistic regression evaluated variables associated with active bleeding. Analyses used IBM SPSS Statistics v26.0. The study is reported per STARD 2015.

Results

Active or high-risk bleeding was confirmed in 10 patients (12.8%). CFT was significantly lower in active bleeders (median 284 ms [IQR 276–289] vs. 305 ms [IQR 299–311]; $p < 0.001$). A CFT cutoff of < 289 ms yielded an AUC of 0.887 (95% CI: 0.749–1.000), with sensitivity 80%, specificity 94%, positive predictive value 67%, and negative predictive value 97%. IVC-CI was significantly lower in active bleeders (median 0.22 vs. 0.33; $p = 0.029$) with an AUC of 0.654 (95% CI: 0.458–0.849). DeLong comparison showed higher discriminatory performance for CFT than IVC-CI ($\Delta AUC = 0.233$; $p = 0.126$), although the difference was not statistically significant. On univariate logistic regression, each 1-ms decrease in CFT was associated with active bleeding (OR 0.842; 95% CI: 0.763–0.930; $p = 0.001$).

Conclusions

CFT is a rapidly obtainable POCUS parameter with high specificity for identifying active or high-risk bleeding in UGIB, with discriminatory performance comparable to BUN and GBS and numerically higher than IVC-CI. Its high negative predictive value (97%) supports its potential as a bedside rule-out tool. Prospective multicentre validation is warranted.

BACKGROUND

Upper gastrointestinal bleeding (UGIB) is one of the most frequent and potentially life-threatening emergencies encountered in the emergency department (ED), with reported annual incidences of 50–150 per 100,000 population [1, 2]. Despite advances in endoscopic therapy and pharmacological management, in-hospital mortality remains approximately 7–10%, and the risk of re-bleeding approaches 10% [3]. Outcomes are strongly determined by the speed with which active bleeding is recognised and definitive intervention initiated [4].

Several clinical scoring systems—including the Glasgow–Blatchford Score (GBS), the Rockall Score, and AIMS65—have been developed to guide risk stratification in UGIB [5, 6]. These tools perform well in identifying low-risk patients suitable for outpatient management but rely predominantly on static clinical and laboratory variables that may fail to reflect ongoing haemodynamic deterioration. A patient sustaining compensated haemorrhagic blood loss may maintain apparently normal vital signs despite clinically significant ongoing bleeding, thereby escaping early detection by conventional scoring alone [7, 8].

Point-of-care ultrasonography (POCUS) has emerged as a valuable real-time adjunct to the physical examination in emergency settings. Two POCUS-derived haemodynamic parameters have attracted interest as volume surrogates: carotid flow time (CFT) and inferior vena cava collapsibility index (IVC-CI). CFT—measured as the systolic ejection interval on the carotid Doppler waveform—serves as a non-invasive surrogate of left ventricular preload and cardiac output [9]. IVC-CI quantifies the respiratory variation in IVC diameter and is widely used as a marker of volume responsiveness [10]. Both parameters can be obtained within minutes at the bedside using standard ultrasound equipment.

Although CFT and IVC-CI have been investigated in hypovolaemia, septic shock, and perioperative volume assessment [11–13], their specific diagnostic value in UGIB for predicting endoscopically active bleeding remains insufficiently characterised. A single prior study by Karadadaş et al. demonstrated that CFT was significantly reduced in UGIB patients with active endoscopic lesions [14], but comprehensive ROC analysis comparing CFT and IVC-CI against each other and against conventional risk parameters has not been reported. The present study addresses this gap.

The aim of this study was to prospectively evaluate the diagnostic performance of CFT and IVC-CI for predicting active or high-risk bleeding—defined by Forrest classification on endoscopy—in adult UGIB patients presenting to the ED, and to compare these POCUS parameters with established clinical and laboratory predictors. We hypothesised that CFT would demonstrate superior discriminatory performance compared with IVC-CI for identifying active or high-risk bleeding, and would perform comparably to established clinical risk markers.

METHODS

Study Design and Setting

This was a prospective, cross-sectional, single-centre observational study conducted in the ED of Kanuni Sultan Süleyman Training and Research Hospital, a tertiary-care academic centre in Istanbul, Turkey (1 September 2022 to 1 September 2023). Ethical approval was granted by the institutional ethics committee (Reference: KAEK/2022.08.188; 11 August 2022). Written informed consent was obtained from all participants or their legally authorised representatives. The study was conducted in accordance with the Declaration of Helsinki and is reported in accordance with the STARD 2015 guidelines for diagnostic accuracy studies, with the STROBE statement applied to observational design elements. As an observational study, prospective trial registration was not mandatory; the study was approved and conducted in accordance with the institutional ethics committee protocol.

Participants

Inclusion Criteria

Adults aged ≥ 18 years presenting to the ED with suspected UGIB—defined by haematemesis, melaena, or coffee-ground vomiting in conjunction with a clinical decision to proceed to upper gastrointestinal endoscopy—were eligible for consecutive enrolment.

Exclusion Criteria

Patients were excluded for: (i) age < 18 years; (ii) pregnancy; (iii) refusal to provide informed consent; (iv) inability to obtain adequate ultrasonographic windows; (v) haemodynamic instability requiring immediate resuscitative intervention precluding POCUS assessment; (vi) known severe valvular heart disease, atrial fibrillation, or cardiac pacemaker use; (vii) known hepatic cirrhosis or portal hypertension (suspected variceal source); (viii) known carotid artery stenosis or prior carotid endarterectomy; (ix) unidentifiable bleeding source; (x) suspected lower gastrointestinal bleeding; or (xi) lower-limb amputation.

Patient Flow

Of 248 patients presenting to the ED with suspected gastrointestinal bleeding during the study period, 92 were excluded (lower GI bleeding source), 55 declined consent, and 33 left before assessment was complete. The remaining 78 patients with suspected UGIB were enrolled. Of these, 45 did not require endoscopy based on clinical assessment (GBS = 0 or clinical decision by attending gastroenterologist); 33 underwent endoscopy, of whom 23 were classified as Forrest IIIa or III (no active bleeding) and 10 as active/high-risk (Forrest Ia–IIc). The study was terminated upon reaching the pre-specified target sample size of 78 patients.

Ultrasound Protocol

IVC Collapsibility Index

IVC assessment was performed using a curvilinear probe (LAS-16AD) via the subcostal longitudinal approach, with the patient supine under spontaneous respiration. Using M-mode imaging, maximum expiratory (IVCmax) and minimum inspiratory (IVCmin) diameters were measured 2 cm distal to the IVC–right atrial junction, proximal to the hepatic vein insertion. IVC-CI was calculated as: IVC-CI = (IVCmax − IVCmin) / IVCmax. One patient with active bleeding had an uninterpretable IVC minimum diameter (IVCmin not recordable); this patient was excluded from IVC-CI analyses, yielding nine evaluable active bleeders for IVC-CI comparisons.

Carotid Flow Time

CFT was measured using a linear probe (PN2-4, 5–10 MHz) placed over the common carotid artery with the patient supine, head rotated 30° contralaterally. Pulse-wave Doppler was applied with insonation angle ≤ 60°. CFT was defined as the interval from the onset of systolic upstroke to the dicrotic notch on the Doppler spectral waveform, measured in milliseconds, and averaged over three consecutive cardiac cycles. Heart rate correction (CFTc) was not applied, as groups did not differ significantly in heart rate (93.80 vs. 86.46 beats/min; p = 0.178), and raw CFT was the pre-specified primary measurement. All assessments were performed using an HM70 EVO ultrasound system (Samsung Medison, Seoul, South Korea) by emergency physicians with ≥ 2 years of ED POCUS experience (> 10 examinations/week). Prior to data collection, the responsible physician completed a standardised training protocol on 15 practice cases under radiological supervision. All measurements were obtained prior to endoscopy and within 30 minutes of initial resuscitation.

Primary Outcome

The primary outcome was the presence of active or high-risk bleeding at upper gastrointestinal endoscopy, defined as Forrest classification Ia (active spurting), Ib (active oozing), IIa (non-bleeding visible vessel), IIb (adherent clot), or IIc (flat pigmented spot)— which were pre-specified as the active/high-risk bleeding group for this study. It should be noted that the classification of Forrest IIc as high-risk varies across guidelines[22]; a pre-specified sensitivity analysis excluding Forrest IIc patients was therefore conducted and is reported separately. Forrest IIIa and III were classified as no active bleeding. Endoscopies were performed by experienced gastroenterologists or upper gastrointestinal surgeons blinded to POCUS findings.

Sample Size

Sample size was calculated a priori by power analysis, assuming an expected AUC of 0.85 for CFT, α = 0.05, and 80% power. This yielded a minimum requirement of 78 patients, which was reached at study termination.

Statistical Analysis

Continuous variables are reported as mean ± SD or median (IQR) based on normality testing (Kolmogorov–Smirnov and Shapiro–Wilk tests). Group comparisons used the Mann–Whitney U test for continuous variables and Fisher's exact test for categorical variables. ROC curve analysis was performed for all candidate variables; optimal cutoff values were identified by the Youden index (maximising sensitivity + specificity − 1). AUC, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) with 95% confidence intervals are reported. Pairwise AUC comparisons were performed using the DeLong method [23]. Univariate binary logistic regression was performed to identify variables associated with active bleeding; a multivariate model was not constructed owing to the limited number of outcome events (n = 10, precluding adequate events-per-variable ratio), and all regression findings should be considered exploratory. Future studies with larger event counts should consider penalised regression approaches (e.g., Firth logistic regression) and formal testing of the incremental value of CFT over established scoring systems such as the Glasgow–Blatchford Score. A pre-specified sensitivity analysis was conducted excluding Forrest IIc patients from the active bleeding group (n = 6). All analyses were performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$ (two-sided).

RESULTS

Study Population

Seventy-eight consecutive patients were enrolled (mean age 47.79 ± 20.36 years; range 18–86; 71.8% male). Active or high-risk bleeding was confirmed in 10 patients (12.8%). The Forrest classification distribution is presented in Table 3. Active bleeders were significantly older (68.10 ± 10.39 vs. 44.81 ± 19.79 years; p = 0.001) and had a higher prevalence of congestive heart failure (40.0% vs. 11.8%; p = 0.042). Fourteen patients (17.9%) required red blood cell transfusion during the ED visit. Complete baseline characteristics are presented in Table 1.

Clinical and Laboratory Parameters

Patients with active bleeding had significantly lower systolic blood pressure (95.40 ± 14.49 vs. 122.03 ± 16.67 mmHg; p < 0.001), lower diastolic blood pressure (p = 0.002), lower haemoglobin (9.20 ± 2.43 vs. 12.34 ± 3.31 g/dL; p = 0.005), lower platelet count (p = 0.005), higher BUN (47.50 ± 21.03 vs. 22.08 ± 25.07 mg/dL; p < 0.001), higher INR (p = 0.015), and higher Glasgow–Blatchford Score (12.40 ± 3.63 vs. 5.89 ± 4.01; p < 0.001). Full data are presented in Table 1.

POCUS Parameters

CFT was significantly shorter in active bleeders (median 284 ms [IQR 276–289] vs. 305 ms [IQR 299–311]; p < 0.001). IVC maximum diameter was also significantly smaller in active bleeders (2.73 ± 0.44 vs. 3.02 ± 0.32 cm; p = 0.033). One patient in the active bleeding group had an uninterpretable IVC minimum diameter measurement and was excluded from IVC-CI analysis; among the nine remaining evaluable

active bleeders, IVC-CI was significantly lower than in non-active bleeders (median 0.22 [IQR 0.16–0.33] vs. 0.33 [IQR 0.26–0.41]; p = 0.029).

Diagnostic Performance

ROC analysis demonstrated that CFT had the highest discriminatory performance among the POCUS parameters (Table 2; Fig. 1). A CFT cutoff of < 289 ms yielded an AUC of 0.887 (95% CI: 0.749–1.000), with sensitivity 80%, specificity 94%, PPV 67%, and NPV 97%. IVC-CI < 0.22 yielded an AUC of 0.654 (95% CI: 0.458–0.849), with sensitivity 50% and specificity 87%. DeLong pairwise comparison indicated CFT had superior discriminatory ability to IVC-CI (ΔAUC = 0.233; Z = 1.53; p = 0.126); this difference did not reach statistical significance. Among conventional parameters, systolic blood pressure < 114 mmHg demonstrated the highest AUC (0.915), followed by BUN (0.874) and GBS (0.873). CFT (AUC 0.887) was comparable to both BUN and GBS in overall discriminatory performance.

Sensitivity Analysis

In a pre-specified sensitivity analysis excluding Forrest IIc patients (n = 4) from the active bleeding group (yielding n = 6 active bleeders vs. 72 non-active), CFT demonstrated an AUC of 0.993 (cutoff < 288 ms; sensitivity 100%; specificity 94%).

Univariate Logistic Regression

Univariate logistic regression identified CFT (OR 0.842 per ms; 95% CI: 0.763–0.930; p = 0.001), IVC-CI, GBS, systolic blood pressure, age, BUN, haemoglobin, haematocrit, and platelet count as variables associated with active bleeding. INR was not associated (p = 0.636). Full results are in Table 4. For IVC-CI, the OR of approximately 0.000 (95% CI: 0.000–0.087) reflects complete separation in the logistic model due to the small event count (n = 10); these estimates should be interpreted with caution and are presented for completeness only. Given the limited number of outcome events, all regression findings should be considered exploratory rather than definitive.

Table 1

Baseline clinical, laboratory, and POCUS characteristics stratified by active bleeding status.

Variable	Active Bleeding (n = 10)	No Active Bleeding (n = 68)	Total (n = 78)	p-value
Demographics & Clinical Presentation				
Age, years — mean ± SD median (IQR)	68.10 ± 10.39 69.0 (63.0–73.8)	44.81 ± 19.79 43.0 (27.8–61.0)	47.79 ± 20.36	**0.001***
Male sex, n (%)	7 (70.0)	49 (72.1)	56 (71.8)	0.578
Congestive heart failure, n (%)	4 (40.0)	8 (11.8)	12 (15.4)	**0.042***
Chronic liver disease, n (%)	2 (20.0)	2 (2.9)	4 (5.1)	0.078
Melena, n (%)	6 (60.0)	21 (30.9)	27 (34.6)	0.076
Syncope, n (%)	1 (10.0)	0 (0.0)	1 (1.3)	0.128
Required transfusion, n (%)	5 (50.0)	9 (13.2)	14 (17.9)	—
Vital Signs				
Heart rate, beats/min	93.80 ± 24.01	86.46 ± 12.87	87.40 ± 14.75	0.178
Systolic BP, mmHg — mean ± SD median (IQR)	95.40 ± 14.49 98.5 (80.2–104.8)	122.03 ± 16.67 120.0 (114.2–128.5)	118.62 ± 18.62	**< 0.001***
Diastolic BP, mmHg — mean ± SD median (IQR)	62.10 ± 14.86 63.5 (52.5–67.8)	77.19 ± 11.65 80.0 (70.0–85.0)	75.26 ± 13.02	**0.002***
Laboratory Parameters				
Haemoglobin, g/dL	9.20 ± 2.43 9.4 (7.4–10.6)	12.34 ± 3.31 12.7 (10.1–15.2)	11.94 ± 3.37	**0.005***
Haematocrit, %	28.95 ± 7.07	41.58 ± 37.62	39.96 ± 35.43	**0.007***
Platelet count, ×10³/µL	193.50 ± 96.28	272.28 ± 88.19	262.18 ± 92.49	**0.005***
WBC, ×10³/µL	9.18 ± 4.66	10.66 ± 3.82	10.47 ± 3.94	0.390
BUN, mg/dL — mean ± SD median (IQR)	47.50 ± 21.03 50.9 (29.4–60.6)	22.08 ± 25.07 13.7 (10.2–22.0)	25.34 ± 25.91	**< 0.001***
INR	1.41 ± 0.33	1.87 ± 2.98	1.81 ± 2.78	**0.015***
Glasgow–Blatchford Score — mean ± SD median (IQR)	12.40 ± 3.63 12.0 (11.0–14.5)	5.89 ± 4.01 4.0 (4.0–9.0)	6.78 ± 4.51	**< 0.001***

Variable	Active Bleeding (n = 10)	No Active Bleeding (n = 68)	Total (n = 78)	p-value
Demographics & Clinical Presentation				
Point-of-Care Ultrasonography Parameters				
IVC maximum diameter, cm	2.73 ± 0.44	3.02 ± 0.32	2.99 ± 0.35	**0.033***
IVC minimum diameter, cm	2.07 ± 0.41	2.00 ± 0.40	2.01 ± 0.40	0.630
IVC-CI †	0.23 ± 0.13 0.22 (0.16–0.33)	0.34 ± 0.11 0.33 (0.26–0.41)	0.33 ± 0.11	**0.029***
CFT, ms — mean ± SD median (IQR)	283.00 ± 15.07 284 (276–289)	304.79 ± 10.28 305 (299–311)	302.00 ± 13.13	**< 0.001***

Mean ± SD with median (IQR) reported where indicated. Comparisons: Mann–Whitney U test (continuous) and Fisher's exact test (categorical). *p < 0.05. † One patient in the active bleeding group had an uninterpretable IVC minimum diameter (IVCmin not recordable) and was excluded from IVC-CI analyses (n = 9 vs. 68). BP, blood pressure; BUN, blood urea nitrogen; CFT, carotid flow time; IVC-CI, inferior vena cava collapsibility index; WBC, white blood cell count.

Table 2

ROC analysis: diagnostic performance for prediction of active/high-risk bleeding.

Variable	AUC	95% CI	Optimal Cutoff	Sens (%)	Spec (%)	PPV (%)	NPV (%)
POCUS Parameters							
CFT †	0.887	0.749–1.000	< 289 ms	80	94	67	97
IVC-CI ‡	0.654	0.458–0.849	< 0.22	50	87	36	92
IVC max diameter	0.708	0.518–0.898	< 2.90 cm	70	62	21	93
Clinical & Laboratory Parameters							
Systolic BP	0.915	0.794–1.000	< 114 mmHg	100	75	37	100
BUN	0.874	0.729–1.000	> 25.9 mg/dL	90	82	43	98
Glasgow–Blatchford Score	0.873	0.729–1.000	> 6.0	100	67	31	100
Age	0.824	0.660–0.987	> 59 years	90	72	32	98
Diastolic BP	0.801	0.630–0.971	< 68 mmHg	80	82	40	97
INR	0.739	0.554–0.924	> 1.18	80	63	24	96
Haemoglobin	0.777	0.600–0.954	< 11.4 g/dL	90	66	28	98
Haematocrit	0.766	0.587–0.945	< 35.2%	90	66	28	98
Platelet count	0.778	0.601–0.955	< 217 ×10³/µL	80	75	32	96

Optimal cutoff values by Youden index. † Primary POCUS parameter of interest. ‡ One patient with uninterpretable IVC minimum diameter excluded (n = 9 active bleeders analysed). DeLong pairwise comparison: CFT vs. IVC-CI, ΔAUC = 0.233, Z = 1.53, p = 0.126. AUC, area under the curve; CFT, carotid flow time; IVC-CI, inferior vena cava collapsibility index; NPV, negative predictive value; PPV, positive predictive value.

Table 3

Endoscopic Forrest classification distribution (n = 78).

Forrest Classification	n (%)	Description / Re-bleeding Risk
Forrest Ia	0 (0.0)	Active spurting haemorrhage — 60–100%
Forrest Ib	1 (1.3)	Active oozing haemorrhage — ~50%
Forrest IIa	0 (0.0)	Non-bleeding visible vessel — 40–50%
Forrest IIb	5 (6.4)	Adherent clot — 20–30%
Forrest IIc	4 (5.1)	Flat pigmented spot — 7–10%
Forrest IIIa	15 (19.2)	Recent stigmata, no active bleeding — <5%
Forrest III	53 (67.9)	Clean-base ulcer — 3–5%
Active/high-risk total (Forrest Ia–IIc)	10 (12.8)	Pre-specified primary outcome group

Active/high-risk group (Forrest Ia–IIc, n = 10) defined per pre-specified protocol based on ESGE re-bleeding risk criteria [22]. Sensitivity analysis excluding Forrest IIc (n = 6 active bleeders): CFT AUC = 0.993, cutoff < 288 ms, sensitivity 100%, specificity 94%.

Table 4

Univariate logistic regression analysis of variables associated with active/high-risk bleeding.

Variable	β	p-value	Odds Ratio	95% CI (Lower)	95% CI (Upper)
Age (per year)	0.074	**0.004***	1.076	1.024	1.132
Glasgow–Blatchford Score (per unit)	0.355	**0.001***	1.427	1.157	1.760
Systolic BP (per mmHg)	-0.130	**< 0.001***	0.878	0.818	0.942
Diastolic BP (per mmHg)	-0.093	**0.002***	0.911	0.858	0.967
IVC max diameter (per cm)	-2.344	**0.022***	0.096	0.013	0.708
IVC-CI §	-10.338	**0.010***	0.000	0.000	0.087
CFT (per ms)	-0.172	**0.001***	0.842	0.763	0.930
Haemoglobin (per g/dL)	-0.293	**0.010***	0.746	0.596	0.934
Haematocrit (per %)	-0.090	**0.016***	0.914	0.850	0.983
Platelet count (per ×10³/μL)	-0.013	**0.015***	0.987	0.976	0.997
BUN (per mg/dL)	0.026	**0.020***	1.027	1.004	1.050
INR	-0.091	0.636	0.913	0.626	1.331

*p < 0.05. § OR ≈ 0.000 for IVC-CI reflects complete separation due to small event count (n = 10); interpret with caution. Multivariate analysis not performed (10 events, 12 predictor variables — insufficient events-per-variable ratio). OR, odds ratio; CI, confidence interval; CFT, carotid flow time; IVC-CI, inferior vena cava collapsibility index.

DISCUSSION

In this prospective study of patients presenting to the ED with suspected UGIB, CFT showed better overall diagnostic performance than IVC-CI for identifying endoscopically confirmed active or high-risk bleeding. Although IVC-CI differed between groups, its discriminatory performance was lower. The findings suggest that CFT may be a useful bedside adjunct for early haemodynamic assessment in UGIB.

CFT as a Haemodynamic Biomarker in UGIB

The physiological rationale for CFT as a volume surrogate is well-established. Acute blood loss reduces left ventricular preload, shortening systolic ejection time and thereby reducing CFT [15]. This has been demonstrated in experimental phlebotomy models [13], in dehydrated patients following fluid resuscitation [11], and in haemodialysis patients before and after dialysis [12]. The high specificity (94%) and NPV (97%) of CFT < 289 ms may be clinically useful: a negative result was associated with a low likelihood of active bleeding in this cohort. In the ED setting, a CFT ≥ 289 ms combined with a low GBS may help support bedside risk assessment together with established clinical scoring systems.

Our findings are consistent with those reported by Karadadaş et al. (2020) [14], who observed lower CFT values in UGIB patients with active endoscopic lesions. An important methodological note: heart rate correction (CFTc) was not applied in our study, as groups did not differ significantly in heart rate (p = 0.178). Raw CFT and corrected CFTc behave differently and are not interchangeable; future studies should specify their correction approach a priori.

IVC-CI in UGIB

IVC-CI was significantly lower in evaluable active bleeders (p = 0.029), consistent with volume depletion. However, one patient had a technically uninterpretable IVC minimum diameter—a real limitation of bedside IVC sonography. The AUC of 0.654 was substantially lower than CFT, consistent with known limitations of IVC-CI in spontaneously breathing patients, including dependence on respiratory effort, intra-abdominal pressure, body habitus, and operator variability [16, 17, 19, 20]. The utility of IVC-CI in GI bleeding has been supported independently by Ayar et al. (2024), who reported that IVC-CI predicted transfusion requirements in UGIB [18], and by Lyon et al. (2005), who demonstrated IVC dimension reductions following 450 mL phlebotomy in healthy volunteers [19]. Our results support IVC-CI as a corroborating rather than primary POCUS marker in this context.

Comparison with Conventional Risk Scores

Systolic blood pressure demonstrated the highest AUC (0.915), reflecting its established role as a haemodynamic marker of severe haemorrhage. GBS achieved 100% sensitivity (AUC 0.873), consistent with its established role as a sensitive screening tool [5, 23], though its specificity of only 67% limits its utility for ruling in active bleeding. BUN demonstrated excellent combined performance (AUC 0.874), reflecting haemoglobin catabolism from upper gastrointestinal blood [21]. CFT showed lower sensitivity but higher specificity than GBS, suggesting that it may complement existing risk stratification tools in patients with suspected UGIB.

Limitations

First, this was a single-centre study with a small sample size (n = 78; n = 10 active bleeders), limiting statistical power. The small number of outcome events may have inflated diagnostic performance estimates and contributed to the wide confidence intervals observed in ROC analyses. The non-significant DeLong comparison (p = 0.126) should therefore be interpreted cautiously. The high negative predictive value observed in this cohort should also be interpreted in the context of the limited sample size. Second, interobserver variability was not formally assessed, though all measurements followed a standardised protocol. Third, one patient had a technically uninterpretable IVC-CI measurement, illustrating a real-world acquisition limitation. Fourth, the study did not systematically document beta-blocker or vasopressor use, which may influence CFT. Fifth, the non-endoscoped group (n = 45) was not analysed, as POCUS parameters were collected in the context of endoscopic decision-making; this introduces a form of spectrum bias, as diagnostic performance was evaluated in a pre-selected population deemed to require endoscopy. Accordingly, the observed performance may not be directly applicable to the broader ED population with suspected UGIB, particularly those at low or indeterminate risk. Sixth, model calibration was not formally assessed; this represents an additional methodological limitation inherent to small diagnostic studies and should be addressed in future work. Finally, external validation in larger, multicentre cohorts is required before clinical implementation.

CONCLUSIONS

Carotid flow time is a rapidly obtainable POCUS parameter that is significantly associated with endoscopically confirmed active or high-risk bleeding in patients presenting with upper gastrointestinal haemorrhage. A CFT threshold of < 289 ms demonstrated high specificity (94%), excellent negative predictive value (97%), and overall diagnostic performance comparable to established risk markers—showing higher discriminatory performance than IVC-CI in this cohort. Sensitivity analysis excluding Forrest IIc patients confirmed the robustness of this finding. These results support the potential role of CFT as a non-invasive bedside adjunct for early risk stratification and triage in UGIB. Prospective multicentre validation with larger event numbers is required to confirm these cutoff values, formally assess interobserver reliability, and evaluate its role alongside conventional risk scores.

Abbreviations

AUC
Area under the curve
BUN
Blood urea nitrogen
CFT
Carotid flow time
CI
Confidence interval
ED
Emergency department
ESGE
European Society of Gastrointestinal Endoscopy
GBS
Glasgow–Blatchford Score
INR
International normalised ratio
IQR
Interquartile range
IVC
Inferior vena cava
IVC-CI
Inferior vena cava collapsibility index
NPV
Negative predictive value
OR
Odds ratio
POCUS
Point-of-care ultrasonography
PPV
Positive predictive value
ROC
Receiver operating characteristic
SD
Standard deviation
STARD
Standards for Reporting of Diagnostic Accuracy Studies
STROBE
Strengthening the Reporting of Observational Studies in Epidemiology
UGIB
Upper gastrointestinal bleeding.

Declarations

Ethics Approval:

Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee (No: KAEK/2022.08.188; 11 August 2022).

Ethics Approval and Consent to Participate

The study was approved by the Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee, University of Health Sciences Istanbul (Reference: KAEK/2022.08.188; 11 August 2022). Written informed consent was obtained from all participants or their legally authorised representatives. The study was conducted in accordance with the Declaration of Helsinki.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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Author Contribution

BY conceptualised and designed the study, performed POCUS measurements, collected and interpreted the data, performed the statistical analysis, and drafted the manuscript. SF, SD and UMK supervised the study design and methodology and critically revised the manuscript for important intellectual content. MU contributed to data collection and patient enrolment. AE contributed to clinical assessment and interpretation of endoscopic data. STF critically revised the manuscript for important intellectual content. All authors read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Availability of Data and Materials

The de-identified dataset supporting the conclusions of this article is available from the corresponding author (BY, bilalyeniyurt@gmail.com) upon reasonable request, in accordance with institutional and

ethical regulations governing the protection of patient data. No publicly accessible data repository is currently used; requests will be reviewed and shared subject to a data-use agreement and institutional approval.

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Figures

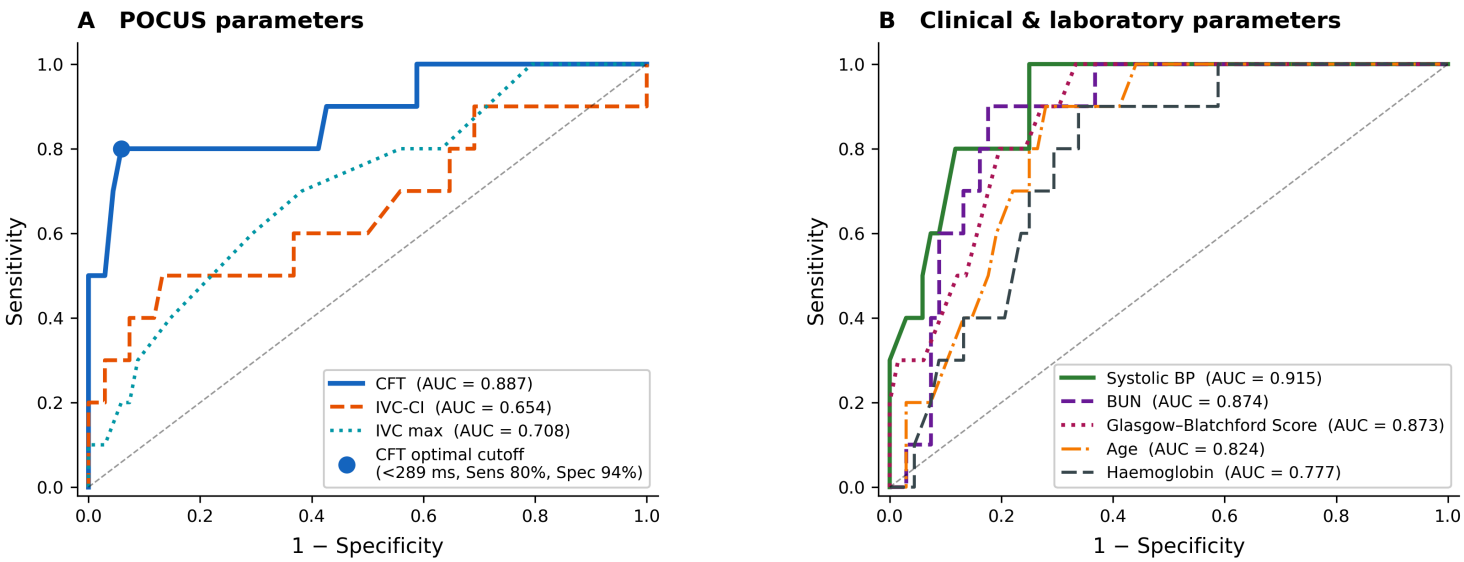


Figure 1. ROC curves for prediction of active/high-risk bleeding.
(A) POCUS parameters: CFT, IVC-CI, and IVC maximum diameter. The optimal CFT cutoff (< 289 ms) is marked (●).
(B) Conventional clinical and laboratory parameters. The diagonal dashed line represents the line of no discrimination.
AUC, area under the curve; CFT, carotid flow time; IVC-CI, inferior vena cava collapsibility index;
GBS, Glasgow–Blatchford Score; BUN, blood urea nitrogen; POCUS, point-of-care ultrasonography.

Figure 1

See image above for figure legend

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