The cause of ischaemic stroke in young patients is often not found despite systematic investigations. Such strokes are classified as cryptogenic. In patients with cryptogenic strokes patent foramen ovale (PFO) can be detected in more than 50%, whereas its prevalence in the general population is at least 25%. Therefore, PFO is likely associated with cryptogenic stroke. The presumed mechanism is paradoxical embolism of venous thrombotic material across the atrial right to left shunt. A thrombus crossing the PFO and subsequently embolizing to the brain has been rarely detected. However, because direct evidence for paradoxical embolisation is rare in the individual clinical situation the potential role of the PFO in stroke is still a matter of debate. Earlier studies have suggested that a patent foramen ovale is an incidental finding in patients with cryptogenic stroke. The presumed mechanism is paradoxical embolism via right to left shunt. After excluding those with a concurrent aetiology for the cerebrovascular event we identified 318 patients who had a PFO and otherwise unexplained ischaemic stroke or TIA. We aimed to define subgroups at increased risk for recurrent cerebral ischaemia and to estimate the effect of antithrombotic treatment on stroke recurrence.

Patients
We identified all patients with ischaemic stroke, transient ischaemic attacks (TIA), or amaurosis fugax, who were admitted to our university based stroke centre between January 1994 and July 2000. The diagnosis of stroke was based on a focal neurological deficit resolving completely within 24 hours. Transoesophageal echocardiography (TEE) had been performed in all patients suspected of paradoxical embolism via right to left shunt. After excluding those with a concurrent aetiology for the cerebrovascular event we identified 318 patients who had a PFO and otherwise unexplained ischaemic stroke or TIA.

The patients were offered several treatment options to prevent a recurrent stroke: endovascular or surgical closure of the patent foramen ovale, or long term antithrombotic treatment.

Abbreviations: PFO, patent foramen ovale; TIA, transient ischaemic attack; ASA, atrial septal aneurysm; TEE, transoesophageal echocardiography; BMI, body mass index; INR, international normalised ratio; PICSS, PFO in cryptogenic stroke study; WARSS, warfarin/aspirin recurrent stroke study.

For these reasons we analyzed the recurrence rate in patients with PFO and cryptogenic stroke. Using survival analyses, we aimed to define subgroups at increased risk for recurrent cerebral embolisation and to estimate the effect of antithrombotic treatment on stroke recurrence.

Methods.
Patent foramen ovale was diagnosed in 318 patients with otherwise unexplained ischaemic stroke or transient ischaemic attack (TIA). One hundred and fifty nine were treated medically (oral anticoagulation 79, platelet inhibitors 80) and represent the study population. The remaining 159 patients underwent endovascular or surgical closure of the PFO and are not part of this study.

Results.
Mean age was 50.7 (SD 13.5) years. The event leading to the diagnosis of PFO was a TIA in 38 patients (23.9%), an ischaemic stroke in 119 (74.8%), and an amaurosis fugax in two patients (1.3%). Forty four patients (27.7%) had experienced multiple cerebrovascular ischaemic events before the diagnosis of the PFO. During mean follow up of 29 (SD 23) months 21 patients (13.4%) had a recurrent cerebrovascular event (seven strokes and 14 TIA). The average annual rate of recurrent strokes was 1.8% and that of recurrent strokes or TIA was 5.5%. When patients with PFO with multiple cerebrovascular events before the diagnosis of the PFO were analyzed separately, the average annual rates of recurrent cerebral ischaemia were 3.6% for recurrent strokes and 9.5% for recurrent strokes or TIA. These rates were significantly higher than in patients with first ever stroke or TIA (p=0.02).

Conclusions.
The study confirms a risk of stroke recurrence that is similar to the rates of previously published series of patients with PFO and cryptogenic strokes. Patients with more than one previous event were at increased risk of recurrent cerebral ischaemia.
Follow up data could not be obtained from two patients; event a standardised telephone questionnaire was used. Themselves were contacted. In order not to miss any recurrent events and treatments. Thereafter, the medical records of all patients and the relevant information concerning recurrent events and treatments. Twenty patients, who had been on antithrombotic treatment for a prolonged period and then decided for some reason to have endovascular or surgical closure of the PFO, were included in the analysis for the time they had been treated medically.

Statistics
Continuous variables are expressed as mean (SD). Nominal variables were compared by \( \chi^2 \) test for contingency tables. Statistical significance was assumed at a value of \( p<0.05 \).

RESULTS
The study population consisted of 93 men and 66 women. Their mean age was 50.7 (13.3) years (range 15 to 77 years). One hundred and twenty one patients (76.1%) were 60 years old or younger at the time when they experienced the ischaemic event that led to the diagnosis of a PFO (fig 1).

This event was a transient ischaemic attack in 38 patients (23.9%), an ischaemic stroke in 119 (74.8%), and an amaurosis fugax in two patients (1.3%). In 90 patients (56.6%) it occurred in the carotid territory and in 69 patients (43.4%) in the vertebrobasilar territory. Forty four patients (27.7%) had experienced more than one cerebrovascular ischaemic event before the diagnosis of the patent foramen ovale.

The vascular risk factors that were considered to increase the risk for stroke or TIA are summarised in table 1. Hyper tension, diabetes mellitus, cigarette smoking, hypercholesterolaemia, and familial history for stroke occurred with similar frequencies in patients with one and in those with multiple previous cerebrovascular events. Obesity was more frequent in the group with more than one prior event (\( p=0.02 \)). There were five patients with coronary artery disease in the group with one cerebral ischaemic event before diagnosis of the PFO. Fifty of the 159 patients (31.4%) did not show any vascular risk factors.

The right to left shunt was minimal in 19 patients (11.9%), moderate in 44 (27.7%), and severe in 96 (60.4%) patients. Thirty three patients (20.7%) had an ASA in addition to the diagnosis of the PFO.

Table 1: Vascular risk factors in patients with one and in patients with multiple ischaemic events before diagnosis of PFO

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>All patients (n=159)</th>
<th>Patients with one ischaemic event (n=115)</th>
<th>Patients with multiple ischaemic events (n=44)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertension</td>
<td>52 (32.7)</td>
<td>37 (32.2)</td>
<td>15 (34.1)</td>
<td>0.79</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>15 (9.4)</td>
<td>10 (8.7)</td>
<td>5 (11.4)</td>
<td>0.55</td>
</tr>
<tr>
<td>Smoking</td>
<td>52 (32.7)</td>
<td>36 (31.3)</td>
<td>16 (36.4)</td>
<td>0.59</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>48 (30.2)</td>
<td>33 (28.7)</td>
<td>13 (34.1)</td>
<td>0.49</td>
</tr>
<tr>
<td>Positive familial history</td>
<td>42 (26.4)</td>
<td>30 (26.1)</td>
<td>12 (27.3)</td>
<td>0.84</td>
</tr>
<tr>
<td>Obesity</td>
<td>82 (51.6)</td>
<td>52 (45.2)</td>
<td>30 (68.2)</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Values are n (%).
PFO. Seventy nine patients received oral anticoagulant drugs. The target international normalised ratio (INR) was 2.0–3.0. In 26 of them the oral anticoagulation was replaced by antiplatelet drugs after 12 (SD 11) months. Platelet inhibitors were given to 80 patients (77 patients were treated with aspirin at a mean dosage of 233 (SD 83) mg/day, three patients were given to 80 patients (77 patients were treated with aspirin and one ischaemic event and the continuous line shows the patients surviving free of recurrence. The dotted line represents the patients indicating an increased risk for stroke recurrence in this group (p=0.053, two tailed Fisher's exact test).

### Table 2 Average annual recurrent cerebral ischaemias in patients with one or in patients with multiple ischaemic events before diagnosis of PFO

<table>
<thead>
<tr>
<th>Patients</th>
<th>Number of recurrent events</th>
<th>Average annual recurrent events</th>
</tr>
</thead>
<tbody>
<tr>
<td>All (n=157):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strokes</td>
<td>7</td>
<td>1.8%</td>
</tr>
<tr>
<td>TIA</td>
<td>14</td>
<td>5.5%</td>
</tr>
<tr>
<td>With one ischaemic event (n=113):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strokes</td>
<td>3</td>
<td>1.1%</td>
</tr>
<tr>
<td>TIA</td>
<td>7</td>
<td>3.7%</td>
</tr>
<tr>
<td>With multiple ischaemic events (n=44):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strokes</td>
<td>4</td>
<td>3.6%</td>
</tr>
<tr>
<td>TIA</td>
<td>7</td>
<td>9.9%</td>
</tr>
</tbody>
</table>

Neither the severity of the right to left shunt, nor the coexistence of an ASA in addition to the PFO were associated with an increased risk for stroke recurrence. The overall cumulative estimate of risk of stroke or TIA recurrence, at 2 years of follow up, in the whole cohort of patients with PFO was 9.2% (95% CI 6.5% to 11.9%). When only strokes were considered, the cumulative risk of recurrence was 4.5% (95% CI 2.5% to 6.5%), at 2 years of follow up.

The average annual rate of stroke recurrence was 1.8% and that of both recurrent strokes or TIAs was 5.5% (table 2). When patients with multiple ischaemic events before diagnosis of PFO were analyzed separately, the average annual rate of recurrent strokes was 3.6% and the rate of recurrent strokes or TIAs was 9.9%. The log rank test for survival data showed a significantly higher risk for recurrent events in this group than in patients without ischaemic events before the qualifying event (p=0.02). However, obesity was more common in the group with multiple ischaemic events.

When patients without obesity were analyzed separately, the risk for recurrent events in the subgroup with multiple ischaemic events before diagnosis of PFO was still significantly higher than in the subgroup with first ever stroke or TIA (p=0.02).

Figure 2 shows the Kaplan-Meier survival curves of patients with one event and those with multiple cerebral ischaemic events before diagnosis of PFO.

#### DISCUSSION

Previous studies have shown an association between PFO and cryptogenic stroke. However, optimal secondary stroke prevention for such patients is not known because randomised trials have not been performed to date.

There are three major studies that assessed the rate of recurrent cerebrovascular events during 2 to 3 years of antithrombotic treatment (table 3). Bogousslavsky et al reported 3.8% of recurrent, non-fatal cerebral ischaemias (stroke and/or TIA)/year during 3 years of prospective follow up in 140 patients.25 Mas et al detected 3.4% annual recurrent events (strokes and/or TIAs) during 2 years of retrospective follow up in 132 patients. A subgroup of 38 patients with an ASA in addition to the PFO showed an increased rate of 9.0% strokes and 22% of TIAs and/or strokes after 2 years.11 De Castro et al reported 7.2% strokes or TIAs at 3 years of prospective follow up in 74 patients. Our 157 symptomatic patients with PFO presented 9.2% recurrent strokes or TIAs and 4.5% strokes at 2 years of retrospective follow up. The average annual rate was 5.5% for strokes and TIAs and 1.8% for strokes only. The rates we found tended to be slightly higher than in the other studies. One reason might be the age of the patients, which exerts an independent effect on the relation between interatrial septal abnormalities and strokes.4 Bogousslavsky et al and Mas et al excluded patients older than 60 years whereas
24% of our patients were older than that. However, there was no association between age and stroke recurrence in our series.

A relevant finding of the present study is that patients with a positive personal history of stroke or TIA before the event leading to the detection of the PFO had a higher rate of recurrent cerebral ischaemia (table 2 and fig 2). Obesity was more frequent in the group with multiple ischaemic events before diagnosis of PFO. However, the higher recurrence rate was unlikely to be associated with body weight. When patients with BMI less than 25 kg/m\(^2\) were analyzed separately, the risk of recurrence remained significantly higher in patients with multiple ischaemic events than in those with one stroke or TIA before diagnosis of PFO. Mas et al and De Castro et al excluded patients with multiple ischaemic events from their studies and Bogousslavsky et al tended to treat such patients surgically.

Several authors have found that atrial septal hypermobility and ASA combined with PFO and also the size of the PFO are independent risk factors for stroke.\(^{12–21}\) Our data do not support this finding. Neither the coexistence of ASA nor the size of the right to left shunt was associated with an increased recurrence rate in our series. A possible explanation of this disagreement could be the relatively small number of only 33 patients with ASA (21%) in our series. Methodological factors might also play a major part in the proper assessment of the size of a right to left atrial shunt, with difficulties comparing the data of different studies. Grading is usually performed size of a right to left atrial shunt, with difficulties comparing the data of different studies. Grading is usually performed

<table>
<thead>
<tr>
<th>Source (1st author)</th>
<th>Number of patients</th>
<th>Stroke</th>
<th>Stroke and/or TIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max(^{12})</td>
<td>132</td>
<td>1.2%</td>
<td>3.4%</td>
</tr>
<tr>
<td>Bogousslavsky(^{20})</td>
<td>140</td>
<td>2.4%</td>
<td>3.8%</td>
</tr>
<tr>
<td>De Castro(^{2})</td>
<td>74</td>
<td>1.8%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Present study</td>
<td>157</td>
<td>1.8%</td>
<td>5.3%</td>
</tr>
</tbody>
</table>

*In the original article the overall cumulative estimate of risk of cerebrovascular event recurrence is given. We derived the average annual event rate from the overall cumulative estimate of risk of stroke or TIA recurrence, at 3 years of follow up, according to the formula 1-(1-P\(^{1/3}\))\(^{1/3}\), where P equals the cumulative event rate at n years of follow up.

To summarise, our study confirms a risk of recurrent strokes and TIs that is similar to the rates of previously published series of patients with PFO and cryptogenic strokes. Patients who had experienced multiple cerebrovascular events before diagnosis of PFO were at increased risk of recurrent cerebral ischaemia.

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