Transcranial Color-Coded Duplex Sonography of Intracranial Veins and Sinuses in Adults
Reference Data From 130 Volunteers
Erwin Stolz, MD; Manfred Kaps, MD; Andreas Kern, MD; Sait Seymen Babacan, BS; Wolfgang Dorndorf, MD

Background and Purpose—Transcranial color-coded duplex sonography (TCCS) of intracranial veins and sinuses in adults is a new, emerging application of ultrasonographic imaging. This study reports a standardized examination protocol for venous TCCS and provides reference data for clinical application.

Methods—In 130 healthy volunteers (mean age, 45.9 ± 16.9 years; range, 14 to 77 years) the intracranial venous system was examined using frequency-based transtemporal TCCS. Identification rate, blood flow velocity, resistance index, and systolic/diastolic ratio were recorded for each examined venous vessel.

Results—Intracranial veins and sinuses show a low pulsatile forward flow with maximal systolic blood flow velocity up to 20 cm/s. Significant side differences of blood flow velocity in the paired venous structures could not be detected. Venous flow velocities decreased with age, whereas resistance indices and systolic/diastolic ratios increased. Women showed higher flow velocities than men. Mean identification rates for all age groups ranged from 70% to 90% for the deep middle cerebral vein, the basal cerebral vein, and the great cerebral vein of Galen. The straight sinus, the transverse sinus, and the rostral part of the superior sagittal sinus could be detected in 55% to 70% of cases. Detection rates were dependent on age and decreased as age increased.

Conclusions—Venous TCCS can reliably image a significant part of the cerebral venous system. This method can provide information on venous hemodynamics in normal subjects and pathological cases. (Stroke. 1999;30:1070-1075.)

Key Words: ultrasonography, transcranial, color ultrasonography cerebral veins cranial sinuses

Recent advances in transcranial color-coded duplex sonography (TCCS) have enabled the examination of the intracranial venous system in adults. This technique has been used for diagnosis and follow-up of patients with cerebral venous thrombosis and for evaluation of changes in venous hemodynamics in patients with supratentorial stroke and head trauma.

However, the introduction of a new technique requires that a substantial set of reference data are available before a method can be used routinely for diagnostics in a clinical setting. This study was undertaken to provide a standardized examination protocol and to supply data on normal blood flow velocities and identification rates of the venous intracranial system in 130 healthy subjects.

Subjects and Methods

Subjects
One hundred thirty healthy volunteers gave informed consent to take part in this study. Their mean age was 45.9 ± 16.9 years (age range, 14 to 77 years). Sixty-nine subjects were male, 58 female. Thirty-five volunteers were already involved in 1 author’s previous studies. The following age groups were defined: G1, ≤40 years (n = 51; mean, 29.3 ± 6.1 years); G2, 40–60 years (n = 42; mean, 50.1 ± 5.9 years); and G3, >60 years (n = 37; mean, 68.4 ± 5.7 years). In all of the volunteers, the deep cerebral veins (deep middle cerebral veins [dMCVs], basal veins of Rosenthal [BVs], great vein of Galen [GV], and internal cerebral veins [ICV]) and posterior fossa sinuses (straight sinus [SRS], transverse sinus [TS], and superior sagittal sinus [SSS]) were insonated through a transtemporal bone window.

To exclude relevant cerebral artery disease, all participants underwent conventional TCCS of the arteries of the circle of Willis, and those >40 years of age also underwent extracranial color-coded duplex sonography.

Examination Technique
Examinations were performed with phased-array ultrasound systems (Hewlett Packard, Sonos 1000 and 2000) equipped with a 2.0- and 2.5-MHz 90° sector transducer. Participants were examined in the supine position by using the transtemporal acoustic bone window. In this study, we used frequency-based color coding of the flow signals.

The depth of the insonation window was adjusted to 10 cm, and the mesencephalon and the arteries of the circle of Willis were identified. The pulse-repetition frequency then was reduced to the
lowest possible setting, and the color gain was adjusted to the optimal signal-to-noise ratio.

The dMCV was identified at an average depth of 5.3 cm adjacent to the middle cerebral artery (MCA) with a flow directed away from the probe. Although it was not possible in all cases to separate the venous flow signal from that of the MCA in color-mode imaging, the venous Doppler velocity spectrum could be identified in pw mode in most volunteers.

The BV was identified after identification of the P2 segment of the posterior cerebral artery after the probe was tilted upward slightly. In this insonation plane, the BV could be followed to the point of entrance to the GV in most participants. In this examination plane, the BV displays a flow signal directed away from the probe. In 6% of the participants, drainage of the BV into the anterior and middle portions of the SRS as normal variant could be identified by TCCS. In approximately 40% of cases, it was possible to insonate the anterior (striate or prepeduncular) segment of the BV after receiving the dMCV. In this segment, the flow is directed toward the probe.

The depth of the insonation window then was increased so that the contralateral skull became visible. Angling the transducer upward approximately 10° from the mesencephalic plane allowed the third ventricle, easily recognizable as echogenic double reflex, to be identified. The pineal region was depicted in the ventricular insonation plane as a highly echogenic structure rostral to the third ventricle. The GV was identified in the midline posterior to the pineal region with a flow directed away from the transducer. Criteria for identification were the higher flow velocities found in the VG than in the ICVs and the BVs; furthermore, the color signal could be followed from the midline toward the apex of the cerebellar tentorium, visible as an echogenic parenchymal structure. In a considerable number of cases, the transtemporal approach indicated the need for a high degree of angle correction; this could be corrected in part by slight alteration of the insonation plane. Because we found no sound ultrasonic criteria to identify the transition of the VG to the SRS, recordings of flow velocities were taken of the portion located rostral of the pineal region.

The ICVs were situated at the choroid plexus in the roof of the third ventricle and followed a S-shaped course to join the GV in the midline; these could be insonated in a significant number of cases in B mode by using the typical double reflex of the third ventricle as a landmark for orientation. Angle correction for the ICVs was not feasible using the transtemporal approach because of the perpendicular insonation plane. The ultrasound anatomy of the deep cerebral veins is illustrated in Figure 1A and 1B. Figure 1C shows venous magnetic resonance angiography in a similar plane for comparison.

To image the posterior fossa sinuses, the transducer was rotated upward to align the insonation plane with the plane of the SRS. The vertex of the cerebellar tentorium and the internal occipital protuberance served as echogenic parenchymal landmark in B mode. In continuation of the flow direction of the VG, the SRS could be visualized as flowing toward the confluens sinuum. Flow-velocity recordings were taken from the middle portion of the SRS. This was to ensure a safe distance from the VG and the confluens sinuum to prevent contamination of measurements. The inferior sagittal sinus could not be unambiguously identified in our series. Identification rates are therefore not reported.

The transverse sinus (TS) could be imaged after the probe was angled downward from the above-described insonation plane. The contralateral TS displays a flow directed away from the transducer, the ipsilateral toward the transducer.

Positioning of the insonation plane 2 to 3 cm above the internal occipital protuberance visualized the rostral part of the SSS, which displayed a flow direction toward the transducer. Angle correction was not feasible due to the transsectional insonation plane. The ultrasound anatomy is illustrated in Figure 2A and 2B. The insonation plane is illustrated in Figure 2C.

**Statistical Analysis**

For statistical analysis, the software package Turbo Statistik 3.0 was used. For comparisons of flow velocities, pulsatility indices, and systolic/diastolic ratios (sdRs) between groups of different ages and sex, a nonparametric test for unrelated samples (Mann-Whitney U test) was used. For comparison of identification rates, a χ²-test was used. For calculation of mean angle-corrected flow velocities, only measurement with angle corrections ≤60° were used. The resistance index (RI) and the sdR were calculated according to the following formulas: $RI = \frac{V_{syst} - V_{diast}}{V_{syst}}$ and $sdR = V_{max} \cdot V_{min}$, where $V_{syst}$ indicates systolic velocity; $V_{diast}$ diastolic velocity.

**Results**

**Identification Rates**

Identification rates of intracranial veins and dural sinuses are summarized in Table 1. Overall, the identification rate was
higher for the cerebral veins than for the dural sinuses ($P < 0.001$). As age increased, the identification rate fell. This was significant in age groups G1 versus G2 for dMCV ($P < 0.01$) and TS ($P < 0.05$) and in age groups G2 versus G3 for RV ($P < 0.05$), dMCV ($P < 0.01$), and TS ($P < 0.01$). For age groups G1 versus G3, the level of significance was reached for BV ($P < 0.05$), dMCV ($P < 0.001$), SRS ($P < 0.01$), TS ($P < 0.001$), and SSS ($P < 0.01$). Identification rates were higher in men than women ($P < 0.05$). The identification rate was lower for the right (n = 87) than for the left (n = 91) TS, although this finding was not statistically significant.

### Table 1. Identification Rates of the Deep Cerebral Veins and Insonated Posterior Fossa Sinuses

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Identification Rate, %</th>
<th>Subjects*/Total Subjects, n/n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Veins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dMCV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All  77.7 202/260</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤40  95.1 97/102</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41–60 76.2 64/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤60  86.6 161/186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;60  55.4 41/74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All  90.8 236/260</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤40  96.1 98/102</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41–60 89.3 75/84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤60  93.0 173/186</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;60  85.1 63/74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GV</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All  90.8 118/130</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤40  94.1 48/51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41–60 92.6 39/42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤60  93.5 87/93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;60  83.9 31/37</td>
</tr>
</tbody>
</table>

*Subjects/Total Subjects indicates subjects in whom the vein or sinus was identified compared with total subjects in whom identification was attempted.

#### Blood Flow Velocities

Normal values of blood flow velocities (FVs) in the intracranial veins and sinuses are summarized in Table 2. FVs in the dural sinuses were higher than in the cerebral veins ($P < 0.05$). FVs...
TABLE 2. Normal Values of Peak Systolic and End-Diastolic FVs of the Intracranial Veins and Sinuses

<table>
<thead>
<tr>
<th></th>
<th>PSV, cm/s</th>
<th>EDV, cm/s</th>
<th>n</th>
<th>Angle, degrees</th>
<th>Depth, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>dMCV</td>
<td>8.7±2.9</td>
<td>5.8±1.9</td>
<td>202</td>
<td>0</td>
<td>5.2±0.5</td>
</tr>
<tr>
<td></td>
<td>10.4±3.9</td>
<td>7.0±2.4</td>
<td>202</td>
<td>27.7±15.3</td>
<td>5.2±0.5</td>
</tr>
<tr>
<td>BV</td>
<td>12.2±3.8</td>
<td>8.7±2.8</td>
<td>236</td>
<td>0</td>
<td>6.2±0.4</td>
</tr>
<tr>
<td></td>
<td>13.8±4.7</td>
<td>9.9±3.7</td>
<td>236</td>
<td>23.6±10.2</td>
<td>6.2±0.4</td>
</tr>
<tr>
<td>ICV</td>
<td>7.2±1.7</td>
<td>4.9±1.1</td>
<td>60</td>
<td>0</td>
<td>7.4±0.5</td>
</tr>
<tr>
<td>GV</td>
<td>11.9±3.6</td>
<td>7.7±2.8</td>
<td>118</td>
<td>0</td>
<td>8.1±0.4</td>
</tr>
<tr>
<td></td>
<td>17.3±8.4*</td>
<td>12.1±5.6*</td>
<td>56*</td>
<td>43.4±22.2*</td>
<td>8.1±0.4*</td>
</tr>
<tr>
<td>SRS</td>
<td>12.1±4.7</td>
<td>8.6±3.7</td>
<td>94</td>
<td>0</td>
<td>9.3±0.6</td>
</tr>
<tr>
<td></td>
<td>18.9±8.6*</td>
<td>13.6±7.1*</td>
<td>69*</td>
<td>43.9±14.3*</td>
<td>9.3±0.6*</td>
</tr>
<tr>
<td>TS</td>
<td>14.0±5.9</td>
<td>9.7±4.8</td>
<td>178</td>
<td>0</td>
<td>11.5±0.9</td>
</tr>
<tr>
<td></td>
<td>17.9±9.8</td>
<td>12.6±7.3</td>
<td>178</td>
<td>24.9±22.3</td>
<td>11.5±0.9</td>
</tr>
<tr>
<td>SSS</td>
<td>9.8±3.6</td>
<td>6.1±2.5</td>
<td>71</td>
<td>0</td>
<td>10.6±2.0</td>
</tr>
</tbody>
</table>

Values are given as non–angle-corrected and angle-corrected FVs. n indicates the number of insonated venous vessels.
*Only angles ±60° were used to calculate mean systolic and end-diastolic flow velocities.

decreased as age increased. For age group G1 versus G2, this was significant for systolic blood FVs in dMCV (P<0.05) and BV (P<0.05) and was pronounced for diastolic blood FVs in dMCV (P<0.01) and BV (P<0.01). The comparison of blood FVs in the age groups G1 versus G3 reached the level of significance for the dMCV (systolic FV, P<0.05; diastolic FV, P<0.01), the BV (systolic FV, P<0.05; diastolic FV, P<0.01), the TS (diastolic FV, P<0.01), and the SRS (systolic FV, P<0.01, diastolic FV, P<0.01). Women tended to have higher FVs than men (see Table 3). Concerning this finding significance was reached for the dMCV (systolic FV, P<0.05; diastolic FV, P<0.05), the BV (systolic FV, P<0.05; diastolic FV, P<0.05), and the SRS (systolic FV, P<0.01; diastolic FV, P<0.01).

Significant side differences in the paired venous structures could not be detected, although the right TS showed a slightly

higher systemic and diastolic FV (18.8±10.6/13.2±7.6 cm/s) than the left TS (16.2±8.6/11.3±6.6 cm/s). These differences in the TS were not statistically significant. Therefore measurements were used to calculate mean FVs, RIs, and sdRs without regard to the side.

**Pulsatility**

RI and sdR were higher in the dural sinuses than in the cerebral veins (P<0.05). The venous pulsatility increased with age (Table 4). Significance was reached in the following age groups: G1 versus G2 for the GV (RI, P<0.01; sdR, P<0.01) and the SRS (RI, P<0.01; sdR, P<0.01); G2 versus G3 for the BV (RI, P<0.01; sdR, P<0.01) and the TS (RI, P<0.05; sdR, P<0.05); and G1 versus G3 for the dMCV (RI, P<0.01; sdR, P<0.01), the BV (RI, P<0.01; sdR, P<0.01), the GV (RI, P<0.05; sdR, P<0.05), and the SRS (RI, P<0.05; sdR, P<0.05), and the TS (RI, P<0.01; sdR, P<0.01). Side differences in the paired venous vessels were not detected. A difference between men and females could be detected only for the SRS (RI, P<0.05; sdR, P<0.05), and men had a higher RI and sdR.

**Discussion**

Unlike both MR angiography and CT angiography as non-invasive imaging modalities of the intracranial venous system, 9

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transcranial ultrasound has not achieved a significant role in the assessment of intracranial venous pathology until now. Conventional transcranial Doppler sonography (TCD) has been used for diagnosis and follow-up in a few patients with cerebral venous thrombosis. A disadvantage of TCD is the need for arterial landmarks to identify the venous vessels. The SRS can be insonated through the occipital bone with TCD; however, other dural sinuses are not accessible. However, TCCS can image the venous system including the posterior fossa sinuses because the orientation is based mainly on parenchymal landmarks. Identification of arterial leading structures is helpful but not a prerequisite.

Promising advances in this field have been reported by several groups using TCCS. Indirect and direct diagnostic criteria have been reported for diagnosis and follow-up in patients with cerebral venous thrombosis. Currently, changes in venous hemodynamics are evaluated in patients with supratentorial stroke and after head trauma. However, as for any new technique, a sound body of reference values is required before clinical decisions can be based on such a method. This study reports normal values in 130 presumably healthy volunteers.

Normal values of FVs and identification rates for the dMCV and BV have been reported by Valdueza and coworkers using conventional TCD in 60 healthy subjects. In this study, the dMCV was identified in only 22% of subjects; the BV, in 93% of subjects. The low detection rate of the dMCV may be explained by the fact that conventional TCD requires insonation of the SRS, which may complicate the separation of the venous Doppler spectrum from that of the artery. Because of the rostral-cranial course of the BV in relation to the posterior cerebral artery, insonation of the BV is usually easier.

Reference data on 120 subjects (mean age, 60 years) have been reported by Baumgartner and coworkers using frequency- and power-based transtemporal TCCS. In this study, the dMCV was identified in 88% and the BV in 97% of cases in the age range of 20–60 years. This is in line with our findings (86.6% and 93.0%, respectively). Identification rates of the GV were not reported in this study. We were able to insonate the GV in 93.5% of cases in subjects aged 60 years of age using the echogenic structure of the pineal gland for orientation.

In subjects aged 60 years of age, Baumgartner et al reported the identification of the SRS in 60% and of the TS in 42% of cases. Our own results with 78.5% and 77.4% are markedly higher. Using TCCS and a temporal bone window, other investigators reported the successful insonation of the SRS in 73% of 30 healthy subjects. Ries and coworkers were able to identify the TS in only 25% of 14 cases with no Doppler recordings sufficient to be used for diagnosis. These discrepancies may reflect the different examination strategies. Differences in equipment are also likely to play a role, although until to now, no comparative studies have addressed this question. In this context, our finding of slightly higher identification rates for left versus right TS is most likely due to technical reasons, because higher detection rates would be expected for the right TS, considering the anatomic literature. However, the slightly higher FVs found in right versus left TS in this study (although this difference was not significant) are in good accordance with the expected results derived from anatomic considerations. The rostral part of the SSS was reported as frequently visualized in 1 study but identification rates were not recorded. However, angle-corrected FV measurements are not possible because of the transsectional insonation plane. Despite this limitation, identification of the rostral part of the SSS proved useful in the assessment of recanalization processes in patients with cerebral venous thrombosis.

Transcerebral insonation identified the SRS in 81% and the GV in 34% of 120 healthy subjects. The high success rate of detection of the SRS depends on selection of the occipital bone window for investigation, which offers a better insonation angle than the temporal bone window. The lower identification rate of the GV in the study of Baumgartner et al versus our study is likely to be caused by the considerable attenuation of the ultrasound intensity by the occipital bone.

We found a decrease in identification rates for venous vessels as age increased more pronounced for the dural sinuses than for the cerebral veins, in line with findings of other investigators. Similar to our results, Baumgartner et al found higher detection rates in men than in women.

Our study reports blood FVs for the dMCV, BV, GV, SRS, and TS with and without angle correction to facilitate comparison with published TCD data. Angle correction was not performed for the ICV and the SSS, because the unfavorable insonation plane excludes any meaningful results. Our data for the dMCV and BV are in good accordance with previously published venous transtemporal TCCS data. FVs in the dMCV are reported to be higher in TCD studies than in TCCS studies; results for the BV correspond with our data. An explanation for the higher dMCV velocities reported by Valdueza and coworkers with conventional TCD might be that the use of insonation depths of up to 7.2 cm led to erroneous insonation of the BV, whereas the study by Canhão et al is limited by the small sample size (17 subjects) and the relatively young age of the healthy participants (mean age, 36.6 years). The higher FVs found in the GV by transcerebral insonation can be explained to be a result of the unfavorable insonation angles created by use of the temporal bone window. In our study, all measurements with angle corrections were dismissed for calculation of mean angle-corrected FVs in the GV and SRS, because very high correction angles produce considerable errors. In our experience, angle correction for measurements of the GV and SRS is not likely to increase diagnostic accuracy. Becker et al reported FVs in the SRS in 30 healthy subjects (mean age, 49 years). Our flow velocity measurements are in line with those reported in that study. FVs found in the TS in a limited number of insonated vessels in the study of Ries et al correspond to ours, whereas Baumgartner and coworkers found higher FVs both in the SRS and TS by transtemporal TCCS. These discrepancies may be explained by the fact that this group used correction angles for the TS that were considerably higher (mean, 42°) than in our study (mean, 24.9°). The use of transcerebral TCCS allows alignment of the insonation beam with the direction of the SRS; therefore, FVs are higher than those established with transtemporal
insonation. Similar to other investigators we found higher FVs in women than in men and a decrease in FV with increasing age, although the resulting small changes in mean FVs are unlikely to affect the clinical use of normative data.

The calculation of the pulsatility index for venous Doppler spectra does not seem feasible because the mean FV cannot be measured reliably as a result of the poor ability of ultrasound systems to correctly envelope the venous spectrum. However, the RI and sDR seem to be sufficient to describe venous pulsatility. The RI and sDR reported in this study for the BV, SRS, and TS are in line with the results obtained in other studies, although the insonation of the middle part of the SRS resulted in a slightly lower RI. Baumgartner et al reported a lower RI for the dMCV than in this study. However, their mean insonation depth of the vessel (4.4 to 4.6 cm) was lower than the one used in this study (5.2 cm), which might explain this discrepancy. The GV showed the same pulsatility than the middle segment of the SRS. As reported by others, we found that pulsatility in the dural sinuses was higher than in the cerebral veins and increased with age.

In summary, high identification rates are possible with the use of transtemporal insonation of the intracranial venous system in adults. Reference values obtained by different investigators are in good accordance with each other despite smaller differences; this proves the reliability of the method for clinical studies. Previous reports indicate that the use of echo-contrast enhancement can even facilitate venous examinations and increase the diagnostic yield.

References
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