Semi-Automated Topographical Scoring for MR Imaging of Ischemic Stroke

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INTRODUCTION

Ischemic stroke results from reduced blood flow to brain tissue and can lead to cell death, or *infarction*, that is detectable by CT or by MR diffusion-weighted imaging (DWI).[1] Neurological scoring methods are used to quantify stroke severity to predict patient outcome and to assess patient suitability for thrombolytic treatment. The National Institutes of Health Stroke Scale (NIHSS) is based on the presentation of neurological deficits, while another scoring method, the Three-item Scale for the Prediction of Stroke Recovery, incorporates the NIHSS, time-from-onset and DWI infarct volume.[2] Compared to these methods, the Alberta Stroke Program Early CT Score (ASPECTS) is unique because it is a topographical scoring system – *i.e.,* location based.[3] ASPECTS is a 10-point scoring scale from which deductions are made based on regional occupancy of an identifiable lesion on computed tomography (CT) images.[3] The ASPECTS approach can be extended to DWI, where excellent inter-modality agreement with CT has been demonstrated.[4] Compared to CT, DWI has a higher contrast-to-noise ratio (CNR) in acute infarction,[5] which may facilitate computer automation of a topographical scoring method. Computer automation may reducing inter-rater variability and slice orientation differences, which have been cited as sources of ASPECTS variability.[6] The purpose of this work is to extend the topographical ASPECTS method to MR DWI images (MR topographical scoring, MR-TS) and investigate the feasibility of computer automation (auto-MR-TS). Our auto-MR-TS approach leverages a validated scoring method that is used routinely in clinical practice and has been used extensively to manage acute therapy, thus providing a strong basis for validation of our methods, with important ramifications for acute diagnosis.

METHODS

A retrospective cohort study was performed using 30 acute ischemic stroke (AIS) patients with an acute diffusion-weighted image (DWI) lesion. Patients were imaged by CT followed by MR within 24 hours of symptom onset. All MR patient data were acquired on a 3 T scanner (Signa VH/i; General Electric Healthcare, Milwaukee, WI) with a quadrature head coil. DWI images were acquired using a single-shot spin-echo EPI (b = 1000 s/mm^2, TR/TE/flip = 7000 ms to 9000 ms/73.1 to 93 ms/90°, 192 × 115 or 144 × 144 acquisition matrix, 32 cm × 19.2 cm or 24 cm × 24 cm FOV and 19 slices, 5 mm thick, with 2 mm gap or 27 contiguous 5 mm slices) to evaluate infarct. With guidance from a stroke fellow with ASPECTS training, a 3-dimensional MR-TS digital atlas was generated by manually tracing regions on T1 anatomical datasets (MNI, www.bic.mni.mcgill.ca/brainweb) at a resolution of 1 mm x 1 mm x 2 mm using the ASPECTS scoring sheet.[3,6] Auto-MR-TS was performed regionally using ADC maps and the MR-TS atlas based on lesion-region overlay in registered space (Fig 1). This methodology is similar to processing methods applied by other groups for CT[7] and MR[8] data. User-assisted region-growing segmentation was employed to define the infarct region on the ADC map. MR-TS was also performed manually (man-MR-TS) by a trained stroke fellow for validation. Non-parametric Friedman and Wilcoxon signed-rank tests were used to compare auto-MR-TS, man-MR-TS and ASPECTS (with $\alpha < 0.05$ chosen as the significance level).

RESULTS

One patient was excluded due to image artifact. Twenty-nine patients underwent further analysis (mean age 64 years, 12 female). There was a significant difference between the three scoring methods (auto-MR-TS, man-MR-TS and ASPECTS). Auto-MR-TS and man-MR-TS were both significantly lower than ASPECTS ($p < 0.001$), although the median difference was only 1 point in both comparisons, in concordance with a previous comparison of manual MR and CT ASPECTS.[4] Seventeen patients (59%) had auto-MR-TS and ASPECTS scores that differed by 1 point or less. Five patients (17%) had larger discrepancies (3-6 points), but all showed clear ADC lesions in ASPECTS regions with no changes seen on CT. There was no significant difference between auto-MR-TS and man-MR-TS ($p = 0.12$), with a median difference of 0 points, and 25 scores (86%) differing by 1 point or less. Fig 2 provides an example of auto-MR-TS compared to ASPECTS where high CNR in the ADC map facilitated automation.

DISCUSSION

The strong agreement between man-MR-TS and auto-MR-TS demonstrates that automated scoring is feasible. The differences between both MR scoring methods and ASPECTS is likely due to differences between CT and MR in infarct assessment,[5] although acquisition delay between CT and MR presents a likely confounding factor. Auto-MR-TS may provide more objective and reproducible topographical scoring and requires further validation in a rater-variability study. The automatic scoring procedure may be extended to include more complex ASPECTS models (currently under investigation), as well as large retrospective studies where reproducibility is desired. DWI is more sensitive to the detection of early ischemic lesions than CT,[5] suggesting that auto-MR-TS scores could be more accurate than those derived from CT.

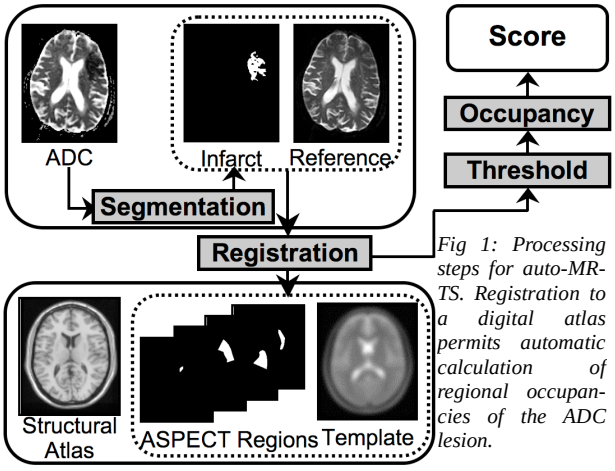

Fig 1: Processing steps for auto-MR-TS. Registration to a digital atlas permits automatic calculation of regional occupancies of the ADC lesion.

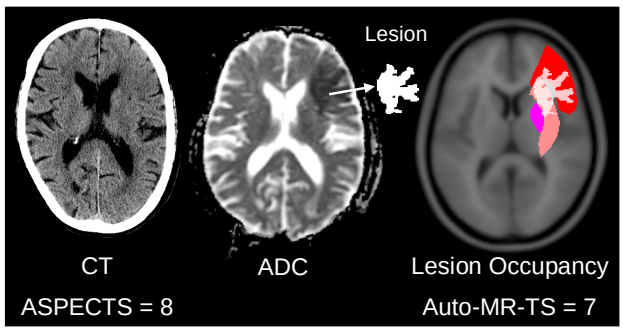

Fig 2: AIS patient, 76-year-old female. The segmented lesion occupies 3 ASPECTS regions, yielding an auto-MR-TS of 7, compared to ASPECTS of 8.

- M1
- Lentiform
- Insular Ribbon

References

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