Diffusion weighted magnetic resonance imaging in the
diagnosis of reversible ischaemic deficits of the brainstem

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P Stoeter, H C Hopf

Objectives: To evaluate the sensitivity of diffusion weighted magnetic resonance imaging (MRI) for the
diagnosis of clinically suspected reversible ischaemic deficits of the brainstem.

Methods: A total of 158 consecutive patients presenting with acute signs of brainstem dysfunction
were investigated using EPI diffusion weighted MRI within 24 hours of the onset of symptoms. High
resolution T1 and T2 weighted imaging was performed as a follow up after a median of six days
Results: Fourteen of the 158 patients had a complete clinical recovery within 24 hours (transitory
ischaemic attack (TIA)), and 19 patients recovered in less than one week (prolonged reversible
neurological deficit (RIND)). Diffusion weighted MRI showed acute ischaemic deficits in 39% of patients
with transient neurological deficits. The detection rate seemed to be higher in patients with longer lasting
symptoms, but the difference between patients with TIA (29%) and RIND (47%) was not significant.

Conclusions: Diffusion weighted MRI is a sensitive indicator of acute ischaemic brainstem deficits even
in patients with reversible neurological deficit. Early identification of patients with TIA and increased
risk of stroke may influence acute management and improve patient outcome.

Recent studies have established diffusion weighted magnetic resonance imaging (MRI) (DWI) in the early diag-
nosis of ischaemic stroke. It measures the diffusion of water molecules mainly in the intercellular space, and DWI
hyperintensities allow the diagnosis of ischaemic tissue damage within minutes of stroke onset in animal models. In
the human, DWI has shown relevant changes even in a substantial proportion of patients with clinical criteria for a hemispheric
transitory ischaemic attack (TIA). TIA is generally defined as acute neurological impairment with a vascular cause
resolving within 24 hours. Obviously some of these patients may experience ischaemic tissue damage.

Little is known about the ability of DWI to show lacunar ischaemia in the brainstem, where routine computed tomog-
raphy (CT) and MRI often fail to detect ischaemic abnormalities. We are not aware of any report on the sensi-
tivity of DWI in the clinical diagnosis of brainstem transitory ischaemic deficits. Reliable diagnosis of ischaemic lesions,
however, is essential in identifying patients with subsequent increased risk of stroke. The aim of our study was to evaluate
the sensitivity of DWI in the diagnosis of clinically suspected reversible ischaemic deficits of the brainstem and to correlate
the duration of neurological deficits and DWI abnormalities.

PATIENTS AND METHODS
From November 1997 to July 2000, we prospectively recruited
158 consecutive patients presenting with acute signs and
symptoms of brainstem dysfunction suspicious of vertebro-
basilar ischaemia. Clinical criteria included acute cranial nerve
dysfunction, oculomotor deficits, and gait or limb ataxia.
Patients underwent MRI following a fixed protocol (see
below).

Ethical approval of the study was granted by the local eth-
ics committee, and patients gave informed consent to the pro-
dedures.

MRI
Biplane echo planar imaging T2 and diffusion weighted (DWI)
MRI was performed in all patients within 24 hours of the
onset of symptoms with a 1.5 T system (Magnetom Vision;
Siemens, Erlangen, Germany). We used DWI echo planar
imaging (TR 4000 ms; TE 103 ms) with separately applied dif-
fusion gradients in the three spatial axes ( b=1164 s/mm³; 128
cells; 250 ms per slice; 20 slices; thickness 3 mm; eight meas-
urements). Axial and sagittal high resolution T2
weighted imaging (TR 3810 ms; TE 90 ms; 256 matrix; slice
thickness 3 mm; FOV 220/210 for transversal and 220/230 for
sagittal slices) and T1 weighted imaging (TR 600 ms; TE 14
ms; 256 matrix; slice thickness 3 mm; FOV 220/210 for trans-
versal and 220/230 for sagittal slices) before and after intravenous application of gadolinium were performed as
soon as patients could tolerate the longer MRI scan (median
6.5 days after the onset of symptoms).

Statistical analyses
Fisher’s exact test was used for statistical correlation analyses. Statistical significance was set at p<0.05.

RESULTS
Thirty three of 158 patients presenting with signs and symp-
toms of acute brainstem impairment met the clinical criteria of a transient reversible neurological deficit. In 14 of these 33
patients, symptoms and signs resolved in less than 24 hours. Nineteen patients had a prolonged reversible neurological
deficit (RIND) persisting for more than 24 hours but less than
one week. Eleven of the 33 patients were women. Age ranged
from 29 to 82 years (mean 63.5). The most common neurological sign was gait ataxia (25 patients). In 12 patients
cranial nerves were affected, mainly the oculomotor and trigeminal nerve. Five patients presented with pathological
nystagmus, four had an internuclear ophthalmoplegia, and

Abbreviations: MRI, magnetic resonance imaging; DWI, diffusion
weighted magnetic resonance imaging; TIA, transitory ischaemic attack;
CT, computed tomography; RIND, prolonged reversible neurological
deficit
four a skew deviation. Other common neurological signs were motor hemiparesis (ten patients) and dysarthria (seven patients). Table 1 gives basic and clinical details.

Sonography and MR angiography showed stenosis of one vertebral artery in three patients. In one patient, acute brainstem signs occurred immediately after a chiropractical manoeuvre, but MR angiography and sonography did not verify vertebral artery dissection. In two patients, echocardiography gave evidence of a cardioembolic cause. Eighteen patients had multiple vascular risk factors, and sonography showed macroangiopathy of the internal carotid artery but no vertebral stenosis or occlusion. In nine patients, the cause of brainstem ischaemia remained unclear.

DWI was applied 2–22.5 hours after the onset of symptoms (mean interval 10.7 hours). It showed acute ischaemic lesions in 13 (39%) of the 33 patients with transient neurological impairment. This included four of 14 (29%) of the TIA group and nine of 19 patients (47%) with RIND (table 2). The difference in the detection rate between patients with TIA and RIND was not statistically significant.

The lesions were located in the pons in seven patients, in the mesencephalon in four patients, and in the medulla in two. High resolution T1 and T2 weighted MRI was performed after a mean of 6.5 days. Of the 13 patients with abnormal DWI, two had no corresponding relevant infarction on follow up imaging (one with TIA and one with RIND). In six patients, follow up imaging disclosed additional pre-existing ischaemic lesions. Lesions detected by high resolution MRI were judged non-acute if no topographically corresponding diffusion abnormality was found by DWI and if lesions did not show signs of acute ischaemia such as T2 hyperintensity or gadolinium enhancement.

### Table 1 Basic and clinical details of patients studied

<table>
<thead>
<tr>
<th>Age</th>
<th>Sex</th>
<th>TIA/ RIND</th>
<th>Clinical signs</th>
<th>DWI lesion</th>
<th>DWI latency (h)</th>
<th>HR-MRI lesion</th>
<th>Non-acute MRI lesion</th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>M</td>
<td>T</td>
<td>Gaze nystagmus to the left, left 5th nerve deficit, gait ataxia</td>
<td>–</td>
<td>3</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>71</td>
<td>M</td>
<td>T</td>
<td>Abduction deficit left eye, gait ataxia</td>
<td>Pons</td>
<td>14</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>70</td>
<td>M</td>
<td>T</td>
<td>Truncal and gait ataxia</td>
<td>Pons</td>
<td>7</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>61</td>
<td>F</td>
<td>T</td>
<td>Left INO, left hemiparesis, gait ataxia</td>
<td>–</td>
<td>5.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>73</td>
<td>M</td>
<td>T</td>
<td>Right ataxia, gaze nystagmus to the left, gait ataxia</td>
<td>–</td>
<td>6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>76</td>
<td>M</td>
<td>T</td>
<td>Left hemiparesis, gait ataxia</td>
<td>Medulla</td>
<td>21</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>69</td>
<td>F</td>
<td>T</td>
<td>Double vision, vertigo, gait ataxia</td>
<td>Medulla</td>
<td>16</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>58</td>
<td>M</td>
<td>T</td>
<td>Double vision, right hemiparesis</td>
<td>Mesenceph</td>
<td>2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>75</td>
<td>F</td>
<td>T</td>
<td>Dysarthria, gait ataxia, left facial paresis</td>
<td>–</td>
<td>18.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>77</td>
<td>M</td>
<td>T</td>
<td>Abduction deficit right eye, right 5th nerve deficit</td>
<td>–</td>
<td>7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>75</td>
<td>F</td>
<td>T</td>
<td>Skew deviation</td>
<td>–</td>
<td>5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>66</td>
<td>F</td>
<td>T</td>
<td>Abduction deficit right eye, gait ataxia</td>
<td>–</td>
<td>6.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>67</td>
<td>F</td>
<td>T</td>
<td>Positional nystagmus, right hemiparesis, gait ataxia</td>
<td>–</td>
<td>2</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>76</td>
<td>M</td>
<td>T</td>
<td>Right INO, gait ataxia</td>
<td>–</td>
<td>18</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>46</td>
<td>M</td>
<td>R</td>
<td>Right 3rd nerve palsy, right hemiparesis, gait ataxia</td>
<td>Mesenceph</td>
<td>14</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>82</td>
<td>F</td>
<td>R</td>
<td>Vertigo, gait ataxia</td>
<td>–</td>
<td>6.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>48</td>
<td>M</td>
<td>R</td>
<td>Right 3rd nerve palsy, gait ataxia</td>
<td>Medulla</td>
<td>21</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>60</td>
<td>F</td>
<td>R</td>
<td>Vertigo, right hemiparesis, gait ataxia</td>
<td>–</td>
<td>15.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>39</td>
<td>M</td>
<td>R</td>
<td>Dysarthria, skew deviation, right hemiparesis</td>
<td>Mesenceph</td>
<td>3.5</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>63</td>
<td>M</td>
<td>R</td>
<td>Dysarthria, right hemiataxia, gait ataxia</td>
<td>–</td>
<td>4</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>29</td>
<td>F</td>
<td>R</td>
<td>Vertigo, dysarthria, right hemiparesis</td>
<td>Pons</td>
<td>8.5</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>79</td>
<td>M</td>
<td>R</td>
<td>Skew deviation, gait ataxia</td>
<td>–</td>
<td>12</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>47</td>
<td>F</td>
<td>R</td>
<td>Vertigo, dysarthria, right hemiparesis</td>
<td>Pons</td>
<td>19</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>73</td>
<td>M</td>
<td>R</td>
<td>Gaze nystagmus to the right, dysarthria, dysphagia</td>
<td>–</td>
<td>21.5</td>
<td>–</td>
<td>–</td>
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<tr>
<td>42</td>
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<td>R</td>
<td>Right 3rd nerve palsy, gait ataxia</td>
<td>Mesenceph</td>
<td>15.5</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>55</td>
<td>M</td>
<td>R</td>
<td>Vertigo, double vision, dysarthria, right hemiparesis, gait ataxia</td>
<td>–</td>
<td>7</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>68</td>
<td>M</td>
<td>R</td>
<td>Vertigo, adduction deficit right eye, right 5th nerve deficit</td>
<td>Pons</td>
<td>12.5</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>60</td>
<td>M</td>
<td>R</td>
<td>Right 3rd nerve palsy, gait ataxia</td>
<td>–</td>
<td>20</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>48</td>
<td>M</td>
<td>R</td>
<td>Adduction deficit left eye, skew deviation, gait ataxia</td>
<td>Pons</td>
<td>19.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>78</td>
<td>F</td>
<td>R</td>
<td>Left INO, gait ataxia</td>
<td>–</td>
<td>2.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>57</td>
<td>M</td>
<td>R</td>
<td>Nystagmus to the right, skew deviation, gait ataxia</td>
<td>–</td>
<td>11</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>62</td>
<td>M</td>
<td>R</td>
<td>Left INO, gait ataxia</td>
<td>–</td>
<td>5.5</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>70</td>
<td>M</td>
<td>R</td>
<td>Dysarthria, vertical gaze paresis, right hemiparesis, gait ataxia</td>
<td>Pons</td>
<td>6</td>
<td>–</td>
<td>+</td>
</tr>
</tbody>
</table>

TIA, Transitory ischaemic attack; DWI, diffusion weighted magnetic resonance imaging; MRI, magnetic resonance imaging; HR, high resolution; RIND, prolonged reversible neurological deficit; INO, internuclear ophthalmoplegia; Mesenceph, mesencephalon.

### Table 2 Number of patients with the DWI detected lesion and the lesion detected by high resolution T1/T2 weighted magnetic resonance imaging

<table>
<thead>
<tr>
<th>DWI lesion</th>
<th>T1/T2 lesion</th>
<th>Total patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIA</td>
<td>4 (29%)</td>
<td>3</td>
</tr>
<tr>
<td>RIND</td>
<td>9 (47%)</td>
<td>8</td>
</tr>
<tr>
<td>TIA/RIND</td>
<td>13 (39%)</td>
<td>10</td>
</tr>
</tbody>
</table>

Values in parentheses are percentages.

TIA, Transitory ischaemic attack; DWI, diffusion weighted magnetic resonance imaging; RIND, prolonged reversible neurological deficit.
In our study, DWI showed acute brainstem lesions in 39% of patients with reversible neurological impairment attributed to brainstem ischaemia. The number of structural abnormalities according to DWI was higher in the group of patients with longer lasting symptoms classified as RIND than in the TIA group. The difference, however, was not statistically significant. The rate of 29% of DWI detected ischaemic changes in the TIA group is lower than the 48% reported in the only formal DWI study on hemispheric TIAs. The incidence of hemispheric DWI abnormalities in patients with RIND has not been reported so far. The rapid reversibility of symptoms and signs does not necessarily mean the absence of structural changes as shown by DWI. Resolution of the clinical impairment within 24 hours may be due to a lesion of a “non-eloquent” area—that is an area where a lesion does not result in any clinical signs—or the transient involvement of a functional structure by the perilesional penumbra. The high density of tracts and nuclei within the brainstem increases the risk of structural lesions becoming symptomatic as compared with the supratentorial condition. To the best of our knowledge, there have been no previous formal studies to evaluate the sensitivity of DWI in patients with transitory ischaemia of the brainstem. In a retrospective study, Linfante et al. reported a much higher yield of diffusion abnormalities in patients with posterior circulation stroke. Patients with reversible deficits, however, were explicitly excluded from the study. Moreover, the specificity and sensitivity of DWI cannot be reliably evaluated from this investigation, because the diagnosis of vertebrobasilar ischaemia was based in part on the result of the DWI.

Studies looking mainly at supratentorial lesions based on routine CT and MRI reported even lower frequencies of acute lesions in patients with TIA, ranging from 12% to 48%. However, CT and routine MRI do not allow accurate differentiation of acute from unrelated non-acute infarctions, and these data usually refer to hemispheric infarction. Brainstem ischaemia was either excluded or represented only in small numbers. A positive correlation between the duration of symptoms and the development of structural infarction on CT and routine MRI has been reported. However, not all investigations could confirm these findings. Our results using DWI show no significant correlation, which is probably because of the small number of patients. In the rat, the development of DWI hypersensitivities and the number of necrotic neurones in the histopathological investigation correlated strongly with the duration of transient middle cerebral artery occlusion.

Figure 1  Mesencephalic lesion of a patient having a transitory ischaemic attack investigated by diffusion weighted magnetic resonance imaging (A) and high resolution T2 weighted magnetic resonance imaging (B).

DISCUSSION

Patients with transient ischaemic symptoms and signs are at significant risk of subsequent ischaemic events. The nature of suspected brainstem impairment often cannot be judged from clinical signs alone and may be due to extra-axial lesions, as in peripheral vestibulopathy, vertebrobasilar migraine, or diabetic cranial nerve palsies. According to our study, DWI also classifies the gross anatomy in the posterior fossa and allows attribution to a vascular region and cause and thus identifies patients with transitory ischaemia and subsequent increased risk of stroke. Kidwell et al. showed that the identification of the vascular regions involved and the clinically suspected TIA mechanism had to be corrected in over one third of patients with transient neurological symptoms as the result of DWI findings. In our study, clinical signs and symptoms were used to make instant decisions about whether patients should be prospectively recruited. It cannot be excluded that some
patients with atypical presentations of brainstem ischaemia escaped investigation and may have altered the statistics.

In conclusion, we suggest that the use of DWI, particularly for infratentorial TIA or RIND, would achieve better identification of the localisation and acuity of ischaemic lesions and improve management of patients at risk of subsequent ischaemic stroke.

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