Lacunar versus non-lacunar infarcts: pathogenetic and prognostic differences

G Landi, E Cella, E Boccardi, M Muscico

Abstract
To characterise the pathogenetic and prognostic features of lacunar infarcts, 88 patients with these infarcts were compared with 103 patients with non-lacunar infarcts. Potential cardioembolic sources were significantly more frequent among patients with non-lacunar infarcts (p = 0.0025). Although the prevalence of hypertension was higher among lacunar infarcts, this difference was not statistically significant. However, the distribution of hypertensive patients in the two groups of lacunar and non-lacunar infarcts was influenced by the presence or absence of cardioembolic sources: hypertension was significantly associated with the presence of cardioembolic sources among non-lacunar infarcts, whereas among lacunar infarcts it was significantly more frequent in patients without a cardioembolic source. This indicates that cardioembolism may exert a confounding effect by suppressing the relation between hypertension and lacunar infarcts. In a mean follow up period of 28-1 months, lacunar infarcts had a significantly lower incidence of stroke recurrence and of myocardial infarction (age-adjusted survival analysis: p = 0.0008); mortality from all causes was also lower in patients with lacunar infarct (age-adjusted survival analysis: 0.04 < p < 0.05). In a multivariate regression analysis, stroke subtype was an independent predictor of new major vascular events. These findings support the lacunar hypothesis and should be considered in the planning of epidemiological and therapeutic studies in patients with cerebral infarction.

CM Fisher's pathological studies related lacunar infarcts to small-vessel disease caused by hypertension. Lacunar infarcts were also limited to specific clinical syndromes, raising the possibility of distinguishing a subgroup of cerebral infarctions on the basis of their pathogenesis. As these patients have a low early case-fatality rate and consequently a low necropsy rate, later attempts to verify this lacunar hypothesis employed CT to recognise such cases during life, and compared lacunar infarcts with other groups of ischaemic strokes by analysing the distribution of vascular risk factors and of several clinical and instrumental variables. The results of these studies suggested that cardiac and arterial embolism may also give rise to lacunar infarcts, and since hypertension was absent in a substantial proportion of cases, the lacunar hypothesis has recently been questioned. Although there is general agreement on the favourable short-term prognosis of lacunar infarcts, only a few studies have reported on their long-term outcome, with contradictory conclusions.

As lacunar infarcts represent almost 25% of all ischaemic strokes and an even higher proportion of stroke survivors, further characterisation of their pathogenetic and prognostic features appears of more than academic interest and may contribute to the design of therapeutic studies after acute stroke. We therefore compared a group of patients with lacunar infarct to another group with non-lacunar ischaemic stroke.

Patients and methods
The detailed method of our study has been described. In brief, we included prospectively 191 consecutive patients with first-ever ischaemic stroke visited at the emergency room of the Policlinico Hospital in Milan within 72 hours after the onset of symptoms and hospitalised at the local neurological department. All patients had a neurological and general physical examination on arrival at the emergency room; this was repeated daily during the first week and twice weekly until discharge, enabling us to subdivide them into two groups according to their neurological state at the time of maximum deficit.

Lacunar infarct (LI) (n = 88), was defined as one of the following syndromes: pure motor stroke (unilateral pure motor deficit involving at least two of three areas—face, arm and leg); pure sensory stroke (unilateral pure sensory deficit involving at least two of three areas—face, arm and leg); ataxic hemiparesis (ipsilateral corticospinal and cerebellar-like dysfunction without other features clearly localising to the posterior circulation); dysarthria—clumsy hand syndrome (severe dysarthria with slight weakness and clumsiness of the hand); and hemichorea/hemiballism (voluntary arhythmic unilateral movements involving at least two of three areas—face, arm and leg). At the time of our study the inclusion of sensorimotor strokes among the lacunar syndromes was still debatable, and these patients were therefore not included in this report.

Non-lacunar infarcts (NLI) (n = 103) included all patients whose clinical picture did not conform to the preceding clinical syn-
were recorded, and residual disability in survivors was established at one month and classified as follows: Not disabled—independent in self-care, with return to pre-stroke activities; Partially disabled—requiring help in activities of daily living, able to walk with or without assistance; Severely disabled—bedridden or confined to a wheelchair, requiring constant care.

All patients who survived their first-ever stroke were followed for at least 12 months or until death, and occurrence of new cerebrovascular events was reported. Stroke recurrence was classified as: mild if there was no or only slight persistent deterioration with respect to previous neurological deficit; severe if deterioration was significant; or fatal. Occurrence of myocardial infarction and of death from other causes were also recorded.

### Statistical methods

The strength of association between the considered variables and the type of stroke (LI or NLI) was calculated by means of odds ratio (OR)\(^{14}\) and their statistical significance was evaluated by chi-square. Confidence intervals of OR were calculated as suggested by Cornfield.\(^{15}\) The significance of the difference between means was tested with two-tailed \(t\) tests for unpaired data. Survival analyses on the cumulative time dependent probability of major vascular events (stroke, myocardial infarction) and of death were carried out by the Kaplan-Meier method and the strength of the association of these probabilities with possible prognostic variables was evaluated by hazard ratio (HR).\(^{16}\) Cox's model was employed to carry out multivariate regression analysis.\(^{17}\)

### Table 1

<table>
<thead>
<tr>
<th>Age*</th>
<th>Lacunar infarcts (n = 88)</th>
<th>Non-lacunar infarcts (n = 102)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>63.5 (12.5) - 66.6 (12.4)</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>55 (62.5%) - 63 (61.2%)</td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>57 (64.8%) - 54 (52.4%)</td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>17 (19.3%) - 17 (16.5%)</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td>36 (40.9%) - 46 (44.7%)</td>
<td></td>
</tr>
<tr>
<td>Previous TIA</td>
<td>20 (22.7%) - 16 (15.5%)</td>
<td></td>
</tr>
<tr>
<td>Cholesterol (mg/dl)*</td>
<td>227 (7) - 223 (0) (57.8%)</td>
<td></td>
</tr>
<tr>
<td>Triglycerides (mg/dl)*</td>
<td>153 (2) (96.6) - 135 (9) (60.6)</td>
<td></td>
</tr>
</tbody>
</table>

* Mean (SD)

### Table 2

<table>
<thead>
<tr>
<th>CT scan (congruous infarct)</th>
<th>Lacunar infarcts (n = 88)</th>
<th>Non-lacunar infarcts (n = 103)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>37 (42.0%) - 71 (68.9%)</td>
<td></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>10 (11.4%) - 19 (18.4%)</td>
<td></td>
</tr>
<tr>
<td>Embologenic heart disease</td>
<td>11 (12.5%) - 35 (32.0%)</td>
<td></td>
</tr>
<tr>
<td>Stenosis/occlusion of symptomotic vessel (doppler)</td>
<td>16 (18.2%) - 27* (27.0%)</td>
<td></td>
</tr>
<tr>
<td>Total with ascertained thromboemolic source</td>
<td>27 (30.7%) - 56* (54.4%)</td>
<td></td>
</tr>
</tbody>
</table>

* available in 100 patients
† four patients had concomitance of embologenic heart disease and pathological doppler findings

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**Figure 1** Comparison of the prevalence of risk factors, clinical and instrumental findings in lacunar and non-lacunar infarcts, showing the odds ratios (OR, vertical bars) and the 95% CI (horizontal bars) on a logarithmic scale. An OR > 1.0 indicates higher prevalence among lacunar infarcts (LI), and an OR < 1.0 a higher prevalence among non-lacunar infarcts (NLI).
Results
Out of our 88 patients with LI, 67 presented with a pure motor stroke, eight with ataxic hemiparesis, six with pure sensory stroke, five with dysarthria—clumsy hand syndrome, and two with hemichorea/ hemiballism. Overall, their age- and sex-distribution was rather similar to those of NLI, as shown in table 1, which also reports the prevalence of cerebrovascular risk factors in the two groups. No significant difference was observed either for continuous variables (age: t = 0.45, p = 0.65; cholesterol: t = 0.64, p = 0.52; triglycerides: t = 1.51, p = 0.13) nor for dichotomous variables (figure 1), although the frequency of hypertension was higher among patients with LI (p = 0.11). Of the 57 patients with LI diagnosed as hypertensive, 46 (80-7%) had known hypertension, while pre-stroke blood pressure levels were reported as normal in eight (14-0%) and were unavailable in three (5-3%); for NLI, the corresponding figures were respectively, 43 (79-6%), seven (13-0%), and four (7-4%). A non-sudden onset of symptoms with a gradual, stepwise or stuttering course up to a maximum deficit was observed in 36 LI (40-9%) as opposed to only 18 NLI (17-5%) (p = 0.006; figure 1).

Results of cardiological and instrumental evaluations are reported in table 2. CT scan demonstrated a congruous infarct (that is, appropriate to the side of symptoms) in 42-0% of LI and in 68-9% of NLI (p = 0.0003; figure 1). All 37 patients with LI and a positive CT scan showed evidence of a lacunar lesion. In contrast, of the 71 patients with NLI who had a congruous infarct visualised at CT scan, 64 had evidence of a cortical or large subcortical lesion, and only seven had evidence of a lacune. With the cardiological findings, no important difference was found in the prevalence of ischaemic heart disease, but atrial fibrillation and other embolic heart diseases were significantly more frequent among NLI (p = 0.0025; figure 1). Occlusion or stenosis of the symptomatic arterial district was demonstrated by angiography in 10 of 19 patients with NLI and in 10 of 42 LI. However, since angiography was performed only in a selected group of patients, we assessed the prevalence of vascular lesions by means of a Doppler ultrasound examination, which was available in 98-4% of our population, and whose sensitivity and specificity in diagnosing stenosis > 50% of the carotid and vertebral arteries was higher than 95% when compared with subsequent angiographic results. Although the higher frequency of obstructive lesions of the symptomatic arterial district among NLI compared with LI did not reach statistical significance (p = 0.21), overall 54-4% of NLI had pathological Doppler results, embolic heart disease or both. The prevalence of such potential thromboembolic sources was significantly lower among LI (p = 0.002) (figure 1).

As the prevalence of embolic heart disease was significantly higher among NLI, we examined the relation between this variable and hypertension in our two groups. As shown in table 3, the distribution of hypertensive patients in our two groups of LI and NLI was influenced by the presence or absence of embolic heart disease: among patients without embolic heart disease hypertension was significantly more frequent in LI (0-04 < p < 0-05), whereas no such relation was apparent among patients with embolic heart disease. Accordingly, among hypertensive patients, cardioembolic sources were more frequent in the group with NLI (p = 0.002), whereas no significant difference was observed in non-hypertensive patients.

Short-term prognosis was significantly better for LI than for NLI both in terms of mortality as a direct consequence of stroke,
and in terms of residual disability at one month (table 4). Among survivors, the cumulative one year probability of stroke recurrence was 7.9% for LI and 11.4% for NLI (OR = 0.67; p = 0.6). The timing of these recurrences is shown in figure 2. Overall, in a mean period of 28.1 months, new vascular events occurred in 30.7% of NLI and in 21.6% of LI (table 4). This difference was even more remarkable if end-points were limited only to major vascular events (stroke, myocardial infarction), as their incidence among NLI (27.3%) was more than twice with respect to LI (13.6%). Survival analysis for major vascular events confirmed the strikingly better long-term outcome of LI (HR = 2.7, 95% CI 1.4–5.2; p = 0.004) (figure 3), which became even more evident when adjusting for age (HR = 3.0, 95% CI 1.6–5.6; p = 0.0008).

When only stroke recurrence is considered, HR was 2.2 (95% CI 1.1–6.6; p = 0.027) and age-adjusted HR was 2.4 (95% CI 1.2–4.8; p = 0.01). Results of a multivariate regression analysis including all tested variables demonstrated that the stroke subtype (that is, LI or NLI) represented—together with age, occurrence of previous TIA, and residual disability at one month—an independent prognostic factor for the subsequent occurrence of major vascular events (table 5).

### Discussion
To test the lacunar hypothesis we compared a group of patients with LI to another group with NLI. Unlike several previous studies, we did not try to subdivide the latter strokes according to their pathogenesis into cardioembolic and atherothrombotic, since this distinction is often difficult or even impossible, and despite extensive investigations up to 40% of cerebral infarcts may remain of undetermined cause. We did not exclude patients with vertebrobasilar strokes because LI may also be located in the brainstem, and because there is no firm evidence that posterior circulation infarcts have a different pathogenesis and prognosis than carotid territory infarcts. Several authors have employed rigid criteria for the diagnosis of LI, requiring absence of haemodynamic or embolic sources or even normal angiographic findings; however, these conditions may be difficult to fulfill, particularly on a large-scale basis, since they would require performance of extensive and often unnecessary instrumental investigations.

In our study we relied on clinical examination for the diagnosis of LI, a simple method which can be easily applied in all settings. However, we included only patients with first-ever stroke, since residual signs of a previous insult may prevent correct diagnosis of a lacunar syndrome. Moreover, since our study was hospital-based, we were able to include patients with acute stroke (91% of them were visited within 24 hours of onset) and to diagnose a lacunar syndrome when they had reached their maximum neurological deficit, as determined by repeated examinations, thus avoiding misdiagnosis in patients whose lacunar syndrome may just represent the outcome of a previously more extended clinical deficit.

Adherence to these criteria may explain why none of our patients with a lacunar syndrome had a non-lacunar lesion visualised at CT scan. Conversely, 6.8% of those with NLI had an appropriate lacunar lesion; although in a recent necropsy study 20% of symptomatic lacunes had presented with aphasias in addition to right hemipareses, such lesions may well represent causal findings, since we observed lacunes also in the asymptomatic hemisphere of 11 (10.7%) patients with NLI.

The 12.5% prevalence of potential cardiac sources of embolism among our LI agrees with previous reports; it was significantly lower than among NLI, which again agrees with other series. Indirect support to the conclusion that embolism occurred more often among NLI is provided by the significantly higher frequency of an abrupt onset of stroke in this group, as this feature has been positively associated with cardiogenic brain embolism.

Although lacunar strokes are commonly attributed to hypertensive arteriopathy, the prevalence of hypertension among LI was not significantly higher in our study as in previous studies, even if different diagnostic criteria for hypertension were considered. These studies concluded that hypertension is no more important in the development of LI.
Lacunar infarcts: is the ischaemic strokes should consider the planning of epidemiological and therapeutic studies after cerebral infarction.

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