Transtemporal power- and frequency-based color-coded duplex sonography of cerebral veins and sinuses.

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Transtemporal Power- and Frequency-Based Color-Coded Duplex Sonography of Cerebral Veins and Sinuses

Ralf W. Baumgartner, Friedrich Gönner, Marcel Arnold, and René M. Müri

PURPOSE: To determine the ability of transtemporal power- and frequency-based transcranial color-coded duplex sonography to aid in the assessment of cerebral veins and sinuses, as well as to provide reference data for flow direction and velocity. **METHODS:** Using a color duplex device equipped with a 2.0/2.5-MHz sector scan, we insonated 120 healthy volunteers and three patients with cerebral venous thrombosis. **RESULTS:** In subjects 20 to 59 years old, deep middle cerebral veins were identified in 88%, basal veins in 97%, straight sinuses in 60%, and transverse sinuses in 42%. The corresponding values for subjects 60 to 79 years old were 53%, 86%, 23%, and 20%, respectively. Velocities were highest in transverse and straight sinuses, slower in basal veins, and slowest in deep middle cerebral veins. Flow was directed lateromedially in the deep middle cerebral vein, rostrocaudally in the basal vein and straight sinus, and mediolaterally in the transverse sinus. Two patients with straight sinus thromboses showed reversed flow direction in the basal veins, and one patient with superior sagittal sinus thrombosis showed elevated velocities in a deep middle cerebral vein. **CONCLUSION:** Transtemporal power- and frequency-based color-coded duplex sonography enabled imaging and velocity measurements in deep cerebral veins in subjects 20 to 59 years old, but detection of the straight and transverse sinuses was low. In older subjects, only the basal vein was regularly assessed.

Index terms: Brain, ultrasound; Dural sinuses; Ultrasound, technique; Veins, cerebral

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Frequency-based transcranial color-coded duplex sonography (TCCD) has been shown to be a reliable method for noninvasive assessment of the basal cerebral arteries (1–4). Recent advances in ultrasonics have enabled the introduction of power Doppler sonography for transcranial imaging (5). This technique has a better signal-to-noise ratio than frequency-based color Doppler imaging (6), allowing the use of higher gain settings in power-based than in frequency-based color imaging and rendering power Doppler sonography better suited for slow velocity, such as occurs in cerebral veins and sinuses.

Normal and thrombosed cerebral veins and sinuses have been studied by means of conventional transcranial Doppler sonography and frequency-based TCCD in newborns, infants, and adults (7–13). The present study was performed to evaluate the ability of power- and frequency-based TCCD to identify cerebral veins and sinuses by means of the temporal window, and to provide reference data for flow direction and velocity that may prove useful in patients with cerebral venous thrombosis.

Subjects and Methods

Subjects included 120 healthy volunteers (60 women and 60 men; mean age, 60 ± 18 years; range, 20 to 79 years) with no cerebrovascular risk factors and no history of cerebrovascular or cardiopulmonary disease. Forty subjects (20 women, 20 men) were 20 to 39 years old (median, 31 years), 40 (20 women, 20 men) were 40 to 59 years old (median, 49 years), and 40 (20 women, 20 men) were 60 to 79 years old (median, 70 years).

Intracranial cerebral veins and sinuses were imaged on an Acuson (Mountain View, Calif) 128 XP/10 unit equipped with a 2.0/2.5-MHz 900-sector scan. Power- and

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From the Departments of Neurology (R.W.B., M.A., R.M.M.) and Neuroradiology (R.G.), Inselspital, University of Bern (Switzerland).

Address reprint requests to Ralf W. Baumgartner, MD, St Elizabeth's Medical Center, 736 Cambridge St, Boston, MA 02135.

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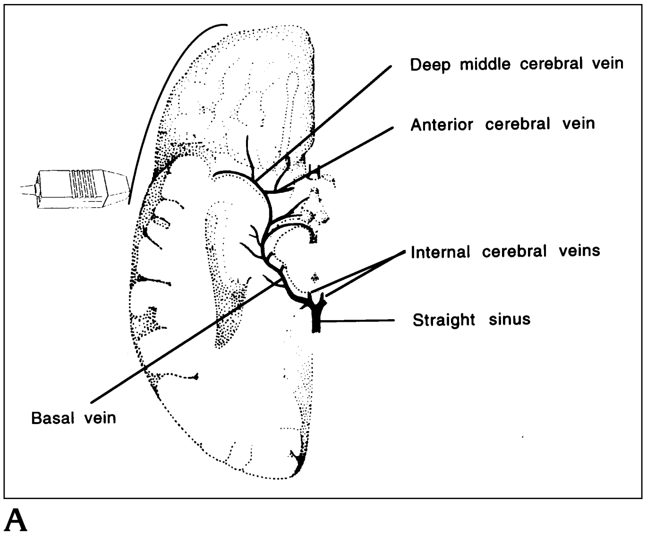
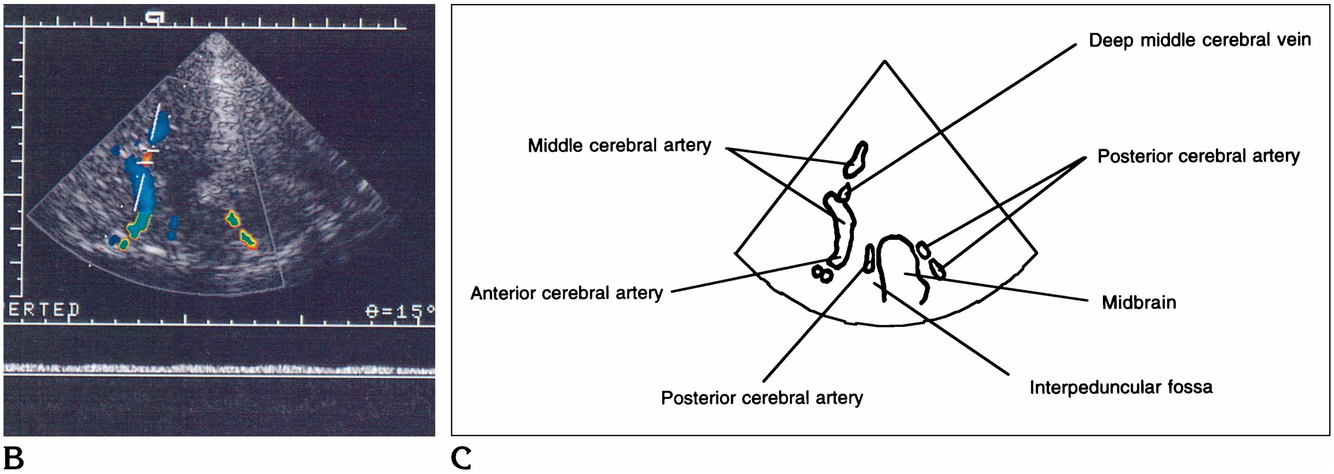
Fig 1. Insonation of the deep middle cerebral vein using transtemporal frequency-based color-coded duplex sonography with an axial scanning plane.

A, Drawing shows the position of the ultrasound transducer with respect to the insonated vein (adapted from Lang [15]).

B, Sonogram delineates the deep middle cerebral vein in *red* located behind the horizontal segment of the middle cerebral artery in *blue*, and its venous Doppler spectra. The anterior and postcommunicating (P2) posterior cerebral arteries are delineated in *green* (aliasing).

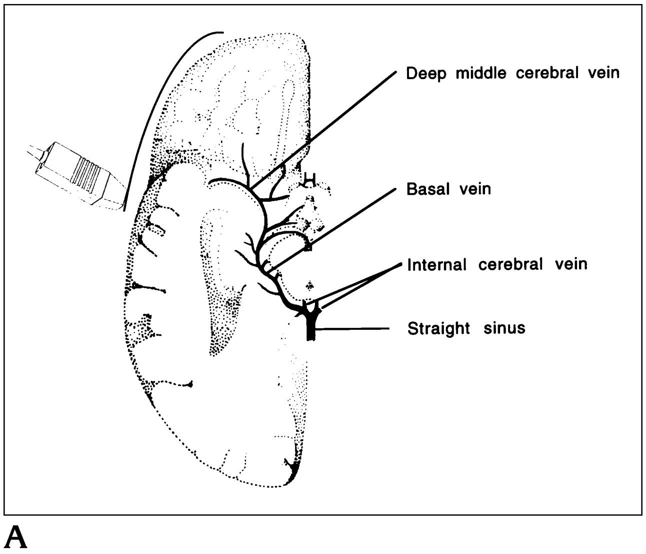
C, Diagram shows corresponding scheme.





frequency-based color Doppler images and pulsed-wave Doppler spectra were obtained using 2.0 MHz; B-mode imaging was performed using 2.5 MHz. Doppler energy was output with a maximal in situ spatial peak time average intensity of 271 mW/cm^2, corresponding to a spatial peak pulse average intensity of 123 W/cm^2.

The subjects were insonated in a supine position through a temporal bone window in the axial plane. The veins and sinuses were identified according to their anatomic location and the direction of flow as described by Huang and Wolf (14), Lang (15), and Ono et al (16); velocity changes were identified during the Valsalva maneuver (7). The deep middle cerebral, basal, internal, and great cerebral veins, and the straight, transverse, inferior, and superior sagittal sinuses were insonated. The deep middle cerebral vein (Fig 1) was identified according to its location above and posterior to the sphenoidal (M1) and/or horizontal part of the insular (M2) segments of the middle cerebral artery, and according to its flow direction opposite the middle cerebral artery (14). The basal vein originates approximately in the lateral third of the surface of the anterior perforated substance by union of the deep middle cerebral vein and the anterior and inferior striate veins (14–16). Since the anterior and inferior striate veins are not identified by TCCD and their modes of confluence are numerous, the point of transition from deep middle cerebral vein to basal vein cannot be reliably detected by sonography. According to anatomic data reported by Lang (15), the anterior perforated substance has a lateral extension of 21 to 30 mm, and its lateral margin is located at an insonation depth of approximately 39 to 45 mm. Consequently, the origin of the basal vein may theoretically reach insonation depths of 49 to 55 mm. To minimize the possibility of confusing the deep middle cerebral vein for the basal vein, the depth used for insonation of the deep middle cerebral vein was always less than 50 mm. The basal vein (Fig 2) was insonated in its second (middle, peduncular) segment, where it runs parallel and somewhat above the posterior cerebral artery (14). Direction of blood flow in this basal vein segment is normally identical to that of the posterior cerebral artery (14). The internal cerebral vein was insonated between the two layers of the tela choroidea of the third ventricle. The great cerebral vein enters the straight sinus at an angle of 90° in 60% of the



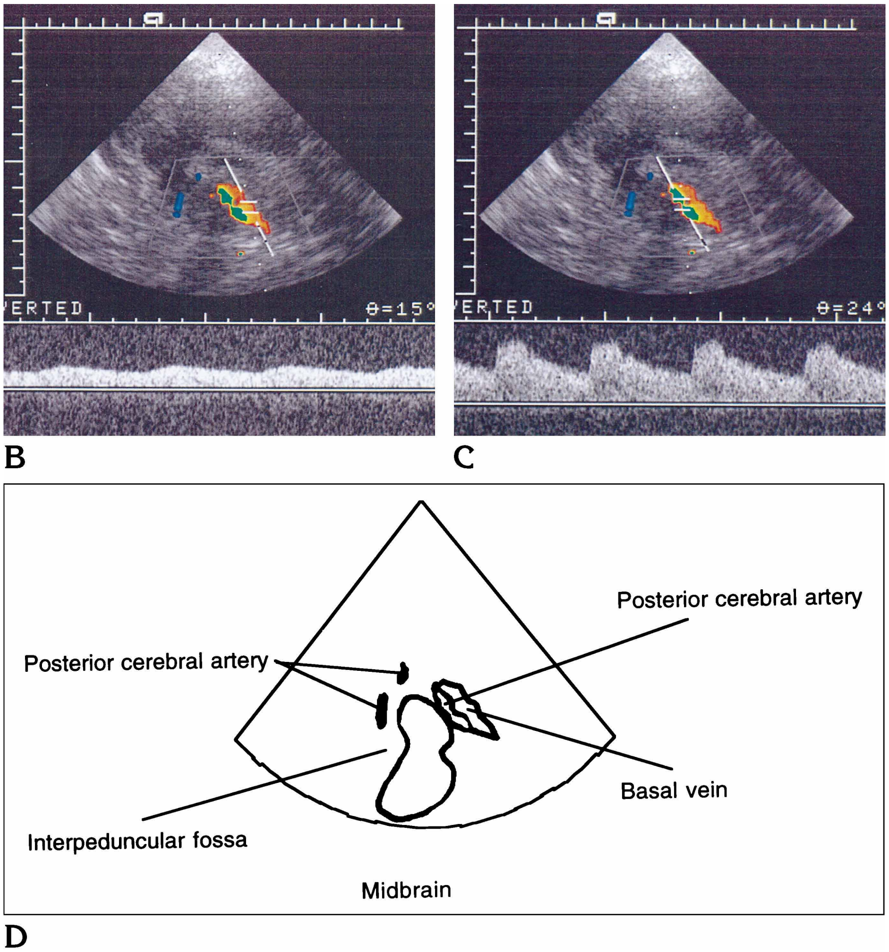


Fig 2. Insonation of the basal vein using transtemporal frequency-based color-coded duplex sonography with an axial scanning plane.

A, Drawing shows the position of the ultrasound transducer with respect to the insonated vein (adapted from Lang [15]).

B, Sonogram delineates the basal vein in *orange* located behind the postcommunicating (P2) segment of the posterior cerebral artery in *green* (aliasing), and the corresponding venous Doppler spectra.

C, Sonogram depicts the Doppler spectra of the postcommunicating (P2) segment of the posterior cerebral artery.

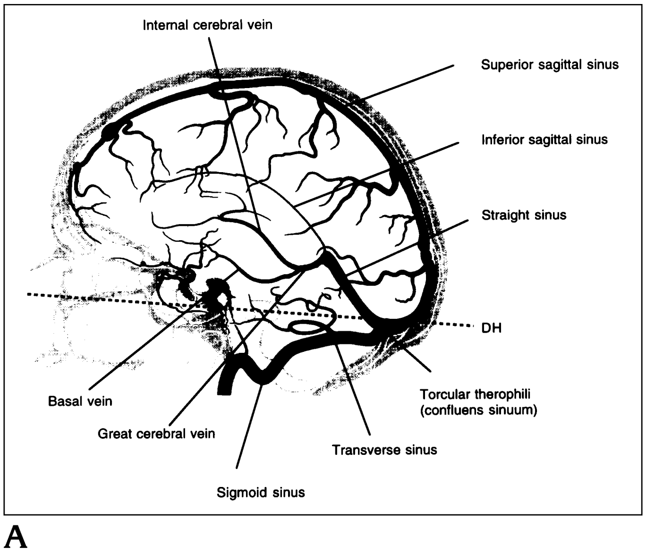
D, Diagram shows corresponding scheme.

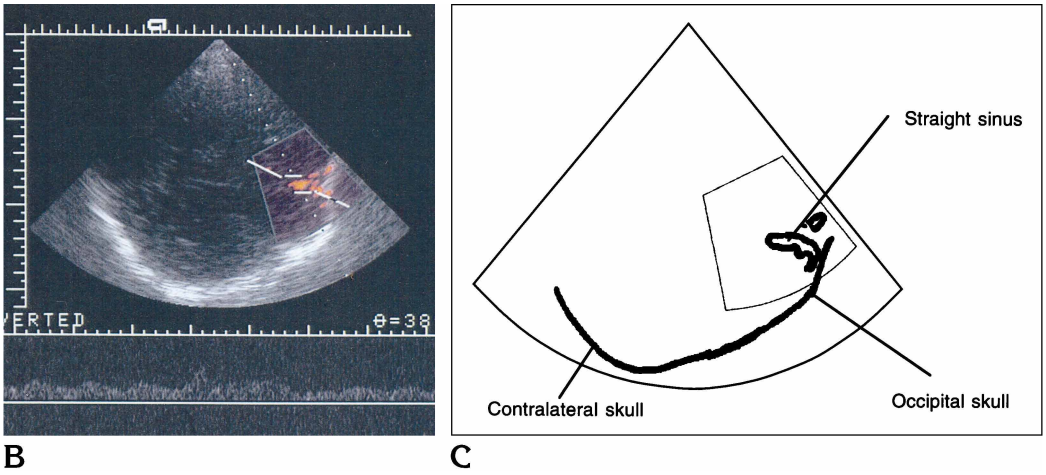
Fig 3. Insonation of the straight sinus using transtemporal power-based color-coded duplex sonography with an oblique axial scanning plane, because the ultrasound transducer is rotated approximately 45° in the sagittal plane.

A, Drawing shows that the straight sinus forms an angle (mean value 52°; range, 4° to 71°) with the “Deutsche horizontale” in the sagittal plane (adapted from Mattle et al [28]).

B, Sonogram delineates the straight sinus in *orange* and its Doppler spectra with a short velocity increase during the Valsalva maneuver followed by a mild and transient decrease of flow velocity.

C, Diagram shows corresponding scheme.





population, at less than 90° in 30%, and greater than 90° in 10% (15). The straight sinus has an oblique course in the sagittal plane with a mean angle of 52° (range, 40° to 71°) with the “Deutsche horizontale,” reflecting a line that joins the deepest part of the orbit with the upper edge of the external acoustic meatus (15) (Fig 3A). Therefore, the transducer was rotated in the sagittal plane to obtain parallel insonation of the great cerebral vein and the straight sinus (Fig 3). We attempted to insonate the straight sinus in the middle of its course to distinguish it from the great cerebral vein and the inferior sagittal sinus proximally, and to distinguish it from the torcular Herophili (confluens sinuum), transverse sinus, and superior sagittal sinus distally. Care was taken to detect venous signals without superposition of Doppler spectra resulting from neighboring branches of the posterior cerebral artery. The transverse sinus (Fig 4) was insonated where it lies in the attached margin of the cerebellar tentorium and courses horizontally along the groove of the squamous portion of the occipital bone. To avoid confusion with the straight sinus, torcular Herophili, and superior sagittal sinus, the Doppler sample volume was placed in the lateral part of the horizontal section of the contralateral transverse sinus, just before it curves anteriorly and downward. The inferior sagittal sinus was searched in its middle and distal thirds, and the superior sagittal sinus in its distal part before it enters the torcular Herophili.

The number of identified veins and sinuses was recorded. Identification was established when the vessel was visualized by means of power- and/or frequency-based TCCD and when spectral analysis delineated Doppler signals, providing reliable determination of velocities. Velocities slower than 4 cm/s were not measured and the vessel was recorded as not detected in order to avoid confusion between slow velocity and background noise. Peak systolic velocities (PSV) and end diastolic velocities (PDV), as well as the corresponding insonation angles and depths, were determined. The angle of insonation was maximally 60°. It is assumed that greater insonation angles result in the measurement of unreliable velocities. Therefore, vessels requiring insonation angles greater than 60° were recorded as not detected. The resistance index for each

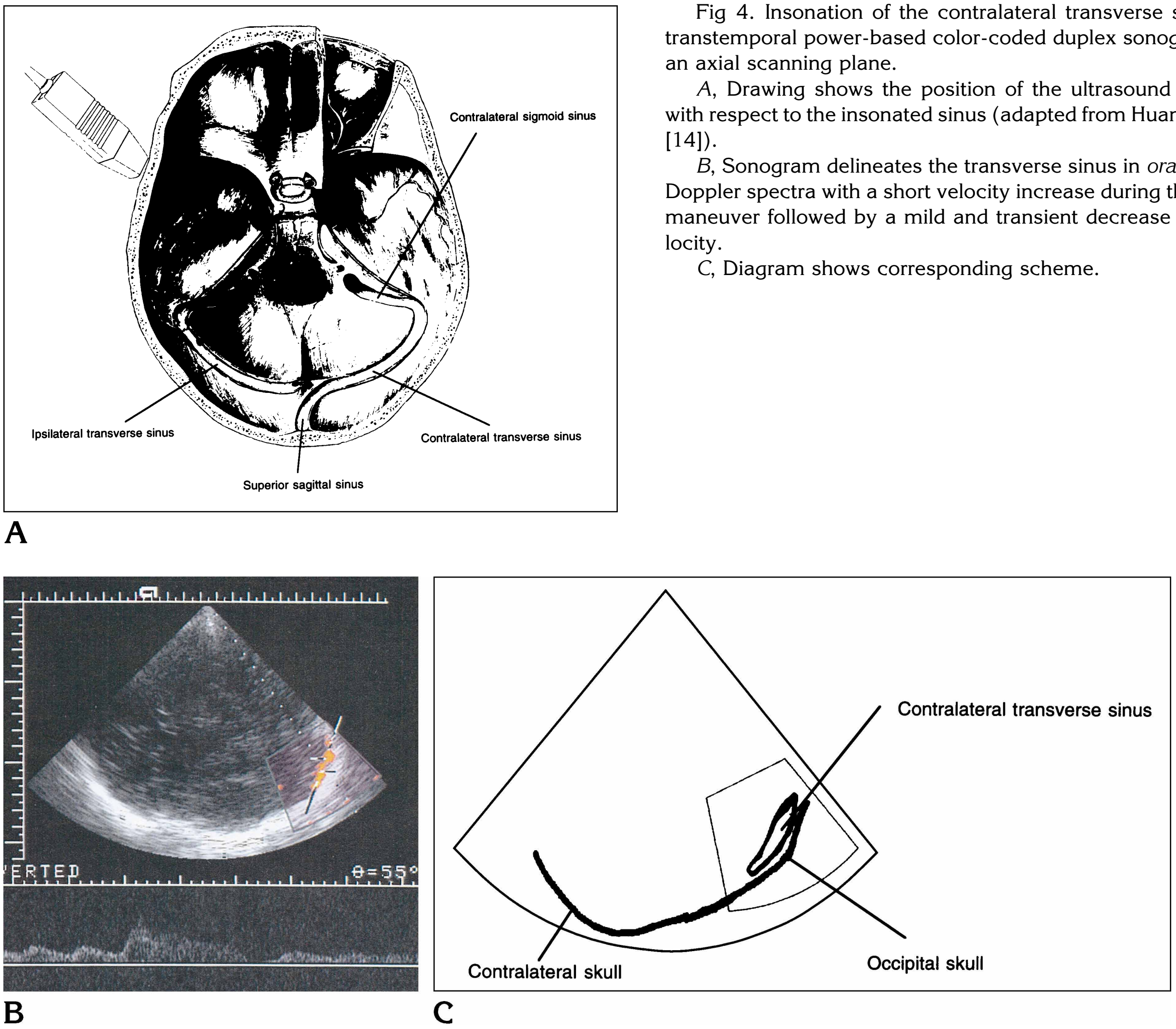


Fig 4. Insonation of the contralateral transverse sinus using transtemporal power-based color-coded duplex sonography with an axial scanning plane.

A, Drawing shows the position of the ultrasound transducer with respect to the insonated sinus (adapted from Huang and Wolf [14]).

B, Sonogram delineates the transverse sinus in *orange* and its Doppler spectra with a short velocity increase during the Valsalva maneuver followed by a mild and transient decrease of flow velocity.

C, Diagram shows corresponding scheme.

cerebral vein and sinus was calculated as PSV − PDV/PSV (17).

Statistical analysis was carried out with the Systat (Evanston, Ill) software package. The number of identified vessels, velocities, resistance indexes, angles, and depths of insonation were compared among the different age groups and between the sexes by nonparametric analysis of variance (Mann-Whitney *U* test). Two-sided *P* values of less than .05 were considered significant.

Results

Results of sonographic detection of the most frequently identified cerebral veins and sinuses are given in Table 1. Cerebral veins were identified more frequently than sinuses in all age groups and both sexes ($P < .001$). All visible straight sinuses were depicted as a short line (Fig 3B) or an oval structure. Both transverse sinuses were identified in 21 subjects (26%) aged 20 to 59 years and in four subjects (10%) aged 60 to 79 years. The internal cerebral vein was visualized in 18 cases (8%). Since the insonation angles were greater than 60°, all internal cerebral veins were defined as not detected. All great cerebral veins and inferior and superior sagittal sinuses were missed.

The number of identified vessels decreased with age. It diminished from the 20-to-39-year age group to both the 40-to-59-year age group (transverse sinus, $P < .01$; straight sinus and basal vein, $P < .05$) and the 60-to-79-year age group (deep middle cerebral vein, straight sinus, and transverse sinus, $P < .001$; basal vein, $P < .01$). The number of identified vessels decreased also from the 40-to-59- to the 60-to-79-year age group (basal vein, $P < .001$; transverse sinus, $P < .05$).

In the 60-to-79-year age group, there was a

TABLE 1: Sonographic detection of the most frequently identified cerebral veins and sinuses according to sex and age

	Age, y	No. of Examined Vessels	No. (%) of Identified Vessels		
			Women	Men	Both Sexes
Deep middle cerebral vein	20–39	80	36 (90)	38 (95)	74 (93)
	40–59	80	35 (88)	31 (78)	66 (83)
	60–79	80	14 (35)†	28 (70)†	42 (53)
	20–59	160	71 (89)	69 (86)	140 (88)
Basal vein	20–39	80	40 (100)	40 (100)	80 (100)
	40–59	80	39 (98)	36 (90)	75 (94)
	60–79	80	31 (78)	38 (95)	69 (86)
	20–59	160	79 (99)	76 (95)	155 (97)
Straight sinus	20–39	40	14 (70)	15 (75)	29 (73)
	40–59	40	12 (60)	7 (35)	19 (48)
	60–79	40	2 (10)*	7 (35)*	9 (23)
	20–59	80	26 (65)	22 (55)	48 (60)
Transverse sinus	20–39	80	23 (58)	20 (50)	43 (54)
	40–59	80	12 (30)	12 (30)	24 (30)
	60–79	80	7 (18)	9 (23)	16 (20)
	20–59	160	35 (44)	32 (40)	67 (42)

Note.—One hundred twenty healthy subjects were examined.

*/† $P < .05$/$P < .01$ that veins were more frequently identified in men than in women (Mann-Whitney *U* test).

tendency for vessels to be identified more frequently in men than in women. This trend was significant for the deep middle cerebral vein ($P < .01$) and the straight sinus ($P < .05$).

Direction of blood flow was identical in all examined veins and sinuses. In the deep middle cerebral vein, flow was directed laterally to medially; in the basal vein and straight sinus, blood flowed rostrally to caudally; and in the transverse sinus, it flowed medially to laterally.

Velocity data concerning the most frequently identified veins and sinuses according to sex and age are given in Table 2. Velocities were fastest in the transverse sinus and straight sinus, slower in the basal vein, and slowest in the deep middle cerebral vein. Women tended to have faster velocities than men in the 20-to-39- and 40-to-59-year age groups. This trend was significant for the basal vein in the 40-to-59-year age group ($P < .01$).

With age, especially PDV values showed a tendency to decrease. This trend was significant when comparing the 20-to-39-year age group with both the 40-to-59-year age group (basal vein, $P < .05$) and the 60-to-79-year age group (deep middle cerebral vein, PSV $P < .05$, PDV $P < .001$; transverse sinus, PSV $P < .05$, PDV $P < .01$; basal vein, PDV $P < .01$; straight sinus, PDV $P < .05$). A comparison between the 40-to-59- and the 60-to-79-year age groups showed a significant velocity decrease (transverse sinus, PSV $P < .05$, PDV $P < .01$; deep middle cerebral vein and straight sinus, PDV $P < .05$).

The resistance indexes are shown in Table 3. They were higher for cerebral sinuses than for veins ($P < .001$), did not differ between the sexes, and increased with age. The resistance indexes were lower in the 20-to-39- than in the 60-to-79-year age group (deep middle cerebral vein, basal vein, and transverse sinus, $P < .001$; straight sinus, $P < .05$). The resistance indexes were also lower in the 40-to-59- than in the 60-to-79-year age group (basal vein, $P < .001$; deep middle cerebral vein and transverse sinus, $P < .05$).

The depth of insonation for each vessel is given in Table 4. The depths of insonation did not vary with age, but there was a trend toward greater depth in men than in women. The trend was significant for the basal vein ($P < .001$) and for the deep middle cerebral vein and transverse sinus ($P < .05$). The insonation angles were higher in the transverse sinus (42°, 15° to 60°) and straight sinus (30°, 4° to 57°) than in the basal vein (9°, 0° to 30°) and deep middle cerebral vein (5°, 0° to 25°) (mean, with 95% confidence intervals). The angles of insonation did not differ significantly with age or between women and men.

To exemplify the potential utility of TCCD in clinical practice, Table 5 presents the findings in three patients with cerebral venous thrombosis. Two-dimensional time-of-flight MR angiography (relaxation time, 27 milliseconds; echo time, 9 milliseconds; flip angle, 50°) was used as the standard of reference. TCCD and MR angiographic studies were performed during the acute stage of disease as well as after a follow-up period of 221 to 434 days. The time from TCCD to MR angiography was 0 to 1 day. The initial TCCD and MR angiographic findings are given in Table 5. Both patients with straight sinus thrombosis had reversed flow direction in the basal veins (Fig 5), whereas the one patient with thrombosis of the superior sagittal sinus had elevated velocities in a deep middle cerebral vein. The presence of elevated velocities was recognized when the velocities were more than 2 standard deviations above the mean value in age- and sex-matched healthy volunteers (see Table 2). TCCD missed a nonthrombosed trans-

TABLE 2: Mean peak velocities in cerebral veins and sinuses according to sex and age

	Age, y	Systolic (95% CI), cm/s			Diastolic (95% CI), cm/s		
		Women	Men	Both Sexes	Women	Men	Both Sexes
Deep middle cerebral vein	20–39	10 (6–14)	9 (6–13)	10 (6–14)	8 (4–11)	7 (4–10)	7 (4–10)
	40–59	10 (3–18)	9 (5–12)	10 (4–16)	7 (2–13)	7 (4–9)	7 (3–12)
	60–79	9 (3–14)	10 (2–17)	9 (3–15)	6 (3–9)	7 (3–11)	6 (3–10)
	20–79	10 (4–16)	10 (5–14)	10 (4–15)	7 (3–12)	7 (4–10)	7 (3–11)
Basal vein	20–39	14 (7–20)	13 (6–20)	14 (7–21)	10 (6–15)	10 (5–15)	10 (5–15)
	40–59	13 (9–17)*	12 (7–17)*	13 (7–18)	10 (6–13)*	9 (4–14)*	9 (5–14)
	60–79	13 (8–18)	13 (6–19)	13 (7–19)	9 (5–13)	9 (5–13)	9 (5–13)
	20–79	14 (8–19)	13 (6–19)	13 (7–19)	10 (6–14)	9 (4–14)	9 (5–14)
Straight sinus	20–39	27 (15–39)	26 (12–39)	26 (14–39)	19 (9–28)	18 (7–28)	18 (8–28)
	40–59	26 (9–43)	26 (16–37)	26 (11–41)	18 (6–29)	18 (11–25)	18 (8–28)
	60–79	19 (16–22)	24 (11–36)	23 (11–34)	17 (7–27)	15 (6–23)	14 (5–22)
	20–79	26 (12–40)	25 (13–38)	26 (12–39)	11 (11–11)	17 (8–27)	17 (7–27)
Transverse sinus	20–39	36 (9–63)	33 (12–54)	35 (10–59)	25 (6–44)	23 (9–36)	24 (7–41)
	40–59	35 (9–62)	31 (17–44)	33 (12–54)	23 (7–40)	20 (12–27)	22 (8–35)
	60–79	26 (6–46)	24 (5–43)	25 (6–46)	15 (2–29)	15 (4–26)	15 (3–27)
	20–79	34 (8–60)	30 (11–49)	32 (9–56)	23 (9–38)*	20 (7–33)*	21 (5–38)

Note.—One hundred twenty healthy subjects were examined. CI indicates confidence interval.

* $P < .01$ that flow velocities were higher in women than in men (Mann-Whitney *U* test).

TABLE 3: Resistance indexes in cerebral veins and sinuses according to age

	Age, y	Mean Resistance Index (95% CI)*
Deep middle cerebral vein	20–39	0.25 (0.13–0.38)
	40–59	0.28 (0.12–0.44)
	60–79	0.32 (0.14–0.50)
	20–79	0.28 (0.12–0.44)
Basal vein	20–39	0.26 (0.13–0.39)
	40–59	0.25 (0.12–0.39)
	60–79	0.31 (0.14–0.49)
	20–79	0.27 (0.12–0.43)
Straight sinus	20–39	0.30 (0.18–0.43)
	40–59	0.34 (0.21–0.47)
	60–79	0.40 (0.27–0.53)
	20–79	0.33 (0.19–0.48)
Transverse sinus	20–39	0.31 (0.20–0.42)
	40–59	0.32 (0.21–0.43)
	60–79	0.39 (0.23–0.56)
	20–79	0.32 (0.19–0.45)

Note.—One hundred twenty healthy subjects were examined. CI indicates confidence interval.

* Peak systolic velocity − peak end diastolic velocity/peak systolic velocity.

TABLE 4: Mean depths used for insonation of cerebral veins and sinuses according to sex and age

	Age, y	Insonation Depth (95% CI), mm		
		Women	Men	Difference†
Deep middle cerebral vein	20–39	44 (36–49)*	46 (38–49)*	NS
	40–59	44 (36–49)*	46 (39–49)*	NS
	60–79	44 (35–49)*	46 (39–49)*	NS
	20–79	44 (36–49)*	46 (39–49)*	$P < .05$
Basal vein	20–39	61 (52–70)	65 (53–77)	$P < .01$
	40–59	65 (54–77)	67 (55–78)	NS
	60–79	64 (53–76)	70 (59–82)	$P < .01$
	20–79	64 (52–75)	67 (55–79)	$P < .001$
Straight sinus	20–39	93 (82–104)	93 (82–104)	NS
	40–59	92 (78–106)	93 (66–120)	NS
	60–79	86 (86–86)	96 (83–108)	NS
	20–79	92 (80–105)	94 (79–109)	NS
Transverse sinus	20–39	108 (91–126)	113 (96–131)	NS
	40–59	112 (99–124)	116 (95–136)	NS
	60–79	107 (93–120)	112 (91–134)	NS
	20–79	109 (93–124)	114 (95–133)	$P < .05$

Note.—One hundred twenty healthy subjects were examined. CI indicates confidence interval; NS, not significant.

* By definition, the maximal depth used for insonation of the deep middle cerebral vein was 49 mm.

† Intersexual difference was calculated using the Mann-Whitney *U* test.

verse sinus, but there was no false-positive thrombosed sinus.

Follow-up MR angiographic studies showed recanalization of all thromboses. TCCD studies revealed normal flow direction, velocities, and resistance indexes in the deep middle cerebral vein, basal vein, straight sinus, and transverse sinus, but missed two nonthrombosed transverse sinuses.

Discussion

Recently, Valdueza et al (11), using conventional transcranial Doppler sonography through

TABLE 5: Sonographic and MR angiographic findings in three patients with cerebral venous thrombosis*

Thrombosis at MR Angiography	Velocity, cm/s	Superior Sagittal Sinus	Superior Sagittal and Straight and Left Transverse Sinuses and Great Cerebral Veins	Straight, Right Transverse, and Sigmoid Sinuses
Deep middle cerebral vein	L PSV/PDV	18/11	8 /6	8 /6
	RI	0.39	0.25	0.25
	R PSV/PDV	22 /15	15 /11	11 /7
	RI	0.32	0.27	0.36
Basal vein	L PSV/PDV	10 /8	−22 /−17	−8 /−6
	RI	0.20	0.23	0.25
	R PSV/PDV	12 /8	−12 /−10	−13 /−8
	RI	0.33	0.17	0.38
Straight sinus	PSV/PDV	27 /20	. . .	. . .
	RI	0.26	. . .	. . .
Transverse sinus	L PSV/PDV	. . .	. . .	31 /18
	RI	. . .	. . .	0.42
	R PSV/PDV	23 /16	. . .	. . .
	RI	0.30	. . .	. . .

Note.—PDV indicates peak end diastolic velocity; PSV, peak systolic velocity; RI, resistance index (peak systolic velocity − peak end diastolic velocity/peak systolic velocity).

* One man, two women, 28 to 67 years old; MR angiography was two-dimensional time-of-flight; no Doppler signals were detected.

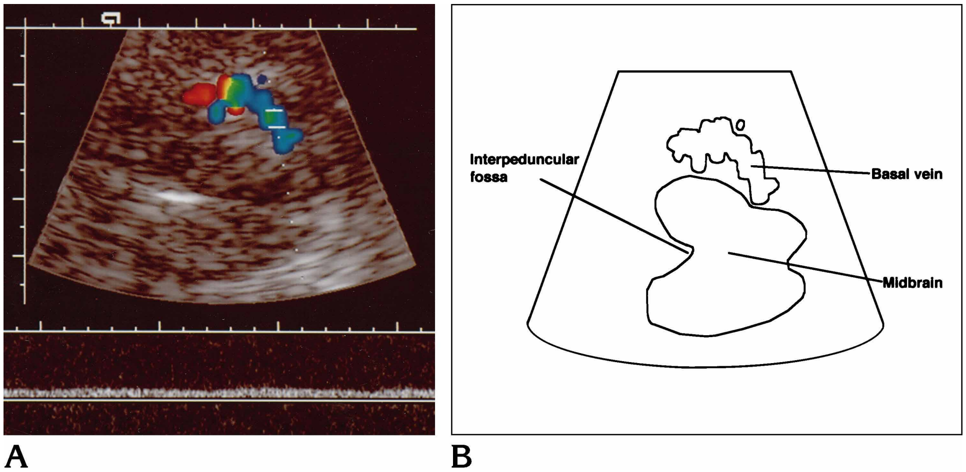


Fig 5. Insonation of the basal vein using transtemporal frequency-based color-coded duplex sonography with an axial scanning plane.

A, Sonogram shows the basal vein in *blue*, indicating reversed flow direction, as confirmed by the corresponding venous Doppler spectra.

B, Diagram shows corresponding scheme.

the temporal bone, reported successful insonation of the deep middle cerebral vein in 22% of 60 healthy volunteers (mean age, 42 years) and of the basal vein in 93%. Using the same sonographic window and frequency-based TCCD, other investigators (8) detected the straight sinus in 73% of 30 healthy subjects (average age, 49 years). Power-based color Doppler sonography is a new method that has a better signal-to-noise ratio than frequency-based color Doppler imaging (6). The latter property allows gain increases in power-based color Doppler sonography over the level at which noise begins to obscure frequency-based color Doppler images. Therefore, power-based TCCD should be the most accurate technique for sonographic assessment of the slow velocities occurring in cerebral veins and sinuses.

In the present power- and frequency-based TCCD study, the deep middle cerebral vein was detected in 88% and the basal vein in 97% of subjects aged 20 to 59 years. In contrast, the straight sinus was identified in 60% and the transverse sinus in 42% of subjects in the same age group. The difference in detection probably resulted from the greater depths used for insonation of the transverse sinus and straight sinus than that used for the deep middle cerebral vein and basal vein, owing to the increased travel path and thus the attenuation of the ultrasound beam. The smaller diameter of the deep middle cerebral vein may explain its lower detection rate compared with the basal vein (14, 15). The internal veins and the inferior and superior sagittal sinuses were not visible. One explanation for this failure is that these vessels are located in the middle of the brain, with large insonation depths and unfavorable (>60°) insonation angles. Unfavorable angles of insonation prevented the measurement of reliable velocities in 18 visible internal cerebral veins that were recorded as not detected. Moreover, it is likely that some inferior and superior sagittal sinuses were not located within the field of insonation. In adults aged 60 to 79 years, the deep middle cerebral vein was identified in 53%, the basal vein in 86%, the straight sinus in 23%, and the transverse sinus in 20%; and the detection rate was especially low in older women. The decrease of vessel detection with age is well known from transtemporal insonation of the cerebral arteries at the skull base. Using contrast-enhanced, frequency-based transtemporal TCCD, Bogdahn et al (18) were able to delineate the straight sinus, inferior sagittal sinuses, internal, and great cerebral veins in 70% of patients with a mean age of 51 years. Using the same sonographic technique and MR imaging and venography as the standard of reference, Ries et al (19) correctly identified 20 of 22 transverse sinuses in 11 patients with sinovenous thrombosis and an average age of 53 years. Therefore, the use of transpulmonary sonographic contrast agents like microspheres of human albumin (20), galactose microparticles (18, 21–24), and the spherosome BY963 (25) may increase the frequency with which TCCD detects cerebral sinuses and veins.

Blood flow was directed lateromedially in all deep middle cerebral veins, rostrocaudally in all basal veins and straight sinuses, and mediolaterally in all transverse sinuses (Figs 1–4). This finding is in accord with the results of previous angiographic and conventional transcranial Doppler studies (11, 14). In our two patients with unilateral transverse sinus and straight sinus thromboses, TCCD showed reversed flow direction in the basal veins (Fig 5). Follow-up sonographic investigations delineated normal anterograde flow direction in the basal veins, whereas MR angiography disclosed complete recanalization of the cerebral veins and sinuses. These observations indicate that in case of obstruction of the normal outflow of the deep sinovenous system, the basal vein may drain into the venous system of the brain stem. Furthermore, the subsequent presence of normal flow direction in the basal vein may predict the recanalization of such thromboses. Velocities were highest in the transverse sinus and straight sinus, slower in the basal vein, and slowest in the deep middle cerebral vein, suggesting that velocities in cerebral veins and sinuses correlate positively with increasing vessel diameter and demand of blood flow.

Velocities measured in the basal veins of our subjects were similar to those reported in a recent conventional transcranial Doppler study (11), whereas deep middle cerebral vein velocities were slower in the present study. The exact point of transition from the deep middle cerebral vein to the basal vein cannot be reliably detected by TCCD, and is located at insonation depths of approximately 49 to 55 mm (15). Therefore, an explanation for the higher deep middle cerebral vein velocities reported by Valdueza et al (11) might be that the use of greater depths of insonation, ranging up to 72 mm, led to erroneous insonation of the basal vein, which showed higher velocities as compared with the deep middle cerebral vein in our study. Finally, the fact that their study (11) had fewer subjects than ours may explain the difference in deep middle cerebral vein velocities found.

Straight sinus velocities and resistance indexes were higher in our study than in a frequency-based TCCD study (8). An explanation might be that power Doppler imaging delineated the optimal place for straight sinus velocity measurements more accurately than the frequency-based technique. Moreover, in our study, higher Doppler energy output intensities and a 2.0- instead of a 2.5-MHz transducer were used. Since most depths used for insonation of the straight sinus were greater than 85 mm in our series, it is likely that these technical differences had an impact on the quality of the recorded Doppler signals.

The straight sinus has an oblique course in the sagittal plane, with a mean angle of 52° (range, 40° to 71°) (Fig 3A). Thus, straight sinus insonation requires an adequate rotation of the ultrasound transducer into the sagittal plane. This maneuver enabled the straight sinus to be seen as a short line (Fig 3B) or an oval structure, probably because the temporal bone window has its smallest extension in the craniocaudal direction (26). Therefore, angle correction may have been inadequate in subjects in whom nonlinear flow was depicted in the straight sinus; however, this caused no significant measurement errors. Aaslid et al (7) reported similar straight sinus velocity values using conventional transcranial Doppler sonography through the occipital window.

We found that sinovenous velocities decreased with age, which is in accord with the results of several studies that showed, by means of different techniques, that blood flow and velocity in arteries and sinuses of the brain decrease with age (3, 27–30). Velocity tended to be faster in women than in men, and this trend reached statistical significance for the basal vein in the 40-to-59-year age group. These results agree with those of several studies showing that women have higher cerebral artery velocity and blood flow than men (3, 31).

One of two patients with thrombosis of the superior sagittal sinus had velocity in one deep middle cerebral vein that became normal after recanalization of the occluded sinus. Elevated deep middle cerebral vein velocity may have reflected an augmented venous drainage through this vessel, compensating for the impaired function of ascending frontotemporal veins.

The resistance indexes were small in our series, indicating lower pulsatility of sinovenous compared with arterial flow. These findings are in accord with the results of previous transcranial sonographic studies (7, 8, 11). The resistance indexes increased with age in both sexes, probably reflecting the age-dependent increase of vascular pulsatility. The resistance indexes were higher in cerebral sinuses than in veins, a result that is in accord with the anatomic finding that the walls of cerebral sinuses are rigid (32) whereas the walls of veins are not.

Insonation depths showed a tendency to be greater in men than in women in all examined veins and sinuses, and this difference was significant for the deep middle cerebral vein, basal vein, and straight sinus. This difference in insonation depth is well known from transcranial insonation of cerebral arteries, and relates to differences of skull and brain sizes between the sexes.

In summary, we have shown that power- and frequency-based transtemporal TCCD enabled imaging and velocity measurements in deep cerebral veins of healthy adults younger than 60 years of age, whereas detection of the straight and transverse sinuses was low. In older subjects, however, only the basal vein was regularly identified. On the basis of our findings, it is likely that TCCD could be useful in supplying information about venous hemodynamics in the acute phase and during the follow-up of patients with cerebral venous thrombosis.

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