VASCULAR TECHNOLOGY
PROFESSIONAL PERFORMANCE GUIDELINES

Intracranial Cerebrovascular Evaluations: Transcranial Doppler Ultrasound and Transcranial Color Duplex Imaging

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PURPOSE

Transcranial Doppler ultrasound (TCD) and transcranial color duplex imaging (TCDI) studies measure blood flow velocities and direction within portions of the intracranial arteries. TCD and TCDI evaluate the anterior and posterior circulation territories to assess and manage patients with cerebrovascular disease. Testing is often performed to detect and monitor vasospasm after subarachnoid hemorrhage and screen children with sickle cell disease for stroke risk. Additionally, these exams can identify intracranial stenosis and occlusion. TCD can detect intracranial emboli and assess vasomotor reactivity.

APPROPRIATE INDICATIONS

Common indications for performance of this examination include, but are not limited to:

- Screening children with sickle cell disease for stroke risk
- Identification and monitoring of vasospasm after subarachnoid hemorrhage
- Detection of intracranial arterial stenosis or occlusion
- Assessment of cerebral vasomotor reactivity
- Support the clinical diagnosis of brain death
- Monitoring the effects of thrombolytic therapy in acute stroke patients
- Evaluation of extracranial stenosis on intracranial hemodynamics
- Detection of cerebral embolization
- Contrast enhanced detection of right-to-left cardiac/extracardiac shunts
- Intra-operative monitoring during carotid endarterectomy or coronary artery bypass graft procedures

CONTRAINDICATIONS AND LIMITATIONS

Contraindications and limitations may include the following:

- Inadequate acoustic windows and/or poor patient positioning
- Restless or uncooperative patients
- U.S. Food and Drug Administration (FDA) recommends the power output of the transducer be reduced to the lowest power that allows a complete orbital examination
- Remove contact lenses prior to the exam
- Output power must not exceed 10% of maximum emitted power or 17mW per cm2 or equivalent
- In emergent or critical care situations, it may be difficult to perform a complete exam
- TCD/TCDI performance during interventional procedures requires additional precautions for the examiner, due to the presence of radiation

PATIENT COMMUNICATION

Prior to beginning the exam, the sonographer or examiner should:

- Introduce self and explain why the examination is being performed and indicate how much time the examination will take.
- Verify the patient's name and date of birth or utilize facility specific patient identifiers.
- Explain the procedure, taking into consideration the age and mental status of the patient and ensuring that the necessity for each portion of the evaluation is clearly understood.
- Respond to questions and concerns about any aspect of the evaluation.
- Educate the patient about risk factors for cerebrovascular disease (when appropriate).
- Refer specific diagnostic, treatment or prognosis questions to the patient's physician.
- Explain the necessity of and remove patient's eyeglasses, contacts and/or head-coverings.

PATIENT ASSESSMENT

Patient assessment should be completed before the evaluation is performed. This includes assessment of the patient's ability to tolerate the procedure and evaluation of any contraindications to the procedure. The sonographer or examiner should obtain a complete, pertinent history by interview of the patient or patient's representative and review of the patient's medical record, if available. A pertinent history includes:

- Previous cardiovascular surgeries
- Current medications or therapies
- Presence of risk factors for cerebrovascular disease
- Presence of symptoms of cerebrovascular disease
- Results of other relevant diagnostic procedures
- Review of prior examinations to ensure the evaluation duplicates prior imaging and Doppler parameters
- Verify the requested procedure correlates with the patient's clinical presentation

PATIENT POSITIONING

Review patient positioning requirements for the examination and determine patient's ability to maintain proper positioning for all portions of the exam:

- Sitting or supine position with head supported or stabilized for transtemporal, orbital and sub-mandibular approach
- Turned to side with neck flexed/chin toward chest to optimize access to foramen magnum for sub-occipital (transforamenal) approach
- Alternatively, the sub-occipital 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
- Patient should be kept awake throughout the exam due to changes in CO_2 during sleep which may affect velocities and result in misdiagnosis
- The TCD examiner should be positioned at the patient's head with arms supported

INSTRUMENTATION

Equipment used for TCD and TCDI is separate and distinct. The majority of velocity reference standards for intracranial studies were obtained at a zero degree angle with non-imaging TCD equipment. Decreased velocities and inferior penetration are reported when comparing TCDI to TCD studies.

- ***Transcranial Doppler Ultrasound Equipment*** **(TCD)**
    - Utilizes a single crystal 1.5-2.5MHz pulsed Doppler probe
    - Equipment and software specifically designed for TCD applications
        - Displays all data in real time including:
            - Sample volume, sample depth
            - Time averaged maximum mean velocity
            - Peak systolic velocity/end diastolic velocity
            - Acceleration time
            - Pulsatility (PI) or resistive indices (RI)
            - Doppler power output and frequency
        - Direction sensitive Doppler blood flow meter
        - Bi-directional Doppler waveform display
        - Audible output and permanent recording of the spectral waveform

- ***Transcranial Color Duplex Imaging Equipment*** **(TCDI)**
    - Duplex imaging scanner with B-Mode, color and spectral Doppler capabilities
    - Utilizes a 1-5MHz transducer probe
        - Displays all data in real time including:
            - Sample volume, sample depth, Doppler angle
            - Time averaged maximum mean velocity
            - Peak systolic velocity /end diastolic velocity
            - Acceleration time
            - Pulsatility (PI) or resistive indices (RI)
            - Doppler power output and frequency
        - Direction sensitive Doppler blood flow meter
        - Bi-directional Doppler waveform display
        - Visual display, audible output and permanent recording of the spectral waveforms with corresponding B-Mode/Color image

EXAM PROTOCOL

TCD and TCDI studies follow a standard imaging protocol for the examination. A complete evaluation includes spectral Doppler analysis of all accessible portions of the major intracranial arteries. Velocities can be measured by automatic tracing or manual cursor placement. Bilateral evaluations are essential for a complete evaluation.

Transcranial Doppler- Complete Examination Protocol

Both TCD and TCDI include **Spectral Doppler waveforms** from the following vessels and *approaches* to obtain mean flow velocities (without angle correction):

Submandibular Window:

- Distal cervical internal carotid arteries (ICA)

Transtemporal Window:

- Terminal internal carotid arteries (TICA)
- M1 segment of the middle cerebral arteries (MCA)
  - Should obtain proximal, mid and distal measurements
- A1 segment of the anterior cerebral arteries (ACA)
- Anterior communicating artery, if detectable (ACoA)
- P1 and P2 segments of the posterior cerebral arteries
- Posterior communicating arteries, if detectable (PCoA)

Transforamenal/Suboccipital Window:

- Terminal vertebral arteries (VA)
- Proximal and distal segments of the basilar artery (BA)

Orbital Window: (may not be appropriate for all patients)

- Ophthalmic Artery (OA)
- Carotid siphon

Transcranial Doppler-Vasomotor Reactivity Protocol

Vasomotor reactivity testing is commonly ordered to evaluate cerebral reserve capacity in patients with unilateral carotid compromises and or basilar artery compromises.

- A 1.5-2.5MHz transducer is used to insonate the MCA's either bilaterally or unilaterally. The patient is then asked to hold his breath for thirty seconds while the targeted artery is monitored.
- A normal response is for the mean flow velocity to reduce and then overshoot the baseline velocity as time expires and breathing resume.
- Many stroke and TIA patients cannot hold their breath that long so to test reserve

capacity an injection of acetlyzolimide (Diamox) can be used which takes about 10 minutes to maximally dilate the arteries, or a tank of air with high pCO2 can be inhaled to precipitate vasodilation.

- This is the ultrasound version of a perfusion study without requiring a contrast medium.

Transcranial Doppler – Emboli Monitoring Protocol

Transcranial Doppler is the only modality that can detect and localize native emboli in real-time.

- A 1.5-2.5 blind pulsed-Doppler transducer is focused on the MCA and in many times fixed to a headband so the test is hands-free after set-up. Some headbands have servomotors inside them that allows for remote steering of the probe at the machine site. In 50-60% of stroke patients bilateral MCA monitoring can be achieved. This can cut the exam time in half.
- Monitoring the basilar artery is difficult and generally done with probe-in-hand, recording 500-750 beats per vessel. Emboli originating from one artery will be localized to an ipsilateral carotid or vertebral source.
- Emboli originating from a cardiac source will spew emboli through all the vessels targeted. M-mode spectral analysis can improve the display of the moving emboli as well as allow a calculation of emboli transit time.
- Testing always follows a complete transcranial Doppler Study.

Transcranial Doppler for Detection of Right-to-Left Cardiac Shunts

- One or both MCA's can be monitored with a 1.5-2.5 MHz pulsed-Doppler transducer.
- In the out-patient lab an RN is brought in to set an IV line in preferably the brachial vein.
    - On inpatient studies, the IV-line is already set reducing exam time.
- An agitated bolus of 9 cc's saline and 1 cc of air is injected without Valsalva. The number of emboli are counted flowing through the target artery within 1 minute of the injection.
- A second injection is performed with a maximum Valsalva maneuver performed when the bolus if halfway injected. The number of microbubbles are counted flowing through the target arteries on this second maneuver.
    - Since the patient is awake and participating many shunts will be detected that are missed by transesophogeal echocardiography.
- If the patient has no acoustic access through the temporal window monitoring the basilar artery is a suitable alternative.
- A complete TCD study is recommended before the Bubble provocation to check for mild intracranial stenosis and native emboli.

DISTINCTIONS BETWEEN TRANSCRANIAL DUPLEX IMAGING (TCDI) AND TCD EXAMS

TCDI combines real time B-Mode imaging of cerebral parenchyma with color Doppler imaging and spectral Doppler analysis of the major intracranial arteries. The standard examination protocol includes bilateral assessment of the distal extracranial ICA, ACA, MCA, PCA, vertebral and basilar arteries.

- Primarily used to assess stroke risk in children with sickle cell disease and to detect and monitor vasospasm following spontaneous subarachnoid hemorrhage
- Mean flow velocities and ratios remain the primary criteria for diagnosis of cerebrovascular disease
    - Waveforms obtained at 2-5mm increments with a 3-6mm sample volume size
    - Spectral analysis includes peak systolic velocity, end diastolic velocity, systolic upstroke or acceleration time, pulsatility index, and time-averaged maximum mean velocity
    - Angle corrected flow velocities may be higher than non-angle corrected flow velocities (should use a zero degree angle)
    - Most diagnostic standards are based on non-imaging TCD studies
- Provides accurate B-Mode and color Doppler imaging of intracranial anatomy
    - Gray scale imaging of bony landmarks or parenchymal abnormalities
        - lesser wing of the sphenoid bone, petrous ridge of the temporal bone and cerebral peduncles
    - Color Doppler imaging of the major intracranial arteries
        - Should depict the ACA, MCA, PCA and vertebrobasilar arteries
        - May detect intracranial aneurysms ≥ 6mm in size
- Limitations compared to TCD remain:
    - poor beam penetration with lower vessel detection rates
    - suboptimal monitoring of emboli or vasomotor reactivity testing

Transcranial Doppler (TCD)

TCD provides spectral Doppler analysis of the major intracranial arteries. Diagnostic criteria should be based on published studies or internally validated criteria. The majority of reference standards were obtained with non-imaging TCD equipment. The standard examination protocol includes bilateral assessment of the distal extracranial ICA, ACA, MCA, PCA, vertebral and basilar arteries.

- TCD can be used to assess stroke risk in children with sickle cell disease and to detect and monitor vasospasm following spontaneous subarachnoid hemorrhage.

- Provides information related to intracranial stenosis or occlusion and cerebral circulatory arrest.
- Gold standard to detect, localize and quantify cerebral embolism in real-time
- Useful for monitoring thrombolysis of acute intracranial occlusions, detecting extracranial ICA stenosis, cerebral microembolism, right-to left cardiac shunts and to assess cerebral vasomotor reactivity
- Mean flow velocities and ratios are the primary criteria for diagnosis of cerebrovascular disease
    - Waveforms obtained at 2-5mm increments with a 3-6mm sample volume size
    - Vessel identification is based on depth and direction of flow
    - Spectral analysis includes peak systolic velocity, end diastolic velocity, systolic upstroke or acceleration time, pulsatility index, and time-averaged maximum mean velocity
    - Calculate mean flow velocity ratios
    - Evaluate Doppler waveform characteristics
    - Document randomly occurring high intensity signals (HITS) associated with embolic phenomenon
- Benefits of TCD when compared to TCDI:
    - better beam penetration and vessel detection rates
    - can quickly evaluate intracranial arteries to perform provocational testing, monitoring of emboli and vasomotor reactivity testing

REVIEW OF THE DIAGNOSTIC EXAM FINDINGS

The sonographer or examiner should:

- Review data acquired during the exam to ensure a complete and comprehensive evaluation has been performed and documented.
- Explain and document any exceptions or limitations to the protocol.
- Document any changes compared with previous exams.
- Record technical findings on a worksheet or other appropriate method (e.g., computer software), and classify results according to the laboratory diagnostic criteria.
- Document the exam date, clinical indications, performing sonographer and exam summary in patient's medical record.

PRESENTATION OF EXAM FINDINGS

The sonographer or examiner should:

- Provide preliminary results when necessary as provided for by laboratory specific guidelines.
- Present record of diagnostic images, data, explanations, and technical worksheet to the interpreting physician. Interpretation must be available within two business days.
- Sonographer and interpreting physician name must appear on the final report. Finalized/signed report should be available within four business days.
- Alert vascular laboratory Medical Director or appropriate health care provider when immediate medical attention is indicated based on departmental guidelines and procedures.

EXAM TIME RECOMMENDATIONS

High quality, accurate results are fundamental elements of TCD and TCDI examinations. A combination of indirect and direct exam components is the foundation for maximizing exam quality and accuracy.

- Indirect exam components include:
    - Pre-exam activities: obtaining previous exam data, initiating exam worksheet and paperwork, equipment and exam room preparation, patient assessment and positioning, patient communication
    - Post-exam activities: exam room cleanup, compiling and processing exam data for preliminary and/or formal interpretation, and exam billing activities.
- Direct exam components include:
    - Equipment optimization and the actual hands-on, examination process.
- While study times may vary depending on testing protocols, patient condition, and clinical complexity of the evaluation being performed, these are the times necessary to provide a quality diagnostic evaluation. Listed are the recommended examination times for performing each CPT related to this guideline, which were derived from the direct time inputs from the Resource Based Relative Value Scale (RBRVS)
    - 93886 73 minutes
    - 93888 49 minutes
    - 93890 73 minutes
    - 93892 83 minutes
    - 93893 76 minutes

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