Heliyon 10 (2024) e40421

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Use of cerebral hemorrhage volume calculation methods in patients with ASPECTS <6

Jia Zhou, Chenyang Huang, Hai Zeng *

Neurosurgery, Second Hospital of Shanxi Medical University, Taiyuan, 030001, China

ARTICLE INFO

Keywords:
Ischemic stroke
Mechanical thrombectomy
Radiographic
Image
Infarct

ABSTRACT

Objective: We aimed to determine whether the ABC/2 can be used as an infarct volume measurement tool for Mechanical thrombectomy (MT) in patients with Alberta Stroke Program Early CT Scores (ASPECTS) < 6.

Methods: Patients with stroke with ASPECTS <6 within 24 h were included in this study, and infarct volume was measured using the ABC/2. The patients were categorized into MT and standard drug groups. They were assessed based on a modified Rankin Scale (mRS) ≤3 at 3 months, intracranial hemorrhage within 48 h, and mortality at 3 months.

Results: ASPECTS <6 showed a significant negative correlation with infarct volume measured using the ABC/2. Compared to drug therapy, the patients who received MT treatment had a higher proportion of achieving an mRS score of ≤3 (OR, 2.60; 95 % confidence interval [CI], 1.04–6.50; P = 0.040), a lower death rate (OR, 0.37; 95 % CI, 0.15–0.92; P = 0.031), and a reduced decompressive craniectomy (OR, 0.10; 95 % CI, 0.01–0.83; P = 0.033); however, intracranial hemorrhage risk significantly increased (OR, 4.35; 95 % CI, 1.12–17.0; P = 0.034).

Conclusion: In the absence of advanced imaging, the ABC/2 can be a useful tool for measuring volume in anterior circulation in patients with ASPECTS <6.

1. Introduction

Mechanical thrombectomy (MT) trials on large core infarcts [1–5] demonstrated that MT treatment was superior to standard pharmacologic therapy for patients with Alberta Stroke Program Early CT Scores (ASPECTS) 3–5 and infarct volumes ≥50 mL or ≥70 mL. These findings indicated that MT for large core infarcts outperformed standard drug treatment. However, these studies used advanced Rapid Processing for Perfusion and Diffusion software to calculate infarct volume. Conversely, there are still many primary care organizations that cannot refine this advanced software examination, thereby limiting the application of infarct volume as an MT criterion in the Chinese population, especially in patients with ASPECTS 0–2, where the adjunctive judgment of infarct volume is frequently needed. The ABC/2 formula [6,7] is widely used for measuring intracerebral hemorrhage volume, and surgeons apply it as a surgical indication, which is relatively convenient and fast in clinical practice. Our study assessed the ABC/2 formula as a measurement tool for infarct volume. In this study, we aimed to verify whether the ABC/2 can be used as a measurement tool for infarct volume before MT treatment and whether it can replicate the results of a multicenter randomized controlled trial of large core infarcts in a real-world setting by comparing the results of MT treatment with those of optimal drug therapy.

* Corresponding author.
E-mail address: zenghai0058@163.com (H. Zeng).

https://doi.org/10.1016/j.heliyon.2024.e40421
Received 6 May 2024; Received in revised form 23 September 2024; Accepted 13 November 2024
Available online 15 November 2024

2. Methods

2.1. Standard of patient

This retrospective study was conducted to collect data on patients with acute large core infarction within 24 h of onset between October 2021 ， and December 2023, at the Second Hospital of Shanxi Medical University. Patients met the following criteria: (1) age ≥18 years; (2) pre-stroke modified Rankin Scale (mRS) = 0 and National Institutes of Health Stroke Scale (NIHSS) ≥6; (3) Angiographic evidence (computed tomography angiography, magnetic resonance angiography, or digital subtraction angiography) proving occlusion of the internal carotid artery or M1 segment of the middle cerebral artery; and (4) CT-ASPECTS <6. The exclusion criteria were midline displacement, acute intracranial hemorrhage, pregnant women, andmalignant tumors.

2.2. Subgroups

Infarct volume size was calculated in patients with ASPECTS <6 using the ABC/2 ([cumulative number of layers x product of length and width at the largest level of the lesion]/2, mL) at CT. MT group was defined as thrombectomy using stent extraction devices and/or contact aspiration, balloon angioplasty, stenting, or intra-arterial thrombolysis if needed, as well as receiving standard drug therapy. The drug therapy group received standard drug therapy alone [8]. Patients who meet the criteria for intravenous thrombolysis stroke guidelines within 4.5 h of onset receive alteplase therapy (Fig. 1).

2.3. Assessment of indicators

The assessment of indicators included the following: (1) the mRS ≤3 at 3 months; (2) Symptomatic intracranial hemorrhage (SICH) occurring within 48 h (based on the definition of the Heidelberg Bleeding Classification [10]), any intracranial hemorrhage (AICH), and mortality at 3 months; and (3) successful reperfusion defined as achieving a modified Treatment in Cerebral Ischemia scale (mTICI) score of ≥2b [9].

2.4. Data collection

ASPECT scores were averaged (rounded) after scoring by two neurointerventionalists who were blinded to subgrouping at that time. Audio interview recordings were completed by telephone at 3 months by a specially trained neurological nurse who was unaware of the subgroups at the time. All patients had a follow-up recording.

2.5. Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, N.Y., USA). Variables are presented as means ± standard deviations or medians (IQR). Classification variables are reported as numbers (%). Analysis was conducted using T-tests, Mann–Whitney tests, or $\chi 2$ test. A one-way binary logistic regression was conducted on the baseline variables, incorporating features with $P < 0.05$ into the multivariate logistic regression for adjustment. Spearman's rank correlation coefficient

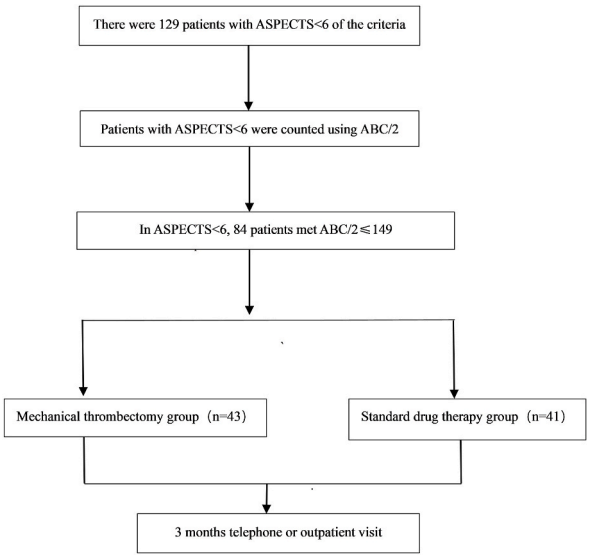

Fig. 1. Flow chart.

was used to determine the correlation between ASPECTS and ABC/2 volume. Inter-observational agreement between ABC/2 vol and ASPECTS was assessed using intraclass correlation coefficients and weighted-kappa.

3. Results

3.1. Correlation results between ASPECTS and ABC/2

The 129 patients with CT-ASPECTS <6 had maximum and minimum infarct volumes of 445 mL and 58 mL, respectively. ASPECTS ≤2 and 3–5 corresponded to ischemic volume ranges of 125–445 mL and 69–271 mL, respectively. ASPECTS <5 corresponded to an ischemic volume >69 mL (Table 1). ASPECTS <6 showed a strong inverse correlation with infarct volume, while ASPECTS 3–5 demonstrated a moderate inverse correlation with infarct volume (Table 2).

3.2. Baseline characteristics

The baseline characteristics of the two groups were similar (Table 3). In the MT group, patients' age was 65.4 ± 13.1 years, with 18 (41.9 %) being female. Among them, 21 (48.8 %) had hypertension, 23 (53.5 %) had heart disease, 6 (14.0 %) had diabetes, 5 (11.6 %) had hyperlipidemia, 31 (72.1 %) had intracranial atherosclerotic, and the NIHSS score was 21 ± 6.0. The median ASPECTS was 4 (2–5) in the MT group. Overall, 76 (91 %) patients underwent CT. Of these, 66 (78.6 %) had an onset to admission <12 h. Intravenous thrombolysis was performed in 23 (27.4 %) patients. TOAST classifications were as follows: atherosclerotic type, 16 (37.2 %) patients; and atherothrombotic combined cardioembolic type, 17 (39.5 %) patients.

3.3. Evaluation of efficacies

In this study, 48.8 % and 26.8 % of patients in the MT and standard drug groups achieved mRS score of ≤3 at 3 months (odds ratio [OR], 2.60; 95 % confidence interval [CI], 1.04–6.50; P = 0.040). The MT group achieved a MTICI ≥2b at 88.4 %. Two (4.7 %) patients in the MT group and none in the drug therapy group experienced SICH within 48 h. AICH within 48 h occurred in 11 (25.6 %) and 3 (7.3 %) patients in the MT and standard drug groups, respectively (OR, 4.35; 95 % CI, 1.12–17.0; P = 0.034). The mortality rate in the MT group at 3 months was 30.2 %, while that in the standard drug group was 53.6 % (OR, 0.37; 95 % CI, 0.15–0.92; P = 0.031). The proportion of those who underwent craniectomy was higher in the standard drug group than in the MT group (OR, 0.10; 95 % CI, 0.01–0.83; P = 0.033) (Table 4 and Fig. 2).

4. Discussion

ABC/2 has been widely used to calculate cerebral hemorrhage volume [6,7,11], offering advantages such as simplicity, speed, and low price in clinical practice. Therefore, it may be used as a measurement tool for large infarct volumes in the absence of RAPID software to compensate for the difficulty of measuring infarct volumes. Since the infarct area tends to be non-circular, the infarct volume will be overestimated when calculated using the formula. Additionally, in the ABC/2 method, C was weighted numerically [14]. However, considering that ASPECTS only cover the middle cerebral artery region and exclude the infarct area of the anterior cerebral artery caused by internal carotid artery occlusion, the infarct volume will be underestimated. Therefore, the overestimation of infarct volume using the ABC/2 may be offset by underestimating ASPECTS. This provides the possibility of using the ABC/2 to measure large infarcts.

The inter-observer agreement between ASPECTS and infarct volume was good. ASPECTS <6 was strongly negatively correlated with infarct volume, and ASPECTS 3–5 was moderately negatively correlated with infarct volume. Furthermore, ASPECTS 0–2 and 3–5 corresponded to infarct volumes of 125–445 mL and 69–271 mL, respectively. ASPECTS <4 always predicted infarct volumes >100 mL, which is similar to that of two previously reported studies [12,13]. The volume ranges for ASPECTS 4 and 5 were relatively close, suggesting that most of the benefit is likely to be driven by a larger ASPECT; specifically, the larger the ASPECT, the smaller the infarct volume and a clearer MT benefit. Moreover, it is interesting to note that the volume of ASPECTS 3–5 was approximately two times that

Table 1
ASPECTS<6 and Volume(mL) correspondence results.

	Volume		
ASPECTS	Median	IQR	Range
0	364	296–405	259–445
1	257	216–318	148–387
2	228	149–254	125–365
3	149	130–181	100–271
4	142	118–167	105–194
5	121	101–147	69–196
3–5	137	116–165	69–271
0–2	283	220–325	125–445

Table 2
ASPECT and ABC/2 correlation results.

	Spearman	P value	95%CI
ASPECTS<6-vol	−0.69	P < 0.01	−0.77–−0.59
ASPECTS 3–5-vol	−0.40	P < 0.01	−0.56–−0.21

Table 3
Baseline characteristics of the patients.

Baseline characteristics	MT group (N = 43)	Standard drug group (N = 41)	P Value
Age, Mean ± SD — yr.[a]	65.4 ± 13.1	68.5 ± 10.7	p = 0.25
Sex — no. (%)			
Female	18(41.9)	17(41.5)	P=0.97
Medical history — no. (%)			
Hypertension	21(48.8)	22(53.7)	P = 0.66
Heart disease	23(53.5)	19(46.3)	P = 0.51
Diabetes	6(14.0)	12(29.3)	P = 0.09
Hyperlipidemia	5(11.6)	4(9.8)	P = 0.99
Intracranial atherosclerosis— no. (%)	31(72.1)	27(65.9)	P = 0.54
Intravenous thrombolysis — no. (%)	14(32.6)	9(22.0)	P = 0.28
NIHSS score, Mean ± SD	21 ± 6.0	20 ± 6.0	P = 0.62
Imaging method used for enrolment—no. (%)			P = 0.25
CT	41(95.3)	35(85.4)	
MRI	2(4.7)	6(14.6)	
Median ASPECTS score (IQR)[a]	4(2–5)	4(2–5)	P = 0.70
Interval between stroke onset and arrival at the hospital— no. (%)			P = 0.09
≤12 h	37(86.0)	29(70.7)	
>12 h	6(14.0)	12(29.3)	
TOAST classifications — no. (%)			
Atherothrombotic	16(37.2)	15(36.6)	Contrast
Cardioembolic	6(14.0)	7(17.1)	P = 0.74
Mixed type[b]	17(39.5)	12(29.3)	P = 0.59
Arteriole occlusion, other and unknown cause	4(9.3)	7(17.1)	P = 0.38

[a] SD represents standard deviation. IQR represents the interquartile range. Alberta Stroke Program Early Computed Tomography Score (ASPECTS), with lower scores indicating more larger infarction.
[b] Atherothrombotic combined Cardioembolic.

Table 4
Evaluation of efficacies.

Outcomes— no. (%)	MT group (N = 43)	Standard drug group (N = 41)	Odds ratio (95 % CI)	P Value
mRS≤3 at 3 months[b]	21(48.8)	11(26.8)	2.60(1.04–6.50)	P = 0.040
MTICI≥2b[c]	38(88.4)	N[a]	N	N
SICH within 48hr[d]	2(4.7)	0(0.0)	N	N
AICH within 48 h	11(25.6)	3(7.3)	4.35(1.12–17.0)	P = 0.034
Mortality at 3 months	13(30.2)	22(53.6)	0.37(0.15–0.92)	P = 0.031
Decompressive craniectomy	1(2.3)	8(19.8)	0.10(0.01–0.83)	P = 0.033

[a] N denotes not applicable or without.
[b] The scoring range of the Modified Rankin Scale is from 0 to 6 points. 0, no disability; 3, independent walking; 6, death.
[c] Modified Treatment in Cerebral Ischemia scale (mTICI) divided into five levels, with higher levels indicating more reperfusion. The definition of successful reperfusion is achieving an mTICI score of≥2b.
[d] Symptomatic intracranial hemorrhage is defined according to the Heidelberg Bleeding Classification system.

of 0–2, suggesting that patients with ASPECTS 3–5 have relatively smaller infarct volumes and benefit more from MT. This aligns with the primary results and subgroup analyses of the ANGEL-ASPECT, SELECT2, TENSION, and TESLA trial analyses, all of which indicated that the benefits were more pronounced in patients with ASPECTS 3–5 because they had smaller infarct volumes, which was also found in our study. While in routine settings one may rely more on ASPECT than on calculating a patient's stroke volume, for patients with weak ASPECTS 0–2 who may benefit from MT, we may need more refined analysis and treatment if we aim to improve the benefit in this group. This could involve the use of precise quantitative methods to calculate infarct volume in patients with ASPECTS 0–2 and determine the lower limit volume or critical volume for benefit in MT treatment. Moreover, calculating the extent of functional areas in patients with ASPECTS 0–2 and investigating whether the reduced benefits in patients are associated with extensive functional area volume death are important considerations for future studies. Therefore, we believe that volume calculations are important for analyzing the disease and treating patients with ASPECTS <6, especially those with ASPECTS 0–2; however, this requires further independent trials.

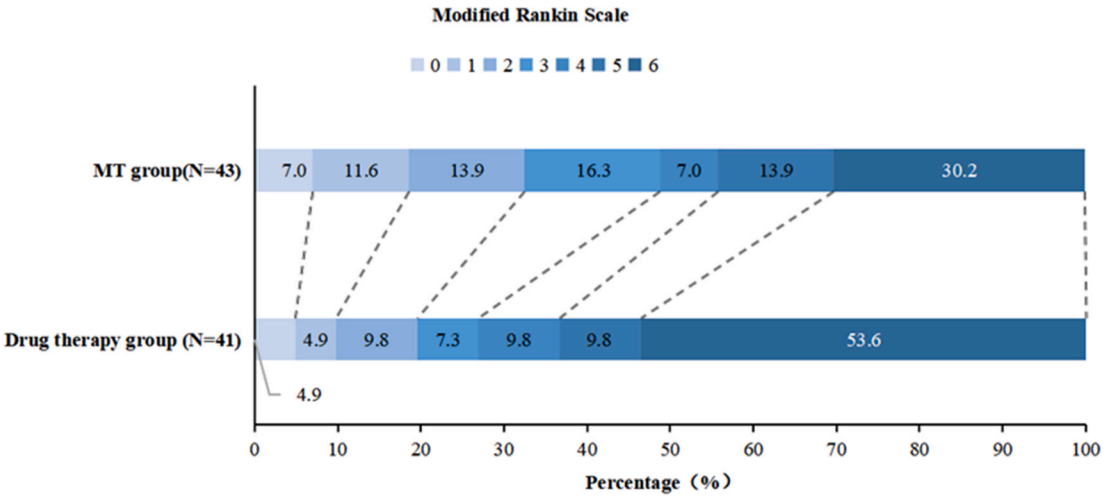

Fig. 2. Distribution of mRS for MT and drug treatment group.

Our trial demonstrated that compared to drug therapy, patients with infarct volumes <150 mL who received MT treatment had a higher proportion of achieving mRS score of ≤3 at 3 months, lower mortality rates (which were similar to those of the ANGEL-ASPECT and SELECT trials [2,3]), and low decompressive craniectomy. Although intracranial hemorrhage risk increased, it does not mask the fact that the final draft is beneficial. From the clinical results, it was observed that patients with infarct volumes <150 mL screened using the ABC/2 method could benefit from MT treatment.

Study limitation and outlook. First, the infarct volume was measured manually to reduce bias by averaging two measurements; second, further research is needed to determine whether these findings can be applied to patients with ASPECTS >6; additionally, this was a retrospective study with a small sample size, and it is necessary to expand the sample size to strengthen the results of the trial. Future studies could also compare the effects of different measurement methods on infarct volume measurements (e.g., with artificial intelligence software methods) as well as investigate the value of the ABC/2 method in other types of cerebrovascular disease.

5. Conclusion

In the absence of advanced imaging, ABC/2 can be used as a tool to measure volume in anterior circulation with ASPECTS <6.

CRediT authorship contribution statement

Jia Zhou: Writing – review & editing, Writing – original draft, Investigation. **Chenyang Huang:** Software, Data curation. **Hai Zeng:** Writing – original draft, Supervision.

Ethical approval

The study is in line with the principles of the Declaration of Helsinki. This retrospective study was approved by the local ethics committee. Patient exemption from informed consent (number:2023KY NO.323, Ethics Committee of the Second Hospital of Shanxi Medical University).

Funding

No.

Declaration of competing interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Acknowledgments

Thanks to Professor Zhu Qingfeng for his guidance on this article.

References

[1] K. Uchida, S. Shindo, S. Yoshimura, et al., Association between Alberta stroke Program early computed tomography score and efficacy and safety outcomes with endovascular therapy in patients with stroke from large-vessel occlusion: a secondary analysis of the recovery by endovascular salvage for cerebral ultra-acute embolism—Japan large ischemic core trial (rescue-Japan limit) [J] 79 (12) (2022) 1260–1266.

[2] X. Huo, G. Ma, X. Tong, et al., Trial of endovascular therapy for acute ischemic stroke with large infarct 388 (14) (2023) 1272–1283.

[3] A. Sarraj, A.E. Hassan, M.G. Abraham, et al., Trial of endovascular thrombectomy for large ischemic strokes 388 (14) (2023) 1259–1271.

[4] M Bendszus, J Fiehler, F Subtil, et al., Endovascular thrombectomy for acute ischaemic stroke with established large infarct: multicentre, open-label, randomised trial[J], The Lancet 402 (10414) (2023) 1753–1763.

[5] O.O. Zaidat, S.A. Kasab, S. Sheth, et al., TESLA trial: rationale, protocol, and design, Stroke: Vascular and Interventional Neurology 3 (4) (2023) e000787.

[6] J.C. Hemphill, D.C. Bonovich, L. Besmertis, et al., The ICH score: a simple, reliable grading scale for intracerebral hemorrhage, Stroke 32 (2001) 891–897.

[7] N.S. Rost, E.E. Smith, Y. Chang, et al., Prediction of functional outcome in patients with primary intracerebral hemorrhage: the FUNC score, Stroke 39 (2008) 2304–2309.

[8] W.J. Powers, A.A. Rabinstein, T. Ackerson, et al., Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association 50 (12) (2019) e344–e418.

[9] O.O. Zaidat, A.J. Yoo, P. Khatri, et al., Recommendations on angiographic revascularization grading standards for acute ischemic, Stroke 44 (9) (2013) 2650–2663.

[10] R. Von Kummer, J.P. Broderick, B.C. Campbell, et al., The Heidelberg bleeding classification: classification of bleeding events after ischemic stroke and reperfusion therapy 46 (10) (2015) 2981–2986.

[11] M. Khan, G.L. Baird, R. Elias, et al., Comparison of intracerebral hemorrhage volume calculation methods and their impact on scoring tools, J. Neuroimaging 27 (1) (2017) 144–148.

[12] C. De Margerie-Mellon, G. Turc, M. Tisserand, et al., Can DWI-ASPECTS substitute for lesion volume in acute stroke? 44 (12) (2013) 3565–3567.

[13] K Lin, S A Lee, W E Zink, What ASPECTS value best predicts the 100-mL threshold on diffusion weighted imaging? Study of 150 patients with middle cerebral artery stroke[J], Journal of Neuroimaging 21 (3) (2011) 229–231.

[14] R.U. Kothari, T. Brott, J.P. Broderick, et al., The ABCs of measuring intracerebral hemorrhage volumes, Stroke 27 (1996) 1304–1305.