Carotid disease in acute stroke

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Abstract

Background: the Oxfordshire Community Stroke Project (OCSP) devised a simple clinical classification for acute stroke which predicted mortality, functional recovery and patterns of recurrent stroke. We aimed to determine whether this could predict the presence of carotid disease and be used to select which patients with acute stroke should be referred for carotid imaging with a view to subsequent carotid endarterectomy.

Methods: we assessed patients with acute stroke admitted to seven hospitals over a 10-month period. Patients were classified according to the OCSP system and their carotid arteries investigated using portable continuous-wave Doppler. Those with abnormal portable assessments had colour duplex Doppler imaging.

Results: of 305 patients with proven or probable cerebral infarction, severe (70-99%) ipsilateral carotid stenosis was found in 16 (16%) of the 101 with partial anterior circulation infarct (PACI), four (4%) of the 100 with total anterior circulation infarct (TACI), none of the 80 with lacunar infarct (LACI and one (4%) of the 24 with posterior circulation infarct (POCI). Complete ipsilateral carotid occlusion was found in 25 (25%) of the TACI group, 11 (11%) of the PACI group, three (4%) of the LACI group and none of the POCI group. Severe carotid stenosis or occlusion was more common in the ipsilateral than the contralateral carotid artery for the TACI and PACI groups (χ² > 0.05), but there was no difference between ipsilateral and contralateral carotid disease in the LACI and POCI groups. If the OCSP classification is used to detect patients with 70–99% carotid stenosis, then the sensitivity is 76% and specificity is 70%.

Conclusion: these findings suggest that ipsilateral carotid disease is an important cause of stroke for those with anterior circulation infarcts but not for those with LACI or POCI. Subjects with PACI should be referred for early carotid imaging to identify those with severe disease who may be suitable for elective carotid surgery.

Keywords: acute stroke, carotid disease, Doppler imaging

Introduction

The Oxfordshire Community Stroke Project (OCSP) devised a classification for acute stroke based on symptoms and signs only [1]. The classification is now widely used. It has prognostic value by predicting mortality, functional recovery and patterns of recurrent stroke [1]. For example, patients with partial anterior circulation infarct (PACI) are at particularly high risk of early stroke recurrence. This pattern of recurrence is consistent with an active source of emboli such as carotid atherosclerosis, but the prevalence of carotid disease in the OCSP subtypes of acute stroke is uncertain. Carotid stenosis in acute stroke has important clinical implications, because carotid endarterectomy in patients with a history of ischaemic stroke and 79–99% ipsilateral carotid stenosis reduces the risk of further stroke [3, 4].

The relationship between the OCSP classification and carotid disease has been previously investigated, but one study failed to differentiate between a complete carotid occlusion (where carotid surgery is contraindicated) and a severe stenosis, and the other recruited a very small number of patients [5, 6].

The aim of this study was to investigate the relationship between the OCSP classification and carotid disease, in order to determine whether the OCSP could be used to select which patients with acute stroke should be preferentially referred for carotid imaging.

Methods

Referral of patients

We collaborated with 44 consultants in seven Manchester hospitals by asking all junior doctors to refer urgently any patient admitted with a possible acute stroke using a 24-h
Classification of acute ischaemic stroke

Patients with hemiparesis, homonymous hemianopia and new disorders of higher cerebral dysfunction e.g. dysphasia, were classified in the total anterior circulation infarct (TACI) group. Those with only two of the above features or with isolated cortical dysfunction (e.g. dysphasia) were classified in the PACI group. Patients with isolated motor or sensory deficits, or sensorimotor strokes or ataxic hemiparesis were classified in the lacunar infarct (LACI) group and those with brainstem or cerebellar signs in the posterior circulation infarct (POCI) group. The maximum recorded deficit was used in the classification. For example, if the initial neurological assessment recorded in the case notes included dysphasia and hemiparesis, the patient was placed in the PACI group, even if the dysphasia had resolved by the time of our assessment. We did not modify the clinical classification according to CT findings, because CT was requested by the referring doctor in only just over half the patients.

Carotid imaging

The carotid arteries were investigated bilaterally by the stroke research fellow using portable continuous-wave Doppler ultrasound after the neurological assessment. The stroke research fellow was therefore blind to the results of the Doppler ultrasound at the time of the neurological assessment. We had previously validated this equipment and demonstrated a sensitivity of 99% and specificity of 83% for diagnosing significant carotid stenosis or occlusion compared with colour duplex Doppler undertaken by an experienced vascular technologist [9]. The low specificity was mainly due to a false-positive diagnosis of carotid occlusion when an internal carotid signal could not be detected for technical reasons (e.g. high carotid bifurcations or a tortuous vessel).

Patients with peak systolic frequencies of over 3.5 kHz (suggesting >50% stenosis) on the portable equipment who were fit for transfer to our vascular studies unit had colour duplex Doppler imaging (ATL Ultramark 9). Disease severity was classified as <50% stenosis, 50–69% stenosis, 70–99% stenosis or complete occlusion. Patients who were unfit for transfer were classified according to the portable carotid Doppler assessment alone. Those with possible occlusion who were fit for surgery were also investigated by intra-arterial digital subtraction angiography in order to distinguish a very tight carotid stenosis from an occlusion. The presence of a major source of cardiac emboli (e.g. atrial fibrillation, prosthetic valve, mitral stenosis, recent myocardial infarct, left atrial or left ventricular thrombus, atrial myxoma, infective endocarditis and dilated cardiomyopathy) was noted [6].

Statistical analysis

χ² tests were used to compare the prevalence of carotid disease in the different OCSP subtypes and 95% confidence intervals (CI) were calculated for the point estimates of the prevalence in the different subtypes.

Results

Classification of patients

During the study period, 485 patients were referred. Of these, 341 presented with focal neurological disturbance lasting between 24 h and 7 days and were classified as acute stroke. Brain CT results were available in 192 (56%). Eighteen (9%) were found to have intracerebral haemorrhage, five had an intracranial tumour and one had a subdural haematoma. A further two patients were subsequently diagnosed as having hypertensive encephalopathy by the referring physician but did not undergo brain CT. Of the remaining 149 patients who did not have a CT scan, 10 (7%) had Siriraj stroke scores of >1 and were classified as cerebral haemorrhage—a proportion which was not significantly different from those who did undergo CT (χ² P>0.05). Hence, 305 patients were classified as acute stroke. Brain CT results were available for 170 of these 305 patients: 140 of these showed an infarct (or multiple infarcts) and 30 showed no infarct. The OCSP classification divided the 305 patients into 100 with TACIs (33%), 101 with PACIs (33%), 80 with LACIs (26%) and 24 with POCIs (8%). The median time from stroke onset to assessment was 2 days (range 0–7).

Accuracy of diagnosis of carotid occlusion by portable Doppler

A total of 70 internal carotid arteries were thought to be occluded on portable Doppler (including patients with 'old stroke', TIA's and 'not strokes'). Colour duplex Doppler results were available on 48 of these arteries, which confirmed occlusions in 37 (77%). For
the purposes of this analysis, it was therefore decided that 77% of those who were too unwell for transfer to our vascular studies unit, and had apparently complete occlusion on portable Doppler, would be categorized as having complete occlusions and the remaining 23% as having <50% stenosis. This is particularly relevant to the diagnosis of carotid occlusion in the TACI group (see below).

**Severe (70–99%) carotid stenosis**

Severe ipsilateral carotid stenosis was found in 16 (16%; 95% CI 9–23%) of the PACI group, four (4%; 0–8%) of the TACI group, none (0%; 0–4%) of the LACI group and one (4%; 0–8%) of the POCI group ($\chi^2 P < 0.05$). All these findings were confirmed on colour duplex Doppler.

**Complete carotid occlusion**

Complete carotid occlusion was found on portable Doppler in 28 (28%; 19–37%) of the TACI group compared with only 13 (13%; 6–20%) of the PACI group, three (3%; 0–7%) of the LACI group and none (0%; 0–14%) of the POCI group ($\chi^2 P < 0.05$).

In the TACI group, 13 of the 28 who were thought to have carotid occlusion on portable Doppler had these findings confirmed on colour duplex Doppler. We categorized 12 (i.e. 77%) of the remaining as complete occlusion. All 13 in the PACI group had complete carotid occlusion on portable Doppler (nine of which were confirmed on colour duplex Doppler and two more by digital subtraction angiography). All three of the LACI group who had complete occlusion had the findings confirmed on colour duplex Doppler; one of these had a temporo-parietal infarct on CT.

**Comparison between ipsilateral and contralateral carotid disease**

The numbers of patients with TACIs, PACIs and LACIs with ipsilateral and contralateral internal carotid disease are shown in Figure 1. In the TACI and PACI groups, there was a significant difference between ipsilateral and contralateral internal carotid disease ($\chi^2 P < 0.05$). For the LACI group, there was no significant difference between the two sides. For the 24 patients with POCI, severe internal carotid stenosis was found in one ipsilateral internal carotid and one contralateral internal carotid ($\chi^2 P = \text{n.s.}$).

**Contralateral carotid disease in patients with ipsilateral carotid occlusion**

The effect of contralateral carotid disease in patients with complete ipsilateral internal carotid occlusion was also assessed. Of the 28 patients in the TACI group thought to have ipsilateral carotid occlusion, five (18%) had severe contralateral carotid stenosis or occlusion.

![Figure 1](image-url)

**Figure 1.** Prevalence of ipsilateral and contralateral carotid stenosis in subjects with a partial anterior circulation infarct, b total anterior circulation infarct and c lacunar infarct. The difference between the ipsilateral and contralateral side was significant ($\chi^2 P < 0.01$) for partial anterior circulation infarct and for total anterior circulation infarct but not for lacunar infarct.
Of the 13 patients in the PACI group with ipsilateral occlusion, two (15%) had severe contralateral internal carotid stenosis (no significant difference between TACI and PACI groups).

**Atrial fibrillation and carotid stenosis**

Atrial fibrillation was found in 30 (30%; 95% CI 21-39%) of the TACI group, 13 (13%; 6-20%) of the PACI group, five (6%; 0-10%) of the LACI group and two (8%; 0-13%) of the POCI group ($\chi^2 P < 0.001$). Fourteen (28%) of the 50 patients in atrial fibrillation had carotid occlusion on either portable Doppler or colour duplex Doppler, compared with 30 of the 225 (13%) patients in sinus rhythm ($\chi^2 P < 0.01$). Only three patients in atrial fibrillation (6%) had severe carotid stenosis as well. There were no patients with other major potential sources of cardiac emboli.

**Selection of patients for carotid imaging using OCSP**

If the OCSP is used to select patients for carotid imaging to identify those with severe stenosis, then an adequate sensitivity and specificity for detecting severe carotid stenosis is important. A $2 \times 2$ table can be constructed to demonstrate the clinical significance of selecting only those with PACIs for carotid imaging (Table 1). The sensitivity of selecting subjects with PACI alone would be $16/21 (76\%)$ and the specificity would be $195/280 (70\%)$.

**Discussion**

This is the largest study to investigate the relationship between the OCSP classification and carotid disease. We have shown that the OCSP predicts the likely prevalence of carotid disease, with severe stenosis being most common in patients with PACIs and complete carotid occlusion in patients with TACIs. Furthermore, there was a significant difference in the prevalence of ipsilateral and contralateral carotid disease in the PACI and TACI groups, but not in the LACI or POCI groups, suggesting that ipsilateral carotid stenosis is an important causative (rather than coincidental factor) in total and partial anterior circulation infarct but not in lacunar or posterior circulation infarct.

Severe carotid stenosis was most common in the PACI group. This may explain why early stroke recurrence is a particular feature of these patients [1]. We did attempt to compare early stroke recurrence in patients with PACIs with and without carotid stenosis as some of the patients in the PACI group underwent urgent carotid endarterectomy as part of a randomized controlled trial comparing urgent with elective carotid endarterectomy [10].

Complete carotid occlusion was most common in the TACI group, with 28% of subjects having occlusion on portable Doppler (half of these confirmed by colour duplex Doppler). This is higher than in the other OCSP subtypes of stroke. Not all our patients underwent digital subtraction angiography, so a few of those with occlusion may have had a 'trickle' flow undetectable on colour duplex Doppler. Previous studies have suggested that sudden occlusion of the internal carotid artery often causes severe neurological deficit (which is in keeping with our finding that occlusion is most common in subjects with TACIs), although carotid occlusion may cause mild neurological deficits or even no symptoms at all [11, 12]. The variability in clinical effects of sudden internal carotid occlusion is thought to be related to the collateral supply, mediated in part by the contralateral carotid artery [13]. However, there were no important differences in contralateral carotid disease between TACI and PACI occlusions, which probably reflects the importance of other factors such as the anatomical integrity of the circle of Willis and collateral flow via the external carotid arteries [14-16].

**Post mortem** studies suggest that the most common mechanism for stroke in patients with carotid occlusion is probably thrombus formation on a severely diseased internal carotid artery [17]. The low prevalence of severe stenosis in subjects with TACIs and a high prevalence of complete occlusion is consistent with the conversion of a tight stenosis into an

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**Table 1.** The clinical significance of selecting only patients with partial anterior circulation infarct (PACI) for carotid imaging

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of subjects, by degree of stenosis</th>
<th>Occlusion, moderate/none</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70-99%</td>
<td>70-99%</td>
<td></td>
</tr>
<tr>
<td>PACI</td>
<td>16</td>
<td>85</td>
<td>101</td>
</tr>
<tr>
<td>TACI, LACI and POCI</td>
<td>5</td>
<td>195</td>
<td>200</td>
</tr>
<tr>
<td>All</td>
<td>21</td>
<td>280</td>
<td>301</td>
</tr>
</tbody>
</table>

Sensitivity = $16/21 (76\%)$; specificity = $195/280 (70\%)$; positive predictive value = $16/101 (16\%)$; negative predictive value = $195/200 (97.5\%)$.

TACI, total anterior circulation infarct; LACI, lacunar infarct; POCI, posterior circulation infarct.
Patients preferential carotid imaging: all who had reasonable strategy would be to offer the following PACIs, those with TACIs who make a good recovery could be reclassified as having a PACI. Therefore, a and carotid occlusion had a cortical infarct on CT and severe stenosis, and one of the three who had LACIs surgical deficit. There were no subjects with LACIs and probably not be suitable for elective carotid endarterectomy because prophylaxis of further strokes is inapplicable due to the severity of the initial neurological deficit. Does this matter? The remaining five patients in our series with severe carotid stenosis had TACIs. Most subjects with TACIs would disease would have been missed. Does this matter? Carotid disease in acute stroke

Can the OCSP be used to select which patients with acute stroke should be referred for carotid imaging? The sensitivity of using the PACI classification to detect severe stenosis was 76% and the specificity 70%. An ideal screening test has a high sensitivity to ensure that all patients with significant disease are detected. If the PACI classification had been used to select patients for carotid imaging, then some patients with severe disease would have been missed. Does this matter? The remaining five patients in our series with severe stenosis had TACIs. Most subjects with TACIs would probably not be suitable for elective carotid endarterectomy because prophylaxis of further strokes is inapplicable due to the severity of the initial neurological deficit. There were no subjects with LACIs and severe stenosis, and one of the three who had LACIs and carotid occlusion had a cortical infarct on CT and could be reclassified as having a PACI. Therefore, a reasonable strategy would be to offer the following patients preferential carotid imaging: all who had PACIs, those with TACIs who make a good recovery and, finally, subjects with LACIs and cortical infarcts on CT. This strategy now needs prospective evaluation.

In summary, we have demonstrated that the prevalence of carotid disease in acute stroke is predicted by the OCSP subtype and we recommend that the OCSP be used to select which patients with acute stroke should be referred for carotid imaging.

Key points

- The Oxford Community Stroke Project (OCSP) classification of acute stroke can be used to determine which patients have carotid disease.
- Severe carotid stenosis is most common in partial anterior circulation infarct (16%).
- Complete carotid occlusion is most common in total anterior circulation infarct (28%).
- The OCSP classification has a sensitivity and specificity of 76% and 70% respectively for detecting severe carotid stenosis, and may be useful in selecting patients for carotid imaging.

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References


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