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Comparison of consistency in acute stroke: Automated ASPECT score software tools and manual consensus scores

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ABSTRACT

Purpose: The Alberta Stroke Program Early Computed Tomography Score (ASPECTS) is a standardized semi-quantitative scoring system. It is widely used to assess the extent of acute ischemic stroke (AIS). We evaluated the consistency of three automatic software packages with the overall and region-specific manual ASPECTS scores of AIS patients.

Methods: Retrospectively, we gathered patients who presented with stroke symptoms between February 2019 and June 2022, and 174 cases were eventually included in the trial. Two radiologists reviewed the NCCT images independently; After four weeks, the same two radiologists began randomly reviewing the DWI images, discussed different scores and give consistent results as ground truth.

Results: Median ASPECTS of the expert consensus reading was 7 (5–9). Good to excellent correlation of ASPECTS total scores among the three software tools (0.70, 0.74 and 0.83). Correlation among ground truth and Rapid-ASPECTS, RealNow-ASPECTS, ShuKun-ASPECTS (ICC = 0.51, Cronbach's α = 0.53), (ICC = 0.60, Cronbach's α = 0.70) and (ICC = 0.52, Cronbach's α = 0.64) respectively. The AUCs for Rapid, RealNow and ShuKun were 0.61, 0.67, and 0.62 respectively. The region-specific results showed a poor to good correlation. The correlations between the non-dominant and dominant cerebral hemispheres and the ground truth were statistically different ($P < 0.05$).

Conclusions: Overall, the scoring consistency between the three automated scoring software and the ground truth is comparable, with RealNow-ASPECTS being no less consistent and effective than Rapid-ASPECTS and ShuKun-ASPECTS, and even better than both. But the consistency grade that still is developable.

1. Introduction

Acute ischemic stroke is one of the leading causes of disability and death globally, severely affecting patients' quality of life and life expectancy [1,2]. Intravenous thrombolysis and endovascular thrombectomy are important early treatment options for acute ischemia that can effectively restore brain tissue perfusion and function, thereby improving patient outcomes [3,4]. However, the accuracy and timeliness of treatment decisions are crucial for the successful application of these therapies.

The Alberta Stroke Program Early Computed Tomography Score (ASPECTS) scoring plays an important role in making treatment decisions in the early stages of acute ischemia [5–7]. ASPECTS is an imaging assessment tool to gauge the extent of acute cerebral ischemia by quantitative analysis of brain CT or MRI images, which can rapidly determine the infarct extent and regions at risk to provide important guidance for treatment decisions [8]. However, traditional manual ASPECTS scoring has some problems, including time-consumption and variability between different scorers, which may lead to inaccuracy and delay of treatment decisions.

Abbreviations: ASPECTS, Alberta Stroke Program Early Computed Tomography Score; AIS, Acute ischemic stroke; AI, Artificial intelligence; CI, Confidence interval; CT, Computed tomography; DWI, Diffusion weighted imaging; ICC, Interclass correlation coefficient; NCCT, Non-contrast computed tomography.

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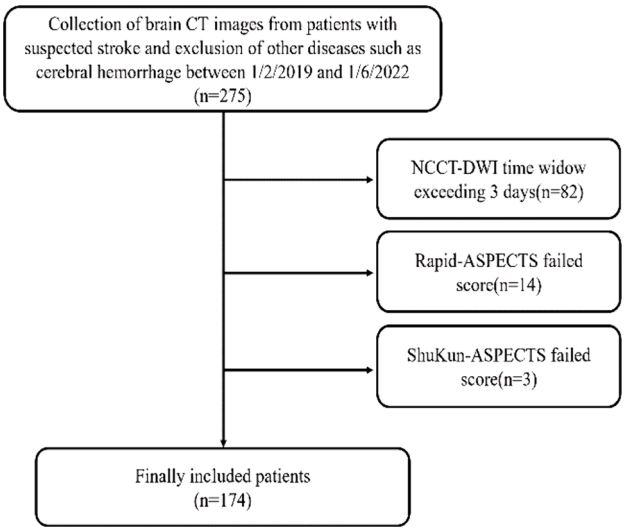


Fig. 1. Study flow chart.

With the rapid development of artificial intelligence technology, the application of AI in ASPECTS assessment has received increasing attention [9–11]. AI software represented by Rapid has proven its role in treatment decision-making of acute cerebral ischemia in clinical practice, providing clinicians with more accurate and rapid ASPECTS evaluations [12–14]. Internationally, various AI-based ASPECTS assessment software has also emerged, offering new tools and approaches for the treatment of acute cerebral ischemia.

In China, due to its large population base and high disease burden of stroke, the application of AI in ASPECTS assessment has also gained

Table 1
Clinical and imaging characteristics of the patient population.

Characteristics	Distribution
NO. of patients	174
Age (Y)	69 ± 13
Men	74 ± 11
Women	66 ± 12
Sex, N (%)	
Men	65 (37.4 %)
Women	109 (62.6 %)
Mean ASPECTS	
Ground Truth	7 (5–9)
Rapid ASPECTS	8 (6–10)
RealNow ASPECTS	9 (8–10)
ShuKun ASPECTS	9 (8—10)
Prevalence of ischemia in the hemisphere	
dominant hemisphere	197 (44.2 %)
non - dominant hemisphere	249 (55.8 %)

Table 2
Comparison of interclass correlation coefficient and 95 % confidence intervals among the three software.

Type of software	Rapid	RealNow	ShuKun
Rapid	\	*	*
RealNow	0.70(0.45,0.81)	\	*
ShuKun	0.74(0.43,0.87)	0.83(0.77,0.87)	\

Note. – 1. * Symbol means $P < 0.01$.
2. Lower and upper 95 % CI of ICC in brackets.

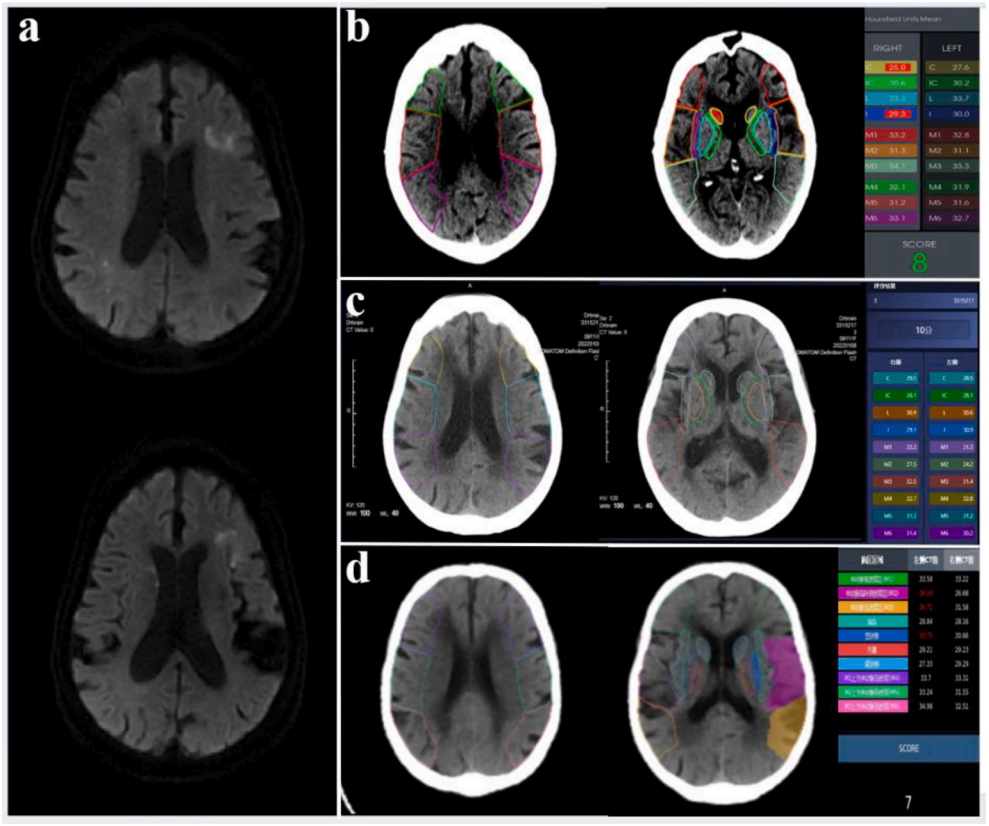


Fig. 2. Automated ASPECT scoring of the same patient with MCA occlusion. a, axial MRI diffusion-weighted imaging sequence images and b, c, d, Axial CT images. a, Two human readers consensus scored 8. b, iSchemaView RAPID ASPECTS scored 8. c, ShuKun ASPECTS scored 10. d, RealNow ASPECTS scored 7.

Table 3
Comparison of correlations between applications and ground truth.

	Ground truth		
	Intraclass correlation coefficient	95 % Confidence intervals	Cronbach's α
Rapid	0.51	0.34, 0.64	0.52
RealNow	0.60	0.23, 0.77	0.69
ShuKun	0.52	0.17, 0.70	0.61

widespread attention. Many domestic ASPECTS assessment software have been introduced, attempting to provide services more tailored to local patient characteristics and needs. However, there is currently a lack of comparative research on the efficacy of these domestic software versus the international standard software Rapid.

Therefore, we plan to conduct this study to evaluate the efficacy of two domestic ASPECTS assessment software (RealNow-ASPECTS, SHUKUN-ASPECTS) versus Rapid in treatment decision-making of acute cerebral ischemia. By comparing their performance in ASPECTS scoring accuracy, time consumption, consistency, etc., we aim to provide clinicians with more comprehensive and accurate decision support for treatment, further optimizing the treatment outcomes of acute ischemic stroke and improving patient survival and quality of life.

2. Methods and materials

2.1. Patients

This was a single-center retrospective study including 275 patients presenting with stroke symptoms who underwent non-contrast computed tomography (NCCT) and magnetic resonance diffusion-weighted imaging (DWI) between February 2019 and June 2022.

Inclusion criteria were as follows: 1. Patients presenting to the hospital with stroke symptoms such as limb numbness and weakness, speech difficulties, facial paralysis, swallowing difficulties, etc. 2. Patients undergoing non-contrast computed tomography (NCCT) and magnetic resonance diffusion-weighted imaging (DWI) sequence examinations of the brain. 3. CT and MRI excluding hemorrhage, tumors, vascular malformations. 4. DWI confirming intracranial high-signal acute ischemic lesions. 5. No intravenous thrombolysis or arterial thrombectomy treatment. 6. No significant motion or other artifacts affecting CT interpretation. Exclusion criteria were: 1. NCCT-DWI time interval exceeding 3 days. 2. Cases where the software analysis was not applicable. After applying the exclusion criteria, 174 cases were included in the trial (Fig. 1).

As shown in Fig. 1, among the 275 cases, all cases were RealNow successes, 14 were Rapid failures and 3 were ShuKun failures, and 82 cases of NCCT-DWI time windows exceeded three days.

2.2. CT and MR scanning programs

Acquisition CT was performed using GE Healthcare, PHILIPS and TOSHIBA scanners and the layer thicknesses of the images were 4 mm, 4.5 mm and 5 mm. MRI was performed on a 1.5-T system (PHILIPS; GE Healthcare) or a 3-T system (PHILIPS; SIEMENS). DWI was obtained with a diffusion gradient b value of 1000 s/mm2. The parameters of DWI included TR = 2245 ms; TE = 90 ms; field of view = 210 × 210; matrix = 140 × 109; section thickness = 5 mm; intersection gap = 1.5 mm; number of slices = 18; flip angle (FA) = 90°.

2.3. Image analysis by neuroradiologists

All NCCT in the dominant hemisphere (left hemisphere) and non - dominant hemisphere (right hemisphere) were retrospectively evaluated by concordant readings from two radiologists with 12 and 18 years of experience and standardized training in ASPECTS, respectively. They

Table 4
Comparison of correlations among applications and ground truth, listed are all ASPECTS segments separately.

		Ground truth		
		Intraclass correlation coefficient	95 % Confidence intervals	Cronbach's α
Left M1	Rapid	0.17	−0.10, 0.38	0.18
	RealNow	0.35	0.12, 0.51	0.35
	ShuKun	0.19	−0.09, 0.40	0.19
Left M2	Rapid	−0.14	−0.53, 0.16	−0.14
	RealNow	0.53	0.36, 0.65	0.53
	ShuKun	0.36	0.15, 0.52	0.39
Left M3	Rapid	−0.17	−0.54, 0.12	−0.18
	RealNow	0.01	−0.30, 0.25	0.01
	ShuKun	−0.19	−0.57, 0.11	−0.20
Left M4	Rapid	0.21	−0.06, 0.41	0.21
	RealNow	0.30	0.07, 0.48	0.32
	ShuKun	0.32	0.09, 0.49	0.34
Left M5	Rapid	0.07	−0.17, 0.28	0.09
	RealNow	0.16	0.09, 0.35	0.19
	ShuKun	0.12	−0.12, 0.31	0.15
Left M6	Rapid	0.07	−0.17, 0.28	0.10
	RealNow	0.16	−0.09, 0.35	0.19
	ShuKun	0.12	−0.12, 0.31	0.15
Left Insular	Rapid	0.05	−0.25, 0.28	0.05
	RealNow	0.45	0.26, 0.59	0.47
	ShuKun	0.07	−0.22, 0.30	0.08
Left Lentiform	Rapid	0.51	0.34, 0.64	0.51
	RealNow	0.55	0.39, 0.67	0.55
	ShuKun	0.52	0.35, 0.64	0.53
Left Internal capsule	Rapid	0.31	0.07, 0.49	0.31
	RealNow	0.38	0.16, 0.54	0.38
	ShuKun	0.26	0.01, 0.45	0.26
Left Caudate	Rapid	0.15	−0.09, 0.35	0.19
	RealNow	0.38	0.17, 0.54	0.39
	ShuKun	0.44	0.24, 0.59	0.44
Right M1	Rapid	0.45	0.25, 0.59	0.44
	RealNow	0.68	0.57, 0.77	0.69
	ShuKun	0.68	0.57, 0.77	0.69
Right M2	Rapid	0.28	0.04, 0.46	0.29
	RealNow	0.59	0.45, 0.70	0.60
	ShuKun	0.57	0.41, 0.68	0.58
Right M3	Rapid	0.57	0.42, 0.68	0.57
	RealNow	0.51	0.33, 0.64	0.53
	ShuKun	0.55	0.39, 0.67	0.57
Right M4	Rapid	0.07	−0.26, 0.31	0.07
	RealNow	0.36	0.14, 0.52	0.37
	ShuKun	0.24	−0.01, 0.43	0.25
Right M5	Rapid	0.35	0.12, 0.51	0.38
	RealNow	0.49	0.26, 0.64	0.54
	ShuKun	0.36	0.13, 0.53	0.40
Right M6	Rapid	0.39	0.18, 0.55	0.42
	RealNow	0.48	0.27, 0.62	0.52
	ShuKun	0.39	0.18, 0.55	0.42

(continued on next page)

Table 4 (*continued*)

		Ground truth		
		Intraclass correlation coefficient	95 % Confidence intervals	Cronbach's α
Right Insular	Rapid	0.53	0.36, 0.65	0.53
	RealNow	0.66	0.53, 0.75	0.67
	ShuKun	0.72	0.61, 0.79	0.73
Right Lentiform	Rapid	0.65	0.53, 0.74	0.66
	RealNow	0.56	0.40, 0.67	0.56
	ShuKun	0.63	0.50, 0.73	0.63
Right Internal capsule	Rapid	0.39	0.18, 0.55	0.39
	RealNow	0.26	0.01, 0.45	0.27
	ShuKun	0.42	0.22, 0.56	0.42
Right Caudate	Rapid	0.46	0.28, 0.60	0.47
	RealNow	0.47	0.29, 0.61	0.48
	ShuKun	0.61	0.47, 0.71	0.61

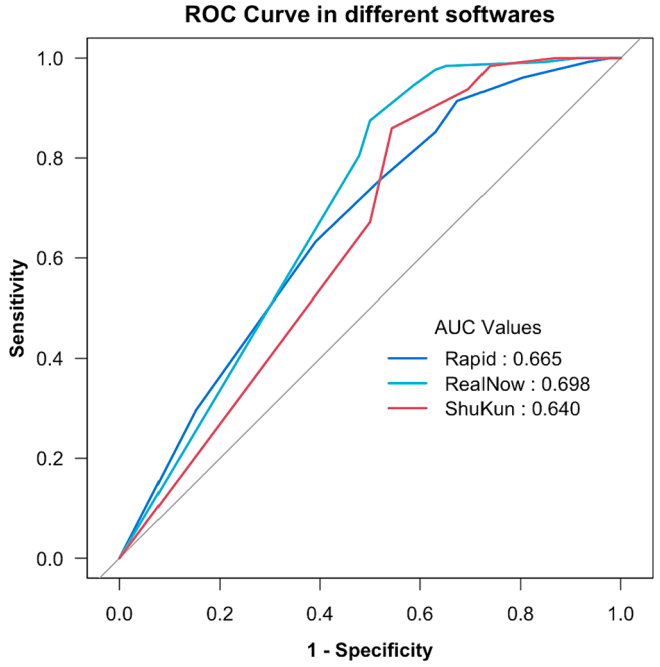


Fig. 3. Score-based (total) receiver operating characteristic (ROC) curve.

underwent standardized training in ASPECTS and were aware of the task of detecting early ischemic changes (EIC) within the intracranial region. However, they were unaware of the specific symptoms, medical history of the patients, the scores from automated software, and were kept blind to each other's ratings. EIC was defined as tissue low density, shallow cerebral sulci or loss of gray-white matter differentiation, as these changes are associated with edema and irreversible damage. Based on a 10-point ASPECT score, the radiologists defined ten regions of interest (VOI) on both brain hemispheres, including the caudate nucleus (C), lentiform nucleus (L), internal capsule (IC), and insular cortex (I), as well as the superficial cortical regions M1-M6. They assigned ischemic or non-ischemic scores to these regions.

The two radiologists first read the NCCT images independently on workstations and gave the scores for each region and the overall score, and after the scores were completed, the data were summarized and screened out the inconsistent data, and the two doctors combined the patient's clinical symptoms and the DWI follow-up images within three days to discuss and give the consistency score as ground truth of this study. At the same time they remain blind to the results of automated scoring software.

2.4. Image analysis by using automated software

RealNow, ShuKun, and Rapid can all achieve the purpose of auxiliary decision support by analyzing NCCT data. All three software support thick-layer data analysis, and all the data in this study are thick-layer data. The automated scoring software automatically finds the area where the lesion is located by analyzing the relationship between the voxels of the NCCT image, and then provides the ASPECTS score of the image.

The automated scoring system is easy to use, and the complete process of image processing has been packaged inside the software. The data is imported into the software, which automatically pre-processed and normalized. Then, based on previous training, regions are automatically segmented and classified as normal or ischemic data, and finally an ASPECTS output score is calculated based on the classification results (Fig. 2).

2.5. Statistical analysis

All statistical analyses were performed using SPSS (version 26.0) and MedCalc for Windows (version 12.3.0.0, MedCalc Software, Mariakerke, Belgium). Normality testing was conducted using the Kolmogorov-Smirnov test. Quantitative data meeting the normality test were expressed as mean ± standard deviation. Otherwise, the expressions of median and quartile are used. Qualitative data were expressed by percentage (%). Correlations were assessed between each of the three automated software and consensus score using the interclass correlation coefficient (ICC) and its 95 % confidence interval (CI), Cronbach's alpha [15–17]. ICC estimates and their 95 % CI were based on an absolutely consistent. Two-way random effects model with the outcome statistics were obtained using the single measurement data results. ICC values were divided into four groups: poor < 0.40, fair $= 0.40$–0.59, good $= 0.60$–0.74, and excellent $= 0.75$–1.00. The effectiveness of automated software scores was evaluated using the area under the receiver operating characteristic (ROC) curve (AUC) [18,19]. Bland-Altman analysis was applied to assess systematic differences between ASPECT scores. Statistical comparisons among the three groups were conducted using multiple corrections, and $P < 0.05$ was considered statistically significant.

3. Results

A total of 174 patients were included in this study and their mean age was 69 ± 13 years, of whom 65 (37.4 %) were male. The consensus scores of the two radiologists were considered as basic facts. The mean score for the consensus scores was 7 (5–9), and the mean scores for the Rapid, RealNow, and ShuKun results were 8 (6–10), 9 (8–10), and 9 (8–10), respectively. The prevalence of ischemia in the dominant hemisphere was 197 (44.2 %) (Table 1).

The three software had average to good correlations with each other for the overall scores (Table 2). RealNow demonstrated the highest correlation between the comparison of basic facts and total automated software scores, however, the intraclass correlation coefficient was only 0.60. Rapid had the lowest correlation with a intraclass correlation coefficient of 0.51 (Table 3). The ground truth was poorly to good correlated with the software scores for each subregion of the dominant, non-dominant side of the cerebral hemisphere. The results showed that the RealNow correlation was slightly better than the other two software. Notably, the results showed overall better results for the non-dominant hemisphere subdivisions than for the dominant hemisphere; the mean correlation was 0.34 ± 0.17 for the dominant hemisphere and 0.52 ± 0.13 for the non-dominant hemisphere, which was statistically

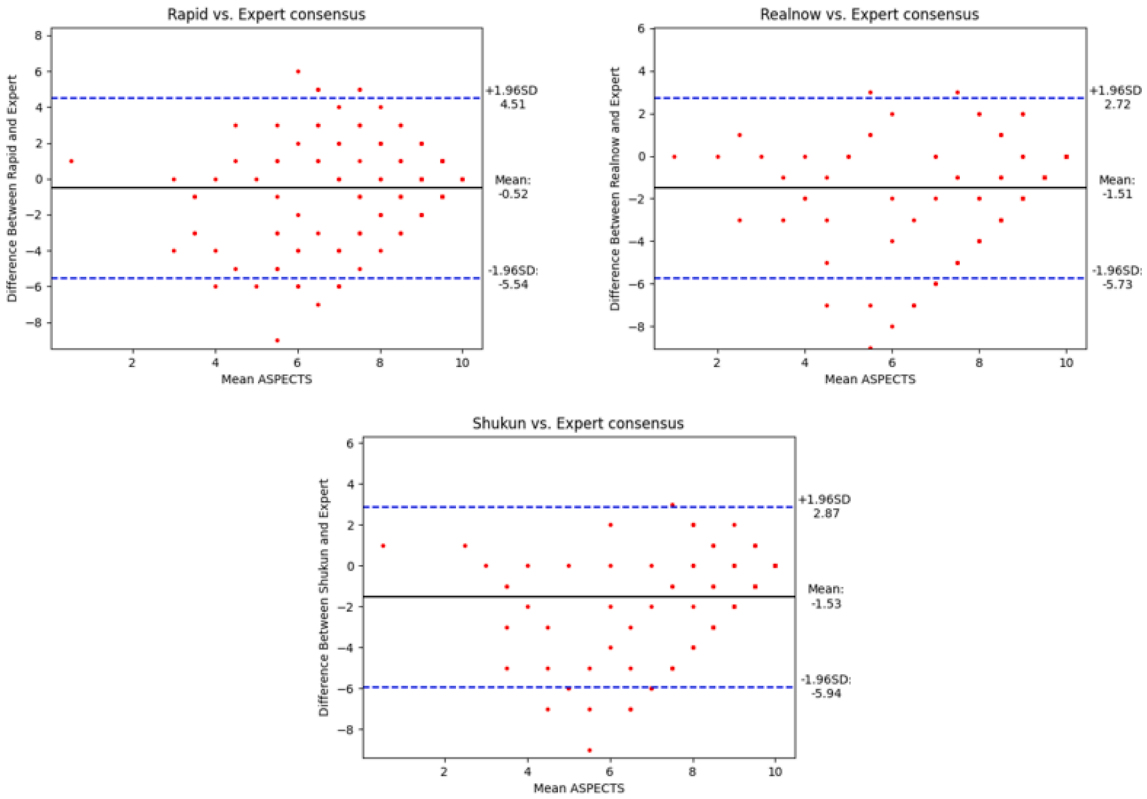


Fig. 4. Bland-Altman diagrams of the rated ASPECTS, illustrating grade of agreement between the different software packages with expert consensus reading.

significant ($P < 0.05$) (Table 4). When ROC curve analysis was performed and AUC assessed, the results showed comparable predictive efficacy between the three software (Fig. 3). The AUCs for RealNow, Rapid, and ShuKun were 0.698, 0.665, and 0.640, respectively.

Fig. 4 is a Bland-Altman diagram showing the consistency between the scores of the three automatic scoring software and the scores of the experts. Bland-Altman graph analysis showed that the scores of the RealNow automatic scoring software had a high degree of consistency with the scores of experts and the fewest outliers. The software for automatic scoring of ShuKun and Rapid has similar consistency with expert scoring, both of which are lower than the results of Rapid.

4. Discussion

There is a great deal of inconsistency in clinicians' subjective scoring of ASPECTS of CT, so machine learning methods are promising to provide standardized and rapid assessments. However, the performance of the ASPECTS domestic software in routine clinical practice has only been tested in a few studies, the main objective of this study was to compare the performance of the automated ASPECTS scoring software separately with the scoring correlation between the ground truth.

An interesting finding was that the mean ASPECTS results indicated that the ground truth ASPECTS was consistently lower than automated scoring. It is possible that because our experts combined clinical symptoms and DWI images from the 3-day follow-up, there is a reversal of the search for infarct lesions on CT images from the DWI data, which would make the ground truth derived by our expert even lower. Hoelter et al. [20] reported software-consensus score agreement of 0.777–0.871, and Austein et al.[21] reported software-consensus score agreement of 0.68–0.72, and all of these results report that automated scoring software can achieve good to excellent agreement with the overall ASPECTS of the ground truth. Notably, in our study, we found only fair to good agreement (0.51–0.60) among the three automated ASPECTS scoring software and the ground truth. One possible explanation for this is that the CT equipment used in our study was of different models from four different manufacturers and the scan layer thicknesses were not the same, which may have had some influence on the results; another explanation is that the ground truth that the cases included in this study showed minor punctate and small patchy haemorrhages on follow-up DWI, but they did not show any abnormal signs on plain CT. It is known that CT is less sensitive than MRI DWI sequences.

In a study of the consistency of the subdivisions of the dominant and non-dominant cerebral hemispheres, it was found that the consistency of the non-dominant hemisphere was better than that of the dominant hemisphere, with a statistically significant difference in the correlation between the two ($P < 0.05$). One possible explanation is that the incidence of ischemic stroke in the non-dominant hemisphere is significantly higher than that in the dominant hemisphere. Another possible explanation is that there are hemispheric differences in the mechanisms of brain function compensation in the different hemispheres after acute middle cerebral artery infarction [22,23].

A comparison of the consistency of the three software shows that RealNow is a little more consistent with the consensus score. And through our understanding, the algorithms of automatic scoring software launched by different companies differ. They may be based on traditional image processing, deep learning algorithms, or a combination of the two methods. With the rise of AI, the core of automatic scoring software is now generally based on deep learning. The deep learning algorithm is a data-driven algorithm. An excellent model requires a large amount of data for training, and the trained model can segment and locate the lesion area. After obtaining the lesion area, make the lesion area more accurate through post-processing, after obtaining these regions, they are registered using the standard template, and finally realize automatic scoring through scoring rules. RealNow-ASPECTS applies exactly this deep learning algorithm, which may make it more consistent with consensus scoring.

There are a number of limitations to our study. Firstly, the consensus score, which was used as the ground truth for this study, was not

obtained from all the patients' long -term follow-up scans and may differ somewhat from the true picture, and no conclusions can be drawn about accuracy, sensitivity or specificity. Secondly, Two radiologists with more than 10 years of experience have just started to score each other blindly, which is a deliberate result, thus reducing the possibility of one doctor having a high or low true value due to other reasons such as fatigue. Thirdly, this study scored a ground truth of 7, which suggests that the degree of ischemia was limited in most cases, and this may have contributed to the low correlation in this study. Fourthly, in clinical work, a conventional cranial plain scan slice thickness of 5 mm is often used, so most of the data from this cohort scanned at 5 mm, whereas Hill MD et al. [24]showed that the ideal slice thickness for automated scoring software should be 1 mm, but as long as the thickness is $\leq$ 6 mm, clinical outcomes can be reliably predicted. Fifthly, although CT-MRI time window is shortened to less than three days, it still does not prevent new onset during this period, thereby reducing the correlation between software and consensus scores.

On the one hand, it is important to note that automated scoring software is only a decision aid and its role is mainly to provide reference advice to less experienced physicians and does not replace the Physician's report. On the other hand, radiologists have access to more information (age, clinical symptoms, etc.) and flexibility to interpret non-standardized images in order to make more accurate judgments. This further emphasizes that a thorough review of the software output by radiologists is mandatory prior to treatment decisions. Future research directions could further clarify whether the thickening of CT scans and different manufacturers' equipment have an impact on each software, to help doctors who refer to the software scores to make a judgement on the credibility of the software scores.

In conclusion, the scoring correlations between the three automated scoring software and consensus scores in this study are comparable and are informative for the low level of seniority of the physicians. More importantly, all three software packages have large scope for improvement.

CRediT authorship contribution statement

Dujuan Liu: Writing – original draft, Investigation. **Jiaqi Yuan:** Formal analysis, Data curation. **Ran Ren:** Formal analysis, Data curation. **Wei Gao:** Writing – review & editing. **Libao Guo:** Resources, Investigation. **Jianming Ni:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] S.K. Feske, Ischemic Stroke[J], Am. J. Med. 134 (12) (2021) 1457–1464, https://doi.org/10.1016/j.amjmed.2021.07.027.
[2] J. Putaala, Ischemic stroke in young Adults[J], Continuum (minneap Minn) 26 (2) (2020) 386–414, https://doi.org/10.1212/CON.0000000000000833.
[3] W. Hacke, M. Kaste, C. Fieschi, et al., Intravenous thrombolysis with recombinant tissue plasminogen activator for acute hemispheric stroke. The European cooperative acute stroke study (ECASS)[J], J. Am. Med. Assoc. 274 (13) (1995) 1017–1025.
[4] R. von Kummer, K.L. Allen, R. Holle, et al., Acute stroke: usefulness of early CT findings before thrombolytic therapy[J], Radiology 205 (2) (1997) 327–333, https://doi.org/10.1148/radiology.205.2.9356611.
[5] M.D. Hill, H.A. Rowley, F. Adler, et al., Selection of acute ischemic stroke patients for intra-arterial thrombolysis with pro-urokinase by using ASPECTS[J], Stroke 34 (8) (2003) 1925–1931, https://doi.org/10.1161/01.STR.0000082483.37127.D0.
[6] J. Naylor, L. Churilov, N. Rane, et al., Reliability and utility of the Alberta stroke program early computed tomography score in hyperacute Stroke[J], J. Stroke Cerebrovasc. Dis. 26 (11) (2017) 2547–2552, https://doi.org/10.1016/j.jstrokecerebrovasdis.2017.05.042.
[7] K. Song, M. Guan, W. Li, et al., Acute ischemic stroke patients with diffusion-weighted imaging-Alberta stroke program early computed tomography score </= 5 can benefit from endovascular treatment: a single-center experience and literature review[J], Neuroradiology 61 (4) (2019) 451–459, https://doi.org/10.1007/s00234-019-02177-1.
[8] P.A. Barber, A.M. Demchuk, J. Zhang, et al., Validity and reliability of a quantitative computed tomography score in predicting outcome of hyperacute stroke before thrombolytic therapy. ASPECTS study group. Alberta stroke programme early CT Score[J], Lancet 355 (9216) (2000) 1670–1674, https://doi.org/10.1016/s0140-6736(00)02237-6.
[9] M.P. McBee, O.A. Awan, A.T. Colucci, et al., Deep learning in Radiology[J], Acad. Radiol. 25 (11) (2018) 1472–1480, https://doi.org/10.1016/j.acra.2018.02.018.
[10] S. Nagel, X. Wang, C. Carcel, et al., Clinical utility of electronic Alberta stroke program early computed tomography score software in the ENCHANTED trial Database[J], Stroke 49 (6) (2018) 1407–1411, https://doi.org/10.1161/STROKEAHA.117.019863.
[11] J.E. Soun, D.S. Chow, M. Nagamine, et al., Artificial intelligence and acute stroke Imaging[J], AJNR Am. J. Neuroradiol. 42 (1) (2021) 2–11, https://doi.org/10.3174/ajnr.A6883.
[12] W. Brinjikji, M. Abbasi, C. Arnold, et al., e-ASPECTS software improves interobserver agreement and accuracy of interpretation of aspects score[J], Interv. Neuroradiol. 27 (6) (2021) 781–787, https://doi.org/10.1177/15910199211011861.
[13] C. Maegerlein, J. Fischer, S. Monch, et al., Automated calculation of the Alberta stroke program early CT score: feasibility and Reliability[J], Radiology 291 (1) (2019) 141–148, https://doi.org/10.1148/radiol.2019181228.
[14] S. Nagel, D. Sinha, D. Day, et al., e-ASPECTS software is non-inferior to neuroradiologists in applying the ASPECT score to computed tomography scans of acute ischemic stroke patients[J], Int. J. Stroke 12 (6) (2017) 615–622, https://doi.org/10.1177/1747493016681020.
[15] J.M. Bland, D.G. Altman, Cronbach's alpha[J], BMJ 314 (7080) (1997) 572, https://doi.org/10.1136/bmj.314.7080.572.
[16] W.S. Browner, T.B. Newman, Confidence intervals[J], Ann. Intern. Med. 105 (6) (1986) 973–974, https://doi.org/10.7326/0003-4819-105-6-973_3.
[17] T.K. Koo, M.Y. Li, A guideline of selecting and reporting intraclass correlation coefficients for reliability Research[J], J. Chiropr. Med. 15 (2) (2016) 155–163, https://doi.org/10.1016/j.jcm.2016.02.012.
[18] J.A. Hanley, B.J. McNeil, The meaning and use of the area under a receiver operating characteristic (ROC) curve[J], Radiology 143 (1) (1982) 29–36, https://doi.org/10.1148/radiology.143.1.7063747.
[19] L.B. Lusted, Decision-making studies in patient management[J], N. Engl. J. Med. 284 (8) (1971) 416–424, https://doi.org/10.1056/NEJM197102252840805.
[20] P. Hoelter, I. Muehlen, P. Goelitz, et al., Automated ASPECT scoring in acute ischemic stroke: comparison of three software tools[J], Neuroradiology 62 (10) (2020) 1231–1238, https://doi.org/10.1007/s00234-020-02439-3.
[21] F. Austein, F. Wodarg, N. Jurgensen, et al., Automated versus manual imaging assessment of early ischemic changes in acute stroke: comparison of two software packages and expert consensus[J], Eur. Radiol. 29 (11) (2019) 6285–6292, https://doi.org/10.1007/s00330-019-06252-2.
[22] J. Gao, C. Yang, Q. Li, et al., Hemispheric difference of regional brain function exists in patients with acute stroke in different cerebral hemispheres: a resting-state fMRI Study[J], Front. Aging Neurosci. 13 (2021) 691518, https://doi.org/10.3389/fnagi.2021.691518.
[23] L. Song, C. Lyu, G. Shen, et al., Application of FLAIR vascular hyperintensity-DWI mismatch in ischemic stroke depending on semi-quantitative DWI-Alberta stroke program early CT Score[J], Front. Neurol. 10 (2019) 994, https://doi.org/10.3389/fneur.2019.00994.
[24] M.D. Hill, A.M. Demchuk, M. Goyal, et al., Alberta stroke program early computed tomography score to select patients for endovascular treatment: interventional Management of Stroke (IMS)-III Trial[J], Stroke 45 (2) (2014) 444–449, https://doi.org/10.1161/STROKEAHA.113.003580.