Assessment of stroke MRI sequences and their relevance to research

Edward Christopher
College of Medicine and Veterinary Medicine, University of Edinburgh

What is the problem?

Magnetic resonance (MR) imaging is a powerful tool used to study the brain and its diseases e.g. stroke, by providing a visual representation of the tissue, including abnormal or injured tissue (see Figure 1). A stroke can occur when blood flow to a region in the brain is cut off, causing brain cells to die due to a lack of oxygen - the region of the tissue that has suffered injury is known as a lesion. It is often the case that different diseases manifest similarly on brain MR images. In the case of MR images of stroke, the stroke lesions in the brain MR images often merge with lesions from other brain diseases making it difficult to locate and outline the boundaries of stroke lesions, which could lead to an incorrect estimation of the extent of damage caused by the stroke, and may lead to false prognosis.

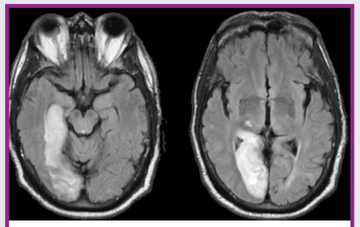

Figure 1 shows two slices of an MR image denoting a large stroke towards the back of the brain.

What are we interested in?

A full MR scan encompasses several sequential shots of planes that cover the whole brain. These planes could be parallel or in different directions. A group of these sequential shots is called a "sequence" and has certain parameters that define the appearance of the images. Several MRI sequences exist, namely diffusion-weighted (DWI), fluid-attenuated inversion recovery (FLAIR) and T1-weighted (T1W), which are routinely acquired together on a single scanning session to image tissue. Each different sequence being better suited to detecting particular tissue components (eg fat, water, blood vessels or lesions) (see Figure 2). Using MR images of stroke patients, we wanted to identify variation in the extent of stroke patients' tissue damage that as indicated by looking at images of the different MRI sequences. By more accurately identifying the extent of injury this could better inform clinical research, an important part of which is to have a clear understanding of the condition of the patients being studied.

We were primarily looking to evaluate the use of DWI in the assessments of cortical strokes (CS, strokes that affect the brain surface, known as the 'cortex'), and compare this with results from other MR sequences in the absence of DWI. Secondly, we wanted to evaluate the variability in the assessments of CS across the different MRI sequences.

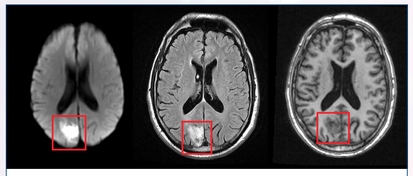

Figure 2 The differing appearances of the same brain through various MR sequences. Note the stroke lesion on the right cerebral hemisphere towards the back of the brain as indicated in the red box, and how the lesion presents differently in different MR modalities. From left to right: Diffusion-weighted image (DWI), fluid-attenuated inversion recovery MRI sequence (FLAIR) and T1-weighted MRI sequence (T1W).

What did we do?

We analysed the DWI, FLAIR and T1W MR images and clinical data from 57 patients who presented with CS to a hospital in Edinburgh. We compared the different images alone and in combination with each other by looking at the images by eye. We used specialised software (called Analyze™) to semi-automatically identify and mark the boundaries of the CS stroke lesions and measure their volume (see Figure 3). We used statistical analyses to identify differences (i.e. extent and distinction from other types of abnormalities that look similar in MRI) and associations of our measurements with clinical parameters, such as age, blood pressure, pulse frequency among others.

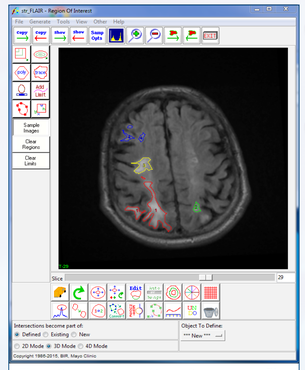

Figure 3 A screenshot of the software Analyze™ used in the study. Each colour represents an independent lesion and delineates the boundaries of the respective lesion.

What did we find?

We found that when DWI CS images were analysed in conjunction with FLAIR, we identified on average +2,571.8 mm^3 additional volume of lesions per patient compared to when DWI was not used. The inconsistencies were often found in the right cerebral hemisphere (right hand side part of the brain). We also found that the use of DWI identified on average +1,102.7 mm^3 additional volume of old CS lesions per patient that were otherwise undetectable from FLAIR alone. Similarly, the inconsistencies were mainly found in the right cerebral hemisphere.

In addition, the use of FLAIR alone identified on average +3,842.6 mm^3 additional volume of the recent CS per patient when compared to T1W alone. The inconsistencies were mainly found in the right cerebral hemisphere. FLAIR also detected on average +884.8 mm^3 additional volume of old CS lesions per patient that were otherwise undetectable from T1W alone, and the inconsistencies were similar in both left and right cerebral hemispheres.

What does it mean?

DWI was found to be the most sensitive among the different MR imaging sequences we studied, being able to detect CS that were otherwise undetectable from FLAIR or T1W alone (see Figure 4). Our results indicate that FLAIR is the second most sensitive MR imaging sequence, followed by T1W. This study supports the criterion that DWI should be strongly considered as the first-choice, or at least, supplementary, MR modality for diagnosing patients with clinical symptoms of CS. Our studies may also lead to better quantification of the extent of CS lesions in patient cohorts participating in clinical research, which may have relevance in study outcomes.

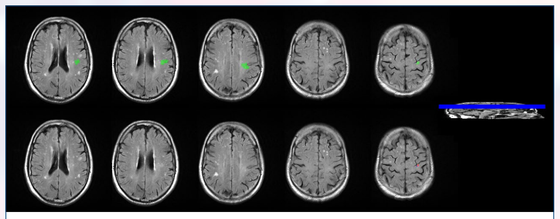

Figure 4 FLAIR MR scan of one of the 57 patients with CS included in the study. Each column represents the same slice level (same planar section within the brain) of the patient. The top row shows the lesion, outlined in green, that was identified by looking at the DWI and FLAIR MR images. The bottom row corresponds to the lesion (red) identified by looking at the FLAIR and T1W images.

Who am I?

I am currently in the third year of the MBChB Medicine programme at the University of Edinburgh, intercalating in Neuroscience Honours. As a medical student, I have a strong interest in the brain and its disorders, and aspire to one day be a clinician-neuroscientist. I would like to thank Medical Research Scotland and Dr Maria Valdés-Hernández for their encouragement and unwavering support throughout the project.

Acknowledgements

We thank the participants of the Mild Stroke Study whose images were used in this study and who made this research possible and the Wellcome Trust and the Row Fogo Charitable Trust for funding the acquisition and processing of the images.

Edward was supervised during his Vacation Scholarship project, *"Inter-observer and inter-MRI sequence differences in the assessment of cortical strokes. Do they matter in research?"*, by Dr Maria Valdés-Hernández.