**Purpose:** To provide non-invasive assessment of the intracranial vessels in the circle of Willis using non-imaging Doppler, which include Time Average Mean Velocity (TAMV) and Pulsatility Index (PI). The protocol includes a complete bilateral study.

**Indications for Transcranial Doppler:**

* Monitoring of vasospasm following subarachnoid hemorrhage
* Intracranial occlusive disease
* Effects of extracranial stenosis on intracranial hemodynamics
* Evaluation of flow following head trauma
* Assess degree of intracranial stenosis in the major basal cerebral arteries
* Assessment of the vertebrobasilar (posterior) circulation
* Monitoring of reperfusion therapies in acute stroke
* Sickle cell disease
* Detection of cerebral emboli
* MoyaMoya disease
* Cerebral circulatory arrest
* Circle of Willis collateral flow

**Equipment:**

**Dedicated Transcranial Doppler Machine**

* 2Mhz pulsed wave transducer for spectral analysis with M-Mode software
* A direction sensitive Doppler blood flow meter
* Doppler waveform monitor that displays bidirectional flow and signal intensity
* Audible output and permanent recording of the waveform
* Evidence of validation for the intended application will be provided if software is used for emboli detection
* Ultrasound gel
* Wash cloths, towels to support patient’s head
* Gloves
* Masks

**Equipment Quality Control:**

* Equipment used for diagnostic testing will be maintained in good operating condition
* Equipment maintenance includes preventative maintenance checks quarterly by vendor, and biomedical engineering to maintain optimal functioning.

**Limitations:**

* Patient is uncooperative
* Post-operative dressings
* Poor positioning of patient
* Inadequate windows

**PROCEDURE**

**Patient Positioning**:

Position the patient comfortably in supine position on the exam table, with head supported for transtemporal window. For transforaminal (suboccipital) window, turn patient’s head to side with neck flexed to optimize foramen magnum.

If the patient is in the Neurocritical Care unit and not able to follow commands, it is sometimes necessary to prop their head for proper positioning in order to assess the transtemporal window, as frequently the patient will turn their head to one side.

* Explain procedure. Obtain patient history by reviewing the patient's medical records and interviewing the patient or patient representative. Record age, gender, race, and current medical status. Document symptoms, relevant risk factors and pertinent lab values.
* Risk factors may include but are not limited to: smoking, diabetes, hypertension, peripheral vascular disease, coronary artery disease.
* Lab values should include hematocrit, hemoglobin, heart rate, cardiac output, blood pressure, pC02, and intracranial pressure.
* Set up equipment.

**TCD Acoustic Windows**

We use acoustic windows which are the natural indentations in the temporal bone that allow us to assess the intracranial arteries.

Transcranial Doppler windows for acquisition of the anterior Circle of Willis include mid-temporal window, anterior window, and posterior window. The suboccipital window is used to insonate the vertebrals and basilar artery. The transorbital window is used to insonate the Ophthalmic artery and ICA Siphon. The Submandibular window is used to insonate the extracranial carotid artery in order to obtain the Lindegaard and Sviri Ratios for evaluation of vasospasm.

**Begin procedure with insonation of the Middle Cerebral Artery (MCA)**

Begin procedure at the right Middle Cerebral Artery (RMCA), in the mid transtemporal window. The power of the transducer may be increased to 100%. Set the depth at 50- 55mm which is the M1 segment. Place a generous amount of gel above the zygomatic arch on the temporal region of the patient’s cranium. Before applying the probe on the patient, use the index finger to slide across the temporal windows to palpate the natural indentations in the skull in the temporal window. Place the probe in the mid temporal window, above the zygomatic arch and anterior to the ear. Aim slightly upward and anteriorly, listening for the strongest signal. If the signal is difficult to locate, move the probe without lifting it out of the window into the posterior temporal window. Use caution to be sure you are insonating the MCA, and not the PCA.

While insonating the MCA, the flow will be toward the transducer, which will appear above the baseline on your screen.

Document the spectral MCA waveform. Move the probe in very small circular motion without lifting the probe out of the window, to be sure you have the strongest signal. After obtaining a clear signal, decrease the depth in intervals to 30- 40 mm, insonating the M2 segment. The M2 segment is also toward the transducer and will be above the baseline. Again, move the probe in a very small circular motion without lifting the probe and follow the sound listening for the highest mean velocity. Take several samples of both M1 and M2 at multiple depths.

**ACA/MCA Bifurcation**

Staying in the same window, continue to follow sound angling the probe anteriorly while increasing the depth until flow becomes bi-directional (both above and below baseline); this will allow you to insonate the MCA/ ACA bifurcation. If a signal is lost while scanning other vessels, return to the bifurcation as this is a landmark area. Store sample of bifurcation.

Depth: 55-65 mm

Flow direction: Bidirectional

Flow velocity not assigned as this is a landmark area

**Anterior Cerebral Artery (ACA)**

Continue to follow sound through the bifurcation, continuing to increase depth to 60-65mm insonating the ACA.The flow will be going away from the probe so will appear on the screen below baseline. Take several samples of the A1 segment and store waveforms at multiple depths up to 75mm. Note that only A1 can be insonated due to the angle of the A2 segment of the ACA.

Depth: 60-80 mm

Flow direction: Away from the transducer

Mean velocity: 50 + 11 cm/ sec

**Terminal Internal Carotid Artery (tICA)**

Return to M1 at a depth of 60 mm, moving the probe slightly inferior to insonate the terminal internal carotid artery (tICA), and store the sample. The terminal ICA signal is located just inferior to the bifurcation at 60-65 mm. The sound will be lower and more pulsatile than the MCA.

Depth: 60-65 mm

Flow direction: Toward transducer

Mean velocity: 39 + 9 cm/sec.

**Posterior Cerebral Artery (PCA)**

Return to the landmark bifurcation and move probe slightly posterior and inferior to the MCA/ ACA bifurcation while at a depth of 60mm. Slowly turn the transducer posteriorly by 10-30 degrees, (usually there is a sound of flow gap) between the bifurcation and the PCA. The PCA signal will have a lower velocity and will become bi-directional as you follow sound increasing depth into the P2 segment. Take a sample at P1 and P2 and store images.

Depth: 60-80 mm

Flow direction: PCA (P1) toward transducer, PCA (P2) away

Mean velocity: 39 + 10 cm/sec

**Vertebral Arteries and Basilar Artery can be insonated in the suboccipital window**

Next, the vertebrobasilar system is insonated within the suboccipital window.

If possible, turn the patient’s head slightly to optimize visualization. Before placing the probe on the patient, using a generous amount of gel, place the index finger to palpate the foramen magnum, just below the hairline to locate the suboccipital window.Place transducer depth at 60mm and aim probe toward the patient’s eyes. Move probe in a small circular movement and locate a vertebral artery (VA) at a depth of 60mm. The flow will be below baseline, as flow is moving away from the probe. Move the probe slowly from left to right to determine which vertebral artery you are on. Continue on the right side. Take sample waveforms of the right VA (RVA) once you have determined you are on the right side. Keep the transducer on the RVA, and while following the sound, continue to increase the depth from 60mm to 75mm to identify the distal RVA.

Continue to follow sound increasing depth to 80mm to insonate the proximal basilar artery (BA). Continue to follow the sound, and store several samples, while increasing depth to the mid BA at 90mm. Store sample of mid BA. Continue to increase depth to 100mm or greater to insonate at the distal BA. Store several samples. While still holding the transducer on the BA, begin to decrease the depth slowly and follow the sound back to the left VA. Take multiple samples and store at depth of 75mm for distal VA and 60mm for proximal VA.

Vertebral Artery (VA)

Depth: 60-75 mm

Flow direction: Away from transducer

Mean velocity: 38 +10 cm/sec.

Basilar Artery (BA)

Depth: 80-120mm

Flow direction: Away from transducer

Mean velocity: 41+10 cm/sec

**Sviri Ratio**

The Sviri ratio is obtained by dividing the mean flow velocity of basilar artery (BA) by those of extracranial vertebral arteries.

To calculate Sviri Ratio(3):

Basilar (mean flow velocity) / (Right Vertebral Artery + Left Vertebral Artery) /2

**Transorbital window for insonation of the Ophthalmic artery and Carotid Siphon**

NB: reduce power to 10% to avoid retinal damage

Place transducer over eyelid, angle medially. It is important to watch for flow direction, as small branches can collateralize with distal branches of the External Carotid Artery (ECA).

Flow direction in the ophthalmic artery is toward the probe, appearing on the screen above baseline. Flow direction in the siphon may be bidirectional. Watch for increased velocities and store images.

Depth: Ophthalmic artery: located 45-52mm

Normal MFV range: 22 +/-4 cm/s

ICA Siphon located 60-64mm

Normal MFV range: 44 +/- 13 cm/s

**Vasospasm**

One of the most widely used procedures for TCD is noninvasively monitoring vasospasm following patients with subarachnoid hemorrhage and is a required procedure in comprehensive stroke centers. Mean flow velocities (mFV) are typically monitored daily for approximately 15 days, and each study is compared to the previous study. It is necessary to obtain Lindegaard ratios (LR) and Sviri ratios in order to determine whether or not elevated mFV is due to vasospasm, hyperemia, or both.

**Obtain Lindegaard Ratio from Submandibular Window**

Proceed to submandibular window to obtain Lindegaard ratio. The Lindegaard ratio is used to determine the severity of vasospasm, and to differentiate elevated mean flow velocity from hyperemia. This ratio is obtained by measuring the mean flow velocity of the ipsilateral MCA / mean flow velocity of the extracranial ICA.A ratio of 3-6 is indicative of mild / moderate vasospasm, and greater than 6 is indicative of severe vasospasm. Elevated mean flow velocities with a Lindegaard ratio of less than 3.0 are suggestive of hyperemia.

**DOCUMENTATION**

Documentation will include grayscale images, Doppler waveforms, depth ranges, and velocity measurements of the following segments:

* MCA at M1 and M2
* ACA
* Cross-filling via anterior cerebral communicating artery (when detectable)
* Terminal ICA (tICA) when detectable
* Collateral flow via PCA when detectable
* PCA at P1 or P2
* Ophthalmic artery when appropriate
* Internal carotid artery (ICA siphon)
* Terminal vertebral artery (VA)
* Proximal, mid and distal basilar artery
* Pulsatility Index (PI)
  + Areas of suspected stenosis or obstruction will include Doppler waveforms and velocity measurements at and distal to the stenosis or obstruction.
  + Lindegaard and Sviri ratios for vasospasm in SAH patients.
  + Store all abnormal waveforms, which may include delayed systolic upstroke, increased pulsatility, high or low diastolic flow, oscillating or reverberating waveforms, short systolic spike, hyperemia, hyperdynamic, or stenosis.

**Review of the Diagnostic Exam Findings**

* Review data to ensure that a complete exam has been performed and documented.
* Record all technical findings required to complete the final diagnosis on a worksheet so that the measurements can be classified according to the laboratory diagnostic criteria.
* Record all findings in the logbook including date, tech, indication, software, ordering physician, and any other necessary information.
* For SAH patients Lindegaard and Sviri index and include findings from previous study (1).

**CITATIONS**

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2. Alexandrov AV. Cerebrovascular Ultrasound in Stroke Prevention and Treatment, Second Edition Blackwell Publishing Ltd 2011.

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4. Sviri GE, Ghodke B, Britz GW et al. Transcranial Doppler Grading Criteria for Basilar Artery Vasospasm. *Neurosurgery,* 2006;59:360-366.

5. Kumar G, Alexandrov AV. Vasospasm surveillance with transcranial Doppler sonography in subarachnoid hemorrhage. J*ournal of Ultrasound in Medicine,* 2015;34:1345-1350.

6. Britz GW, Sviri GE. Vertebrobasilar Vasospasm after Aneurysmal Subarachnoid Hemorrhage: Review. *Journal of Neurology and Stroke,* 2018;8:10.15406/jnsk.2018.08.00278.