Rate of Successful Recording of Blood Flow Signals in the Middle Cerebral Artery Using Transcranial Doppler Sonography

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Background and Purpose: To assess the usefulness of transcranial Doppler sonography, we investigated the rate of blood flow signal recording failure in the middle cerebral artery in Japanese subjects. Furthermore, we studied the effect of increased emitted power on the rate of successful recording in some of the patients in whom recording failure had been detected at the standard transducer power of 100 mW/cm².

Methods: To evaluate the rate of successful recording, we measured blood flow signals in 597 patients (age range, 16 to 89 years) for screening of cerebrovascular disease by using a 2-MHz range-gated, pulsed-wave Doppler instrument at the standard transducer power. In 18 elderly patients with recording failure at the standard power, we assessed the effect of increased emitted power of 400 mW/cm² on flow signal recording.

Results: Blood flow signals were recorded in 920 (77.1%) of the 1194 middle cerebral arteries of the 597 patients studied. The rate of successful recording of bilateral middle cerebral artery flow signals (70.9%; 423 of 597 patients) decreased with age, especially in females (17.0% in women aged 70 years or older). In 12 of 18 elderly patients with recording failure at the standard power, blood flow signals could be detected at the increased emitted power of 400 mW/cm².

Conclusions: The rate of successful recording of blood flow signals in Japanese subjects decreases with advancing age, especially in females. Increasing the emitted power markedly improves the successful recording rate. (Stroke 1993;24:1192-1195)

KEY WORDS • cerebral arteries • Doppler • Japan

Transcranial Doppler sonography (TCD) is a widely accepted noninvasive method of monitoring real-time changes of blood flow signals in several central nervous system disorders.¹ However, a major limitation of TCD is the relatively high frequency of failure to record blood flow signals in elderly female patients. Halsey² reported that the recording failure of TCD increased with advancing age in both white and black women, and was most pronounced in elderly black women. In our previous TCD studies, we have also experienced difficulty in detecting blood flow signals in elderly female subjects,³,⁴ although there are few reports⁵ on the rate of blood flow signal recording failure in Oriental people to the best of our knowledge.

In this study, we assessed the rate of blood flow signal recording failure of the middle cerebral artery (MCA) in male and female Japanese subjects of various ages. Furthermore, we evaluated the effect of increased emitted power on the rate of successful recording in certain patients.

Subjects and Methods

To evaluate the rate of recording failure, we studied 597 consecutive patients who were examined for screening of cerebrovascular disease (CVD) in the First Department of Internal Medicine in Osaka University Medical School between January 1, 1986, and December 31, 1992. They consisted of 451 males and 146 females who ranged in age from 16 to 89 years. For these subjects, 323 patients (248 males and 75 females) had neurological deficits or symptoms or a prior history of cerebral accident, including transient ischemic attacks (CVD patients), and 274 patients (203 males and 71 females) had nonspecific neurological complaints such as headache, lightheadedness, and dizziness (CVD-suspected patients).

The first TCD studies on the rate of recording failure were conducted using a 2-MHz range-gated, pulsed-wave Doppler instrument at the standard transducer power of 100 mW/cm² (TC2-64, Eden Medical Electronics Inc, Uberlingen, FRG). An ultrasonic transducer was placed between the lateral margin of the orbit and the ear above the zygomatic arch. The MCA flow signals were recorded at the depth (45 to 55 mm) showing the highest Doppler velocity.
Successful Recording of Middle Cerebral Artery Flow Signals

<table>
<thead>
<tr>
<th>Age group (y)</th>
<th>&lt;40</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>≥70</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All patients</td>
<td>43</td>
<td>58</td>
<td>155</td>
<td>171</td>
<td>170</td>
<td>597</td>
</tr>
<tr>
<td>Both MCAs</td>
<td>32</td>
<td>52</td>
<td>120</td>
<td>120</td>
<td>99</td>
<td>423</td>
</tr>
<tr>
<td>Right MCA only</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>12</td>
<td>20</td>
<td>39</td>
</tr>
<tr>
<td>Left MCA only</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>14</td>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>Not detected</td>
<td>6</td>
<td>3</td>
<td>27</td>
<td>25</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>Males</td>
<td>25</td>
<td>47</td>
<td>123</td>
<td>133</td>
<td>123</td>
<td>451</td>
</tr>
<tr>
<td>Both MCAs</td>
<td>18</td>
<td>42</td>
<td>101</td>
<td>103</td>
<td>91</td>
<td>355</td>
</tr>
<tr>
<td>Right MCA only</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Left MCA only</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>7</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td>Not detected</td>
<td>3</td>
<td>2</td>
<td>17</td>
<td>14</td>
<td>14</td>
<td>50</td>
</tr>
<tr>
<td>Females</td>
<td>18</td>
<td>11</td>
<td>32</td>
<td>38</td>
<td>47</td>
<td>146</td>
</tr>
<tr>
<td>Both MCAs</td>
<td>14</td>
<td>10</td>
<td>19</td>
<td>17</td>
<td>8</td>
<td>68</td>
</tr>
<tr>
<td>Right MCA only</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>11</td>
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<td>10</td>
<td>11</td>
<td>25</td>
<td>50</td>
</tr>
</tbody>
</table>

MCA, middle cerebral artery.

We then assessed the effect of increased emitted power on the rate of successful recording in some elderly patients in whom recording failure had been observed at the standard transducer power between November 28, 1991, and December 31, 1992. We were able to obtain informed consent to the study of increased emitted power from 18 (7 men, 11 women; age range, 67 to 86 years; mean age, 74.9±7.2 years) of the elderly patients with recording failure.

The second TCD study was conducted using a Medasonic Transpect Doppler instrument (Medasonics, Freemont, Calif) with a hand-held transducer operated in the range-gated, pulsed-wave mode at 2 MHz. The instrument power was adjusted to at least 800 mW/cm² emitted power, corresponding to an in situ intensity of 800 mW/cm² spatial peak temporal average.\(^2\)\(^,\)\(^3\) We used 400 mW/cm² (50% of emitted power) for detection of MCA flow signals in this study. An ultrasonic transducer was placed in the same position as described above and firmly fixed so that we would not dislocate it during the recording with stepwise reduction of the emitted power from 400 to 200 to 80 mW/cm². To ensure safe recording, the product of time and intensity should be less than 50 J/cm².\(^7\) The exposure time at 400 mW/cm² emitted power was limited to less than 120 seconds. Therefore, once emission was started, we made an effort to finish the TCD examination as soon as possible in order not to exceed the time limit.

The \(\chi^2\) test was used for comparison of the successful recording rates of MCA flow signals according to sex and age and of the rates of MCA flow signal detection at each emitted power.

**Results**

Blood flow signals were recorded in 920 (77.1%) of the 1194 MCAs of the 597 patients studied, and the rate of successful recording of bilateral MCA flow signals was 70.9% (423 patients) (Table, Fig 1). The rate of successful recording of bilateral MCA flow signals decreased with advancing age (\(P<.01\)), especially in females. In the 47 female patients aged 70 years or older, this rate was only 17.0% (8 patients). There was no
significant difference in the rate of successful recording between CVD and CVD-suspected patients.

During the examination at 400 mW/cm² emitted power, none of the 18 patients reported any discomfort, such as vibration or feverish feeling, in relation to the increased emitted power. At least one MCA flow signal could be recorded at 400 mW/cm² power in 12 of 18 patients (6 of 7 males and 6 of 11 females). Flow signals were clearly detected in 19 of the 36 MCAs (52.8%). Bilateral MCA flow signals could be recorded in 7 patients (3 males and 4 females), only the right MCA signal in 4 (3 males and 1 female), and only the left MCA signal in 1 female. We also could clearly distinguish at least one MCA flow signal from the background noise at even 200 mW/cm² power in 7 of 18 patients (3 of 7 males and 4 of 11 females). Flow signals were clearly detected in 11 of the 36 MCAs (30.6%). Bilateral MCA flow signals were recorded in 4 patients (2 males and 2 females), only the right MCA flow signal in 2 (1 male and 1 female), and only the left MCA flow signal in 1 female. However, this distinction was not even possible at 80 mW/cm² power (Fig 2). Increase of the emitted power was strongly correlated with decrease of the rate of recording failure of the MCA flow signals (P < .01).

Discussion

Several authors have reported that the detection of the MCA flow signal is more difficult in females than in males and in elderly than in younger patients a2, a3 at the standard transducer power of 100 mW/cm². It has been suggested that the rate of recording failure is related to the thickness of the temporal bone, which absorbs and scatters the applied ultrasound energy. Ackerman et al, a9 using computed tomography, also found that the average parietal bone width in both males and females increases slightly with age, although the average bone mass decreases with age in females, probably because of postmenopausal changes. In our study, the rate of successful blood flow signal recording from bilateral MCA was found to decrease with advancing age, especially in females: the rate in women aged 70 years or older was only 17.0%. Halsey a2 reported that the rates of successful recording of any MCA flow signal were significantly different from others among the 51- to 99-year-old groups (ie, the rates were progressively lower in white men [approximately 80%], white women [approximately 75%], black men [approximately 65%], and black women [approximately 30%]). But in Aaslid's laboratory in Bern, Switzerland, the failure rate of patients in their series was only 5%, a10 suggesting that the failure rate in European subjects would be very low compared with that of other races. To compare with Halsey's study, among Japanese patients aged 50 years or older in this study, any MCA flow signal was successfully recorded in 334 of 379 males (88.1%) and 71 of 117 females (60.7%). Hashimoto et al a5 also reported that, among 280 Japanese (163 men and 117 women) aged older than 60 years, the rate of any MCA flow signal was 84% in men and 36% in women. These findings suggest that, among patients aged 51 to 99 years, the rate of successful recording in Japanese men is almost the same as that in white men, while that in Japanese women is intermediate between those in black men and black women.

Halsey a2, 6 has also reported that temporal bone window thickness is an important determinant of recording difficulty and that increase of the emitted power might significantly improve the rate of successful recording. We evaluated the effect of this increase on the rate of the recording in Japanese subjects by considering the safety requirements in ultrasound. It is widely accepted that no serious detrimental effects have been observed even after a very long exposure time when the average intensity is less than 100 mW/cm². The American Institute of Ultrasound in Medicine issued the following statement with regard to hazards: "Biological effects have not been demonstrated even at higher intensities, when the product of intensity and exposure time was less than 50 J/cm²."

In our study, based on the above statement, the exposure time at 400 mW/cm² emitted power was safely limited to within 120 seconds, and no hazardous side effects have been observed in any subject.

From our results, the use of 400 mW/cm² emitted power increased the rate of successful recording in
subjects with bone changes associated with aging. However, the flow signals of 17 MCAs were not detected even at 400 mW/cm² power, which is four times as great as the standard transducer power. Particularly in elderly women, no MCA flow signals could be detected in 5 of 11 patients. Although increase of the emitted power exceeding 400 mW/cm² might further improve the rate of successful recording, the safe exposure time would be too short to detect and monitor the MCA flow signals accurately. Therefore, to improve the recording rate, we should also consider increasing the sensitivity of the transducer, for instance, by amplifying the backscattered rather than the emitted ultrasound.

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