Textural Analysis of Early Features of an Ischaemic stroke on the initial Non-contrast CT head using TexRad™

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Introduction

In 2014, 6.7 million deaths were caused by stroke making it the 2nd most common cause of death worldwide(1).

Current stroke diagnosis protocol

Patients presenting to A&E with stroke symptoms receive a non-contrast head computed tomography (CT) scan. If no haemorrhage is observed, and it is within 4.5 hours of the presentation of symptoms then patients are treated pragmatically with thrombolysis (2). The CT scans of patients presumed to have an ischaemic stroke are often reported as normal. The reason for this is multifactorial: a) it is too early for the typical changes to have occurred, b) the CT is relatively insensitive to change, c) there was no occlusion.

Existing literature

Research on the subject has shown that there is a difference in the texture of non-ischaemic and visibly ischaemic brain tissue, as seen in subacute ischaemic stroke (3-7). However, there are no papers that have demonstrated a difference in the texture of potentially ischaemic and non-ischaemic tissue, such as in acute stroke, when it could potentially make a difference to management.

Aims

To use TexRad™, a textural analysis software, to separate ischaemic and non-ischaemic tissue based on the changes seen in the tissue characteristics following vascular occlusion earlier than can be determined by visual inspection.

Ethical approval

Local Trust ethics approval and University ethics approval were granted to use the anonymised imaging data.

Subject selection

This is a retrospective cohort study of a sample of 39 patients, 22 males (mean age 72.1) and 17 females (mean age 77.0), from University Hospitals Coventry and Warwickshire (UHCW) who were diagnosed as having an ischaemic stroke. Patients with any evidence of haemorrhage or pre-existing brain lesions on the initial scan were excluded.

Experimental method

The patients had an initial non-contrast enhanced CT scan, were thrombolysed and then had a ~24 hour CT scan. Slices from the 24 hour follow up scan, which had evidence of infarction, were downloaded and anonymised along with the anatomically corresponding slice from the initial scan in DICOM format.

Region of interest identification and CT textural analysis (CTTA)

- CTTA was performed using Texture + Radiology (TexRad™)
- Regions of interest (ROI) (730 pixels±5%, n=796) were identified according to *Figure 1*, whilst considering midline shift and avoiding subarachnoid space
- multiple ROI were used on larger infarcts
- ROIs was processed using the filtration-histogram method, which highlights structures of particular sizes within the ROI (spatial scale filtration/SSF) and extracts textural information (mean pixel intensity, standard deviation, mean of positive pixels, entropy, kurtosis and skewness), resulting in 33,432 data points

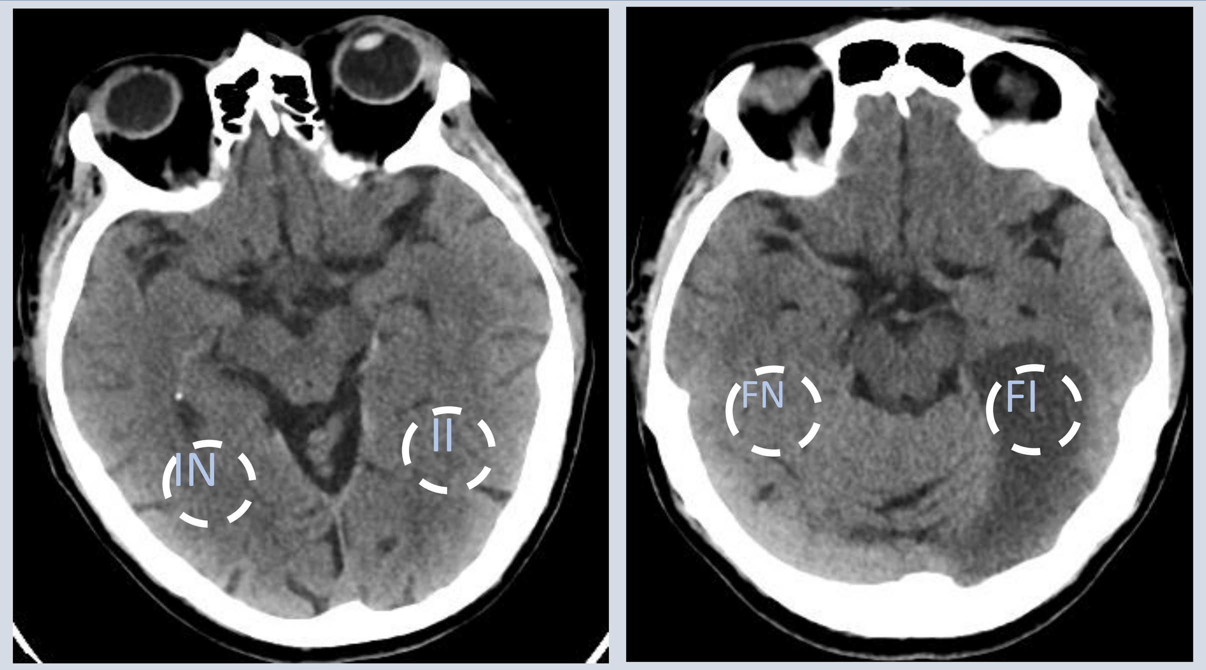

Figure 1: An initial and follow up CT head scan showing progression of an ischaemic stroke. IN= Initial normal side , II= infarct side on the initial scan, FN= Normal side on the follow up scan, FI= Infarct side on follow up scan

Data mining

- Waikato Environment for Knowledge Analysis (Weka) was used to process the data
- In each case 66% of the data was used to train a classifier, and the remaining 34% used to test this model (4 repeats)
- baseline accuracy was calculated using the ZeroR classifier, which predicts that all data belongs to the majority class
- the decision tree classifier J48, which identifies trends in training data, was used to predict the class of new data
- classifier effectiveness was determined by the % accuracy (% acc) that it correctly classified data

Radiology reports

- radiology reports were used to determine the presence, side (17 right, 22 left) and cerebral arterial supply (36 middle, 2 posterior, 1 anterior) of infarcts
- The percentage accuracy that initial CT scan radiology reports recognised areas of ischaemia was also calculated

Results

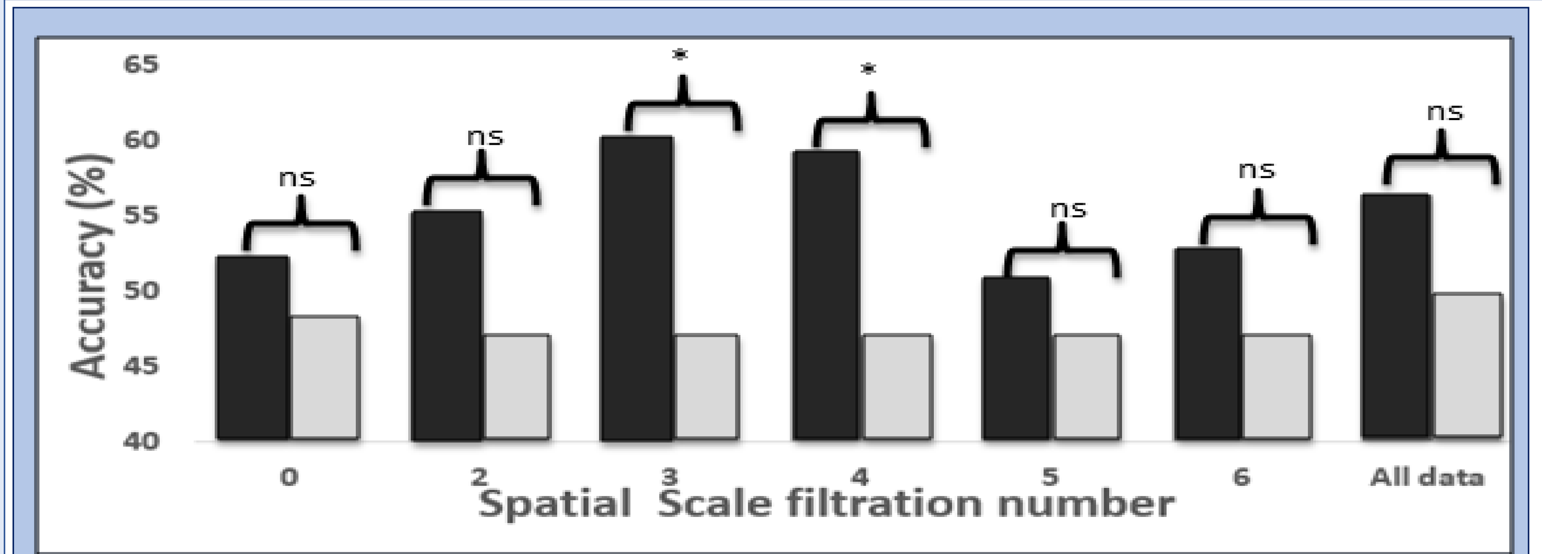

Figure 2: A bar chart showing the % accuracy of the ZeroR and J48 at classifying IN vs II data for different SSF filters

Comparison	ZeroR % acc	J48 % acc	p-value
IN vs FN	49.1	50.2	0.080
FN vs FI	44.7	69.0	0.014
II vs FI	50	66.1	0.012
II vs IN	47	60.2	0.017

Figure 3: A table showing the mean% accuracy of the ZeroR and J48 classifiers for the SSF 3 filter

Initial scan radiology report % accuracy: 38.4%

Discussion

Overview

Use of the filtration-histogram method of textural analysis, in particular SSF 3, revealed that it is possible to identify correctly an area of infarct with an accuracy of 60.2% ($p=0.017$) (*Figure 2*) vs 38.4% accuracy of visual inspection by radiologists.

Results

- The lack of a statistically significant difference between IN and FN ($p=0.08$) (*Figure 3*) indicates that the CTTA is reliable and that it is not affected by any difference in CT scanning technique, slice parameters or image analysis.
- All other 3 comparisons were found to be statistically significant.
- The fact that J48 is more accurately able to distinguish between FN and FI (69% accuracy) compared to II vs FI (66.1%) is reasonable as it may be possible to determine this with visual inspection in some cases.

Epidemiology

- There was a slightly higher percentage of males in this study (56.4%) who had a stroke than the Coventry CCG (49.4%) in a similar period of time
- he mean age of stroke in men (72.1 vs 72.6) and women (77 vs 81.7) in this study was similar to the CCG.

Literature review

While there are a small number of papers looking at classifiers as a means of separating infarct from normal brain tissue (3-7), none have used the follow up scan as a means of defining the region of infarction in the initial scan.

Conclusions

This is a first study, using known regions of infarction, to identify and predict from the initial CT imaging with image analysis classifiers the area of potential future infarction. The TexRad™ software has been demonstrated to identify the potential infarction with greater accuracy than a reporting radiologist.

Next steps could include textural analysis of initial CT heads without visible infarcts, by placing ROI in key areas affected by strokes and correlating this with clinical symptoms to predict the likely location.

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