Editorial comment on “Automated quantitative lesion water uptake in acute stroke is a predictor of malignant cerebral edema”

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Key Points

- In patients with acute ischemic stroke, automated measurements of net water uptake in baseline CTA and NCCT scans can be used as predictor for developing malignant cerebral edema.
- A creative approach can lead to broader usability of automated tools.

In patients with an acute ischemic stroke (AIS) caused by a large vessel occlusion (LVO), malignant cerebral edema (MCE) is a life-threatening complication. Shortly after interruption of perfusion, brain volume increases due to abnormal fluid accumulation in the cerebral parenchyma eventually resulting in MCE [1]. Cerebral edema can lead to a myriad of problems, mainly due to the resulting mass effect. Since the intracranial cavity cannot expand, compensation mechanisms for maintaining normal intracranial pressure (ICP) levels are limited [2]. As compensation, intracranial tissue shifts occur due to raised ICP, leading to progressive neurological deterioration of the patient and mortality rates as high as 78% without surgical intervention [3]. According to the guideline for healthcare professionals from the American Heart Association, osmotic therapy and brief moderate hyperventilation are reasonable interventions in AIS patients with brain swelling [4]. In patients who deteriorate neurologically within 48 h as a result of brain swelling associated with an unilateral MCA infarction despite medical therapy, decompressive craniectomy may be considered (> 60 years of age) or reasonable (≤ 60 years of age) [4].

In clinical practice, measurements of intracranial pressure and non-invasive monitoring based on assessments of clinical neurological deterioration are used to predict development of

MCE [5]. Quantitative lesion net water uptake (NWU) is an image-based measurement of the density (in Hounsfield units) in infarcted brain areas, and can be used for predicting MCE development [6]. NWU is also a predictor for poor functional outcome (Modified Rankin Scale 5–6 at 90 days) [7]. Delineation of the infarct region or ischemic core is needed to calculate NWU [6]. The infarct region may be obtained by manual segmentation from non-contrast CT images (NCCT) or CTA angiography source images (CTA-SI) but is subject to interobserver variability. Ischemic core assessment requires CT-perfusion imaging (CTP).

In this issue, Shi et al [8] present an innovative approach to predict MCE by using software to measure NWU in baseline CTA-SI and baseline NCCT. This software was initially developed and validated to rate the Alberta stroke programme early CT score (ASPECTS) on baseline NCCT in patients with an acute ischemic stroke in the middle cerebral artery (MCA) territory, which proved to be comparable to visual ASPECTS rating by expert readers [9, 10]. In ASPECTS, ten brain regions in the affected cerebral hemisphere are scored visually for presence of acute ischemic stroke damage [10].

To this end, Shi et al [8] used the automated ASPECTS tool (syngo.via Research Frontier, ASPECT Score-Tool v2.0.3; Siemens Healthineers) to compute mean densities of the ten ASPECTS regions, from which they compute a relative mean density difference for the combined affected regions (HUi) by comparison with the same regions in the non-affected hemisphere (HUC), the ASPECTS-NWU: (HUC minus HUi) divided by HUC [6].

The novel automated approach enables precise measurements of subtle changes in ASPECTS-NWU. This study confirmed the superiority of ASPECTS-NWU on CTA-SI (AUC, 0.88; 95% CI: 0.82–0.94; $p < 0.001$) in comparison to NCCT

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ASPECTS-NWU (AUC, 0.71; 95% CI: 0.62–0.80; $p < 0.001$) for predicting development of MCE, when using automated assessments.

The presented results are promising, but caution is warranted when interpreting the results. The authors state that software segmentation errors remain, a relatively small sample from a single center was assessed ($n = 146$), and the study was retrospective in nature.

Although CTA-ASPECTS-NWU shows good reliability in predicting MCE development, comparison with manual NWU calculation on the same dataset would add more insight in superiority of ASPECTS-NWU performance. The ten ASPECTS region sizes range from the small nucleus caudate to the large M1-6 regions. Since there was no correction for region size in the ASPECTS-NWU calculation, small ASPECTS regions contributed with relatively more weight, while in manual NWU calculations every voxel contributed equally to the NWU calculation [6, 7].

The baseline collateral score and CTA-ASPECTS-NWU perform similar in predicting MCE and only slightly better than baseline National Institute of Health Stroke Scale (NIHSS) and ASPECTS. However, for manually obtained parameters, interrater variability is present or specific expertise is needed. Therefore, seamless integration of a software solution with equal performance in the clinical setting could be preferable.

A strength of this paper is the use of a multivariable logistic regression for prediction taking into account also clinical parameters (age) and other imaging parameters (collateral score) alongside CTA-ASPECTS-NWU to predict MCE development, yielding an AUC of 0.94 (95% CI: 0.90–0.98; $p < 0.001$).

The paper demonstrates that a creative approach can lead to broader usability of automated tools. Core principles in radiological research are met: direct clinical relevance, precise quantification, and innovation.

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Declarations

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Methodology

• Editorial Comment

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