VASCULAR TECHNOLOGY
PROFESSIONAL PERFORMANCE GUIDELINES

Transcranial Doppler in Pediatric Patients with Sickle Cell Anemia: (Non-Imaging)

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Transcranial Doppler in Pediatric Patients with Sickle Cell Anemia: (Non-Imaging)

**PURPOSE**

Transcranial Doppler (TCD) studies use pulsed Doppler ultrasound to non-invasively evaluate intracranial arterial hemodynamics. Ischemic stroke will occur in over 10% of children with homozygous Sickle Cell Anemia (HbSS) by the age of 20. The Stroke Prevention Trial in Sickle Cell Anemia (STOP Trial) used TCD to screen and identify children at greatest risk of ischemic stroke. Patients with increased velocity flow in the distal Internal Carotid Artery (dICA) and the proximal Middle Cerebral Artery (MCA) are at highest risk for stroke. The STOP trial reported a 10% incidence of stroke/year. Once identified, confirmed and treated with transfusion therapy, children with intracranial stenosis showed >90% reduction in stroke risk if hemoglobin S was less than 30%. A precise and well documented technical protocol, combined with an experienced vascular technologist and interpreting physician are crucial elements of the TCD Sickle Cell Protocol. Changes in intracranial flow must be documented on two consecutive abnormal TCD studies, with Time Averaged Mean of the Maximum (TAMM) velocities of >200 cm/sec in the dICA or proximal MCA. Elevated velocities in other intracranial vessels are included in the evaluation of these children, but the focus of the exam is careful evaluation of the distal internal carotid and proximal middle cerebral arteries.

**COMMON INDICATIONS**

Indications for performance of a Transcranial Doppler Evaluation for sickle cell anemia include:

- Presence of Sickle Cell anemia with no prior stroke in a child between the ages of 2–16 years
- Abnormal findings on a previous TCD screening examination (dICA or MCA TAMM with velocities of >170 cm/sec (Conditional) or >200cm/sec (Abnormal)

**CONTRAINDICATIONS AND LIMITATIONS**

- Children should be evaluated when healthy: hypoxia, hypercarbia, fever, sickle chest syndrome, pneumonia, hypoglycemia, and other processes can result in an increase in cerebral blood flow and velocity
- Hypocarbia and recent transfusions can decrease CBF and flow velocity, so it is crucial to document if/when a transfusion has occurred
- Children must remain awake and alert during the TCD examination: sleeping results in increased CO2 and can cause increased velocities and misdiagnosis; crying may also result in hyperventilation, which can abruptly impact velocities
- Restless or agitated children may be unable to maintain the appropriate position for a complete exam; providing entertainment with movies or music can often provide
- an adequate opportunity to complete the exam; variations in exam performance, i.e., child sitting in examiner’s lap, may also be necessary, and should be noted in the technical report
GUIDELINE 1: PATIENT COMMUNICATIONS AND POSITIONING

Patient assessment can be performed prior to the exam; however, since most patients with Sickle Cell anemia are under the care of a Pediatric Hematologist, their clinical status is known. The initial screening exam is performed to document presence or absence of elevated velocities, and will be followed by a confirmatory exam if elevated velocities are documented.

1.1 Prior to initiating the TCD examination, the vascular technologist should:
   a. Measure the bi-temporal head diameter and record on a technical worksheet
   b. Record age, gender, and current lab values, if known
   c. Current medical status: should be healthy without fever, cough, or any symptoms of illness that could impact physiology
   d. If child has had recent transfusion, this should be recorded
   e. Child with previous stroke is not usually a candidate for TCD screening or clinical exam
   f. Current medications should be recorded on technical worksheet

GUIDELINE 2: PATIENT ASSESSMENT

The technologist/sonographer/examiner should:

2.1 Explain the purpose of the Transcranial Doppler Evaluation in terms that are understood by the child, if age appropriate, and the parents and indicate the usual exam length

2.2 Provide a brief summary of exam purpose and carefully explains exam procedures

2.3 Respond to questions and address concerns expressed by the patient or parent/guardian about the TCD exam

2.4 Educate the patient (parent/guardian) about risk factors, 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, hair ornaments or head-coverings

2.7 Explain the importance of remaining awake and breathing normally throughout the examination.

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
   b. Turned to side with neck flexed/chin toward chest to optimize access to foramen magnum: suboccipital (transforaminal) 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. Alternate exam positions that provide access to temporal window may be adapted to keep patient from moving, crying or becoming restless.
   e. Assure the patient that if they remain quiet and calm, the exam will be finished much more quickly
   f. 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.
   g. 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 out 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 3A-D: EXAMINATION GUIDELINES

Measurement of head diameter is useful prior to the examination: calipers are positioned just anterior to the ear, above the zygomatic arch; the measurement of the bi-temporal diameter provides the vascular technologist with a good estimate of the head diameter, and by dividing that number in half, the depth of the midline is approximated. Because the depth of the ‘bifurcation’ or the termination of the intracranial internal carotid artery into the MCA and ACA is about 10 mm. from the midline, the examiner can use these rough approximations to help with vessel identification.

3.1 Head diameter increases with age; most children examined in the STOP trial, 2-16 years of age, had head diameters between 110 mm to 140 mm.; by dividing the measurement of the head diameter by two, the depth of the midline can be estimated. The location / position of the Doppler sample volume is shown on the TCD system and is labeled “DEPTH”; this depth setting indicates the distance from the transducer to the point where flow is being sampled and is useful in vessel identification.

3.2 In most children, the temporal bone is easy to penetrate with low frequency ultrasound and may provide multiple insonation windows; therefore, it is important to make a technical note of the temporal window (anterior, middle or posterior) used for the exam, should a follow-up examination be performed.

3.3 The temporal windows of older children may be more difficult to insonate, resulting in incomplete evaluations; in these patients, it may be necessary to complete the entire exam from one side; such findings, though helpful, should be carefully documented to prevent confusion and misdiagnosis of flow direction or velocity.

3.3 The STOP Trial did not include the orbital exam; however, if a temporal window cannot be identified, the orbital exam may be useful, as it provides access to the carotid siphon. The power must be decreased for this approach.

3.4 The STOP Trial protocol is considered standard of practice, and requires waveform acquisition at every 2mm, to insure accurate vessel identification, and TAMM.

3.5 The basilar artery is evaluated from the suboccipital approach; several waveforms are recorded to document presence of flow, direction of flow and flow velocity. In the presence of intracranial stenosis of the anterior circulation, the vertebrobasilar system (posterior circulation) may serve as a collateral to maintain cerebral perfusion.

3.6 The velocity measurement used for Sickle Cell studies is the Time Averaged Mean of the Maximum (TAMM) velocity. Use of peak systolic velocity will result in false positive results.

3.7 An abnormal finding must be verified with a second exam, preferably within a one to two week period.

3.8 Conditional exams, those with elevated velocities between 170-199cm/sec should be monitored, and repeated within 3-6 months to document potential progression to abnormal status.

3A: DIAGNOSTIC CRITERIA

Diagnostic criteria should be based on published criteria (STOP data is the accepted standard) that are internally validated.

3.1A 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. Mean flow velocity in all vessels may exceed 140cm/sec due to anemia; only vessels with a focal increase of >170cm/sec are classified as conditional or abnormal
c. Identify vessels based on depth of the pulsed Doppler sample volume and flow direction

d. 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, particularly in the distal Internal Carotid artery or proximal Middle Cerebral Artery, indicative of stenosis; and increase in flow velocity in other basal cerebral arteries, indicative of collateral effects

e. Document presence of collateral flow in basal cerebral arteries and branch vessels, as they may be support findings of intracranial stenosis.

3.2A 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

3B: PUBLISHED CLASSIFICATION OF MEAN FLOW VELOCITY: STOP STUDY
Classification: Mean Flow Velocity Criteria (TAMM)
Normal: All vessels: < 170 cm/sec cm/sec
Conditional: >170 /sec< 200 cm./sec dICA, MCA, Intracranial Bifurcation
Abnormal: > 200 cm/sec MCA, Intracranial Bif, dICA
  ▪ To be considered Abnormal: velocities of >200 cm/sec in the ICA and MCA must be documented in two TCD studies
  ▪ Elevated velocities in other intracranial vessels should be documented and monitored, though treatment is not indicated

3C: INSTRUMENTATION REQUIREMENTS
Instrumentation requirements include/require:
3.1C 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, for this evaluation, only the Basilar Artery (BA) recordings, though the Vertebral Arteries can be documented and traced to the BA. The orbital exam, which normally includes evaluation of the Ophthalmic Artery (OA) and the Carotid Siphon (internal carotid artery), 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.

3.2C Windows utilized:
   a. Transtemporal Window Arteries accessible using the Transtemporal approach:
      1. Middle Cerebral Artery (MCA)
      2. Anterior Cerebral Artery (ACA)
      3. “Bifurcation” (Terminal segment of the ICA)” of the ICA into the MCA 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
      4. Vessel depths generally encountered in children

<table>
<thead>
<tr>
<th>Transtemporal Head Diam</th>
<th>MCA Depths mm</th>
<th>ICA Depths mm</th>
<th>PCA Depths</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 cm (120mm)</td>
<td>30-54</td>
<td>48-54</td>
<td>40-60</td>
</tr>
<tr>
<td>13 cm</td>
<td>30-58</td>
<td>50-58</td>
<td>42-66</td>
</tr>
<tr>
<td>14 cm</td>
<td>34-62</td>
<td>56-62</td>
<td>46-70</td>
</tr>
<tr>
<td>15 cm</td>
<td>40-66</td>
<td>56-66</td>
<td>50-76</td>
</tr>
</tbody>
</table>

3.3.C 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 in children will normally be higher than adults. Values used for the adult patient should not be applied to children.

3.4C The location and depth of intracranial arteries will depend on the head size: smaller children have smaller heads and the depths will be more shallow than those seen in adults or older children. Teenaged children may have depths and flow directions very similar to adults, though the TAMM will be globally higher due to their younger age.
   a. Middle Cerebral Artery Window: Transtemporal Depth Range: 30-50 mm Flow Direction: Toward transducer Spatial Relationship: Anterior Mean Velocity: highest of all intracranial vessels under normal conditions
   b. ACA/MCA Bifurcation Window: Transtemporal Depth: 50-60 mm Flow Direction: Bi-directional Spatial Relationship: Anterior 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: 55-70mm Flow Direction: Away from the transducer Spatial Relationship: Anterior Mean Velocity: under normal conditions, flow velocity in the ACA is less than MCA
   d. Posterior Cerebral Artery Window: Transtemporal Depth: 50-60mm Flow Direction: PCA (P1) Toward transducer, PCA (P2) Towards and away from transducer Spatial Relationship: Posterior & Inferior to MCA/ACA bifurcation Mean Velocity: less than MCA, ACA, ICA under normal conditions. PCA
originates from top of Basilar at midline, and may be more easily identified if depth is increased to level of midline, then decreased to track route of P-1 and P-2 segments.
e. Terminal Internal Carotid Artery Window: Transtemporal Depth: 50-60mm Flow Direction: Toward or away from transducer Spatial Relationship: Inferior to MCA/ACA bifurcation Mean Velocity: less than MCA, waveform may be damped due to unfavorable angle of insonation.
f. Ophthalmic Artery Window: Transorbital Depth: 40-60 mm Flow Direction: Toward transducer Mean Velocity: Varies with disease severity; waveform has pulsatile characteristic with low diastolic flow, until tracked to Carotid Siphon, where diastolic flow component increases
g. Carotid Siphon Window: Transorbital Depth: 40-60mm Flow Direction Supraclinoid - Away from transducer Genu - Bi-directional Parasellar - Toward transducer
h. Basilar Artery Window: Transforamenal (Suboccipital) Depth: 70-90 mm Flow Direction: Away from transducer Mean Velocity: under normal conditions, less than anterior circulation.

GUIDELINE 4: REVIEW OF THE DIAGNOSTIC EXAM FINDINGS
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.
4.2 Explain and document any exceptions to the routine TCD protocol, so that study limitations, omissions or revisions are adequately explained.
4.3 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).
4.4 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.
4.5 Alert the medical director of technical results when findings indicate a need for immediate medical care or intervention.
4.6 Specific protocols for exam performance may need to be altered, due to patient presentation or cooperation. Document any changes in protocol on the technical worksheet

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, 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 25 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 either ARDMS (RVT credential), CCI (RVS credential), or AART (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

REFERENCES

- Jones AM, Seibert JJ, Nichols FT et.al. Comparison of Transcranial Doppler Imaging (TCDI) and Transcranial Doppler (TCD) in children with sickle cell anemia. Pediatric Radiol 2001; 31: 461-469.