Diabetes mellitus is an important risk factor for ischemic cerebrovascular disease. Besides increasing the likelihood of a stroke, the presence of diabetes mellitus or hyperglycemia may aggravate the severity of the acute ischemic event. In two series, in-hospital mortality after cerebral infarction was greater among diabetic than among nondiabetic patients. In a retrospective study, Pulsinelli et al reported that cerebral infarction was worse among patients whose glucose values were >6.6 mmol/l. Other studies suggest that "reactive hyperglycemia" is due to the major stress of the vascular event and is a marker for poor prognosis. However, other studies could not find a correlation between serum glucose concentration at admission and either the subsequent course or mortality of cerebral infarction. One study noted that hyperglycemia combined with a normal glycosilated hemoglobin may suggest poor prognosis after stroke. The relations between serum glucose concentrations and either the severity of stroke or its outcome have not been established. We prospectively evaluated the ability of serum glucose concentrations and neurologic deficits at admission to predict the outcome of patients treated with naloxone within 48 hours of the onset of progression of cerebral infarction.

Subjects and Methods

Between May 1984 and November 1985, 65 patients were admitted to a study of naloxone for the treatment of acute or progressing cerebral infarction. Patients were treated within 48 hours of the latest progression of symptoms at either the University of Cincinnati or University of Iowa Hospitals. Patients with cerebral infarction due to cardiogenic embolism, small vessel arteriopathy (lacuna), large artery atherothrombosis, or atheroembolism were treated. Diagnoses were made using the criteria developed for the Harvard Cooperative Stroke Registry. Reasons for exclusion of prospective subjects have been described. Patients and relatives were asked about a history of diabetes mellitus or any past treatment for elevated blood glucose levels. Any management with glucose-containing intravenous fluids was also noted. Serum glucose concentration was among the blood studies obtained upon admission to the hospital. Diabetes mellitus or marked hyperglycemia were not reasons for exclusion from this study. No food or glucose-containing fluids were given during the 24 hours of naloxone treatment. Insulin was administered as clinically indicated to those patients with elevated serum glucose concentrations. All patients received naloxone in a regimen previously described. In the previously reported dose escalation study, 27 patients received doses of naloxone ranging from 2.5 to 200 mg/m² loading dose. An additional 38 patients were treated at Level VI (160 mg/m² loading dose). Other treatment included bed rest, supplemental oxygen, and intravenous saline in a quantity to maintain adequate urinary output. Pretreatment medications were continued.

Neurologic assessments were done at admission and repeated frequently during the 24-hour naloxone infusion; 15 clinical parameters were independently graded. For the purposes of this study, scores of the assessed parameters were combined to give a total score. A stroke was defined as mild when the total
neurologic deficit score was ≤10, as moderate when the score was 11–24, and severe if the total score was ≥25. Neurologic deficits and outcome were assessed at 7–10 days and 3 months after the stroke. Serum glucose concentrations were measured at admission and again at 24 and 48 hours and 7–10 days after the stroke and categorized: ≤5.6, 5.7–7.2, 7.3–9.4, ≥9.5 mmol/l. Computed tomography (CT) was performed before treatment and 7–10 days and 3 months after treatment. The extent of any ischemic lesion seen on CT was localized to anatomic structures and vascular distributions using standard templates.11 Volume of brain infarction on CT was determined using a computer program using digitizing methods, and patients were grouped according to lesion volume on CT (> or <50 cm³).

We compared neurologic deficit at admission, outcome, and CT lesion volume among diabetic and nondiabetic patients and among patients grouped by serum glucose concentration. Results were evaluated for the influence of types of acute ischemia and CT lesion volume. Outcomes among those patients with hemispheric lesions in the distribution of the middle cerebral artery (MCA) or its branches were separately analyzed.

**Results**

Data were collected from 34 men and 31 women who ranged in age from 40 to 84 (mean 64.4, median 64) years. The interval from latest progression of neurologic symptoms to admission ranged from 0 to 41.5 (mean 6.22) hours. Sixty patients were seen within 24 hours of their ictus. On admission, neurologic deficits were mild in 20 patients, moderate in 22, and severe in 23. By 7–10 days, neurologic deficits were mild in 32 patients, moderate in 11, and severe in 19. Three patients died as a result of their cerebrovascular events within 10 days; their admission glucose concentrations were 5.6, 5.9, and 10.8 mmol/l. By 3 months, 14 patients had recovered completely, 38 had recovered partially, and 6 were stable. Four additional patients had died by 3 months, all from nonneurologic causes. In general, the degree of recovery was related to the severity of signs noted on admission. Complete recovery occurred in nine of those 20 patients with mild strokes but in none of those 23 with clinically severe events.

Twenty-one patients were diabetic; eight were using insulin and 10 were taking oral hypoglycemic agents before their vascular events. The outcomes of stroke were similar among diabetic and nondiabetic patients. On admission, serum glucose concentrations for all 65 patients ranged from 4.3 to 34.2 (mean 9.5, median 13.7) mmol/l and among the diabetic patients from 6.2 to 34.2 (mean 15.4, median 13.7) mmol/l (Figure 1). The relation of admission glucose concentration to outcome is shown in Table 1.

Twelve patients had lacunar infarctions; six of the 12 patients were diabetic. The neurologic deficits among these patients were mild in seven and moderate in five. All 12 patients survived; three recovered completely and seven recovered partially. Serum glucose concentrations among the 12 patients were 5.0–22.0 (mean 9.4) mmol/l. Neither admission serum glucose concentration nor history of diabetes influenced outcomes among these patients.

Large vessel thrombotic infarctions were diagnosed in 42 patients and embolic events were diagnosed in 11; 44 of these were in the distribution of the MCA. Twelve of these 44 patients with MCA distribution infarction were diabetic; their glucose concentrations were 10.9–53.9 mmol/l. Neurologic deficits were mild in 4 patients, moderate in 2, and severe in 6. One diabetic patient died of a massive infarction. Serum glucose concentrations among the 32 nondiabetic patients with MCA distribution infarction were 4.3–17.9 mmol/l; neurologic deficits were mild in 4, moderate in 11, and severe in 17. Two nondiabetic patients died. The degree of recovery and neurologic condition among patients with MCA distribution events were not influenced by

**TABLE 1. Correlation of Serum Glucose Concentration at Admission and Volume of Infarction by Computed Tomography With Outcome at 3 Months**

<table>
<thead>
<tr>
<th>Serum glucose concentration</th>
<th>Patients</th>
<th>Outcome at 3 months</th>
<th>Lesion volume (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Diabetic</td>
<td>Complete recovery</td>
</tr>
<tr>
<td>≤5.6</td>
<td>18</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>5.7–7.2</td>
<td>15</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>7.3–9.4</td>
<td>12</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>≥9.5</td>
<td>20</td>
<td>18</td>
<td>3</td>
</tr>
</tbody>
</table>

*1 patient died before second computed tomogram could be obtained.
either admission glucose concentration or history of diabetes mellitus.

CT examinations 7–10 days or 3 months after treatment showed infarctions in 52 patients; 11 had normal studies and one died before a second CT could be obtained. Lesion volume ranged from 0 to 507 cm³ (Figure 2). Mean volumes of nonlacunar infarctions were 36 cm³ in diabetic and 65 cm³ in nondiabetic patients. The mean lesion volume was 105 cm³ among 20 patients with a serum glucose concentration of \( \leq 5.6 \text{ mmol/l} \) and 44.1 cm³ among 20 patients with a serum glucose concentration of \( \geq 9.5 \text{ mmol/l} \). Four of the five largest infarctions as determined by CT were among patients whose serum glucose concentrations were normal at admission. Patients who arrived with the most severe neurologic deficits had, in general, the largest lesions by CT.

**Discussion**

Our experience suggests that neither history of diabetes mellitus nor elevated serum glucose concentration at admission to the hospital is very helpful in predicting the outcome of an acute ischemic cerebrovascular event or the size of infarction by CT. The severity of neurologic deficits on admission and the type of cerebral infarction remain the most important prognostic factors. Most patients with mild strokes or lacunar infarctions do well whether they are hyperglycemic or have a history of diabetes or not. Our results are similar to those reported by other clinical investigators. 6,12

Our study does have limitations. Our primary purpose was to evaluate the possible efficacy of naloxone. Naloxone increases the acute insulin response to glucose, glucose disappearance, and second-phase insulin secretion. 13 However, there is no evidence of a selective benefit of naloxone for ischemic events accompanied by hyperglycemia. Our patients who had severe deficits had poor outcomes despite naloxone therapy, a result not influenced by the presence of hyperglycemia. Results in patients receiving drugs other than naloxone will probably be similar.

Our study has several advantages compared with previous clinical studies relating serum glucose concentration to outcome of acute cerebral infarction. We prospectively collected data in 65 intensively studied patients admitted within hours after the onset of stroke. The sample was representative of the population of acute cerebral infarction. The neurologic and CT examinations were performed at standardized time intervals, and the examinations were analyzed quantitatively.

Hyperglycemia at the onset of cerebral ischemia in animal models may influence the extent of brain injury. 14–17 However, not all animal models have shown this effect. 16,19 Recently, Ginsberg et al 19 reported that hyperglycemia may lessen the extent of one type of experimental brain infarction. Even if hyperglycemia at the onset of cerebral ischemia affects prognosis, using the glucose concentration at admission to predict that at the onset of stroke is a practical impossibility in most patients. The stroke may induce secondary hyperglycemia, and patients may eat or be given glucose-containing intravenous fluids because concern about hypoglycemia causing focal neurologic deficits often prompts administration of glucose to a diabetic patient with an acute stroke.

The prognosis of stroke relates to the site and size of cerebral infarction. The best prognostic factors remain the cause of cerebral ischemia and the severity of neurologic deficits. Concern about the potentially adverse impact of hyperglycemia has already prompted recommendations that serum glucose concentrations of patients with acute stroke be kept in a near-normal range. 3,20 This recommendation is appropriate for most acutely ill patients, regardless of whether they have had a stroke. However, pending more convincing clinical data, we question whether vigorous treatment of hyperglycemia begun hours after the onset of stroke will improve outcome.

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**KEY WORDS** • cerebral infarction • glucose • naloxone
Comparison of admission serum glucose concentration with neurologic outcome in acute cerebral infarction. A study in patients given naloxone.

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Stroke. 1988;19:455-458
doi: 10.1161/01.STR.19.4.455

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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