Clinical Radiology 78 (2023) e313–e318

Contents lists available at ScienceDirect

Clinical Radiology

journal homepage: www.clinicalradiologyonline.net

Diagnostic accuracy of a decision-support software for the detection of intracranial large-vessel occlusion in CT angiography☆

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ARTICLE INFORMATION

Article history:
Received 16 February 2022
Received in revised form
5 October 2022
Accepted 15 October 2022

AIM: To investigate the real-world clinical performance of the decision-support software "e-CTA" (e-Stroke Suite, Brainomix Limited, Oxford UK) for the detection of acute intracranial large-vessel occlusion (LVO) on computed tomography (CT) angiography at a UK district general hospital.

MATERIALS AND METHODS: The retrospective study included 300 consecutive CT angiograms of the head and neck performed between 8 March 2021 and 20 May 2021. e-CTA findings were recorded and compared with the radiologist report. Cases in which there was disagreement between e-CTA and the radiologist were reviewed by a sub-specialist vascular radiologist as the reference standard.

RESULTS: The incidence of intracranial LVO was 7%. e-CTA correctly identified 18 of 21 intracranial proximal LVOs (86%). There were 34 false positives. The sensitivity was 0.86 (95% confidence interval [CI], 0.64–0.97), with specificity of 0.88 (95% CI, 0.83–0.91). The positive predictive value was 0.35 (95% CI, 0.27–0.43). The negative predictive value was 0.99 (95% CI, 0.96–1.00).

CONCLUSION: Sensitivity, specificity, and negative predictive values were similar to those reported in the literature (Seker *et al.*, Int J Stroke. 2021; 17:77–82); however, the positive predictive value for e-CTA was significantly lower. In practice, this meant that over half of all reported occlusions by the software were false positives. Radiologists should be aware of these metrics in order to assign appropriate weight to software findings when formulating a report. Differences in population demographics, scanners, CT protocols, and incidence are all factors potentially influencing software accuracy. Local validation testing may help provide accuracy metrics more relevant to individual institutions.

☆ The findings of this retrospective study were presented in the form of an e-Poster at the European Conference of Radiology in March 2022.

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https://doi.org/10.1016/j.crad.2022.10.017

Introduction

The incidence of intracranial large vessel occlusion (LVO) in acute ischaemic stroke is high, accounting for up to 31% of cases.[1] Stroke is the second leading cause of death and disability worldwide,[2] with ischaemic stroke secondary to LVO associated with worse neurological outcomes and increased morbidity and mortality.[3–5]

Mechanical thrombectomy (MT) drastically improves outcomes for patients with proximal anterior LVO.[6–11] Some benefit from MT has been observed for patients treated >24 h from the onset of symptoms[12]; however, it is clear that outcomes following MT are time dependent, with time to treatment strongly associated with improved functional outcome.[13,14]

Performing computed tomography (CT) angiography during initial imaging evaluation of stroke patients improves detection of LVO and increases the detection of patients eligible for MT treatment.[15] It is recommended that patients meeting the thrombectomy criteria should receive non-invasive intracranial vascular imaging alongside the initial unenhanced CT head.[16] With increasing caseloads for on-call radiologists, prompt and accurate identification of LVO remains crucial. Artificial intelligence (AI) decision-support systems have been developed to aid radiologist decision-making and reduce time to treatment.[17]

e-CTA is an AI software produced by Brainomix Limited, Oxford UK, that uses advanced algorithms, AI, and large data analytics to detect intracranial carotid and middle cerebral artery (MCA) occlusions automatically.[18] It has been previously reported to have a similar diagnostic accuracy to an experienced neuroradiologist for the detection of LVO.[19]

The aim of the study was to investigate the real-world clinical performance of e-CTA for the detection of acute intracranial LVO on CT angiogram at a UK district general hospital, following the introduction of the software to the Trust in March 2021.

Materials and methods

Study population

This retrospective study was performed at a UK district general hospital from June 2021 to August 2021 with local governance approval as a service evaluation. Ethics review was not required.

All consecutive CT angiograms requested as part of an "acute stroke series" (unenhanced CT head and CT angiography) performed from when the software went live at 09.00 on 08 March 2021 until 6 June 2021 were identified from the radiology information system (RIS). CT angiograms performed for other indications, such as for suspected vertebral dissection or to investigate known sub-arachnoid haemorrhage, were not included. This resulted in a sample of 387 cases. The first 333 consecutive cases were reviewed on the picture archiving and communication system (PACS). Thirty-three cases were excluded, resulting in a working sample size of 300 cases. Exclusions were made due to missing or incomplete e-CTA report (n=19), CT angiogram not performed (n=12), duplicate study (n=1). The information downloaded from PACS included baseline demographics, time, and date of the CT angiogram acquisition.

Image acquisition

CT angiography was performed using the Aquilion ONE/Genesis Edition, (Cannon Medical Systems, Truro, Cornwall, UK) CT system. The protocol was as follows: injection of an 80 ml bolus of iohexol (350 mg iodine/ml or equivalent), given at a speed of 4 ml/s. SmartPrep was used to monitor aortic contrast opacification. When contrast medium reached the arch of the aorta, the single-phase CT angiography series (carina to vertex) was started manually. Axial, coronal, and sagittal views were reconstructed at 0.625 mm thickness with 40% adaptive statistical iterative reconstruction (ASiR). e-CTA reports were generated at the time of scanning and the reports were available as additional series within the PACS event. The e-CTA software output included a straightened axial unenhanced series of the head, maximum intensity projection (MIP) reformatted images of the head in angiographic phase, and a text/image-based report of the relevant findings.[18] This report included evaluation of the contrast scan timing as evaluated by the e-CTA software (Electronic Supplementary Material Fig. S1).

Data measures, collection, and analysis

The e-CTA and radiologist reports were scrutinised in the PACS. The following data measures were recorded for both the e-CTA and corresponding radiologist reports: (1) has an intracranial LVO been reported and (2) what is the location of the reported LVO? The radiology reports were used as the reference standard regarding presence of LVO; however, cases in which there was discrepancy between the e-CTA and radiologist report were identified. These cases underwent further arbitration in the form of additional review by a sub-specialist vascular radiologist.

Detection by the e-CTA software is limited to occlusions in the intracranial carotid artery terminal segment, middle cerebral artery M1 segment, and proximal middle cerebral artery M2 segment, as shown in Fig. 1. For this reason, abnormalities in any other vessel, such as in the posterior circulation, were not included in the analysis. Assessment of contrast phase timing was also performed using the e-CTA output, with peak arterial phase considered optimal.

Statistical analysis

Diagnostic accuracy of the e-CTA software was evaluated using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), calculated in Microsoft Excel. Ninety-five per cent confidence intervals were calculated using the MedCalc Diagnostic test evaluator tool.[20] Chi-squared tests were calculated using the Social Science Statistics Chi Square Calculator for 2 × 2.[21]

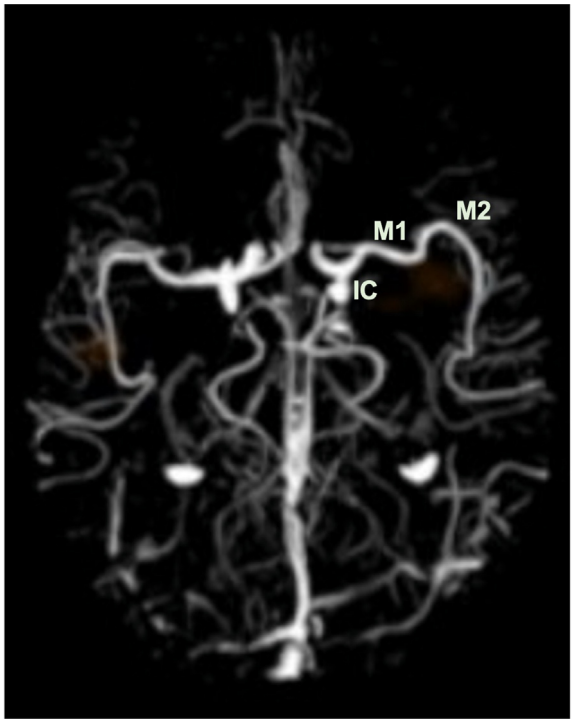

Figure 1 Axial maximum intensity projection intracranial angiogram demonstrating the vessels assessed by the e-CTA software (IC, intracranial carotid artery terminal segment; M1, middle cerebral artery segment 1; M2, middle cerebral artery segment 2 proximal aspect).

Results

A total of 151 (50.3%) of the patients included in the study were male, and 149 (49.6%) were female. The mean age was 71 years, with a standard deviation of 14 years. The incidence of intracranial LVO was 7%.

Accuracy of the e-CTA software is summarised in Table 1. The e-CTA software correctly identified 18 of 21 intracranial proximal LVOs (86%). There were 34 false positives. The sensitivity was 0.86 (95% confidence interval [CI], 0.64–0.97), with specificity of 0.88 (95% CI, 0.83–0.91). The positive predictive value was 0.35 (95% CI, 0.27–0.43). The negative predictive value was 0.99 (95% CI, 0.96–1.00). Examples of false-positive and false-negative results are shown in Figs 2 and 3.

Discrepancies were found between e-CTA and radiologist reports in 43 cases. Of these, six cases were identified for which the e-CTA report outcome was favoured over the initial corresponding radiology report, following arbitration by a subspeciality vascular radiologist. This included four "under-calls" by the original radiologist (original radiologist missed a true LVO occlusion that was identified after arbitration and by the e-CTA software) and two "over-calls" (original radiologist reported an LVO that was considered not present after arbitration and according to the e-CTA software).

Table 1
Confusion matrix demonstrating accuracy of the e-CTA software.

	e-CTA positive	e-CTA negative
True positive	18	3
True negative	34	245

Of the 300 cases included, 127 (41%) were acquired in the optimal peak arterial phase. Table 2 describes a summary of contrast phase in relation to software error. There was no statistically significant difference in the frequency of software error between peak-arterial phase scans and non-peak arterial phase scans (chi-squared; [1, N=300] = 0.21, p=0.65).

Discussion

The present study investigated the diagnostic performance of the e-CTA software for detection of intracranial LVO in a real-world clinical setting. Sensitivity of the e-CTA software was congruent with that reported in the existing literature when taking into account CIs.[19] Specificity was slightly lower in this real-world study (0.88, 95% CI, 0.83–0.91 compared with 0.96, 95% CI, 0.91–0.98).

The positive predictive value was much lower in this real-world cohort at 0.35 (95% CI, 0.27–0.43) compared with 0.96 as stated in the literature published in collaboration with the e-CTA software developer.[19] This can partly be explained by the relatively low incidence of LVO in the real-world cohort at 7%. In contrast, the study by Seker *et al.*[19] used a similar sample size of 301 cases for validation but with an incidence of LVO at 53% (160 of 301 cases). This highlights the importance of prospective validation of new AI tools in the clinical setting. It also suggests that positive and negative predictive values are unlikely to transfer to real-world clinical settings unless the validation set reflects the real-world incidence. The low positive predictive value meant that more than half of all reported occlusions by e-CTA were false positives. It should also be noted that in a very small subset of six cases the e-CTA software report was eventually favoured over the original radiology report after arbitration. Together the results presented suggest it may be valuable for radiologists to review the output of e-CTA carefully and double-check any areas highlighted (or not highlighted) by the software, but not be unduly influenced by the software should they disagree with it.

The 7% incidence of LVO in this study was relatively low compared with that reported elsewhere in literature. For instance, some articles have reported rates of LVO in excess of 30% for patients presenting with symptoms of acute ischaemic stroke.[1] The exact cause of the low incidence is not entirely clear; however, it should be noted that the 7% figure presented here represents only a subset of the patients presenting with symptoms of acute stroke, namely those who underwent CT angiography within the thrombectomy treatment window. The true overall incidence may differ when also considering patients presenting outside of this window. Furthermore, institutions favouring rapid diagnosis of treatable LVO via

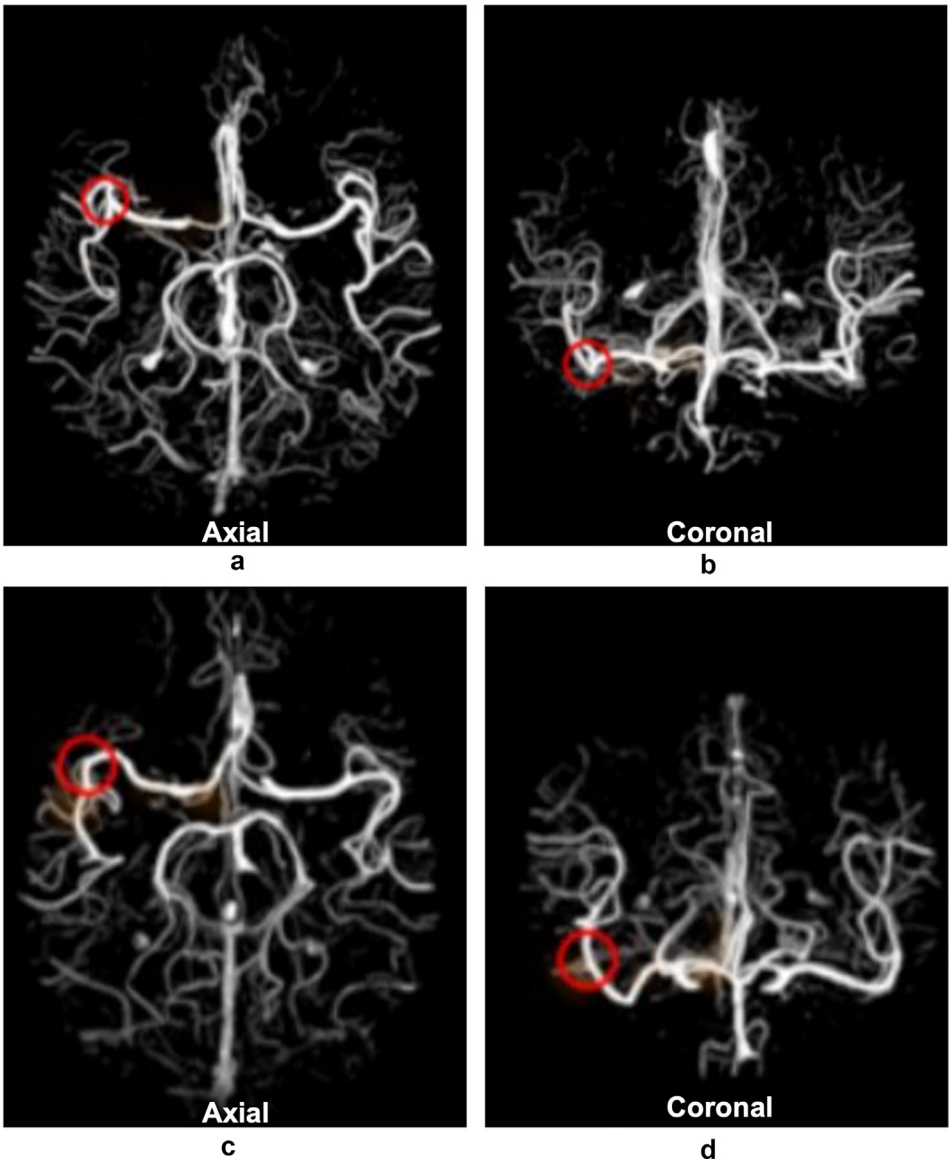

Figure 2 False positives. (a) Axial and (b) coronal maximum intensity projections from intracranial CT angiograms are shown from two separate cases (a and b and c and d). Red circles indicate the location of suspected LVO as annotated by the e-CTA software. Closer inspection of the images along with the axial CT slices (not shown) reveals no evidence of LVO at these sites.

early CT prior to senior clinical review may have a larger proportion of normal examinations as a result, thus reducing the incidence. Regional differences in investigation pathways therefore may result in differences in incidence that could affect the performance of an AI algorithm.

It is likely that contrast phase timing was less optimal than in the previously published study and this may also partly explain the differences in performance; however, it should be noted that no significant difference in software error was identified in scans with non-optimal contrast timing in the current study.

One major limitation of the present study was that only cases with discrepancy between e-CTA and radiologist report underwent further additional review by a vascular radiologist. This potentially introduces bias favouring e-CTA accuracy as some radiologists may have agreed incorrectly with an e-CTA false positive or false negative. Secondly, given the low incidence, a larger sample size would narrow the confidence intervals of the accuracy metrics.

Differences in local populations, scanners, local CT protocols, and incidence are all possible factors influencing the accuracy of e-CTA and other AI software. It is important to be aware that real-world accuracy may differ from published metrics depending on the relevance of the validation data used. Offline testing of AI software, in situ, before going live, is one possible strategy if there is any doubt as to the relevance of published accuracy metrics to local institutions. These factors should be considered when introducing new AI software into routine practice in radiology.

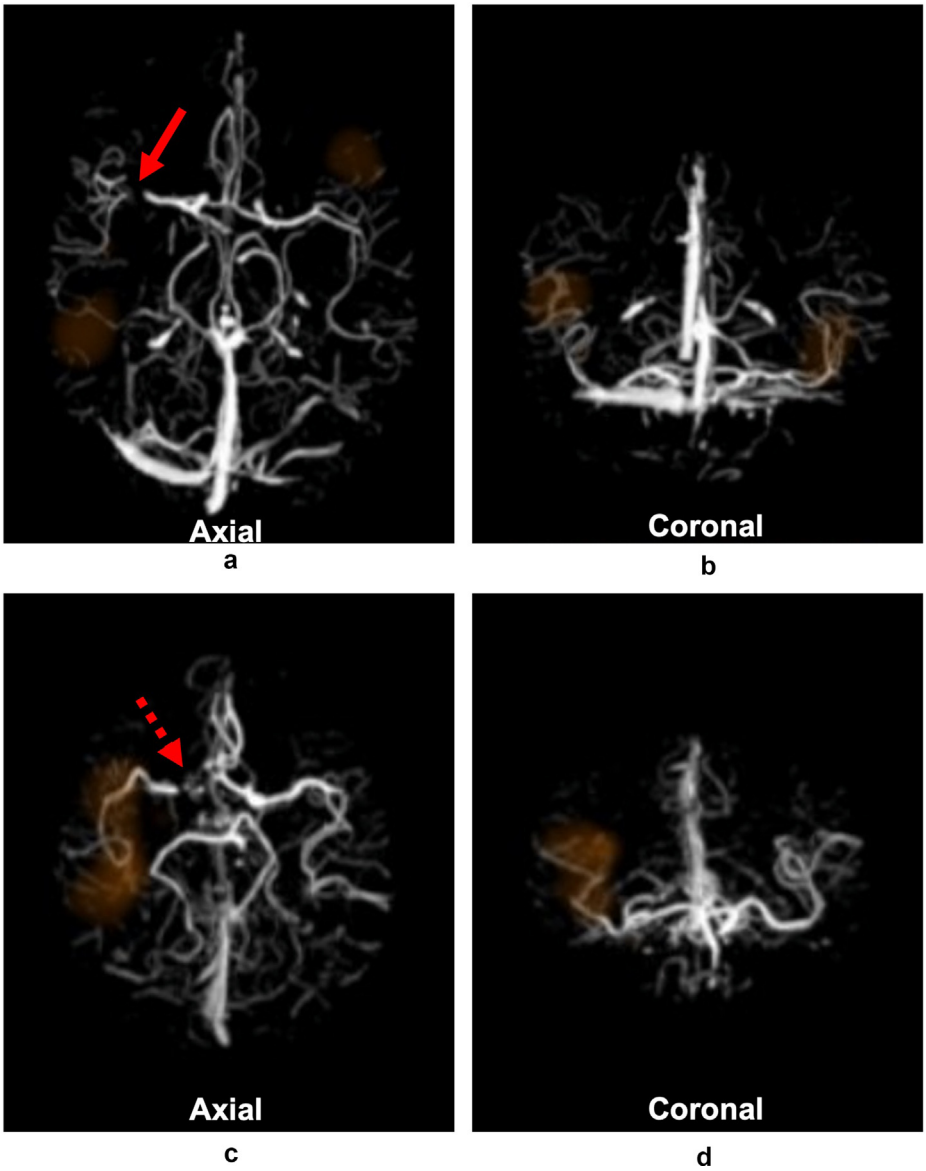

Figure 3 False negatives. (a) Axial and (b) coronal maximum intensity projections from intracranial CT angiograms are shown from 2 separate cases (a and b and c and d). Fillings defects are demonstrated in the distal right M1 segment (a, solid red arrow) and proximal right M1 segment (c, dashed arrow). The e-CTA software failed to identify these LVOs.

Table 2
Table showing the relationship between contrast phase and frequency of error in the e-CTA output.

	e-CTA error	e-CTA correct
Peak arterial	14	110
Not peak art	23	153

Lastly, the e-CTA software is licensed as a decision-support tool to aid clinical radiologists rather than to be used in isolation for diagnostic purposes. Knowledge of the accuracy of a decision-support tool, as applied to their specific local population, is likely to be helpful for radiologists in deciding how much weight to attribute to the software output.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crad.2022.10.017.

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