VASCULAR TECHNOLOGY
PROFESSIONAL PERFORMANCE GUIDELINES

Intracranial Cerebrovascular Evaluation Transcranial Doppler (Non-Imaging) and Transcranial Duplex Imaging (TCDI)

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**PURPOSE**
Transcranial Doppler (TCD) studies use pulsed Doppler ultrasound to noninvasively evaluate intracranial arterial hemodynamics. By insonating the Circle of Willis and vertebrobasilar circulation through the natural cranial windows (orbit, temporal bone and foramen magnum), focal intracranial lesions, flow disturbances and other findings within the arterial system can be identified and quantified. These evaluations are performed to document changes in intracranial flow velocity consistent with vasospasm, focal intracranial arterial stenosis (narrowing) and collateralization. Additionally, Transcranial Doppler can identify intracranial emboli and assess vasomotor reactivity.

**COMMON INDICATIONS**
Some of the more common indications for performance of a Transcranial Doppler Evaluation include:
- Diagnosis and management of intracranial occlusive disease
- Evaluation of the effects of extracranial stenosis on intracranial hemodynamics
- Identification and monitoring of vasospasm following subarachnoid hemorrhage
- Evaluation of intracranial flow following head trauma
- Intraoperative monitoring of intracranial flow during surgery to include detection and documentation of intraoperative and postoperative changes
- Assessment of vasomotor reactivity for specific indications
- Identification of, and monitoring of, intracranial vasculopathy in patients Sickle Cell Anemia
- Quantification of degree of intracranial stenosis (>65%) in the major basal cerebral arteries
- Monitor flow patterns within Arteriovenous Malformations, and identify the vascular supply to these malformations
- Assessment of the vertebrobasilar (posterior) circulation so that collateral and unusual pathology can be identified.

**CONTRAINDICATIONS AND LIMITATIONS**
Inability to Insonate: The Temporal bone above the zygoma usually provides a favorable “window” for TCD insonation; inability to insonate occurs more frequently with advancing age, in women over 60+ years of age, with a higher incidence of failure among black/African Americans. These deficiencies may be bilateral or unilateral.
- Restless or uncooperative patients: may include children, post-operative, stroke, or head injury patients
- Orbital examination concerns: ultrasound exposure to the eye should be minimized; the U.S. Food and Drug Administration (FDA) require that the power output of the transducer be reduced to the lowest power that allows a complete orbital examination. As an additional precaution, remove contact lenses prior to the exam.
- Access to Patient: in emergent or critical care situations, it may be difficult to perform a complete TCD evaluation due to the critical status of the patient and limited access due to treatment. Care should be taken to optimize the clinical exam by moving the instrument closer to the bedside and soliciting the help of another
examiner to optimize the examination. TCD performance during an interventional procedure requires additional precautions for the examiner, due to the presence of radiation.

GUIDELINE 1: PATIENT COMMUNICATIONS AND POSITIONING

Patient assessment must be performed prior to the Transcranial Doppler Evaluation. It includes evaluation of the patient’s ability to tolerate the procedure and notation of any contraindications to the procedure. Prior to initiating the TCD examination, the vascular technologist/sonographer/examiner should:

1.1 Obtain a complete, pertinent patient history by reviewing patient’s medical record and current notes, and then interviewing the patient or patient representative. This documented history should include:
   a. Record age, gender, race, and current medical status
   b. Documented symptoms of cerebrovascular disease which may include: aphasia, dysphasia, visual disturbances, numbness, tingling, weakness or paralysis of extremities and syncope, vertigo or headaches
   c. List relevant risk factors for cerebrovascular disease or intracranial findings, which may include but is not limited to: smoking, diabetes, hypertension, peripheral vascular diseases, history of diabetes or hypertension, coronary artery disease, previous stroke, transient ischemic attack (TIA), family history of cerebrovascular, coronary artery, or vascular disease.
   d. Document pertinent laboratory values for hospitalized patients, which may include: hematocrit, hemoglobin, heart rate, cardiac output, blood pressure and intracranial pressure.
   e. Note current medications or therapies
   f. Obtain results of prior noninvasive or invasive procedures whose results could guide the examination or support or explain the TCD findings.

1.2 Verifies the requested procedure and confirms that it is appropriate for the patients’ presentation or suspected diagnosis. After discussion with the Medical Director, if the ordered procedure is not considered appropriate for the clinical presentation or condition, the ordering physician should be contacted for clarification or explanation of request. The patient’s age, type of examination and clinical setting may impact the technical performance of the examination. Modifications in the protocol should follow written procedures for the facility.
GUIDELINE 2: PATIENT ASSESSMENT

The technologist/sonographer/examiner should:

2.1 Explain the purpose of the Transcranial Doppler Evaluation and indicate the usual exam length when indicated by patients’ mental status/age.

2.2 Provide a brief summary of exam purpose and carefully explains exam procedures as seen in #2.1 above.

2.3 Respond to questions and address concerns expressed by the patient about the TCD exam.

2.4 Educate the patient about risk factors when appropriate with patient condition, symptoms of transient ischemic attacks (TIA’s), and stroke.

2.5 Refer specific diagnostic, treatment or outcome questions to the patient’s physician.

2.6 Explain the necessity of and remove patient’s eyeglasses or head-coverings.

2.7 Explain the importance of remaining awake and breathing normally throughout the examination. (see 2.8.e below)

2.8 Review patient positioning requirements for the examination and determine patient’s ability to maintain proper positioning for all portions of the exam, which include:

   a. supine position with head supported or stabilized: transtemporal, orbital and sub-mandibular approach
   b. turned to side with neck flexed/chin toward chest to optimize access to foramen magnum: suboccipital (transforamenal) approach
   c. if patient is restless or uncomfortable on their side, the suboccipital exam can be performed with patient in sitting position, arms crossed and supported by stretcher or bedside table, head resting on arms so that neck is supported and relaxed, providing access to foramen magnum. This position should not be used if patient is unsteady or unstable.
   d. lateral decubitus position can also be used for suboccipital exam if other positions fail
   e. patient should be kept awake throughout the entire exam, because changes in CO2 occur while sleeping, resulting in elevated TCD velocities, which could result in misdiagnosis.
   f. The TCD examiner must also be positioned properly for the examination; optimally, sitting at the head of the bed/stretcher, with instrumentation in easy reach and arms supported. In some settings, it is helpful to wear headphones to block background noise and increase concentration on the quality of the Doppler signal. If the vascular technologist cannot be positioned optimally, with easy access to the patient or instrumentation, the assistance of another technologist or the use of a remote control may improve the quality of the examination, improve data acquisition and decrease length of exam time. This is particularly important in critical care or emergency settings.
GUIDELINE 3: EXAMINATION GUIDELINES

3.0 Diagnostic criteria should be based on published criteria that are internally validated.

3.1 Technical protocols for exam performance should include evaluation of the basal cerebral arteries, with spectral waveform data acquired at 2-4mm increments from all vessels.

To achieve complete and accurate results, the Transcranial Doppler Evaluation should:

a. Verify the presence or absence of flow in all vessels
b. Identify vessels based on depth of the pulsed Doppler sample volume and flow direction

c. Record mean velocity (TAMM or time averaged mean of the maximum velocity) and waveform characteristics, including pulsatility, systolic/diastolic velocities and ratios, evidence of turbulent flow, systolic upstroke delays, side to side asymmetry in mean velocity or a focal increase in velocity, indicative of stenosis, vasospasm or collateral effects
d. Document randomly occurring high intensity signals (HITS), associated with the detection of embolic phenomena.
e. Upon completion of the TCD examination, the vascular technologist follows local protocols/guidelines and provides a report of technical findings to the interpreting physician to be used to render a final interpretation which will direct clinical management

3.2 Instrumentation requirements include/require: Bi-directional pulsed Doppler instrumentation, specifically designed for TCD applications, with appropriate frequencies (1.5-2.5 MHz) focus and resolution to adequately penetrate the temporal bone, and resolve intracranial findings

a. Spectral waveform analysis, with appropriate technology to resolve and display variable amplitude and frequency data. TCD velocities have historically been reported as Time Averaged Mean of the Maximum (TAMM) rather than peak systolic, end diastolic or mean velocities. It is important that the examiner understands the calculation being provided by the ultrasound system, so that if this data is compared to the gold standard, all values are the same.
b. Instrumentation with the ability to display all data in real time, including depth of sample volume, size of sample volume, time averaged mean of the maximum velocity, peak and end diastolic velocities, pulsatility index, power output and frequency of transducer.
c. Data presentation in real time and in some hard copy format, as dictated by local capabilities. Video clips and hard copy presentations are desirable. All waveforms should be appropriately identified or labeled and unusual findings documented.
d. The standard examination protocol includes assessment of the intracranial vessels supplying the anterior and posterior portions of the brain: The “anterior circulation”, refers to the terminal/distal internal carotid artery (dICA), Middle Cerebral Artery (MCA), Anterior Cerebral Artery (ACA), Posterior Cerebral Artery (PCA) and Communicating Arteries (ACoA and PCoA), when functional; the “posterior circulation” refers to vessels accessed through the suboccipital window, or Foramen magnum, and include the paired vertebral arteries (VA) and Basilar Artery (BA). The orbital exam includes evaluation of the Ophthalmic Artery (OA) and the Carotid Siphon (internal carotid artery). In some instances, measurement of mean flow velocity in the distal cervical internal carotid in the neck requires the “submandibular” approach, just at the angle of the jaw. The submandibular ICA velocity is required for calculation of rations used in the assessment of intracranial Vasospasm. The OA evaluation is not routinely used for the evaluation of pediatric patients with Sickle Cell anemia, because of patient intolerance of the procedure. However, when the transtemporal exam is inadequate, the OA exam may add valuable information to the clinical exam of Sickle Cell patients.
3.3 Windows Utilized:
   a. Transtemporal Window - Arteries accessible using the Transtemporal approach:
      1. Middle Cerebral Artery (MCA)
      2. Anterior Cerebral Artery (ACA)
      3. Terminal segment of the ICA “Bifurcation” of the ICA into the and ACA
      4. Posterior Cerebral Artery (PCA)
      5. Terminal ICA
      6. Anterior Communicating Artery (when identified as a collateral pathway)
      7. Posterior Communicating Artery (when identified as a collateral pathway)
   b. Orbital Window
      1. Ophthalmic Artery (OA)
      2. Siphonous portion of the Internal Carotid
   c. Transforamenal Window (Suboccipital)
      1. Vertebral arteries (VA)
      2. Basilar Artery (BA)
      3. Posterior Inferior Cerebellar Artery (PICA)-branch of Basilar Artery - may be encountered when evaluating BA
   d. Submandibular Window
      1. Retromandibular distal cervical internal carotid artery

3.4 Vessel Identification: Vessel depths and mean flow velocities are derived from published scientific literature. Flow velocities measured in intracranial cerebral arteries are impacted by several factors: anatomy, physiology, disease processes and instrumentation. In general, mean flow velocity decreases with age, changes in response to variables such as changes in CO2, blood pressure and heart rate, abnormal hematocrit, presence of fever, medications and current medical condition. These factors should be recorded for the interpreting physician, as they may impact the findings. The term “spatial relationship” refers to the anatomical relationship of one vessel to another. These relationships should be kept in mind during this exam, to help assure the vessel identified is correct.

3.5 Insonation windows and normal values in the adult patient:
   a. Middle Cerebral Artery Window: Transtemporal Depth: 30-60 mm Flow Direction: Toward transducer
      Anterior Mean Velocity: 55 ± 12 cm/sec
   b. ACA/MCA Bifurcation Window: Transtemporal Depth: 55-65 mm Flow Direction: Bi-directional former and posterior Mean Velocity: flow velocity is not assigned to bifurcation flow; this is a landmark area to locate surrounding intracranial vessels.
   c. Anterior Cerebral Artery Window: Transtemporal Depth: 60-80 mm Flow Direction: Away from the transducer
      Anterior Mean Velocity: 50 ± 11 cm/sec
   d. Posterior Cerebral Artery Window: Transtemporal Depth: 60-70 mm Flow Direction: PCA (P1) Toward transducer, PCA (P2) Towards and away from transducer: Posterior & Inferior to MCA/ACA bifurcation
      Mean Velocity: 39 ± 10 cm/sec
   e. Terminal Internal Carotid Artery Window: Transtemporal Depth: 55-65 mm Flow Direction: Toward or away from transducer: Inferior to MCA/ACA bifurcation Mean Velocity: 39 ± 9 cm/sec
   f. Ophthalmic Artery Window: Transorbital Depth: 40-60 mm Flow Direction: Toward transducer Mean Velocity: 21 ± 5 cm/sec
   g. Carotid Siphon Window: Transorbital Depth: 65-70 mm Flow Direction Supraclinoid - Away from transducer Genu - Bi-directional Parasellar - Toward transducer
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3B: Examination Technique for the Adult Patient: Transcranial Duplex Imaging (TCDI)

3.1 TCDI combines spectral waveform analysis, gray scale and color flow imaging. Because assessment of mean flow velocity remains the primary criteria for diagnosis of intracranial hemodynamics, the technical protocols for exam performance should combine the previously noted evaluation of the basal cerebral arteries; technical protocols for exam performance should include evaluation of the basal cerebral arteries, with spectral waveform data acquired at 2-4mm increments from all vessels. In addition, the transcranial duplex should:

a. Identify the presence of a temporal window, placing the imaging transducer at the zygomatic region of the temporal bone and angling the probe in a slightly anterior angle
b. Orient the transducer so that the imaging plane is a transverse oblique view, so that the anterior and posterior intracranial structures are visualized with gray scale: with a depth display of 14-16 cm., the ipsilateral hemisphere is displayed at the top of the gray scale monitor and the contralateral at the bottom.
c. Adjust the image depth range to 8-10 cm. so that the ipsilateral hemisphere is visualized
d. Adjust the power levels and image sector for optimal size and frame rate to improve gray scale resolution.
e. Angle the transducer slightly inferiorly to display the bony landmarks in gray scale: the brightly reflective anterior structure is the lesser wing of the sphenoid bone and the petrous ridge of the temporal bone visualized posteriorly
f. Visualize the “heart shaped” moderately echogenic cerebral peduncles by angling the transducer posterior/inferiorly,
g. Document the landmarks in gray scale, maximize the color box and turn on the color display; once the intracranial vasculature is identified, minimize the color box and optimize color gain to interrogate the anterior circulation
h. Identify the MCA: runs adjacent to the sphenoid bone, with flow toward the transducer (usually displayed in red for forward flow)
i. Identify the ACA: runs toward the midline, away from the transducer, and is displayed in blue for ‘reverse’ flow. This segment of the ACA is referred to as the A-1 segment (pre-communicating)
j. Follow the A-2 segment of the ACA: turns superiorly, and may be visualized at the level of the midline, coursing superiorly (color coded in blue, away from transducer)
k. Angle the transducer posteriorly, to identify flow in the PCA; using the cerebral peduncles as a landmark, the contralateral P-1 segment of the PCA is displayed in red, coursing around the peduncles
l. Decrease the color gain, since the mean flow velocity in the PCA is lower than the MCA
m. Identify the contralateral PCA: displayed in blue because flow is away from the transducer
n. Visualize the P-2 segment of both PCA’s; these arteries may be difficult to visualize due to their anatomic course

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p. Use the color flow image of each artery to visualize the vessel and “sweep” the sample volume across the length of the vessel; then, follow the entire length of each artery, and position the Doppler sample volume for spectral data acquisition. Spectral waveforms are captured every 2-4mm, depending on the local protocol.

q. Record mean velocity (TAMM or time averaged mean of the maximum velocity) and waveform characteristics, including pulsatility, systolic/diastolic velocities and ratios, evidence of turbulent flow, systolic upstroke delays, side to side asymmetry in mean velocity or a focal increase in velocity, indicative of stenosis, vasospasm or collateral effects

r. After completing the temporal examination, the vertebro-basilar examination is completed:

s. Position the patient on their side, head bowed toward the chest to maximize access to the suboccipital area (atlas)

t. Position the transducer in the suboccipital area, inferior to the nuchal crest, with the ultrasound beam aimed superiorly, as if it would exit between the eyes

u. The gray scale display will document a dark, anechoic circular opening, the foramen magnum, and the bright reflection of the occipital bone

v. After visualizing the gray scale structures, the color box is positioned and color is turned on; flow in the right vertebral (displayed on the left of the screen) and the left vertebral (right of the screen) will be displayed as flow away from the transducer, color coded blue

w. The Basilar Artery, deep to the vertebrals, is visualized near the midline and color coded in blue, indicating flow away from the transducer

x. If both vertebral arteries and the basilar artery are captured in the same image, a “Y” shaped color image is displayed, indicating a patent and normally directed vertebrobasilar system

y. The depth of the vertebrals is usually 6.5-8.5mm, and the basilar depth is 8-10mm.

z. Mean flow velocities in the posterior, vertebrobasilar circulation is lower than the anterior (MCA/ACA/ICA/PCA) circulation. The sampling of flow in the vertebrobasilar system should follow the same procedure described previously.

Upon completion of the TCDI examination, the vascular technologist follows local protocols/guidelines and provides a report of technical findings to the interpreting physician to be used to render a final interpretation which will direct clinical management

3.2 Instrumentation requirements include/require: 3.2.1. Duplex Instrumentation includes gray scale imaging, color flow and range-gated pulsed Doppler (1.0-2.0 mHz) frequencies sufficient to visualize intracranial anatomy in adults and children, depending on the application. The imaging system should display all data in real time, including depth of sample volume, size of sample volume, time averaged mean of the maximum velocity, peak and end diastolic velocities, pulsatility index, power output and frequency of transducer.

a. Spectral waveform analysis, with appropriate technology to resolve and display variable amplitude and frequency data. Transcranial velocities have historically been reported as Time Averaged Mean of the Maximum (TAMM) rather than peak systolic, end diastolic or mean velocities. It is important that the examiner understands the calculation being provided by the ultrasound system, so that if this data is compared to the gold standard, all values are the same.

b. Velocities obtained with TCD and TCDI do not use angle correction, but assume a zero to 30 degree angle of insonation.

c. The arterial segments have different mean flow velocities; under normal conditions, the highest value is the MCA, followed by the ACA, ICA, PCA, VA and BA. Flow velocities are usually symmetric, and decrease with age; velocities can change significantly in response to biologic factors, changes in respiration or local disease processes
d. Modest differences in velocities reported by TCD and TCDI have been noted; TCDI velocities are usually 15% lower than TCD velocities; when reporting findings, it is important to validate findings and adjust diagnostic criteria accordingly.

e. Data presentation in real time and in some hard copy format, as dictated by local capabilities. Video clips and hard copy presentations are desirable. All waveforms should be appropriately identified or labeled and unusual findings

GUIDELINE 4: REVIEW OF THE DIAGNOSTIC EXAM FINDINGS

The technologist/sonographer/examiner should:

4.1 Review data acquired during the Transcranial Doppler Examination to ensure that a complete and comprehensive evaluation has been performed and documented when indicated. Waveforms should be acquired every 2-4mm, beginning at the shallowest depth (36-38mm) to the midline (65-75mm). It is suggested that one full ‘sweep’-containing 3-5 consecutive waveforms, should be acquired at each depth. This allows for a complete assessment of hemodynamics with a sufficient number of waveforms to calculate an accurate mean flow velocity measurement at each depth. Simply dropping a Doppler sample volume randomly in each arterial segment is discouraged, and may cause the examiner to miss an area of abnormal flow velocities.

4.2. Amount of data acquired for any specific protocol can vary depending on the indication for the exam. The number of vessels insonated and number of sample volumes recorded along the course of each vessel to complete an exam protocol should be developed within each laboratory.

4.3 Explain and document any exceptions to the routine TCD protocol, so that study limitations, omissions or revisions are adequately explained. The timing of an examination, and the frequency of TCD repeat studies may vary considerably, depending on the presenting symptoms and diagnosis.

4.4 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 (these criteria may be based on published or internally validated data) (see appendix).

4.5 Document exam date, clinical indication(s), technologist performing the evaluation and exam summary in a laboratory logbook or other appropriate medium, i.e. computer software.

4.6 Alert the medical director of technical results when findings indicate a need for immediate medical care or intervention.

4.7 Specific protocols for exam performance may need to be altered, due to patient presentation, disease process, injury or event. Specialized protocols can be developed using the guidelines provided here, to reflect the specialized exam being performed on an outpatient, in the OR, the ICU, Emergency Room, interventional suite or bedside.
GUIDELINE 5: PRESENTATION OF EXAM FINDINGS
5.1 Presents recording of diagnostic spectral waveforms and the technical worksheet with pertinent and technical observations about the TCD examination to the interpreting physician for use in rendering a diagnosis and for archival purposes.

GUIDELINE 6: EXAM TIME RECOMMENDATIONS
High quality, accurate results are fundamental elements of the Transcranial Doppler examination. A combination of indirect and direct exam components is the foundation for maximizing exam quality and accuracy.
6.1 Indirect exam components include pre-exam activities: review all prior diagnostic data pertinent to the TCD examination; complete pre-examination paperwork and prepare the exam room and instrumentation. Prepare the patient for the exam by explaining the procedure (when appropriate for patient condition), completing the history and physical and positioning the patient for the study. Post-exam procedures: cleanup; compiling, processing, reviewing exam data for preliminary/or formal interpretation activities; and, patient communication; exam charge and billing activities. Recommended time allotment is 15-45 minutes.
6.2 Direct exam components include equipment optimization and the actual hands-on, examination process. Recommended time allotment is 30-60 minutes.

GUIDELINE 7: CONTINUING PROFESSIONAL EDUCATION
Certification is considered the standard of practice in vascular technology. It demonstrates an individual’s competence to perform vascular technology at the entry level. After achieving certification from ARDMS (RVT credential), CCI (RVS credential), or ARRT (RT-V credential), the individual must keep current with:
7.1 Advances in diagnosis and treatment of cerebrovascular disease
7.2 Changes in Transcranial Doppler Evaluation protocols or published laboratory diagnostic criteria
7.3 Advances in ultrasound or other technology used for the Transcranial Doppler Evaluation
7.4 Advances in other technology used for the Transcranial Doppler Examination

APPENDIX
It is recommended that published or internally generated diagnostic criteria should be validated for each ultrasound system used. When validating ultrasound diagnostic criteria, it is important to realize that equipment, operator and interpretation variability is inherent to this process.
REFERENCES