CLINICAL AUDIT

Diffusion weighted magnetic resonance imaging for acute stroke: practical and popular

P L Tan, D King, C J Durkin, T M Meagher, D Briley

Postgrad Med J 2006;**82**:289–292. doi: 10.1136/pgmj.2005.038299

See end of article for authors' affiliations

Correspondence to:
Dr T Meagher, Department
of Radiology, Stoke
Mandeville Hospital,
Mandeville Road,
Aylesbury,
Buckinghamshire HP21
8AL, UK; tom.meagher@
smh.nhs.uk

Submitted 11 June 2005
Accepted 24 October 2005

Aim: To evaluate the feasibility and impact of diffusion weighted magnetic resonance imaging (DW MRI) as the first line neuroimaging of stroke at a district general hospital.

Methods: Prospective audit of all in-patients admitted with clinically suspected acute stroke and referred for imaging over a consecutive 17 week period. The data collected included scan type, time from cerebral event to imaging request, and time from formal radiological request to neuroimaging. Clinicians' (general physicians, neurologists, and radiologists) perceptions were assessed by a questionnaire.

Results: 148 patients had neuroimaging for clinically suspected stroke during this period. Eighty one per cent of patients (120 of 148) had DW MRI as first line. Ninety two per cent of these patients had DW MRI within 24 hours of the formal radiological request. Twenty eight patients did not undergo DW MRI because lack of MRI safety, clinical state, unavailability because of maintenance service or lack of trained staff. Clinicians found the introduction of the DW MRI based service a significant improvement on computed tomography, especially for equivocal cases.

Conclusion: DW based MRI service is both feasible and sustainable in the setting of a district general hospital and most clinicians feel that this is a significant improvement to stroke services.

Stroke is characterised by a rapidly developing neurological deficit that can lead to considerable morbidity and mortality and it is a common cause of admission to hospitals. In the UK there are 130 000 new cases of stroke per annum, a number that is increasing with an ageing population. From a clinical perspective, it is important to distinguish haemorrhagic from non-haemorrhagic stroke and to exclude other less common underlying conditions such as tumour or subdural haemorrhage.

Current National Clinical Guidelines for Stroke (updated in 2004) from the Royal College of Physicians recommend brain imaging for all patients with suspected stroke within 24 hours of the event. Early imaging is considered to improve care and be cost effective.¹ Neuroimaging with computed tomography (CT) is most commonly used for the assessment of stroke although its principal role is to exclude haemorrhage or other abnormality rather than to identify stroke. CT examination of acute ischaemic stroke will typically appear normal in the first few hours after stroke onset.^{2–6} CT is particularly sensitive to acute haemorrhage.

Diffusion weighted magnetic resonance imaging (DW MRI) measures change in the local magnetic field attributable to restricted diffusion after cell death. This requires echo planar capability and high gradients and is available on many MRI systems installed in recent years in the UK. MR involving diffusion weighted imaging (DWI) shows far greater contrast and is superior at highlighting tissue injury within minutes of a cerebral infarct (figs 1, 2, and 3), with a reported sensitivity and specificity of 88%–100% and 86%–100% respectively.^{7–11} The interpretation of DW MRI is straightforward and carries higher interobserver and intraobserver reproducibility than CT.¹² The early accurate detection of acute ischaemic stroke is now assuming greater importance as thrombolysis is licensed for treatment of acute stroke and novel neuroprotective agents are entering clinical use.¹³

The use of DW MRI as a first line investigation for acute ischaemic stroke has been described previously.^{14–16} DW MRI clearly has advantages over CT but is often perceived to be difficult. The aim of this study is to find out if DW MRI is

feasible in a district general hospital over the long term and to estimate the clinical impact of such a service.

METHODS

The departments of neurology and radiology at our hospital agreed to implement DW MRI as first line neuroimaging for in-patients with clinically suspected stroke, based on published evidence.^{2–8 15–16} An initial audit¹⁷ showed DW MRI could be done on a routine basis at a district general hospital. The average examination time for examination is 13 minutes for MRI and 11 minutes for CT.¹⁷ Our hospital serves a population of about 220 000 patients and admits about 250 patients per annum with stroke. The radiology department does 6000 CT and 4500 MR studies per annum. Stroke studies using MRI are typically done between 0900 and 1700 hours and are not routinely done out of hours. Out of hours imaging for stroke is done if there is an atypical presentation or reduced Glasgow coma scale and is usually imaged by CT, which is available over 24 hours. MRI availability out of hours for this indication is dependent on the MRI training of the on-call radiographer.

All patients who were admitted with a clinically suspected stroke and referred to the department of radiology underwent neuroimaging. DW MRI was the first line neuroimaging technique. There was no age or sex exclusion. CT scan was performed in patients with suspected subarachnoid haemorrhage or if MR was contraindicated (for example, pacemaker, neurosurgical clip) or was unavailable.

MRI studies were performed using 1.5 Tesla Siemens Symphony system with quantum gradients. The study protocol included an axial T2 weighted gradient echo sequence that is considered sensitive to cerebral haemorrhage (acquisition time one minute), and diffusion weighted sequence (acquisition time one minute). No T1 weighted sequence was used unless a mass lesion was identified. CT examinations were done using Siemens Somatom Plus 4

Abbreviations: CT, computed tomography; DW MRI, diffusion weighted magnetic resonance imaging

Figure 1 CT brain scan of a patient presenting with acute stroke showing acute intracerebral haemorrhage centred on left basal ganglia.

system, with 4 mm sections of posterior fossa and 10 mm sections of cerebrum.

Data were collected over a consecutive 17 week period. Patients were identified by radiology request forms that queried acute stroke. Data collection included questions relating to the time span (rounded to 24 hours) from the primary cerebral event to the request for neuroimaging, and the time span (rounded to 24 hours) from formal radiological request to the actual scan.

Thrombolysis was not routinely offered to patients with suspected stroke during the period of the data collection.

A questionnaire was sent to all on-call general physicians,⁷ neurologist,¹ and radiologists⁸ to find out if DW MRI was felt to be helpful in diagnosis, and if the service was detrimental to other users of the MRI.

RESULTS

Altogether 148 consecutive patients over a period of 17 weeks satisfied the criteria for inclusion into the audit. Of these patients, 126 (85%) had DW MRI, with 116 patients (78%) having DW MRI only, four patients (3%) had a DW MRI and subsequent CT scan, and six (4%) patients had a CT followed by a DW MRI investigation. The remaining 22 (15%) had a CT only. Lack of availability of MRI was the commonest reason for a primary CT scan (table 1). Five patients who had an initial CT scan had a subsequent MRI scan to clarify diagnosis, and one because of clinical deterioration. Three patients had a subsequent CT scan after initial MRI to clarify diagnosis, and one because of clinical deterioration.

One hundred and twenty (56 female) patients (median age 79 years; range: 33–97 years) with clinically suspected acute stroke underwent DW MRI as the first line investigation. Of these, 110 patients (92%) had a DW MRI within 48 hours of the radiological request. Eighty cases had a formal radiological request for DW MRI within 48 hours of the neurological event. Out of these requests, DW MRI was performed in 100% of cases within 24 hours.

A diagnosis of acute infarct was made in 58 (48%) patients. Other diagnoses in the cohort included old ischaemia in 37

Figure 2 T2 combined gradient echo/fast spin echo sequence in same patient showing low signal change corresponding to deoxyhaemoglobin typical of acute haemorrhage and also a focus of increased parietal cortical signal change indicating either acute or old infarction.

(31%), haemorrhage in three patients, neoplasm in two patients, and normal in 15 patients (12.5%) (table 2).

There were 15 responses from 16 questionnaires sent to the clinicians. There was strong agreement (14 of 15) that DW MRI had a significant advantage over CT in equivocal cases of stroke, and it was also agreed that DW MRI had advantage over CT in clinically definite stroke. More contentious areas

Figure 3 Diffusion weighted MRI image (B1000) showing high signal at the margin of the haemorrhage indicating that this is haemorrhagic transformation of infarct rather than primary intracerebral haemorrhage. A separate focus of acute infarction is visible in the deep white matter.

Table 1 Reasons for CT as the primary investigation in acute stroke patients

Reasons CT was performed	Number of cases
Contraindication for MRI	8
Unavailability of MRI scanner because of maintenance servicing	2
Patient restless/confused	2
Lack of MR trained personnel/on call	4
Time/MR machine constraints	12

were confidence in interpreting haemorrhage where nine respondents agreed strongly or weakly that interpreting of images by non-radiologists was too complex (table 3). It was generally agreed that access to the MRI service was not compromised and that MR safety was not an important issue.

DISCUSSION

Imaging in acute stroke is necessary to differentiate haemorrhagic from non-haemorrhagic stroke, to affirm diagnosis in equivocal cases, and to exclude less common diagnoses such as neoplasm or subdural haemorrhage. When this protocol was started, national clinical guidelines for stroke advocated imaging within 48 hours, although it has been argued that imaging sooner than this is cost effective.¹ European and North American guidelines call for earlier imaging of stroke.^{18, 19} Patients with cerebrovascular events have a very high risk of early recurrence.²⁰ It is also known that some imaging changes can be very transient. Early imaging is mandatory if thrombolysis is a consideration.

CT is the current gold standard in the UK and it is almost universally available in acute admitting hospitals, although MRI capacity has improved significantly in recent years. In many US acute hospitals, DW MRI has gained acceptance as a powerful diagnostic technique for suspected stroke.²¹ There is clear evidence that DW MRI is more sensitive and specific for identifying acute stroke compared with CT and conventional MRI.^{2, 6, 11, 22, 23} Importantly interobserver agreement is significantly higher because of the high contrast of acute stroke on DW images.

One of the perceived potential drawbacks of MRI has been the lengthy time required for imaging. In the present climate of increasing economic pressures these issues cannot be ignored. However, modern scanners capable of ultrafast imaging permit examination times that compare favourably with CT. Our own findings with this protocol have found no

Table 2 Diagnoses found on DW MRI

Diagnosis	Number of cases
Acute infarct	58
Ischaemia (old)	37
Normal	15
Haemorrhage	3
Primary or secondary tumour	2
Subdural haematoma	1
Hypoxic injury	1
Demyelination	1
Encephalitis	1
Cavernous haemangioma	1

significant differences in the examination times between MRI and CT (DW MRI median 13 minutes, CT 11 minutes).¹ DW MRI is a feasible alternative to CT for imaging of acute stroke.

CT continues to be the imaging standard for detection of intracerebral haemorrhage. However, present MRI techniques have improved and now are sensitive in detecting early haemorrhage.^{24–28} In a multicentre study,²⁹ trained medical students reproduced a high level of accuracy in identifying haemorrhage on MRI. In our initial audit,¹⁷ a higher re-imaging rate after initial MRI scan occurred in patients with intracerebral haemorrhage. The rate has fallen as confidence in MRI has increased. The survey from the clinicians shows that, in general, clinicians view the use of DW MRI as favourable. This clinical view has resulted in an increase in MRI studies after CT particularly in diagnostic dilemmas.

In our audit, we were able to image 92% of the patients (110 of 120 patients) with DW MRI within 48 hours of request and 80 (67%) within 24 hours of request thereby conforming to the Royal College of Physicians' national clinical guidelines for stroke (2004). Of these, however, 80 cases (67%) had a formal radiological request within 48 hours of ictus. Delays in patients reaching hospital and delays in referral contributed to this late imaging rate. The entire process from recognition of symptoms to imaging needs to be improved to achieve best practice standards.

Patient safety remains paramount. All patients undergoing MRI are evaluated with a safety questionnaire. If there are problems of communication, for example, through dysphasia and confusion, the medical team is contacted and the study proceeds only if safety checks can be confirmed. No patient has come to any harm in the past four years although one

Table 3 Questionnaire response on use of DW MRI in stroke

Total response	1	2	3	4	5	Don't know
1 DW MRI has an important impact on stroke diagnosis in equivocal cases	1				14	
2 DW MRI has a significant advantage over CT in clinically definite stroke	1			6	8	
3 I am confident on excluding haemorrhage with DW MRI	1	4	1	5	4	
4 The availability of DW MRI has been a significant improvement to the stroke service	1			2	11	
5 I would be equally happy to have CT in clinically suspected stroke	5	5	2	1	1	1
6 If DW MRI is normal, this effectively excludes stroke as a working diagnosis		1	1	8	5	1
7 Patient safety has not proved a problem with use of MRI in suspected stroke		2	1	4	8	
8 Access to MRI for other studies has been compromised by a policy of using MRI for suspected stroke	4	4	1	2	3	1
9 Interpretation of DW MRI is too complex for non-radiologists	4	4		4	3	

1. Disagree strongly. 2. Disagree weakly. 3. Neither agree nor disagree. 4. Agree weakly. 5. Agree strongly.

patient who signed the safety questionnaire was discovered to have a neurovascular clip on the preliminary scan. The study was abandoned and the patient came to no harm.

DW MRI service for acute stroke is both feasible and sustainable in the setting of a district general hospital and most clinicians feel that this is a significant improvement. It has been practical and popular.

Authors' affiliations

P L Tan, D King, T M Meagher, Department of Radiology, Stoke Mandeville Hospital, Aylesbury, UK

D Briley, Department of Neurology, Stoke Mandeville Hospital

C J Durkin, Department of Medicine for Older People, Stoke Mandeville Hospital

Funding: none.

Competing interests: none to declare.

Guarantor: Dr Tom Meagher

Ethics: this work is based on published material and the authors consider this a service development, agreed by departments of radiology and neurology. Ethics approval was not deemed necessary. Data interpretation was undertaken as a commitment to audit the new process and was returned to the trust audit office.

REFERENCES

- 1 Wardlaw JM, Farrall AJ. Diagnosis of stroke on neuroimaging. *BMJ* 2004;**328**:655–6.
- 2 Lansberg MG, Albers GW, Beaulieu C, et al. Comparison of diffusion-weighted MRI and CT in acute stroke. *Neurology* 2000;**54**:1557–61.
- 3 Brott T, Marler JR, Olinger CP, et al. Measurements of acute cerebral infarction: lesion size by computed tomography. *Stroke* 1989;**20**:871–5.
- 4 Bryan RN, Levy LM, Whitlow WD, et al. Diagnosis of acute cerebral infarction: comparison of CT and MR imaging. *AJNR Am J Neuroradiol* 1991;**12**:611–20.
- 5 von Kummer R, Allen KL, Holle R, et al. Acute stroke: usefulness of early CT findings before thrombolytic therapy. *Radiology* 1997;**205**:327–33.
- 6 Mohr JP, Biller J, Hilal SK, et al. Magnetic resonance versus computed tomographic imaging in acute stroke. *Stroke* 1995;**26**:807–12.
- 7 Gonzalez RG, Schaefer PW, Buonanno FS, et al. Diffusion-weighted MR imaging: diagnostic accuracy in patients imaged within 6 hours of stroke symptom onset. *Radiology* 1999;**210**:155–62.
- 8 Lovblad KO, Laubach HJ, Baird AE, et al. Clinical experience with diffusion-weighted MR in patients with acute stroke. *AJNR Am J Neuroradiol* 1998;**19**:1061–6.
- 9 Marks MP, de Crespigny A, Lentz D, et al. Acute and chronic stroke: navigated spin-echo diffusion-weighted MR imaging. *Radiology* 1996;**199**:403–8.
- 10 Mullins ME, Schaefer PW, Sorensen AG, et al. CT and conventional and diffusion-weighted MR imaging in acute stroke: Study in 691 Patients at presentation to the emergency department. *Radiology* 2002;**224**:353–60.
- 11 van Everdingen KJ, van der GJ, Kappelle LJ, et al. Diffusion-weighted magnetic resonance imaging in acute stroke. *Stroke* 1998;**29**:1783–90.
- 12 Schulz UG, Briley D, Meagher T, et al. Abnormalities on diffusion weighted magnetic resonance imaging performed several weeks after a minor stroke or transient ischaemic attack. *J Neural Neurosurg Psychiatry* 2003;**74**:734–8.
- 13 Brott T, Bogousslavsky J. Treatment of acute ischemic stroke. *N Engl J Med* 2000;**343**:710–22.
- 14 Read SJ, Jackson GD, Abbott DF, et al. Experience with diffusion-weighted imaging in an acute stroke unit. *Cerebrovasc Dis* 1998;**8**:135–43.
- 15 Schellinger PD, Jansen O, Fiebach JB, et al. Feasibility and practicality of MR imaging of stroke in the management of hyperacute cerebral ischemia. *AJNR Am J Neuroradiol* 2000;**21**:1184–9.
- 16 Sunshine JL, Tarr RW, Lanzieri CF, et al. Hyperacute stroke: ultrafast MR imaging to triage patients prior to therapy. *Radiology* 1999;**212**:325–32.
- 17 Buckley BT, Wainwright A, Meagher T, et al. Audit of a policy of magnetic resonance imaging with diffusion-weighted imaging as first-line neuroimaging for in-patients with clinically suspected acute stroke. *Clin Radiol* 2003;**58**:234–7.
- 18 Adams HP Jr, Adams RJ, Brott T, et al. Guidelines for the early management of patients with ischemic stroke: a scientific statement from the Stroke Council of the American Stroke Association. *Stroke* 2003;**34**:1056–83.
- 19 Brainin M, Olsen TS, Chamorro A, et al. Organization of stroke care: education, referral, emergency management and imaging, stroke units and rehabilitation. European stroke initiative. *Cerebrovasc Dis* 2004;**17**(suppl 2):1–14.
- 20 Coull AJ, Lovett JK, Rothwell PM. Population based study of early risk of stroke after transient ischaemic attack or minor stroke: implications for public education and organisation of services. *BMJ* 2004;**328**:326.
- 21 Hacke W, Warach S. Diffusion-weighted MRI as an evolving standard of care in acute stroke. *Neurology* 2000;**54**:1548–9.
- 22 Barber PA, Darby DG, Desmond PM, et al. Identification of major ischemic change. Diffusion-weighted imaging versus computed tomography. *Stroke* 1999;**30**:2059–65.
- 23 Singer MB, Chong J, Lu D, et al. Diffusion-weighted MRI in acute subcortical infarction. *Stroke* 1998;**29**:133–6.
- 24 Atlas SW, Thulborn KR. MR detection of hyperacute parenchymal hemorrhage of the brain. *AJNR Am J Neuroradiol* 1998;**19**:1471–7.
- 25 Ebisu T, Tanaka C, Umeda M, et al. Hemorrhagic and nonhemorrhagic stroke: diagnosis with diffusion-weighted and T2-weighted echo-planar MR imaging. *Radiology* 1997;**203**:823–8.
- 26 Linfante I, Llinas RH, Caplan LR, et al. MRI features of intracerebral hemorrhage within 2 hours from symptom onset. *Stroke* 1999;**30**:2263–7.
- 27 Schellinger PD, Jansen O, Fiebach JB, et al. A standardized MRI stroke protocol: comparison with CT in hyperacute intracerebral hemorrhage. *Stroke* 1999;**30**:765–8.
- 28 Tong DC, Albers GW, Yenari MA, et al. A standardized MRI stroke protocol: comparison with CT in hyperacute intracerebral hemorrhage. *Stroke* 1999;**30**:1974–5.
- 29 Fiebach JB, Schellinger PD, Gass A, et al. Stroke magnetic resonance imaging is accurate in hyperacute intracerebral hemorrhage: a multicenter study on the validity of stroke imaging. *Stroke* 2004;**35**:502–6.