Neurology Asia 2024; 29(4) : 963 – 971

CT swirl sign in primary intracerebral haemorrhage and association with haematoma expansion

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Abstract

Background & Objective: Haematoma expansion is an important predictor of poor clinical outcomes for primary acute intracerebral haemorrhage (ICH). Swirl sign is described as an area which is hypodense or isodense surrounded by hyperdense acute haemorrhage. This study aimed to describe swirl sign in ICH, its prevalence and to determine if the presence of swirl sign, swirl volume and the ratio of swirl to initial haematoma volume are associated with haematoma expansion and to predict clinical outcome in ICH. *Methods:* One hundred and sixty-three patients who had spontaneous ICH with initial (CT1) and repeat CT (CT2) within 96 hours were included. Presence of swirl sign, its volume and the ratio of swirl volume over haematoma volume in initial and repeat CT were calculated using semi auto-segmentation from 'ITK snap'. Statistical analysis using Spearman's correlation coefficient and chi-square test were done to assess the relationship between the data parameters with haematoma expansion as well as functional outcome and mortality at 1 month. *Results:* Chi-square test showed a significant association between the presence of swirl sign with the haematoma expansion ($p < 0.001$) and mRS score at 1 month ($p < 0.05$). Spearman correlation showed a significant moderate correlation between swirl sign and volume of haematoma expansion ($r = 0.518$, $p < 0.001$). Ratio of swirl volume/initial haematoma volume demonstrated low correlation but however significant with haematoma expansion ($r=0.28$ $p < 0.05$).
Conclusion: Swirl sign, its volume as well as the ratio of swirl volume over initial haematoma are associated with haematoma expansion. It can be used as a predictor of mortality and functional outcome at one month.

Keywords: Swirl sign, intracerebral haemorrhage (ICH), haematoma expansion, modified Rankin scale (mRS)

INTRODUCTION

Stroke is a prevalent global health problem and is the second foremost cause of mortality worldwide[1] and is one of the top three leading causes of death in Malaysia.[2] It accounted for 7.8% of total deaths in Malaysia in 2018.[2] Spontaneous intracerebral haemorrhage accounts for 10-20% of the total cerebrovascular accident cases worldwide[4] and 20% of cerebrovascular accidents in Malaysia.[3] In a hospital-based prospective study in Malaysia, Sia *et al*. observed that the admission mortality rate for patients with spontaneous intracerebral haemorrhage in Malaysia is 43.9%.[5]

Primary intracerebral haemorrhage is known as bleeding in the brain parenchyma without an underlying secondary cause such as coagulopathy, vascular malformation or tumour.[6-8] Computed tomography (CT) is the imaging modality of choice and is the gold standard in diagnosing intracerebral haemorrhage.[9,10] As CT is widely available in most hospitals, it is the first imaging modality that is done in patients who present acutely to the emergency department.

The factors that contribute to 30-day mortality for patients with intracerebral haemorrhage are volume of haematoma, haematoma expansion, intraventricular extension of haemorrhage, initial Glasgow coma scale, older age and infratentorial location of haematoma.[11-14]

The functional outcome of patients with intracerebral haemorrhage and morbidity caused

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Date of Submission: 15 May 2024; Date of Acceptance: 23 July 2024

https://doi.org/10.54029/2024mrp

by it can be assessed with a modified Rankin scale (mRS), and it has been found to be a clinically relevant and valid tool in the assessment of recovery and functional outcome of stroke patients.[15]

Swirl sign in CT refers to the presence of an area of low density (30 –50 HU, hypodense or isodense to brain parenchyma) surrounded by a hyperdense haemorrhage.[16,17] It denotes actively extravasating un-clotted blood. The hypo or isodense area depicting the swirl sign may be round, irregular or streak-like in appearance.[16] Selariu *et al*. concluded that swirl sign in intracerebral haemorrhage is a predictor of mortality and functional outcome at 1-month and 3-months, respectively.[16] Ng *et al*. reported that the swirl sign was associated with the expansion of the intracerebral haematoma.[18] However, to date, assessment of swirl sign was done in previous studies qualitatively and no quantitative estimation or calculation of the swirl volume was done. Thus, the aim is to assess the swirl volume quantitatively using a semi-automated approach and explore the association of swirl sign and haematoma expansion in intracerebral haemorrhage.

METHODS

This was a retrospective study involving 163 patients with primary intracerebral haemorrhage to University Malaya Medical Centre (UMMC) between January 2015 to June 2019. Ethical approval was secured from the institution's Medical Research Ethics Committee (MECID NO 201888-6583).

Patients with primary ICH within the study period who had initial non-contrast-enhanced CT of the brain with a repeat CT within 96 hours were identified. Patients who underwent surgical evacuation in between the two CT examinations and had concurrent intracranial vascular abnormalities, trauma, haemorrhagic transformation after ischemic stroke or tumour were excluded from the study.

The modified Rankin scale (mRS) was used to assess functional status at 30 days. mRS grades the physical disability from 0 to 6, where 0 denotes that a patient is asymptomatic, whereas 6 denotes death.[19] Data on 30-day mortality status and modified Rankin scale at 30 days was obtained via the EMR system either when the patient was in a hospital inpatient or during the patient's outpatient appointment at the neurology/ rehabilitation clinic. Assessing the ability to ambulate without assistance[16], mRS ≤ 3 is defined as a favourable outcome, and mRS ≥ 4 is taken as an unfavourable outcome.

CT imaging and swirl volume assessment

CT scans were performed on a Philips Ingenuity core 128-slice CT scanner (Philips Medical Systems, Amsterdam, the Netherlands). The imaging protocols for CT include axial CT brain with slice thicknesses of 3.0 mm and 1 mm.

The unenhanced axial CT brain images of the enrolled patients were reviewed by a radiology trainee and a consultant neuroradiologist using a DICOM viewer (OsiriX MD11.0, Geneva, Switzerland). Figure 1 demonstrates a swirl sign in intracerebral haemorrhage in axial, sagittal and coronal views of non-contrast enhanced CT brain.

The haematoma and swirl volume were segmented using ITK-SNAP software v3.2 (http://www.itksnap.org/pmwiki/pmwiki.php?n=Downloads.SNAP3). This application was used for semi-automatic segmentation using active contour methods and manual delineation.

The CT images for segmentation were downloaded from PACS in DICOM (Digital Imaging and Communications in Medicine) format. The active 3D semi-automated method was used to segment and determine the volume of the haematoma. Two-sided threshold limits were adjusted to create a speed image. The initialisation seed was placed within the haematoma region. As the contour evolves, and segmentation image of the haematoma was created. The volume was then calculated and recorded (in mm^3). Figure 2 shows acute brainstem intracerebral haemorrhage (A-C) and the segmentation images of the haematoma (D-F) in axial, sagittal and coronal views in a non-contrast-enhanced CT brain.

The ITK-SNAP application then auto-calculates the segmented hematoma volume, as shown in Figure 3. The swirl volume was manually segmented, as shown in Figure 4. Similarly, the ITK-SNAP application then auto-calculates the segmented swirl volume, as shown in Figure 5.

The swirl volume ratio was taken as the swirl volume divided by the initial haematoma volume, as shown in Equation 1.

$$Swirl\ ratio = \frac{Swirl\ volume}{Initial\ haematoma\ volume} \quad \text{---- Eq. 1}$$

The expansion of the haematoma was determined quantitatively by subtracting the haematoma volume in the initial CT from the repeated CT using the same technique.

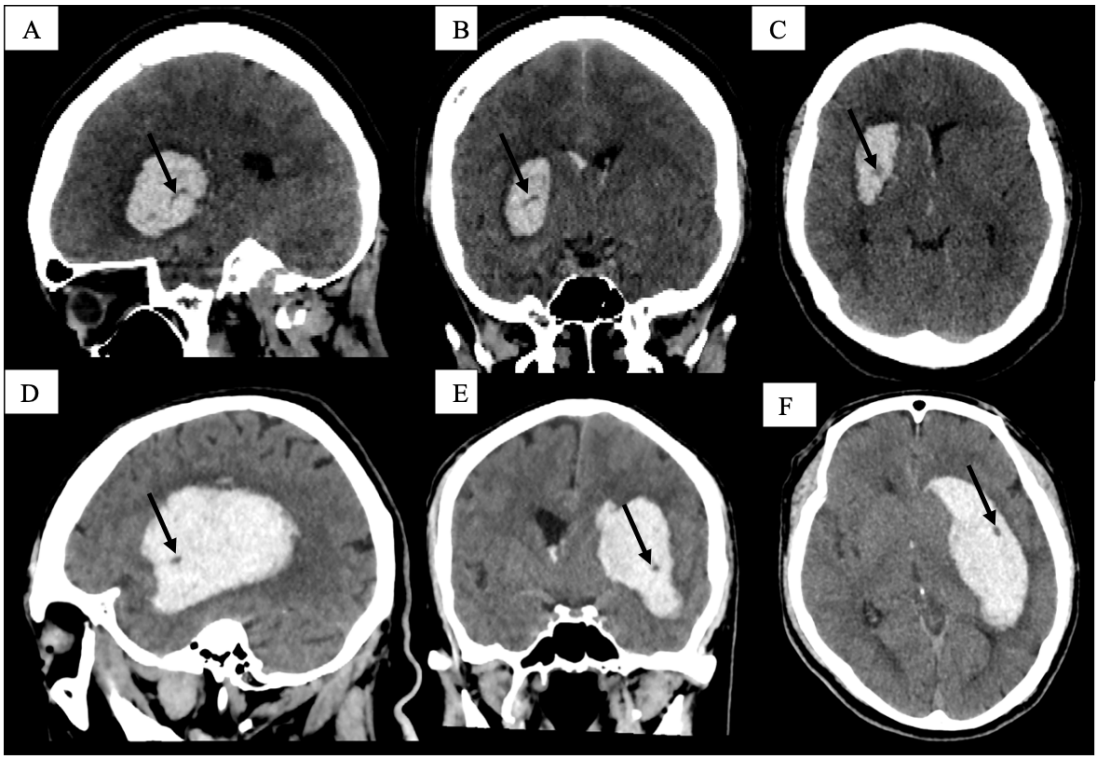

Figure 1. Non-contrast enhanced CT of the brain in sagittal, coronal and axial views in two different patients (A-C) and (D-F) demonstrating swirl signs in acute intracerebral haemorrhage (arrow).

Statistical analysis

Statistical analysis was performed using IBM SPSS (IBM Corporation, Armonk, NY). Continuous variables were analysed and presented as mean ± standard deviation, while categorical variables were presented as absolute values or percentages. As the data is non-parametric, the Spearman rank correlation test for significance between continuous data and the Chi-square test was used to test the association between categorical variables and statistical significance was assumed if the p-value < 0.05.

The chi-square test was used to analyse the association between patient demographic data and swirl signs, the association between swirl signs and mortality, and functional outcomes.

The Spearman test was used to study the correlation between swirl sign and haematoma expansion. The correlation between swirl volume and the ratio of swirl volume/initial haematoma volume with haematoma was also analysed with the Spearman test.

RESULTS

Table 1 demonstrates the demographic data of patients with intracerebral haemorrhage. From this study, out of 163 patients, male subjects constituted almost two-thirds of the total subjects. More than one-third (35%) had a swirl sign within the intracerebral haemorrhage. Statistical analysis performed using the Chi-square test demonstrated no statistical significance between gender, age, or ethnicity and the presence of a swirl sign.

More than 80% of acute primary ICH occurs in supratentorial location; more than half occurs in deep location (basal ganglia and internal capsule) whilst one-third in the lobar region. Intraventricular haemorrhage occurred in 60% of patients with acute intracerebral haemorrhage.

In patients with a swirl sign present, almost all (93%) had haematoma expansion, compared to only 45.3% in those without a swirl sign present. Patients with a swirl sign had greater haematoma expansion than those without a swirl sign present.

Statistical analysis using the chi-square test shows a significant association between the presence of a swirl sign and the presence of haematoma expansion, $p<0.001$). Analysis using the Spearman correlation test showed there is a moderate correlation ($r=0.518$) with a high significance between the presence of a swirl sign and the volume of haematoma expansion, $p<0.001$. (Table 2)

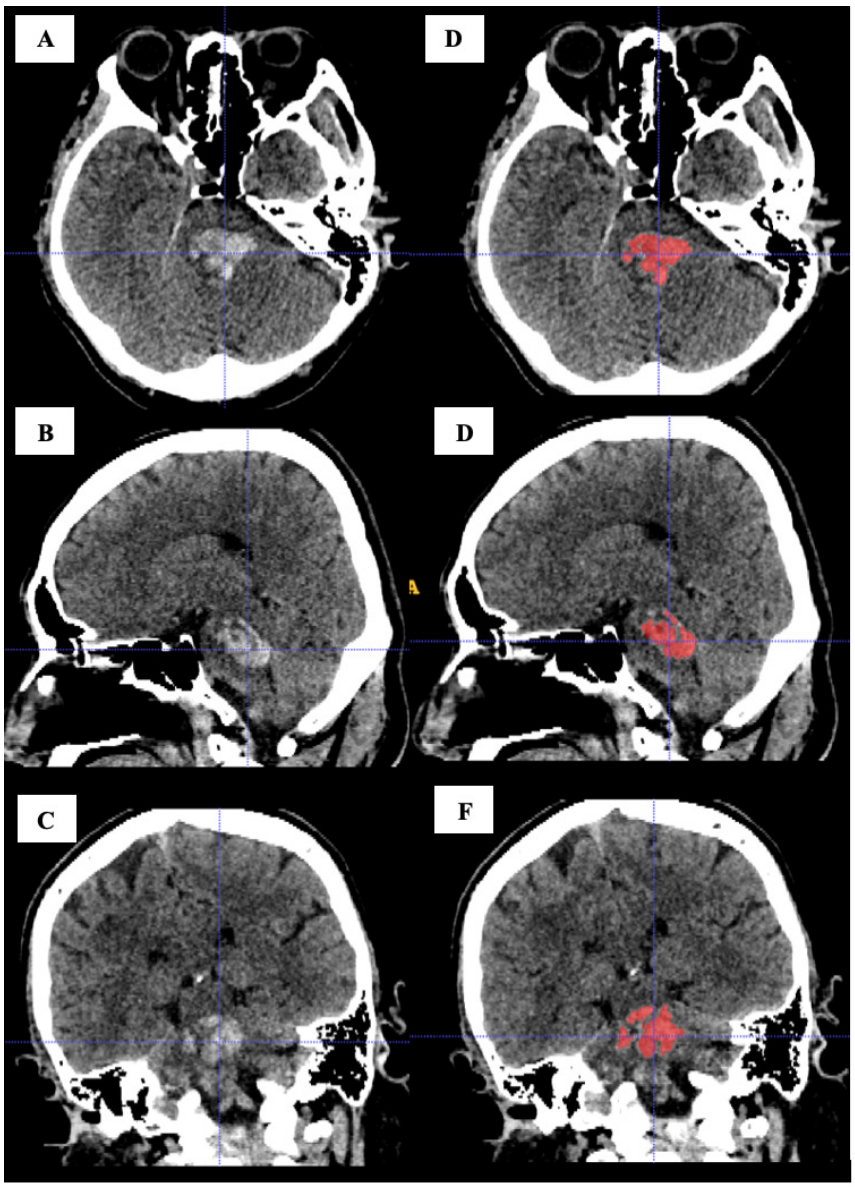

Figure 2. Non-contrast enhanced CT brain. Axial, sagittal and coronal views (A-C) showing the acute brainstem haematoma and segmentation of the haematoma in axial, sagittal and coronal views (D-F).

Analysis of the correlation between swirl volume and haematoma expansion showed moderate correlation between swirl volume and haematoma expansion (r=0.391, p-value = 0.003). Statistical analysis using Spearman correlation revealed a significant positive, however low correlation between the ratio of swirl sign volume to initial haematoma volume and haematoma expansion (r =0.278, p-value = 0.036).

Figure 6 demonstrates the distribution of mRS scores among those with and without swirl signs. The median mRS of patients with swirl signs at 1-month was 5. In patients without swirl sign present, more than one-third of patients had a favourable outcome, while out of 57 patients with swirl sign present, less than 20% had a favourable mRS outcome. Chi-square test analysis did show a significant association between swirl sign and functional outcome at 1-month, p=0.032.

In patients with swirl sign present, more than two-fifths (2/5) did not survive at 1-month, compared to more one-fifth (1/5) without swirl sign. Statistical analysis using the chi-square test did show a significant association between the presence of swirl sign and mortality at 1-month (p =0.02). (Table 3)

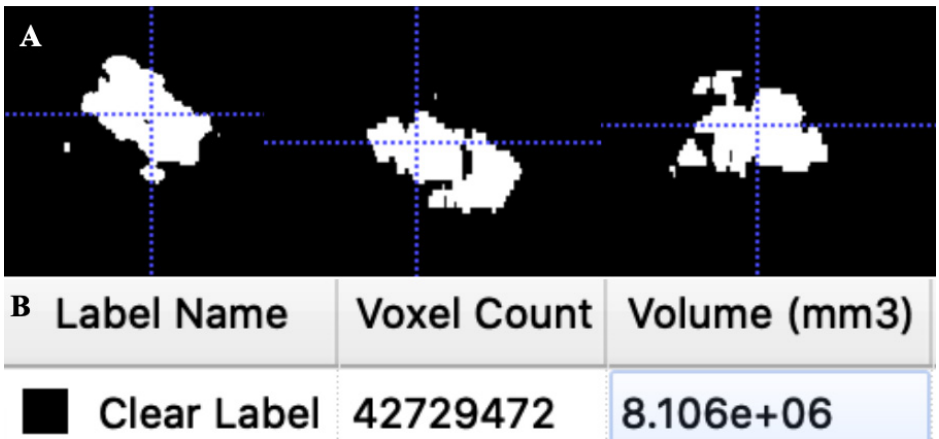

Figure 3. Segmented haematoma (A) and volume of haematoma in mm^3. The haematoma volume was auto-calculated by the ITK-SNAP application after segmentation of the haematoma in 3 planes.

DISCUSSION

Swirl sign in acute primary intracerebral haemorrhage has been explored in a few studies before.[10,16,18] Assessment of swirl signs was done qualitatively in previous studies, and no quantitative estimation or calculation of swirl volume was performed. To our knowledge, this is the first study that assessed the swirl volume quantitatively and attempted to assess the association of the ratio of swirl volume with haematoma expansion. Quantitative assessment of the swirl volume was done using a semi-automated method with ITK-SNAP. The semi-automated method of assessing swirl volume in this study was done by manual segmentation of the swirl area manually drawing the ROI of the swirl area. This

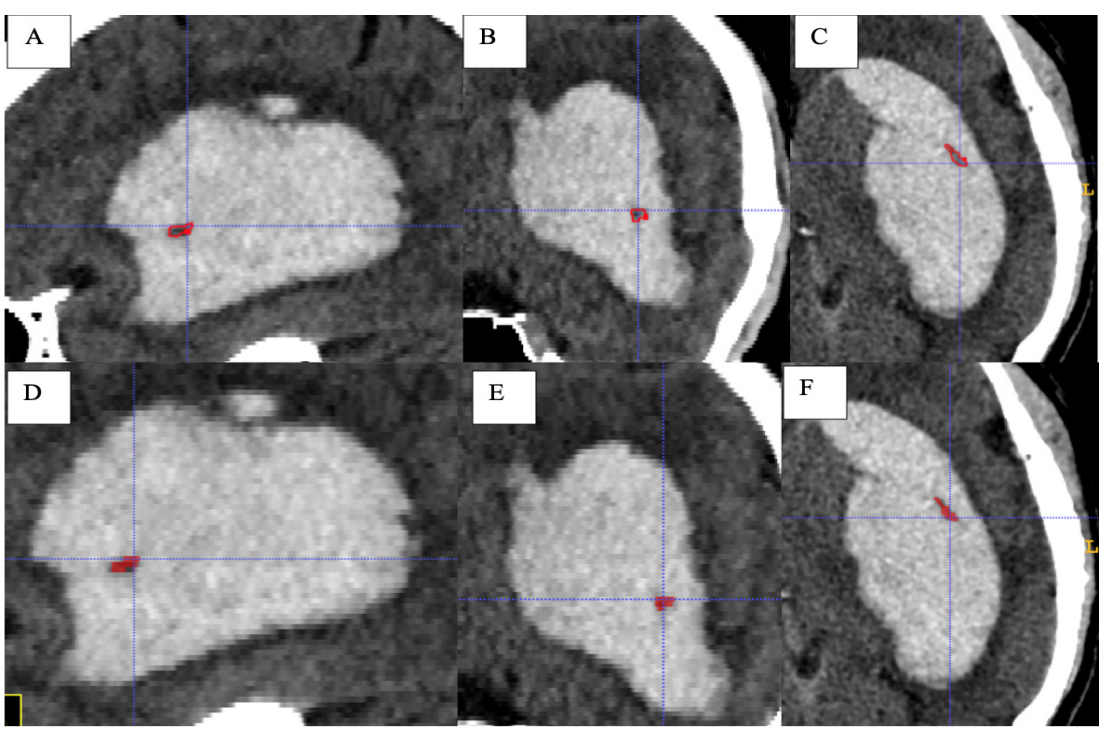

Figure 4. Magnified axial non-contrast-enhanced CT of the brain in sagittal (A, D), coronal (B, E) and axial (C, F) depicting manual ROI annotations of boundaries of swirl (A-C) in intracerebral haemorrhage and segmentation result of the swirl volume (D-F).

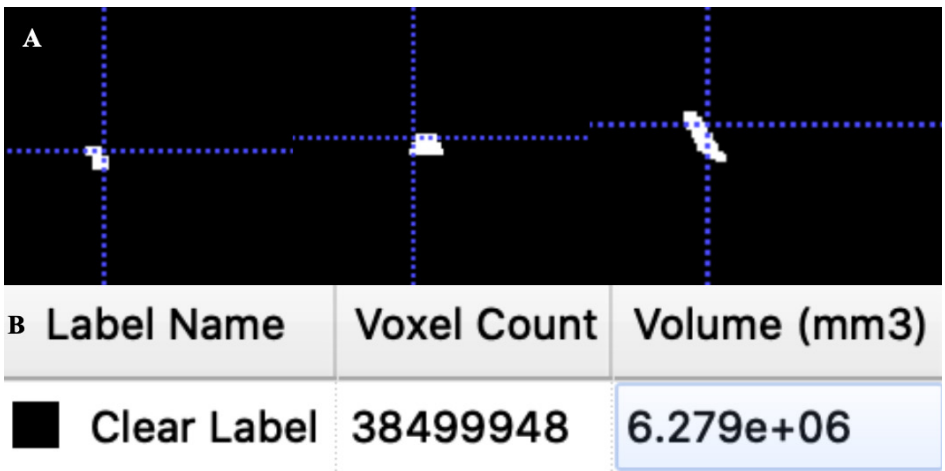

Figure 5. (A) Segmented swirl volume and the calculated volume voxel number and mm^3. The volume of the swirl was auto-calculated by the ITK-SNAP application after segmentation of the swirl in 3 planes.

allows for objective quantification of swirl on CT.

This is the first study to examine the association of swirl signs with haematoma expansion and mortality as well as the functional outcome at 1-month in a multi-ethnic Asian population. Swirl sign was detected in 35% of our study population. This is almost similar to findings by Selariu *et al.* and Ng *et al.* where swirl sign was documented in 30% and 42.9% of their study subjects respectively. We discovered a strong association between the presence of a swirl sign and the volume of haematoma expansion

Table 1: Table showing the demographic data of patients with intracerebral haemorrhage

Demographic data	Intracerebral haemorrhage (Total: 163)	Presence of a swirl sign (Total: 57, 35%)	Absence of swirl sign (Total: 106, 65%)	p-value*
Gender				
• Male	105 (64.4%)	38 (66.7%)	67 (63.2%)	
• Female	58 (35.6%)	19 (33.3%)	39 (36.8%)	0.733
Age				
• Elderly	94 (57.7%)	35 (61.4%)	59 (55.6%)	
• Non-elderly	69 (42.3%)	22 (38.6%)	47 (44.3%)	0.510
Ethnicity				
• Malay	67 (41.1%)	24 (35.8%)	43 (64.2%)	
• Chinese	63 (38.7%)	17 (27%)	46 (73%)	
• Indian	21 (12.9%)	10 (47.6%)	11 (52.4%)	
• Others (foreigners)	12 (7.3%)	6 (50%)	6 (50%)	0.216
Location of intracerebral haemorrhage				0.308
• Deep	91 (55.8%)	35 (38.5%)	56 (61.4%)	
• Lobar	50 (30.7%)	16 (32%)	34 (68%)	
• Brainstem	9 (5.5%)	1 (1.1%)	8 (88.9%)	
• Cerebellar	12 (7.4%)	4 (33.3%)	8 (66.7%)	
• Multiple	1 (0.6%)	1 (100%)	0 (0%)	
Haematoma expansion				
Yes	101 (62%)	53 (93%)	48 (45.3%)	<0.001
No	62 (38%)	4 (7%)	58 (54.7%)	

*p-value calculated using Pearson chi-square test.

Table 2: Correlation of swirl sign with haematoma expansion

Swirl sign	Maximum haematoma expansion (cm^3)	Minimum haematoma expansion (cm^3)	Mean (cm^3)	Standard deviation (cm^3)	p-value
Present	102.4	-7.6	13.1	20.2	
Absent	38.7	-60.6	0.9	9.2	<0.001

(p <0.001). The mean absolute growth (13.1cm^3) (which was auto-calculated post-segmentation of haematoma) is higher in patients with swirl signs compared to the subjects without the presence of swirl signs. These findings are in line with the retrospective study by Ng *et al*., where there is a significant association between the presence of a swirl sign and haematoma expansion.[16,18]

Ours is the first study to explore the correlation of swirl volume with haematoma expansion as well as the ratio of swirl volume/initial haematoma volume with haematoma expansion in acute intracerebral haemorrhage. We found that there is a significant, moderate correlation between swirl volume with haematoma expansion. Similarly, significant although low correlation was found between the ratio of swirl sign/initial haematoma with the volume of haematoma

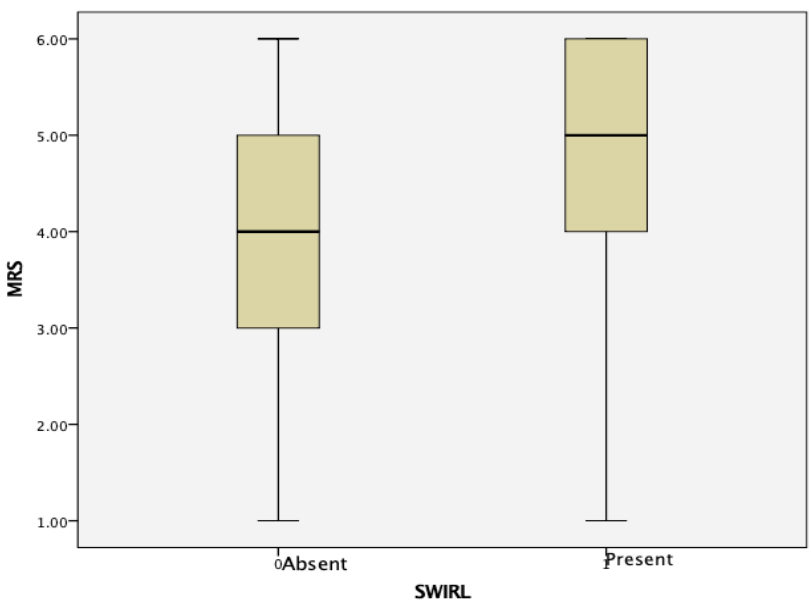

Figure 6. Boxplot showing the distribution of mRS among those with and without the presence of swirl sign.

Table 3: Table showing the association of the presence of swirl sign with functional outcome and mortality at 1-month

		Swirl sign		
		Present	Absent	p-value
mRS at 1-month	Favourable	11 (19.3)	38 (35.8)	
	Unfavourable	46 (80.7)	68 (64.2)	<0.05
Death at 1-month	Yes	23 (40.4)	24 (22.6)	
	No	34 (59.6)	82 (77.4)	<0.05

Figures between parenthesis are percentages.

mRS modified Rankin Scale, mRS ≤3: favourable outcome, mRS ≥4: unfavourable outcome.

expansion. These likely suggest that although the presence of a swirl sign alone is sufficient to predict haematoma expansion, a larger swirl suggests bigger haematoma expansion.

In 2012, Selariu *et al.* concluded that swirl sign correlates with poorer functional outcomes and higher mortality. We found that our study also is in line with these findings. In our study, there is a significant association between swirl sign and functional outcome at 1 month, where out of 57 patients with swirl signs present, only 19.3% had favourable functional outcomes, whereas 35.8% of those without had a favourable functional outcome. Similarly, we also found that there is a significant association between the presence of swirl sign and mortality at 1-month. In the patients with swirl sign present, 40.4% were dead at 1-month whereas 22.6% of patients without swirl sign were dead at 1-month. Patients with swirl sign also had more massive haematoma at presentation with mean haematoma volume of 13.1cm^3 compared to those who do not have swirl sign (mean initial haematoma volume of 0.9cm^3).[16]

Hypertension has been described in many literatures as one of the important risk factors for developing intracerebral haemorrhage.[20-23] It is a significant as well as an independent risk factor for intracerebral haemorrhage.[20] In our study, we found that 71.2% of our subjects have hypertension as morbidity. However, although more than 70% of our patients had hypertension, we found no association of hypertension with the presence of a swirl sign. Our study is similar to previous studies where hypertension was found in 74.4% of patients in a study by Yousuf *et al*. and 84.9% of patients in a study done by Sia *et al*..[5,6,24] Hence, hypertension remains a major risk factor in our population.

The limitation of this study is that the study is a retrospective cross-sectional study. Thus, our assessment of a patient's functional outcome with mRS was done retrospectively by accessing electronic medical record (EMR) instead of a prospective survey using a questionnaire. Patients were given mRS score after accessing the clinical review in the neurology, or stroke rehabilitation clinic during follow up. In future studies, the assessment of mRS with questionnaires should be considered. Another limitation of this study is that this study assessed the swirl volume quantitatively using a semi-automated method with ITK-SNAP which involves manually drawing the ROI of the swirl area. The possible issue in this method is likely the consumption of time that is needed to delineate the ROI of every slice manually. However, familiarity with this technique can help in this.

In conclusion, our study demonstrated that the presence of a swirl sign shows a strong association with haematoma expansion in patients with acute intracerebral haemorrhage. Swirl volume and the ratio of swirl sign volume/ initial haematoma volume are also predictors of haematoma expansion. The presence of swirl signs is also strongly associated with risk of mortality and unfavourable functional outcome (mRS) at 1 month after acute intracerebral haemorrhage. Thus, it can be used to predict the prognosis of patients with acute intracerebral haemorrhage. Thus, here we conclude the presence of a swirl sign can predict the expansion of haematoma as well as mortality and functional outcome at 1 month.

ACKNOWLEDGEMENT

The authors acknowledge the assistance of the following staff members from the Department of Biomedical Imaging, Faculty of Medicine, Universiti Malaya, for technical support.

DISCLOSURE

Conflict of interest: None

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