One quarter of strokes occur in the posterior circulation.\(^1\)\(^2\) Atherosclerotic stenosis of the vertebral artery most commonly occurs at the origin, and embolisation from such lesions is an important cause of posterior circulation stroke.\(^4\)\(^5\) Approximately one in five posterior circulation strokes occurs in the setting of extracranial vertebral artery stenosis,\(^6\)\(^7\) but the optimal management of such patients is unclear.

Carotid endarterectomy is widely used for the treatment of extracranial symptomatic carotid artery stenosis, but vertebral artery stenosis is often managed by medical treatment alone. Surgery for extracranial vertebral artery stenosis, in the form of endarterectomy and vessel revascularisation (bypass or transposition), has been reported to be associated with good outcome and low mortality.\(^8\)\(^9\)\(^10\) However, such operations are not widely undertaken because it is difficult to gain access to the vertebral artery at its origin.

Percutaneous endovascular treatment of vertebral artery stenosis is much less invasive than surgery and could prevent recurrent embolic or haemodynamic symptoms in this patient group. The carotid and vertebral artery transluminal angioplasty study (CAVATAS) showed a similar risk of stroke or death with endovascular treatment and surgery within 30 days after the procedure, in patients with severe symptomatic carotid artery stenosis.\(^11\)\(^12\) The two treatment modes also appeared equally effective at preventing ipsilateral stroke, or death and disabling stroke, in any vascular territory for up to three years after randomisation.

To date, at least 5210 carotid angioplasty and stenting procedures in 4757 patients have been reported, with an overall technical success rate of 98.4% and a combined rate of minor and major stroke and procedure related death of 3%.\(^13\) In contrast, there are little over 100 reported cases of endovascular intervention with primary stenting for extracranial vertebral artery stenosis. These early reports of selected non-randomised cases have shown high technical success rates, comparable to extracranial carotid stenting, with a complication rate of minor stroke or transient ischaemic attack (TIA) of only 3% and no related deaths during short term follow up.\(^14\)\(^15\)\(^16\)\(^17\)\(^18\) In the vertebral stenosis arm of the CAVATAS study, very few patients were randomised and the data have not been analysed to date.

We report the outcome after endovascular treatment for symptomatic vertebral artery stenosis in 14 patients who were followed up prospectively at a single centre between 1992 and 2001.

**METHODS**

**Patient selection and characteristics**

Fourteen patients underwent vertebral balloon angioplasty (PTA) and stenting between 1992 and 2001 at Atkinson Morley’s Hospital (St George’s Hospital NHS Trust). All but one of the patients had symptomatic posterior circulation TIA or stroke, usually with recurrent symptoms despite maximum antiplatelet treatment. The antiplatelet regimen used was aspirin monotherapy in the earlier stages of the study, and combination treatment with aspirin and dipyridamole in the later stages. An episode of posterior circulation ischaemia was defined as the sudden onset of two or more symptoms attributable to the posterior circulation which, after adequate investigation, were presumed to be of a non-traumatic vascular origin. Vertebral stenosis was usually detected by colour Doppler ultrasound or magnetic resonance angiography, and confirmed by intra-arterial catheter angiography before any endovascular intervention.

In the one patient who had had symptoms attributable to anterior circulation ischaemia, computed tomography of the brain showed a left parietal infarct, and catheter angiography showed bilateral internal carotid artery occlusion, a normal...
Patients were followed up by a neurologist immediately after the procedure, and then at annual intervals. Restenosis was defined as an increase in stenosis at one year. More recently treated patients were followed up with catheter angiography at one being greater than 0.8 m/s, peak systolic velocity in the vertebral artery was recorded as stenosis (% stenosis). The balloon was deflated and the degree of residual stenosis was crossed with a 0.014 inch (0.35 mm) wire. In the first four patients treated by simple balloon angioplasty, a 3–4 mm angioplasty balloon (with a diameter less than that of the distal disease-free vertebral artery) was then placed across the stenosis and inflated to 8 atm using a standard pressure inflation device. Inflation was maintained for about 15 seconds. The balloon was deflated and the degree of residual stenosis was viewed angiographically. The dilatation was repeated up to three times. In the four patients treated by balloon angioplasty alone, 300 mg of aspirin daily was given for at least one week before the procedure and continued indefinitely after discharge.

Table 1  Characteristics of patients treated with vertebral percutaneous transluminal angioplasty or stenting, and immediate angiographic result

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Presenting symptom</th>
<th>CT/MRI findings</th>
<th>Angiographic findings pretreatment</th>
<th>PTA (sten) result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>71</td>
<td>Posterior circulation TIA</td>
<td>Bilateral cerebellar infarcts</td>
<td>LV: 80% stenosis</td>
<td>0% stenosis</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>67</td>
<td>Posterior circulation TIA</td>
<td>Normal</td>
<td>LV: 70% stenosis</td>
<td>0% stenosis</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>54</td>
<td>Anterior circulation stroke</td>
<td>Left parietal infarct</td>
<td>LV: 80% stenosis</td>
<td>53% stenosis</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>63</td>
<td>Posterior circulation stroke</td>
<td>Left PCA infarct</td>
<td>RV: 50% stenosis</td>
<td>32% stenosis</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>61</td>
<td>Posterior circulation stroke</td>
<td>Normal</td>
<td>LV: 80% stenosis</td>
<td>0% stenosis (sten)</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>41</td>
<td>Posterior circulation stroke</td>
<td>Right medullary infarct, left PCA infarct</td>
<td>RV: 80% stenosis</td>
<td>10% stenosis (sten)</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>39</td>
<td>Posterior circulation stroke</td>
<td>Right PICA artery infarct</td>
<td>LV: 70% stenosis</td>
<td>20% stenosis (sten)</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>44</td>
<td>Posterior circulation stroke</td>
<td>Bilateral PICA infarcts</td>
<td>LV: 80% stenosis</td>
<td>40% stenosis (sten)</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>59</td>
<td>Posterior circulation stroke</td>
<td>Right pontine infarct</td>
<td>RV: 90% stenosis</td>
<td>10% stenosis (sten)</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>66</td>
<td>Posterior circulation TIA</td>
<td>Left pontine, bilateral cerebellar and occipital infarcts</td>
<td>RV: 70% stenosis</td>
<td>0% stenosis (sten)</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>62</td>
<td>Posterior circulation TIs</td>
<td>Old right hemispheric infarct</td>
<td>LV: 70% stenosis</td>
<td>0% stenosis (sten)</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>48</td>
<td>Posterior circulation TIs</td>
<td>Normal</td>
<td>LV: 80% stenosis</td>
<td>0% stenosis (sten)</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>67</td>
<td>Posterior circulation stroke</td>
<td>Right occipital infarct</td>
<td>RV: 90% stenosis</td>
<td>20% stenosis (sten)</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>45</td>
<td>Posterior circulation stroke</td>
<td>Normal</td>
<td>LV: 90% stenosis</td>
<td>20% stenosis (sten)</td>
</tr>
</tbody>
</table>

F, female; ICA, internal carotid artery; LV, left vertebral; M, male; PCA, posterior cerebral artery; PICA, posterior inferior cerebellar artery; R, right; RV, right vertebral; SCA, subclavian artery; TIA, transient ischaemic attack.

right vertebral artery, 80% stenosis to the origin of the left vertebral artery, and patent posterior communicating arteries bilaterally. Left vertebral PTA was done in order to improve cerebral blood flow in both the anterior and the posterior circulations.

Table 1 shows the clinical presentation and angiographic findings of the patients undergoing endovascular intervention. The mean age of the group was 56 years (range 39 to 71). All subjects were white and nine were male. Seven were hypertensive, defined as having a history of raised blood pressure and on antihypertensive drug treatment or with a blood pressure of ≥ 160 mm Hg systolic or 95 mm Hg diastolic. Eleven had hypercholesterolaemia, defined as a fasting cholesterol level of more than 6 mmol/l or were already being treated with lipid lowering agents. These definitions used to categorise patients as hypertensive and hypercholesterolaemic were taken from the original CAVATAS criteria and were used throughout the series of patients for consistency. Eleven patients were current or ex-smokers. Two suffered from ischaemic heart disease. Two were diabetic. All were in sinus rhythm, with no cardioembolic source for their stroke. Seven had concomitant carotid artery stenosis of > 50%. All patients were on treatment with 75 to 300 mg of aspirin daily. Two patients were also taking 200 mg of dipyramidole modified release twice daily, and one was also on treatment with warfarin.

Five patients were randomised to receive endovascular treatment in CAVATAS, while the remainder were treated according to physicians' consensus of best treatment. In the latter group, all patients had either recurrent symptoms in the vascular territory of a significantly stenosed vertebral artery (70% stenosis or more), or had posterior circulation ischaemic symptoms in the presence of a less severe stenosis occurring in a dominant vertebral artery (the other being atretic or occluded), with no patent posterior communicating artery on the side of the stenosis seen on catheter angiography.

CAVATAS received approval from the local hospital ethics committee, and written informed consent was obtained from all patients by the treating neuroradiologist. The first five patients underwent follow up catheter angiography at one year. More recently treated patients were followed up with vertebral artery colour Doppler ultrasound examination. If the peak systolic velocity in the vertebral artery was recorded as being greater than 0.8 m/s, catheter angiography was then done. Restenosis was defined as an increase in stenosis at one year to more than 50%, using the method described below. Patients were followed up by a neurologist immediately after the procedure, at one and six months after the procedure, and then at annual intervals.

PTA procedure
All endovascular procedures were undertaken under local anaesthesia by a single interventional neuroradiologist (AC). The degree of vertebral artery stenosis was determined from the catheter angiogram using the following formula:

% stenosis = 100 (1 − A/V)

where A is the diameter of the residual lumen at the point of maximum stenosis, and V is the width of disease free distal vertebral artery at the point where the walls were approximately parallel. This is similar to the method used to measure carotid stenosis in the North American symptomatic carotid endarterectomy trial. A 6 F sheath was inserted percutaneously under local anaesthesia into the right femoral artery, or, in two of the 14 patients, through a brachial puncture. A 6 F guiding catheter was then inserted into the subclavian artery over an exchange wire. Under roadmapping and after intravenous anticoagulation with heparin, the stenosis was crossed with a 0.014 inch (0.35 mm) wire. In the first four patients treated by simple balloon angioplasty, a 3–4 mm angioplasty balloon (with a diameter less than that of the distal disease-free vertebral artery) was then placed across the stenosis and inflated to 8 atm using a standard pressure inflation device. Inflation was maintained for about 15 seconds. The balloon was deflated and the degree of residual stenosis was viewed angiographically. The dilatation was repeated up to three times. In the four patients treated by balloon angioplasty alone, 300 mg of aspirin daily was given for at least one week before the procedure and continued indefinitely after discharge.

In the 11 patients in whom a stent was deployed, a guiding catheter was exchanged into the subclavian artery. Through this guiding catheter, a balloon expandable stent loaded over a 0.014 inch wire (Medtronic™ AVE INX, or previously S670 and AVE coronary stents) was introduced through the guiding catheter. After guiding the wire through the stenosis on roadmapping, the stent was placed (still under roadmapping) across the stenosis with the proximal end positioned at the origin of the vertebral artery from the subclavian artery. The stent was deployed at the same time as the stenosis was dilated by inflation of the angioplasty balloon. This procedure was also done under anticoagulation with heparin, which was continued for a further 24 hours afterwards. All the patients
were treated with 300 mg aspirin daily, and a second antiplatelet agent (either dipyramidole 100 mg three times daily plus dipyramidole MR 200 mg twice daily, or clopidigrel 75 mg once a day) was routinely prescribed for one week before stenting and for one to three months after the procedure. Thereafter patients were maintained on aspirin monotherapy unless they developed further symptoms during follow up.

RESULTS

Balloon angioplasty alone group

The first four patients treated with simple balloon angioplasty were followed up for a mean of 68.5 months (range 60 to 76). Vessel dilatation was achieved in all patients, with a mean improvement in stenosis from 73 (18)% before treatment to 21 (26)% after treatment (p = 0.059; paired t test). None of the patients had a major complication during or immediately after PTA, and none had a TIA or stroke within 30 days of the procedure. One patient had a brachial haematoma which resolved spontaneously. Follow up catheter angiography at one year showed restenosis of the PTA site in all patients, with a mean degree stenosis at one year of 71% (table 2), although all the patients remained asymptomatic at that time (fig 1).

During further follow up, one patient had a posterior circulation TIA 18 months after the initial PTA. This patient was retreated with vertebral artery primary stenting with an excellent anatomical result (fig 2). The patient remains asymptomatic, and colour Doppler ultrasound has not shown any restenosis five years after stent insertion. The three other patients treated by simple balloon angioplasty subsequently had no further symptoms of posterior circulation ischaemia. However, two of the patients died during follow up—one died five years after the procedure from ischaemic heart disease and the other, more than five years after the procedure from pneumonia.

Primary stenting group

Ten patients (Nos 5–14) were treated by primary stenting and have been followed up for a mean of 19.7 months (range 1 to 48). All stenoses were treated successfully, with a mean improvement in angiographic stenosis severity from 82 (8)% before treatment to 13 (13)% after treatment (p < 0.001; paired t test). One patient experienced two posterior circulation TIAs, each lasting less than five minutes, 72 hours after stenting. Thus the risk of TIA after stenting in this series was 20%. There were no other immediate or early complications. Follow up colour Doppler ultrasound examination showed evidence of restenosis in only one case, six months after the procedure, which was found to be a 55% stenosis on catheter angiography. The patient remained asymptomatic and subsequent colour Doppler ultrasound examinations, including the latest scan done three years after stenting, have shown normal velocities. None of the stented patients has reported posterior circulation stroke symptoms during the prospective follow up. Two patients had right middle cerebral artery territory strokes, six and 18 months, respectively, after stenting. Both events were attributable to coexistent carotid disease. One patient died as a result of the stroke. Another

![Figure 1](http://jnnp.bmj.com/)

Digital subtraction angiograms in a patient showing (A) severe vertebral artery origin stenosis before treatment, (B) successful vessel dilatation immediately after balloon angioplasty, and (C) severe restenosis at follow up angiography one year later.
Vertebral artery origin angioplasty and stenting

The duration of follow up differed in the two methods, good views of the vertebral artery origin stents were obtained with colour Doppler ultrasound in all patients during follow up at six months, and one year after stent insertion. Higashida et al used a combination of Doppler ultrasound, magnetic resonance angiography, and catheter angiography to follow up patients after proximal vertebral artery PTA and showed restenosis in only three of 34 patients (9%) in their series. However, the proportion of patients who had vertebral artery origin stenosis rather than more distal vessel disease was not specified in that series.

Chastain et al have followed up the largest reported series of patients after extracranial vertebral artery stent placement for the treatment of symptomatic (> 60%) vertebral artery stenosis. Forty four of 49 patients underwent angiographic follow up at six months, and 48 of the 55 vessels treated (87%) had involvement of either the origin or proximal extracranial vertebral artery. A moderate degree of restenosis (27.3 (19.6)%) was seen in five vessels—that is, in 10% of treated vessels. These results are in keeping with results of our series, with a low restenosis rate after primary stenting for vertebral artery origin stenosis.

Our experience suggests that the outcome after treatment of vertebral artery origin stenosis is similar to that seen after endovascular treatment of renal artery ostial stenosis. Conventional angioplasty in the latter group has a high failure rate owing to elastic recoil and the condition is better managed by stenting.

The results of our case series suggest that, from a technical viewpoint, primary stenting for vertebral artery atherosclerotic stenosis at the vessel origin has a high success rate and a low complication rate. In the light of the advances in secondary preventive treatment for stroke patients over the past decade, data from well designed randomised clinical trials are required to compare the outcome after endovascular treatment with best medical care alone in this patient population. Before a definitive trial, further data from an intermediate sized pilot study are required to determine sample size calculations.

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