Differentiation Between Intracerebral Hemorrhage and Ischemic Stroke by Transcranial Color-Coded Duplex-Sonography

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Background and Purpose—The differential diagnosis of intracerebral hemorrhage versus ischemic stroke has critical implications for stroke management. Transcranial color-coded duplex sonography (TCCS) has been shown to identify intracerebral hemorrhages and intracerebral vessel occlusions. We conducted this study to evaluate the sensitivity and specificity of TCCS in this differential diagnosis and in the detection of stroke complications.

Methods—One hundred fifty-one patients (58 women, 93 men; mean age, 65.6 years [range, 32 to 89 years]) with acute hemiparesis were enrolled in this prospective study. On admission all patients had a complete neurological examination. A cranial CT scan and a sonographic examination of the brain parenchyma and all extracranial and intracranial cerebral arteries were conducted. The sonographer was blinded for the radiological findings.

Results—According to CT criteria, 60 patients had an intracerebral hemorrhage and 67 patients had an ischemic stroke, and in 24 patients CT findings were inconclusive, showing neither bleeding nor an ischemic stroke. On sonographic examination, 18 patients (12%) had no sufficient acoustic bone window. Of the remaining 133 patients, 126 (95%) were diagnosed correctly by sonography in agreement with CT. Sonography missed 3 atypical bleedings (2 with upper parietal location). In 4 patients without bleeding, an intracerebral hemorrhage was suspected by TCCS because of increased white matter echo density due to microangiopathy. Stroke complications depicted by CT (disturbance of cerebrospinal fluid circulation, hemorrhagic transformation, midline shift, ventricular bleeding) (n=54) were correctly shown by TCCS in 45 patients (83%). No complication was missed that would have required further treatment.

Conclusions—In comparison to the “gold standard” of CT, TCCS identified stroke complications and differentiated between intracerebral hemorrhage and ischemic stroke with reasonable sensitivity. Thus, if CT is not readily available, TCCS may complement clinical examination in patients with acute stroke. In addition, it may also be useful in detecting stroke complications in the follow-up of stroke patients. (Stroke. 1998;29:2563-2567.)

Key Words: cerebral hemorrhage ■ cerebral ischemia ■ stroke, acute ■ tomography, x-ray computed ■ ultrasonography

Stroke is the most common neurological disorder causing death or disability among adults in industrialized nations. Ischemic events account for ~85% of all strokes, and hemorrhages account for ~15%. The management of the 2 disorders differs substantially, and therefore the differentiation of cerebral infarction and cerebral hemorrhage and the identification of stroke complications is important in acute stroke. A reliable differentiation is not possible on the basis of clinical examination alone. Even sophisticated clinical stroke scoring systems for the differential diagnosis of infarct versus hemorrhage revealed a poor accuracy. At present, one of the most accurate methods of distinguishing cerebral hemorrhage from infarction is CT. Although CT is very sensitive in the detection of intracerebral hemorrhage, it can be inconclusive in early stages of cerebral ischemic infarction. CT currently also serves to identify important stroke complications.

Depending on local conditions, ready access to CT facilities on admission may not be available everywhere. Large population-based studies revealed that approximately one third of the patients with acute stroke had no CT before treatment was started, and this applied even to centers experienced with stroke management.

Transcranial color-coded duplex sonography (TCCS) is a diagnostic tool that allows a 2-dimensional imaging of brain parenchyma and a color-coded imaging of the intracranial vessels. The method is noninvasive and mobile, and bedside examination is feasible. Previous studies have shown that...
TCCS permits the detection of intracerebral hemorrhages and intracerebral vessel occlusions.\textsuperscript{9–11} TCCS is currently being applied only in a few centers, but ultrasound systems suitable for TCCS are widely available even in general hospitals.

The aim of our study was to assess the sensitivity and the specificity of TCCS in the differentiation between intracerebral hemorrhage and ischemic stroke and to examine whether intracerebral complications of cerebrovascular diseases can be detected.

Subjects and Methods

Two tertiary care centers, both with 24-hour access to CT, were involved in this prospective study. Compared with general hospitals, more patients with complicated course of stroke or intracerebral hemorrhages are referred to these institutions. This results in a selection of the stroke patients toward cases in which active therapy was considered on referral.

From June 1996 to June 1997, we investigated 151 patients (93 men, 58 women; mean age, 65.6 years [range, 32 to 89 years]) with acute hemiparesis suggestive of stroke. The time from the first onset of symptoms was recorded. On admission all patients had a complete neurological examination. All patients received a complete sonographic examination of the brain parenchyma and all extracranial and intracranial cerebral arteries and a CT examination (CT 9800, CT-Max, General Electric or Somatom DR, Siemens AG). Although we preferred to perform the sonographic examination before CT examination, this was not possible in 85 patients because of ethical or logistic considerations. In these cases the sonographer was strictly blinded for the CT findings and was not involved in any therapeutic decision. The ultrasound examination was done at least 24 hours after admission.

Sonographic examination was performed with a color-flow ultrasound system (Siemens Sonoline Ellegra, Siemens AG or Acuson 128 XP/4). Technical details of TCCS for the evaluation of brain parenchyma and the intracranial vessels have been described previously.\textsuperscript{12,13} The extracranial cerebral arteries of the anterior and posterior circulation were assessed with a 5-MHz linear array, and the intracranial blood vessels of the anterior and posterior circulation were assessed with a 2.0- to 2.5-MHz phased-array transducer. Extracranial and intracranial arteries were examined bilaterally by color flow imaging, and angle-corrected blood flow velocities were determined with integrated pulsed wave (PW) Doppler. In a second step, the depiction of brain parenchyma was performed transtempo-

Figure 1. TCCS image showing large intracerebral hemorrhage in the left hemisphere. Insonation from the left temporal bone window, 2.5-MHz transducer, B-mode. The intracerebral hemorrhage is depicted as a hyperechoic mass lesion (1); horizontal arrows mark the extension of the lesion; (2) indicates anterior horn of the right lateral ventricle and (3) the third ventricle; and up arrows indicate falx cerebri.

Figure 2. TCCS image showing occlusion of the middle cerebral artery. Insonation of the circle of Willis from the left temporal bone window, 2.5-MHz transducer, color mode. In contrast to the left anterior cerebral artery (1) and left posterior cerebral artery (2), no signal from the left middle cerebral artery could be obtained. Arrows mark the occluded vessel, which is depicted as a hyperechoic line without any evidence of blood flow in the color mode.
A width of 0.9 cm of the third ventricle and lateral ventricles, as previously described. A ventricular enlargement was determined by width measurement of the third ventricle and lateral ventricles, as previously described.15 A width of 0.9 cm of the third ventricle and >2 cm of the frontal horn of the lateral ventricle was considered a ventricular enlargement.

The results of the sonographic examination were compared with the results of the corresponding CT off site by an independent neuroradiologist (E.H.). Sensitivity, specificity, and predictive value of the test were calculated.16

Results

The average time interval between the first onset of symptoms and admission was 7 hours (range, 1 to 24 hours). The CT examinations of the 151 patients (Table 1) showed an intracranial hemorrhage in 60 cases; 67 patients had an ischemic cerebral infarction. In 24 patients, an intracranial hemorrhage was missed (diameter <1 cm). In another patient, TCCS failed to detect a basal ganglia bleeding even though the patient had an adequate acoustic bone window. In this patient CT showed a large basal ganglia bleeding with an extensive midline shift. We suggest that the enormous rise of intracranial pressure resulted in a decrease of echogenicity of the intracerebral hematoma. In patients with sonographically identified hematomas, no pathological color Doppler or PW Doppler findings of the basal cerebral arteries were observed except for slightly elevated ratios of systolic and diastolic velocities in some patients, indicating increased intracranial pressure.

CT could exclude an intracranial hemorrhage in 80 of those 133 patients, whereas ultrasound gave no evidence for an intracranial hemorrhage in 76 patients. In 4 patients with clinical evidence of ischemic stroke and marked microangiopathy on CT scan, TCCS showed a diffuse increase of the echo density of the white matter, which was misinterpreted as an intracerebral bleeding. Color Doppler and PW Doppler recordings of the 76 patients with normal B-mode image of the brain parenchyma showed a vessel stenosis or occlusion in 36 patients (47%) (middle cerebral artery in 20 patients, internal carotid artery in 15 patients, vertebral artery in 1 patient) and a normal flow in the extracranial and intracranial cerebral arteries in 37 patients (49%). In 3 cases (4%) we could obtain an adequate B-mode image but no sufficient Doppler recording of the basal cerebral arteries (Table 2).

In summary, a correct sonographic diagnosis was made in 126 (95%) of the 133 evaluable patients. The sensitivity of ultrasound in the detection of intracranial hemorrhage was 94%, and specificity was 95% (Table 3). The positive predictive value of TCCS was 91%, and the negative predictive value of TCCS was 95%. If we included the patients with insufficient bone window, TCCS would diagnose strokes correctly in 83%. However, with an insufficient bone window neither a false-positive nor a false-negative result can emerge.

CT scans depicted 54 stroke complications, eg, midline shift, ventricular enlargement, hemorrhagic transformation, and ventricular bleeding in the 133 patients who could be examined by ultrasound (Table 4). In comparison, TCCS showed 45 (83%) of these complications. No complication that required further treatment was missed. In particular, small ventricular bleedings restricted to the occipital horns were not identified in 7 patients. A midline shift was not identified by TCCS in 2 cases of the 23 midline shifts recorded by the neuroradiologist. In both cases the midline shift was <0.5 cm. Ventricular enlargement and hemorrhagic transformation were precisely determined by ultrasound.

Discussion

This study shows that TCCS allows a differentiation between intracranial hemorrhage and ischemic stroke in the vast majority of patients. In 95% of our cases, stroke subtypes were identified correctly when 18 patients not suitable for sonography were excluded. These findings confirm data of previous studies.9–11

Although TCCS is remarkably sensitive, it cannot match the sensitivity of CT in the detection of intracerebral hemorrhages. At present CT is unequivocally the method of choice in examining patients with acute stroke. However, a signifi-
cantal number of physicians in Europe have no 24-hour access to CT or MRI, and in approximately one third of stroke patients specific treatment was started without having a definite diagnosis. Therefore, sonographic examination could be considered when CT is not readily available to complement clinical examination provided that technical development of ultrasound (harmonic imaging, tissue harmonic imaging, 2.5 D-array-sector probes) will further improve its reliability and the quality of images so that its diagnostic yield will become generally acceptable. In comparison to CT, ultrasound is noninvasive and more widely available; 2- to 2.5-MHz phased-array transducers needed for transcranial sonography are also used for echocardiography and are part of the standard equipment of modern ultrasound systems.

At present, ≈15% of the patients cannot be examined by TCCS because of narrow temporal acoustic bone windows, and frontal and parasagittal regions of the brain are difficult to assess when the bone window is narrow. For this reason 2 intracerebral hemorrhages were missed in the present study. Another problem is cerebral microangiopathy, which leads to a slight and diffuse increase in echo density of the white matter resembling the sonographic pattern of intracerebral hemorrhage. It is therefore necessary to investigate both hemispheres: If the examiner finds an identical pattern of increased echo density in both hemispheres, microangiopathy is more likely than bleeding. In addition, as Seidel and coworkers have observed, a hemorrhagic transformation of an ischemic stroke may be misinterpreted as a primary intracerebral bleeding. The fact that the sonographic diagnosis of an acute ischemic stroke is exclusively based on the (color-) Doppler-sonographic identification of a vascular occlusion constitutes a further limitation. If an occluded vessel is recanalized in the acute stage of ischemic infarction, brain echo density is not altered, and therefore no sonographic clue points toward a cerebral infarction. While an occlusion of smaller branches of the basal cerebral arteries cannot be detected by TCCS, a comparison of MR angiography and TCCS demonstrated equal sensitivity of both methods in the identification of vascular occlusions of the major basal cerebral arteries.

TCCS provides a real-time display of the affected brain and of intracerebral complications in the course of the disease, such as a disturbance of CSF circulation and space-occupying effects. Ventricular bleeding can also be recognized by means of TCCS. Therefore, the method is suitable for the follow-up of stroke patients.

In conclusion, TCCS is a mobile, noninvasive, and cost-effective method that allows a distinction between intracerebral hemorrhage and ischemic stroke in the majority of patients and provides insights into the dynamic evolution of cerebrovascular diseases and resulting complications. Although the accuracy of TCCS is at present inferior to that of CT, technical improvements in the future will make TCCS more reliable and suitable for the differentiation of stroke subtypes.

### Acknowledgments

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### TABLE 2. Doppler/Color Duplex Findings in 76 Patients Without Sonographic Evidence of Intracerebral Hemorrhage

<table>
<thead>
<tr>
<th>CT Findings</th>
<th>ICA Stenosis</th>
<th>ICA Occlusion</th>
<th>MCA Stenosis</th>
<th>MCA Occlusion</th>
<th>VA/BA Stenosis</th>
<th>VA/BA Normal</th>
<th>VA/BA Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infarction MCA territory</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>11†</td>
<td>3</td>
<td>17</td>
<td>42</td>
</tr>
<tr>
<td>Infarction PCA territory</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>3</td>
</tr>
<tr>
<td>Infarction VA/BA territory</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>1</td>
<td>...</td>
<td>1</td>
</tr>
<tr>
<td>Hemodynamic infarction</td>
<td>1</td>
<td>...</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Lacunar infarction</td>
<td>...</td>
<td>...</td>
<td>1</td>
<td>...</td>
<td>...</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Normal CT</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>...</td>
<td>14</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>12</td>
<td>1</td>
<td>37</td>
<td>73‡</td>
</tr>
</tbody>
</table>

ICA indicates internal carotid artery; MCA, middle cerebral artery; VA/BA, vertebrobasilar circulation; and PCA, posterior cerebral artery.
†Two patients with combined MCA/anterior cerebral artery occlusion.
‡Three patients with sufficient B-mode image but insufficient Doppler recording.

### TABLE 3. Comparison of CT and TCCS in the Differentiation Between Intracerebral Hemorrhage and Ischemic Stroke

<table>
<thead>
<tr>
<th>TCCS Diagnosis</th>
<th>Hemorrhage</th>
<th>No Hemorrhage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT diagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>50</td>
<td>3</td>
</tr>
<tr>
<td>No hemorrhage</td>
<td>4</td>
<td>76</td>
</tr>
</tbody>
</table>

Sensitivity and specificity for TCCS calculated from these data were 94% and 95%, respectively.

### TABLE 4. Visualization of Stroke Complications by CT and TCCS (CT=100%)

<table>
<thead>
<tr>
<th>Complication</th>
<th>CT</th>
<th>TCCS (% of CT Findings)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midline shift</td>
<td>23</td>
<td>21 (91%)</td>
</tr>
<tr>
<td>Ventricular enlargement</td>
<td>6</td>
<td>6 (100%)</td>
</tr>
<tr>
<td>Hemorrhagic transformation</td>
<td>3</td>
<td>3 (100%)</td>
</tr>
<tr>
<td>Ventricular bleeding</td>
<td>22</td>
<td>15 (68%)</td>
</tr>
<tr>
<td>All complications</td>
<td>54</td>
<td>45 (83%)</td>
</tr>
</tbody>
</table>
References


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