EUROPEAN SOCIETY OF NEUROSONOLOGY
AND CEREBRAL HEMODYNAMICS

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**5th Congress of the European Academy of Neurology**

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**Hands-on Course 13**

## EAN/ESNCH: Neurosonology – from basics to clinical applications (Level 1-2)

# Intracranial artery protocol

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# Transcranial Color-Coded Duplex Ultrasonography

# Intracranial Artery Protocol

**Eva Bartels**

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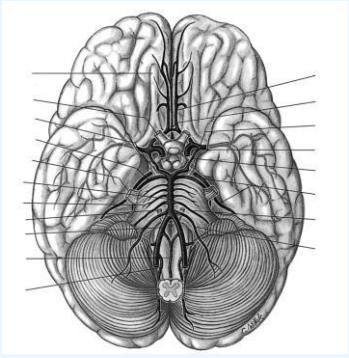
Munich, Germany

- No disclosures

## Transcranial Dopplersonography
(Aaslid et al.1982)

The Doppler signal obtained is assigned to a specific artery on the basis of indirect parameters:

- depth of the sample volume
- position of the transducer
- flow direction
- compression tests



## Transcranial Color-Coded Duplex Ultrasonography

- Color-coding of the Dopplersignal enables the visualization of blood flow in intracranial vessels through the intact skull.

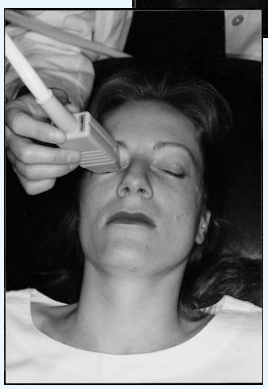
## Transcranial Color-Coded Duplex Ultrasonography

- Color-coding of the Dopplersignal enables the visualization of blood flow in intracranial vessels through the intact skull.
- The arteries of the circle of Willis can be identified by their **anatomic location** with respect to the brain stem structures and by determination of **the flow direction.**

## Examination technique

### Insonation

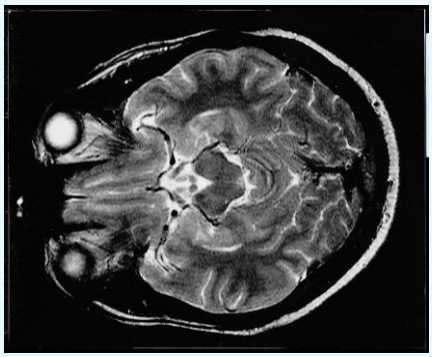
- transtemporal
- suboccipital
- transorbital

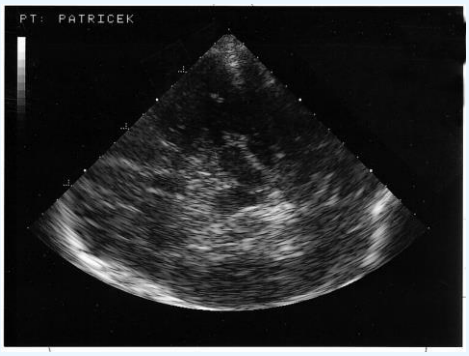


Bartels Eva:

Color-Coded Duplex Ultrasonography of the Cerebral Vessels /

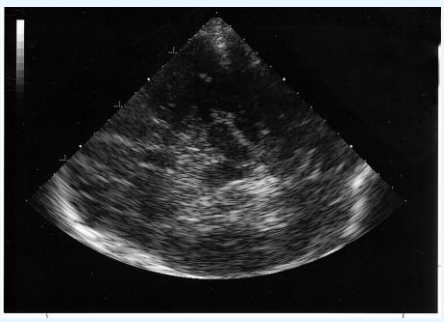
Farbduplexsonographie der hirnversorgenden Gefässe Schattauer Stuttgart,1999





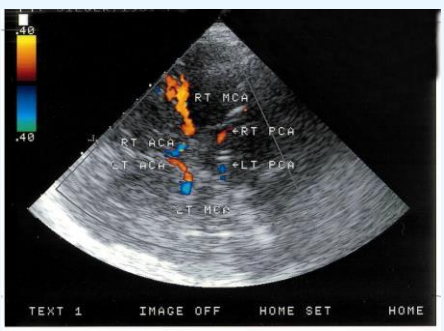

## Examination technique

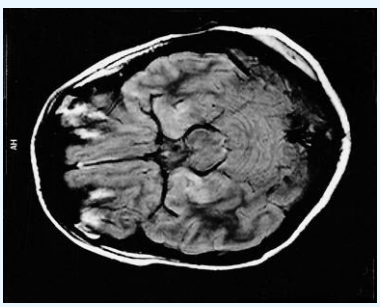
For easier anatomical orientation on the screen, first the cerebral structures in the midline – the butterfly-shaped mesencephalic brain stem, surrounded by the hyperechogenic basal cistern – are displayed with B-mode ultrasonography.

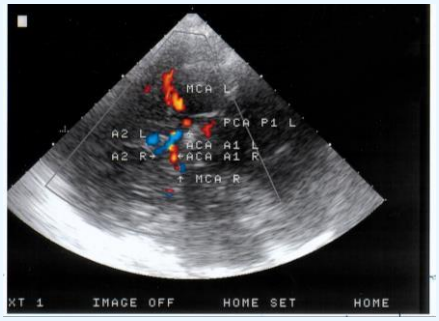


## Examination technique

Subsequently, the color mode can be switched on to render the basal cerebral arteries visible.

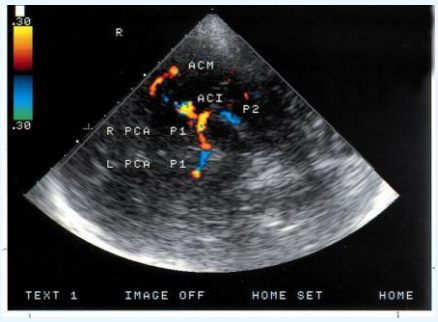


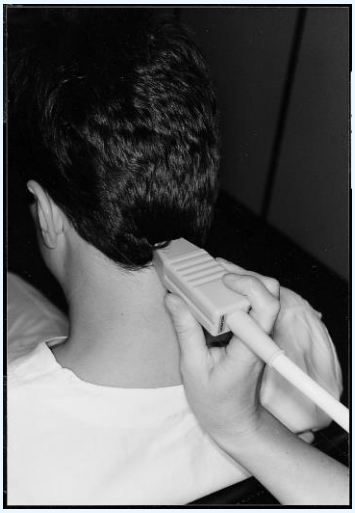



## Examination technique

- anterior part
- posterior part
  of the circus of Willis

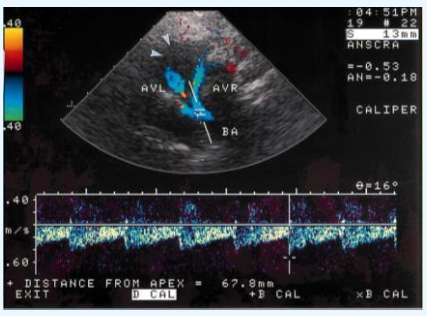



## Transnuchal (suboccipital) insonation



Examination technique

Orientation on the B-mode image: *hypoechoic structure of the great foramen*



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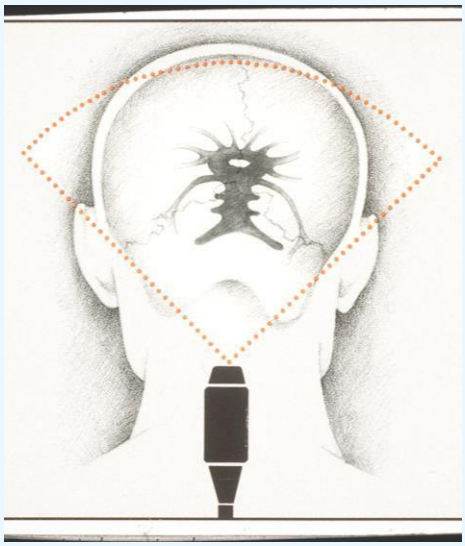

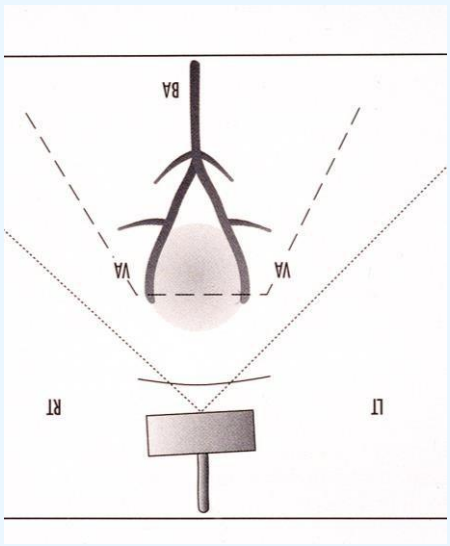


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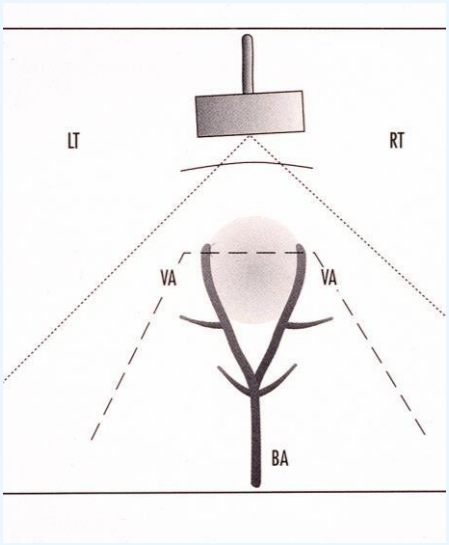
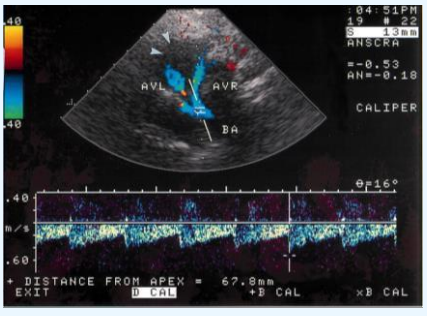



Examination of the proximal portion of the basilar artery and the intracranial segments of the vertebral arteries (coded blue).



## Advantages of the transcranial color-coded duplex ultrasonography

- Imaging of the **anatomical position** and **course** of the vessels

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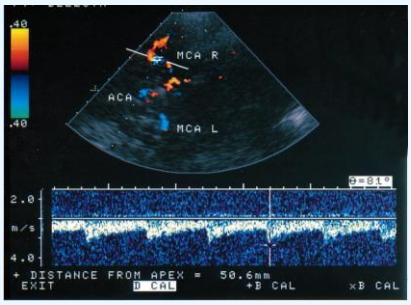
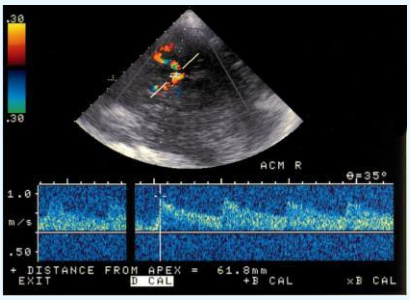
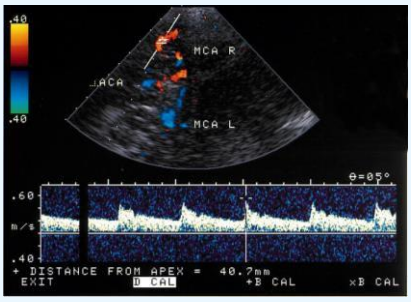
**Pitfalls** associated with angle-corrected measurement of flow velocity:

tortuosity of the vessel course



## Advantages of the transcranial color-coded duplex ultrasonography

- Imaging of the **anatomical position** and **course** of the vessels
- **Angle-corrected measurement** of blood flow velocities (more exact)
- Better assessment of **pathological findings**

## Pathological Findings

- Vascular processes
- Cerebral parenchyma disorders
- Vascularized tumors
- Arteriovenous malformations
- Venous system
  - cerebral venous thrombosis

## Pathological Findings

- **Vascular processes**
  - *Stenosis* of the cerebral artery
  - *Occlusion* of the cerebral artery
  - *Collateral supply* in extracranial carotid artery occlusive disease

## Pathological findings

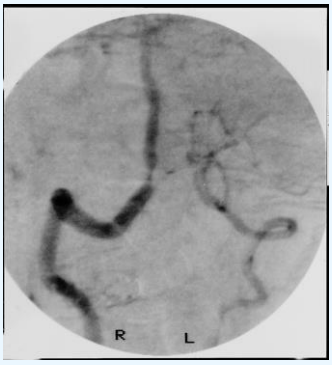
### Stenosis

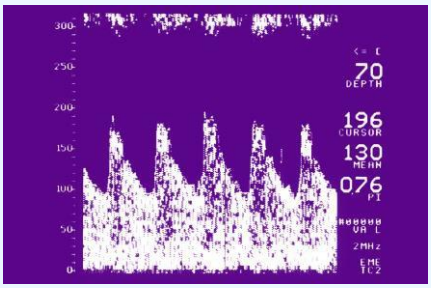
- Aliasing phenomenon
- Changes of the Doppler spectrum
- Quantification (?)

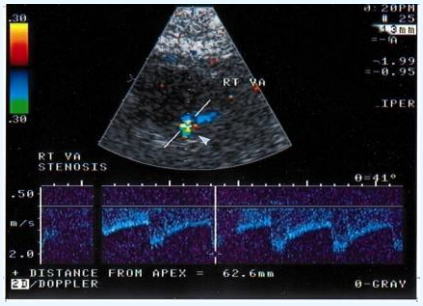
Pathological:
max. syst. velocity >160 cm/s
mean-velocity > 90 cm/s

## Pathological findings

Stenosis in the vertebrobasilar system



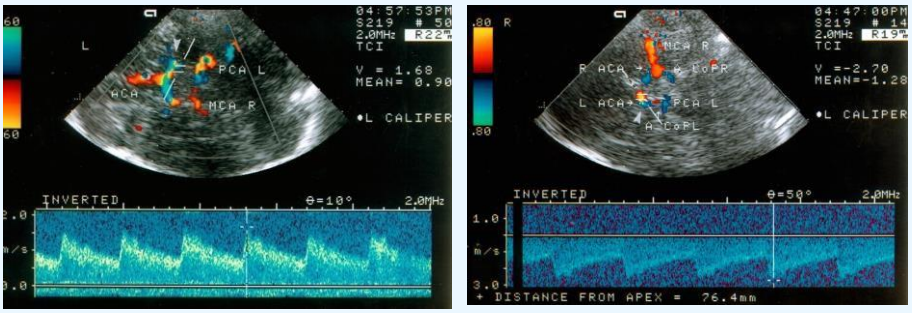




## Occlusion of a cerebral artery

A color-coded signal cannot be obtained at depths of insonation corresponding to the occluded artery, although neighboring arteries can be imaged well.

## Occlusion




**Criteria for the diagnosis of MCA occlusion:**

- Lack of detectable flow in the MCA
- Good visualization of the ipsilateral PCA
- Detection of the collateral flow

## Pathological Findings

- Vascular processes (stenosis, occlusion)
- Vascularized tumors
- Arteriovenous malformations

  Angioma
  Aneurysm
  Fistula

## Pathological Findings

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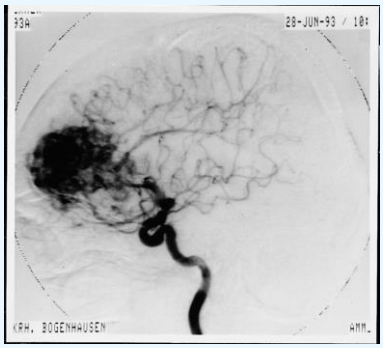
## Arteriovenous Angioma

- pathological connection between the arterial and the venous system




- Nidus – consisting of numerous vascular convolutions

## Arteriovenous Angioma

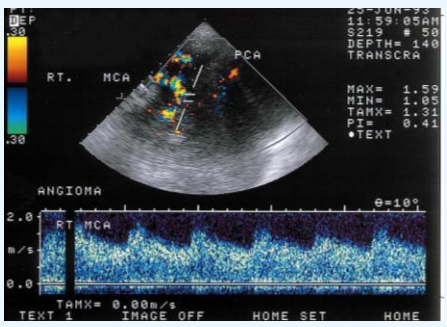
- The color-coded pattern of the *vascular convolutions* is very typical - with different color shades
- *Aliasing - phenomenon*



## Arteriovenous Angioma

**Feeding arteries** – characteristics

- *Hyperperfusion* - increased systolic and diastolic blood flow velocity
  - low peripheral resistance
- *Low pulsatility* of the Doppler spectrum (PI < 0.6)



## Arteriovenous Angioma

**Visualization** – Sensitivity = 77,5%

***Localization!***

## Arteriovenous Malformations

**Visualization of the AVMs corresponding to their localization.**

| Localization | visualized AVMs | missed AVMs | total |
|---|---|---|---|
| temporal-basal | 10 | 1 | 11 |
| temporal-parietal-basal | 6 | 0 | 6 |
| parietal | 3 | 3 | 6 |
| occipital | 2 | 2 | 4 |
| frontal-basal | 2 | 1 | 3 |
| frontal | 2 | 0 | 2 |
| cerebellar | 6 | 2 | 8 |
| | 31<br>77.5 % | 9<br>22.5% | 40<br>100% |

Bartels Eva, Ultrasound in Medicine 2005; 24:1511-1517

## Arteriovenous Angioma

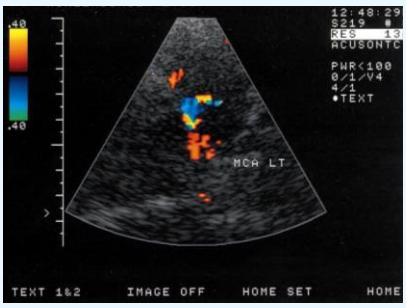
**Visualization** – Sensitivity = 77,5%

***Localization!***

- Problems: Imaging of angiomas located in both *cortical and subcortical* regions (parietal, occipital, frontal and cerebellar)
- Axial scanning plane
  Sensitivity = 90%
  Diameter > 1 cm

## Arteriovenous Angioma

**Visualization** – Sensitivity = 77,5%




- Axial scanning plane
  Sensitivity = 90%
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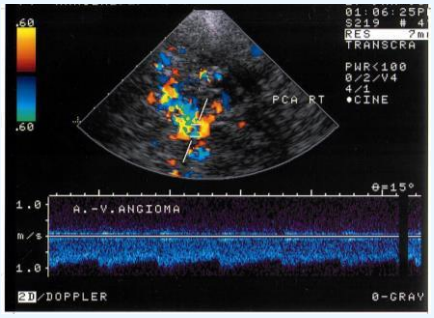
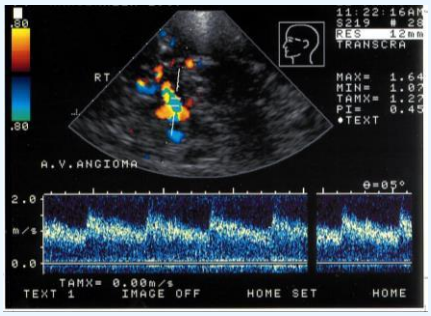
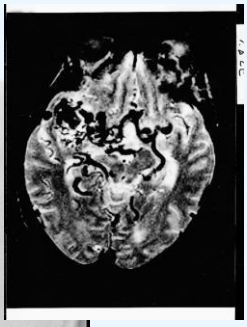



- Embolization
  - follow up

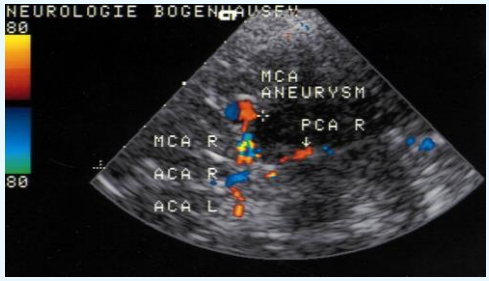


## Pathological Findings

- Vascular processes (stenosis, occlusion)
- Vascularized tumors
- Arteriovenous malformations

  Angioma
  Aneurysm
  Fistula

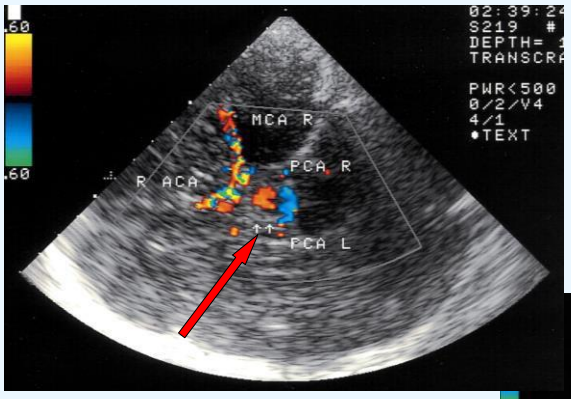
## Vascular Malformations
## Cerebral aneurysms

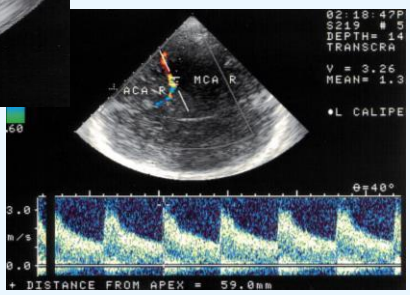



a typical color-coded pattern:

one half of the aneurysm is coded blue, another half red – according to the in- and outflowing blood.

Vasospasm – aneurysm of the top of the basilar artery.



## Pathological Findings

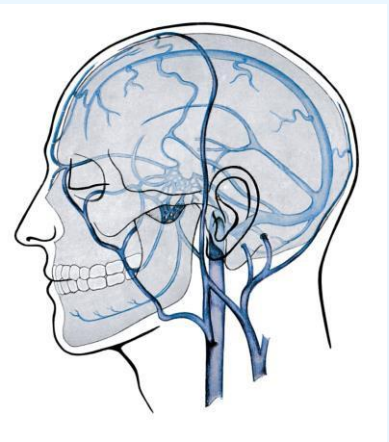
- Vascular processes (stenosis, occlusion)
- Vascularized tumors
- Arteriovenous malformations
- Cerebral parenchyma disorders

## Which veins can be imaged?

**Upper sinus group**
**Lower sinus group**

**Deep (inner, central) cerebral veins**

- Basal vein of Rosenthal
- Internal cerebral vein
- Great cerebral vein of Galen



Bartels Eva: Color-Coded Duplex Ultrasonography of the Cerebral Vessels / Farbduplexsonographie der hirnversor-genden Gefässe, Schattauer Stuttgart

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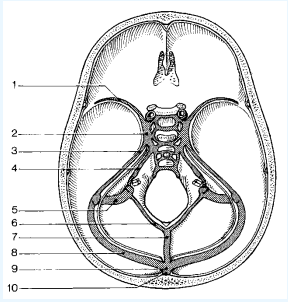
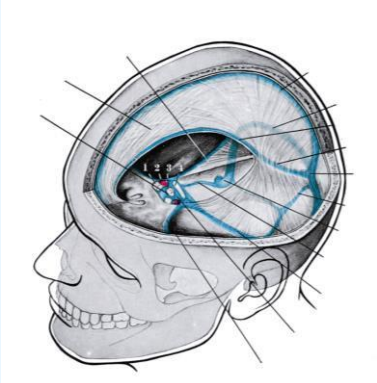



## Deep (inner, central) cerebral veins

## Upper sinus group

## Lower sinus group

- Cavernous sinus
- Superior petrosal sinus
- Inferior petrosal sinus
- Sigmoid sinus
- Basal venous plexus



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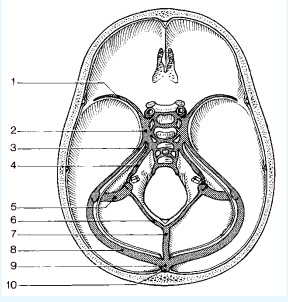


## Deep (inner, central) cerebral veins

## Upper sinus group

- Inferior sagittal sinus
- Straight sinus
- Confluence of sinuses
- Transverse sinus
- Sphenoparietal sinus

(Superior sagittal sinus)

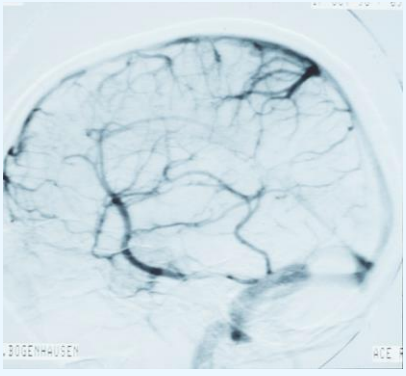

**TABLE 2. Normal Values of Venous Flow Velocities**

| | Flow Velocities, cm/s | | | Angle | Insonation | Success |
|---|---|---|---|---|---|---|
| | Peak Systolic | End Diastolic | n | Correction, Degree | Depth, cm | Rate, % |
| Deep middle cerebral vein | 10.3±3.9 | 7.1±2.6 | 114 | 28.4±15.4 | 5.2±0.5 | 76 |
| | 8.5±2.9 | 5.7±1.9 | 114 | 0 | | |
| Basal vein | 13.9±5.1 | 10.0±3.6 | 133 | 22.3±9.5 | 6.3±0.4 | 89 |
| | 12.4±4.0 | 8.9±3.0 | 133 | 0 | | |
| Great cerebral vein of Galen | 19.4±11.3 | 13.6±7.4 | 25* | 53.8±5.9* | 8.1±0.4 | 89 |
| | 10.6±3.7 | 7.5±2.8 | 67 | 0 | | |
| Straight sinus | 20.9±9.6 | 15.6±8.0 | 39* | 47.4±7.2* | 9.3±0.4 | 71 |
| | 13.1±5.1 | 9.4±4.0 | 53 | 0 | | |
| Transverse sinus | 19.3±10.8 | 13.6±8.0 | 101 | 27.7±21.8 | 11.6±1.0 | 67 |
| | 14.9±6.7 | 10.4±5.3 | 101 | 0 | | |
| Superior sagittal sinus | 10.6±3.6 | 6.7±2.6 | 39 | 0 | 10.9±0.9 | 52 |

Values are mean±SD.
Only measurements with an insonation angle of ≤60° were included.

Stolz et al.: Stroke 1999;30:70-75

**Stolz et al., Stroke 1999; 30: 70-75**

## Color-coded duplex ultrasonography of the cerebral veins

**Technical parameters for venous imaging – detection of low-velocity flow**

- Puls repetition frequency (PRF) has to be set to the lowest value
- The color box has to be as small as possible
- The frame rate and the wall filter have to be adjusted
- The global gain and intensity threshold have to be optimized

## Which veins can be imaged?

**Upper sinus group**
**Lower sinus group**

**Deep (inner, central) cerebral veins**

- Basal vein of Rosenthal
- Internal cerebral vein
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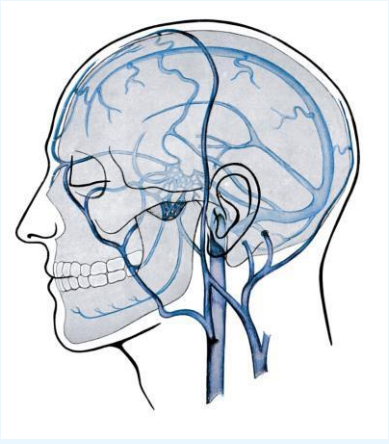

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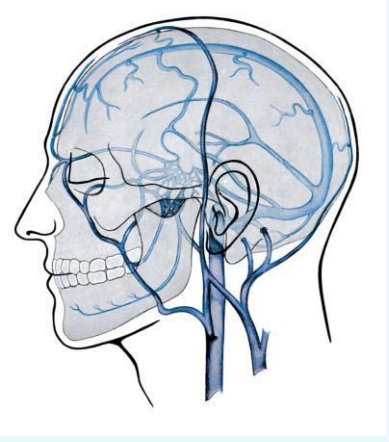
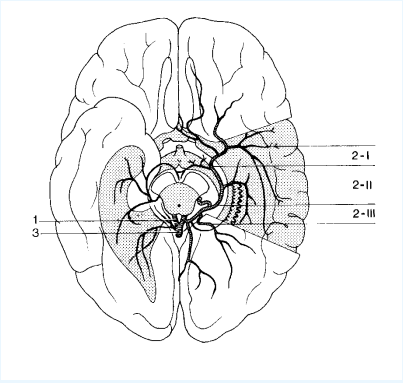


# Color-coded duplex ultrasonography of the cerebral veins – Examination technique

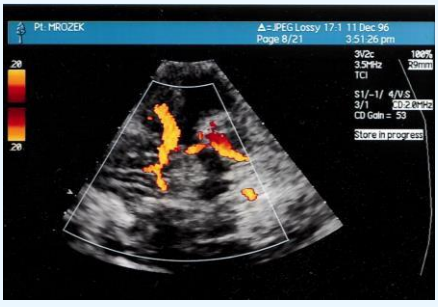
- **Basal vein of Rosenthal**

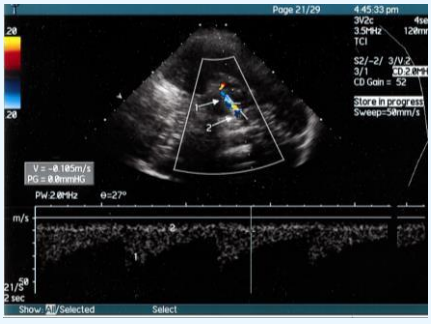
- mesencephalic segment

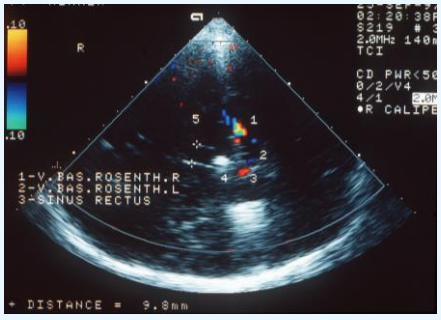
can be easily be displayed after imaging the PCA by slightly tilting the transducer occipitally and apically

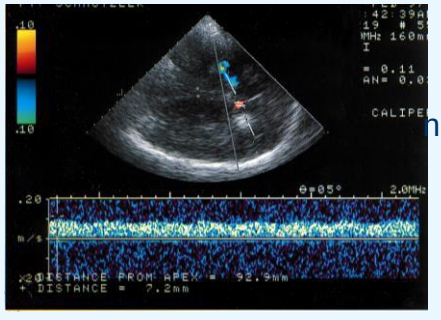



## Basal vein of Rosenthal



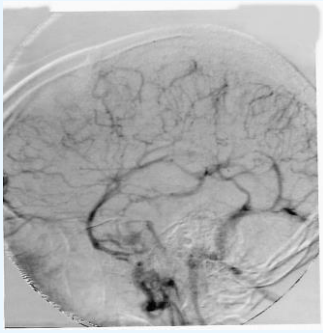



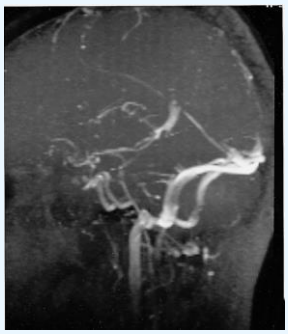



- **Cerebral venous thrombosis of the superior sagittal sinus**

- A venous occlusion cannot be detected **directly** using ultrasonography.
- The venous drainage via collaterals can be visualized.
- In the case of a thrombosis, the blood flow velocity in the draining collaterals is **increased.**
- The intracranial veins can be imaged at once without low flow settings.





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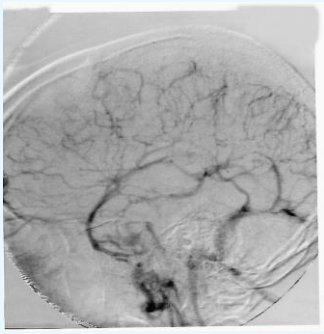

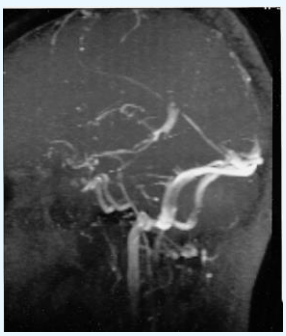

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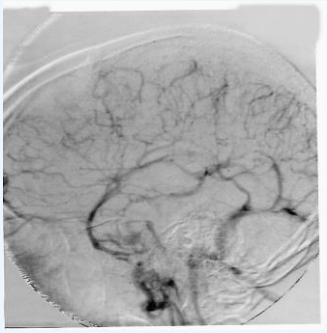

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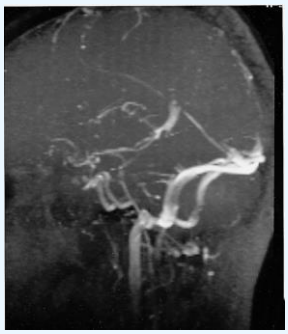

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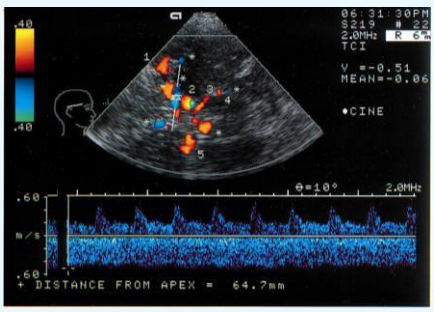
- **Cerebral venous thrombosis**

- numerous blue coded areas beside the regular anatomical course of the basal cerebral arteries can be recognized on the screen corresponding to the diagonal sections of the veins.



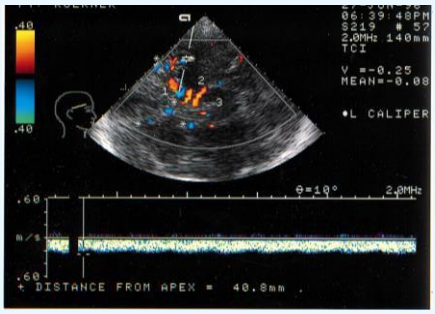


**Typical venous signal:**
- low amplitude pulsatile flow
- increased mean blood flow velocities
-imaging of small peripheral veins

- **Cerebral venous thrombosis**

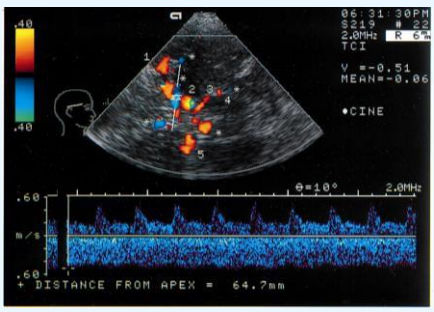
- numerous blue coded areas beside the regular anatomical course of the basal cerebral arteries can be recognized on the screen corresponding to the diagonal sections of the veins.

Cerebral veins which are not routinely detectable
can be imaged
(small cortical veins).

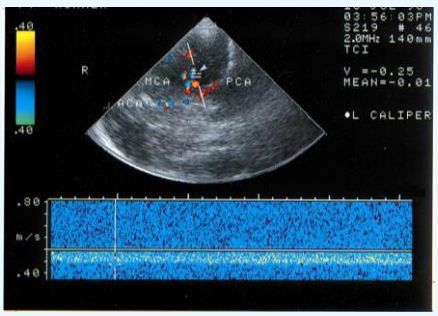



- **Cerebral venous thrombosis**

33 years old patient -
Follow – up two weeks later:




Reduced, but still increased blood flow velocities:
middle cerebral vein -
(max.syst.vel.25 cm/s)



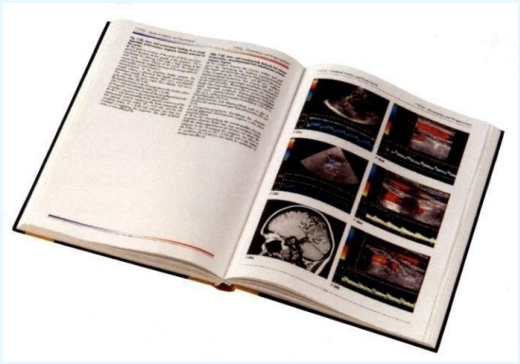
## Cerebral venous thrombosis

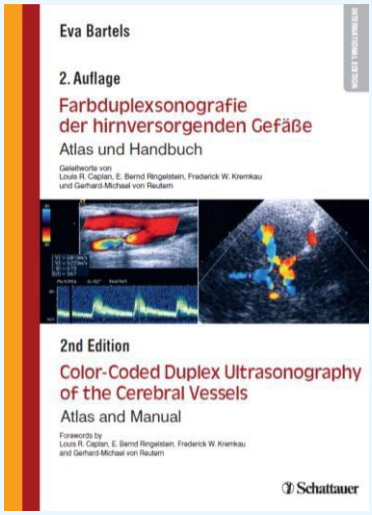
### Conclusion

A **venous occlusion** cannot be detected directly. The diagnosis is made on the basis of **indirect** findings, i.e. the detection of increased number of venous collaterals.

In **follow-up** examinations, it is possible to noninvasively obtain information regarding the dynamics of the disease, which is important for therapeutic decisions (determining the duration of the anticoagulant therapy).

Thank you for your attention!



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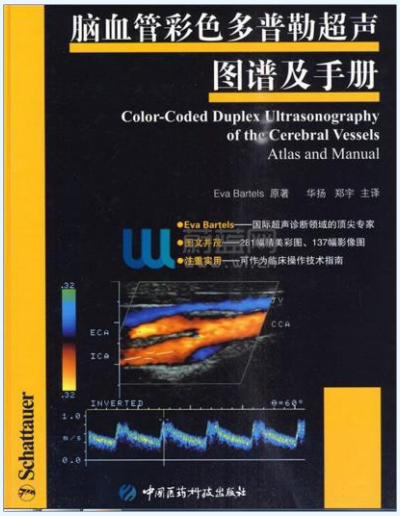


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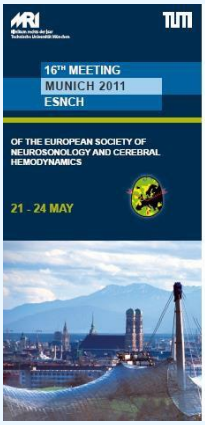


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