RESEARCH ARTICLE

The accuracy of patient's demographic and NCCT brain findings in predicting the vascular aetiology of non-traumatic intracranial haemorrhage. A retrospective cohort study

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Abstract

Objective: To investigate the accuracy of patient demographic data and non-contrast computed tomography brain scan findings in predicting the vascular aetiology of non-traumatic intracranial haemorrhage.

Method: The retrospective cohort study was conducted from April 15 to October 15, 2023, at Armed Forces institute of radiology and imaging (AFIRI) Rawalpindi, Pakistan, and comprised data from May 1, 2022, to September 30, 2023, of patients aged >18 years who presented with non-traumatic intracranial haemorrhage and underwent computed tomography angiography for the detection of underlying vascular lesions. Non-contrast computed tomography criterion was used to predict the presence of vascular aetiologies in patients of non-traumatic spontaneous intracranial haemorrhage. Independent predictors of vascular aetiology were identified, and the vascular intracerebral haemorrhage scoring system was crafted which was internally validated. Data was analysed using SPSS 25.

Results: Of the 237 patients with mean age 55.9±14.5 years (range: 18-85 years), 136(56%) were male and 101(42%) were female. Vascular aetiology was confirmed in 153(64.5%) patients. Independent predictors included age <55 years (odds ratio: 2.94, 95% confidence interval: 1.48-5.83), lobar location (odds ratio: 2.89, 95% confidence interval: 1.47-5.67), absence of hypertension (odds ratio: 5.12, 95% confidence interval: 2.67-9.82), and perilesional oedema (odds ratio: 2.76, 95% confidence interval: 1.34-5.67). The vascular intracerebral haemorrhage score ranged 0-8, and showed good discrimination (area under the receiver operating characteristic curve: 0.81, 95% confidence interval: 0.75-0.87). A cut-off value of ≥4 yielded sensitivity 82%, specificity 74%, and Youden's index 0.56.

Conclusion: The vascular intracerebral haemorrhage score demonstrated effectiveness in anticipating the presence of vascular causes. After external validation, the scoring system may assist in triaging patients for computed tomography angiography.

Keywords: Vascular aetiology, Intracranial haemorrhage, VICH score, CT angiography. (JPMA 76: 1277; 2026)

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Introduction

Non-traumatic spontaneous intracranial haemorrhage (SICH) is a critical neurological emergency that comprises approximately 10-15% of acute stroke cases.[1] While many instances of intracranial haemorrhage (ICH) are attributed to conditions such as hypertension (HTN), amyloid angiopathy and coagulation disorders, others result from underlying vascular factors, like aneurysms, arteriovenous malformations (AVMs), dural venous thrombosis, and various vascular abnormalities.[2] The precise identification of the vascular cause behind non-traumatic ICH is of utmost importance as it guides clinical management and treatment strategies.[3] Although advanced imaging techniques have significantly enhanced diagnosis of vascular aetiology of ICH,[4] demographic patient data and findings from non-contrast computed tomography (NCCT) scans remain crucial elements of the diagnostic process, particularly in resource-constrained settings, or when interpreting CT angiography (CTA) poses challenges,[5] especially when surgical or endovascular interventions are options to mitigate the risk of further haemorrhage.

Digital subtraction angiography (DSA) is increasingly being supplanted by CTA as the preferred diagnostic modality for identifying vascular causes of SICH.[6] This transition is primarily due to the invasiveness of DSA and the associated potential risks of inducing neurological damage.

CTA offers several advantages when compared to invasive angiography.[7] It is a readily available and non-invasive method that provides quick results, which is especially beneficial for critically ill patients. CTA is also cost-effective, generally safe, and highly effective at detecting vascular issues. However, it is essential to be aware that CTA does involve exposing patients to a higher radiation dose, around 2.5mSv, and the contrast dye used intravenously can potentially cause kidney problems, especially in those

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with a history of kidney issues. Therefore, it is wise to carefully consider clinical and imaging criteria to determine if CTA would be most beneficial for a patient, or the more invasive digital catheter angiography (DSA), especially in settings with limited resources.

Previous studies have found specific factors in both patient data and NCCT scans that are linked to a higher likelihood of uncovering underlying vascular issues in cases of non-traumatic ICH.[5] These factors include being younger in age, not having a history of HTN or coagulation disorders, and having haemorrhages in certain brain regions, like the lobar frontal and temporal areas, subarachnoid space, or involving multiple compartments.

The current study was planned to determine the reliability of patient demographics and CT scan findings in predicting the vascular causes of non-traumatic ICH.

Materials and Methods

The retrospective cohort study was conducted from April 15 to October 15, 2023, at a Armed Forces institute of radiology and imaging (AFIRI) Rawalpindi Pakistan, and comprised data from May 1, 2022, to September 30, 2023. After approval from the institutional ethics review committee, the sample size was calculated using the World Health Organisation (WHO) calculator[8] with 95% confidence interval (CI), 5% margin of error, and reported prevalence of non-traumatic ICH approximately 15-20%. With Z=1.96, d=0.05 (±5%) and *p*=0.15 (15% prevalence), the equation was:[9]

$$n = \frac{(1.96)2\ x\ 0.15\ x\ (1-0.15)}{(0.05)2} = \frac{3.8416\ x\ 0.1275}{0.0025} = 196$$

With Z=1.96, d=0.05 (±5%) and P=0.20 (20% prevalence), the equation was:

$$n = \frac{(1.96)2\ x\ 0.20\ x\ (1-0.20)}{(0.05)2} = \frac{3.8416\ x\ 0.16}{0.0025} = 246$$

The sample was raised using non-probability consecutive sampling technique from among those with a confirmed diagnosis of non-traumatic ICH who also underwent multi-detector CTA (MDCTA) for the confirmation of vascular aetiologies. The institutional radiology information system (RIS) was using the following terms and variants: 'intracerebral haemorrhage,' 'intraparenchymal haemorrhage,' 'ICH,' 'lobar haemorrhage,' 'deep haemorrhage' and 'subarachnoid extension'. The identified cases were cross-checked against CTA scheduling logs within 24 hours of NCCT. Diagnostic coding was confirmed using ICD-10 codes where available (e.g., I61.x for non-traumatic ICH).[10]

The data included was related to patients aged 18 years or older who had non-traumatic ICH confirmed by NCCT scans, and for whom CTA brain had been obtained within 48 hours. Data was excluded for patients with a history of road traffic accident (RTA) or any trauma, evidence of ischaemic stroke on CT brain, known bleeding disorders, and presence of severe artefacts in non-contrast CT brain or CTA.

MDCTA and examination was conducted utilising a 160-MDCT scanner equipped with automated exposure control. The NCCT scans were carried out using a head holder and axial technique, employing parameters of 140kV, 250mA, and a slice thickness reconstruction of 0.62mm. For MDCTA, imaging encompassed the region from the base of the 1st cervical vertebra to the top of the vertex. This procedure involved the injection of 90ml of iodinated contrast material at a flow rate of 5ml per second, followed by a subsequent injection of 40ml of normal saline at the same flow rate.

All MDCTA and NCCT examinations underwent interpretation by two radiologists. One of these radiologists specialised in interventional procedures and had approximately three years of experience, while the other was a diagnostic radiologist with seven years of experience. In instances where there was a disparity in their interpretations, a third expert opinion was also sought. Interobserver agreement for key imaging features (e.g., lobar location, perilesional oedema, subarachnoid extension) was calculated using Cohen's kappa (κ) statistic. Agreement was substantial to near-perfect across variables, with κ values ranging from 0.72 to 0.86.

The viewing of the imaging studies was conducted using a standard Picture Archiving and Communication System (PACS) workstation. The radiologists were tasked with documenting various aspects, including the location of the haemorrhage (whether it occurred in the lobar region, deep grey matter, pons, infratentorial area, or involved multiple compartments), the presence of associated intraventricular or subarachnoid haemorrhage (SAH), and the presence of significant perilesional oedema.

Furthermore, the likelihood of vascular aetiologies was categorised into three categories: high probability, indeterminate probability and low probability, with high probability indicating the presence of dilated vascular channels accompanied by calcification or heightened attenuation of dural veins, low probability indicating ICH occurring within the deep grey matter or pons in the absence of accompanying high-probability criteria, and indeterminate probability meaning lesions that did not fit within any of the aforementioned categories.[6]

The CTA images were also evaluated by the same

diagnostic radiologists, and the findings were interpreted as positive or negative depending upon the presence of vascular aetiologies (aneurysms, AVMs, dural venous thrombosis, dural venous anomaly [DVA] or dural AV fistulas).

Additional diagnostic data, such as magnetic resonance angiography/venography (MRA/MRV), DSA, or any findings from surgical or pathological assessments, were also documented. If these supplementary diagnostic methods identified a vascular lesion that had not been detected by CTA, the results were incorporated into the final analysis.

Patient demographic data, including age, gender and medical history (particularly HTN and diabetes mellitus [DM]), was recorded. The primary outcome measure was the accurate determination of the vascular aetiology of ICH, with a specific focus on hypertensive and cerebral amyloid angiopathy-related ICH.

Data was analysed using SPSS 25. Data was presented as frequencies and percentages or mean +/- standadrd deviation as appropriate. Chi-square tests and logistic regression models were used to explore how demographic factors and CT scan results related to the causes of ICH. P<0.05 was considered statistically significant. Leveraging the independent predictors of vascular aetiology, a pragmatic scoring system was crafted to forecast the probability of vascular lesions in individuals suffering from ICH. The scoring system was internally validated.

Results

Of the 237 patients with mean age 55.9±14.5 years (range: 18-85 years), 136(56%) were male and 101(42%) were female (Table 1).

Vascular aetiology was confirmed in 153(64.5%) patients; 81(53%) in patients aged 18-55 years, and 72(47%) aged >55 years (p<0.001). Among the 153 (64 %) patients with vascular aetiologies, 71(46.4%) were male and 82(53.6%) were female.

The most common vascular aetiology was intracranial aneurysms 113(47.6%) (Table 2).

HTN was strongly associated with hypertensive non vascular ICH (p<0.001). There were 66(46%) patients with a documented history of HTN who presented with specific vascular aetiology and 87(92%) of the non-hypertensive patients were diagnosed with vascular aetiologies.

Intracranial lobar haemorrhage and haemorrhage within deep grey matter were strongly indicative of non-vascular ICH (p<0.001).

Overall, 65(27.4%) individuals were classified as having a low probability of an underlying vascular cause for ICH, while 110(46.4%) were had a high probability, and 62(26%) fell into the indeterminate category.

Among those with high probability, 98(89%) were true positive, and 12(10.9%) were false positive. Among those with low probability, 49(75%) were correctly identified as true negatives, while 16(24.6%) were false negatives. NCCT examinations categorised as high and low probability exhibited positive predictive values (PPVs) of 89% and negative predictive values (NPVs) of 75%, respectively. Among the patients with intermediate probability, 39(63%) had underlying vascular lesions causing ICH (Table 3).

Independent predictors included age <55 years (odds ratio [OR]: 2.94, 95%CI: 1.48-5.83), lobar location (OR: 2.89, 95%CI: 1.47-5.67), absence of HTN (OR: 5.12, 95%CI: 2.67-9.82), and perilesional oedema (OR: 2.76, 95%CI: 1.34-5.67) (Table 4).

The VICH score ranged 0-8 (Table 5), and showed good discrimination (area under the receiver operating

Table-1: Demographic characteristics of patients presenting with acute non-traumatic intracranial haemorrhage (ICH).

Characteristics	Male (n=136, 56%)	Female (n=101, 42%)	Total (n=237)
Age median (years),	58 (18-85)	58 (18-85)	58 (18-85)
Hypertension			
No	41 (30.1)	53 (52.4)	94 (39.6)
Yes	95 (69.8)	48 (47.5)	143 (60.3)
Diabetes mellitus			
No	87 (63.9)	76 (75.2)	163 (68.7)
Yes	49 (36)	25 (24.7)	74 (31.2)

Table-2: Vascular causes of non-traumatic intracranial haemorrhage (ICH) among the patients.

Cause of haemorrhage	n (%)
Non vascular	84(35)
Aneurysms	113(47.6)
AVM	16(6.7)
Dural vein thrombosis	17(7)
Dural arteriovenous fistulas.	0(0)
Deep vein anomaly	5(2)
Cavernoma	2(0.8)

AVM: Arteriovenous malformation.

Table-3: Multi-detector CTA findings in lieu of non-contrast computed tomography (NCCT) probability.

	Non vascular	Aneurysm	AVM	DVT	DVA	Cavernoma	Total
Low	49(74)	13(21)	3(4.5)	0	0	0	64
Intermediate	23(35)	30(50)	4(6)	5(6)	1(1.5)	0	63
High	12(10.5)	70(65)	9(7.8)	13(11	4(3.5)	2(1.7)	110
Total	84(34)	113(49)	16(6.5)	18(7)	5(2)	2(0.8)	237

CTA: Computed tomography angiography, AVM: Arteriovenous malformation, DVT: Deep venous thrombosis, DVA: Dural venous anomaly.

Table-4: Univariate and multivariate regression analyses pertaining to factors influencing the likelihood of a vascular cause for intracranial haemorrhage (ICH).

				Univariate regression analysis		Multivariate regression analysis		
		n (%)	Positive CTAs (%)	*p*-value	OR, (95% CI))	*p*-value	OR, (95% CI))	Reference group
All patients		237(100)	153(64)					
Gender	Male	136(57)	71(46.4)	0.459	1.89 (1.02–3.52)	0.005	2.45 (1.31–4.58)	Male
	Female	101(42.6)	82(53.5)					
Age group	18-55 years	106(45)	81(76)	0.608	2.01 (1.08–3.74)	0.001 1.34, (0.80–2.24)	2.94 (1.48–5.83)	Age > 55 years
	>55 years	131(55)	72(55)					
Known HTN	Yes	143(60)	66(46)	0.000	2.45 (1.31–4.58)	0.000	5.12 (2.67–9.82)	Hypertension present
	No	94(40)	87(92)					
Diabetes mellitus	Yes	74(31)	33(45)	0.794	1.87 (1.02–3.42)	0.000	2.45 (1.31–4.58)	Diabetes mellitus present
	No	163(69)	120(74)					
Haemorrhage site	Lobar	99(42)	53(54)	0.148	2.34 (1.21–4.52)	0.003	2.89 (1.47–5.67)	Deep grey matter haemorrhage
	Deep grey matter	37(16)	6(16)					
	Pons	6(2.5)	1(16.6)					
	Infratentorial	6(2.5)	2(33)					
	Multi compartmental	106(48)	85(80)					
IVH	Yes	96(40.5)	76(79)	0.003	2.76 (1.39–5.47)	0.204	1.34 (0.84–2.15)	No IVH
	No	141(59)	77(55)					
SAH	Yes	144(61)	123(85)	0.000	9.12 (4.72–17.6)	0.000	8.45 (4.31–16.5)	No SAH
	No	93(39)	30(32)					
SDH	Yes	9(4)	6(66.6	0.297	1.45 (0.39–5.41)	0.225	1.21 (0.33–4.42)	No subdural haemorrhage
	No	228(96)	147(64)					
Considerable oedema	Yes	80(34)	54(67)	0.003	2.01 (1.03–3.91)	0.000	2.76 (1.34–5.67)	No Oedema
	No	157(66)	99(63)					

CTA: Computed tomography angiography, IVH: Intraventricular haemorrhage, SAH: Subarachnoid haemorrhage, SDH: Subdural haemorrhage, OR: Odds ratio, CI: Confidence interval.

Table-5: Calculation of vascular intracerebral haemorrhage (VICH) score.

Parameters	Points
NCCT categorisation	
High probability	2
Intermediate	1
Low probability	0
Age group (years)	
18-55	1
>55	0
No hypertension or diabetes mellitus	
Yes	1
No	0
Lobar haemorrhage	
Yes	1
No	0
Associated IVH or SAH	
Yes	1
No	0
Associated oedema	
Yes	1
No	0

Total VICH score range: 0-8; cohort mean 4.2±1.6; NCCT: Non-contrast computed tomography, IVH: Intraventricular haemorrhage, SAH: Subarachnoid haemorrhage.

Table-6: Positive CTAs and the vascular intracerebral haemorrhage (VICH) score.

Score	n (%)	Positive CTAs(%)
0	11(4.6)	0
1	54(23)	16(30)
2	62(26)	39(63)
3	59(25)	48(81)
4	40(17)	39(98)
5	7(3)	7(100)
6	4(1.7)	4(100)

characteristic curve [AUROC]: 0.81, 95%CI: 0.75-0.87). A cut-off value of ≥4 yielded sensitivity 82%, specificity 74% and Youden's index 0.56. The VICH was applied to the sample (Table 6), and the accuracy of NCCT categorisation and VICH was compared (Table 7).

Discussion

The current study provides critical insights into the accuracy of patient demographic data and NCCT scan findings in predicting the vascular aetiology of non-traumatic ICH. These findings hold profound implications for clinical practice and patient care.

In the study, 57% patients were male, and 43% were female. The observed rate of identifying vascular causes and obtaining positive results in CTAs within the study was 64%, with 52% among males and 81% among females.

Table-7: Comparison of the diagnostic accuracy on non-contrast computed tomography (NCCT) categorisation and vascular intracerebral haemorrhage (VICH) score.

		Sensitivity	Specificity	Accuracy	PPV	NPV
NCCT categorization	Intermediate and low probability	41%	89%	77%	80%	70%
	High probability	75%*	81%	80%*	86%	74%*
VICH score	4 or >4	75%*	91%*	78%	98%*	40.7%

NCCT: Non-contrast computed tomography, VISH: Vascular intracerebral haemorrhage, PPV: Positive predictive value, NPV: Negative predictive value; *$p<0.05$.

The current study reaffirms the well-established association between advanced age and non-vascular aetiologies of ICH.[11]

The strong association between HTN and hypertensive ICH observed in this study underscores the importance of monitoring and managing blood pressure in individuals at risk for vascular ICH. HTN is a modifiable risk factor, and the results emphasise the need for aggressive blood pressure control to reduce the incidence of ICH in hypertensive individuals.[12]

Cranial CTAs are now widely accepted as a diagnostic modality to detect vascular aetiologies in ICH[13] but the exposure of radiation and risk of contrast-induced nephropathy (CIN) are two setbacks of this modality[14] and it is good to use the NCCT scan as a guide to predict who may benefit most from the CTAs.[15]

In this study, NCCT categorisation yielded positive and negative predictive values of 80% and 74%, respectively. These results are closely aligned with those of a previous investigation.[6]

This study highlights specific radiological characteristics as valuable diagnostic markers for vascular aetiologies of ICH. Lobar haemorrhage is strongly suggestive of cerebral amyloid angiopathy-related ICH, while deep haemorrhage is indicative of hypertensive ICH.[16]

Non-invasive procedures are more helpful in the early detection of the cases. Globally, healthcare systems are working to develop more non-invasive techniques for confirmation of patient's aetiology.[17] In the current study, the VICH scoring system was developed to predict the likelihood of underlying vascular lesions in patients experiencing non-traumatic ICH. The practicality of the VICH score stems from its straightforward calculation process, which involves the assessment of NCCT based on NCCT categorisation, the location of the haemorrhage, the presence of perilesional oedema, and the consideration of clinical factors routinely gathered during a patient's emergency presentation, such as age and medical history, including HTN and DM.

In this study, none of the patients with a VICH score of 0 were found to have an underlying vascular cause when subsequently evaluated with CTA. However, for patients with VICH scores of 1 and 2, the likelihood of an underlying vascular aetiology on CTA was 30% and 63%, respectively. This finding is particularly encouraging, especially in healthcare settings where neurovascular assessments are not readily accessible.

The VICH score may assist clinicians in triaging patients for CTA, pending external validation.

The current study has several limitations. Firstly, this was a retrospective analysis conducted at a single institution. Prospective studies with a broader range of clinical and imaging variables may provide further insights. Secondly, as the VICH score was derived from a single-centre cohort, its generalisability may be limited, and it requires external validation.

Despite the limitations, however, the current study opens several promising avenues for future research. Investigating blood or cerebrospinal fluid biomarkers associated with specific vascular aetiologies of non-traumatic ICH could offer a non-invasive and potentially more precise diagnostic approach. Future studies may explore the application of advanced imaging techniques, such as perfusion CT or magnetic resonance imaging (MRI) to further refine the differentiation of ICH aetiologies. The integration of machine learning algorithms into clinical practice holds promise for enhancing diagnostic capabilities, potentially leading to automated, accurate and rapid ICH diagnosis. Prospective studies can provide real-time insights into the practical application of the current findings in clinical practice and assess the impact of tailored treatment approaches on patient outcomes.

Conclusion

The VICH score demonstrated effectiveness in predicting the vascular aetiology of non-traumatic ICH. After external validation, the scoring system may assist in triaging patients for computed tomography angiography.

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NA, SN, SA, MZA & TS: Concept, design, critical review, data acquisition, analysis, interpretation, drafting, revision, final approval and agreement to be accountable for all aspects of the work.