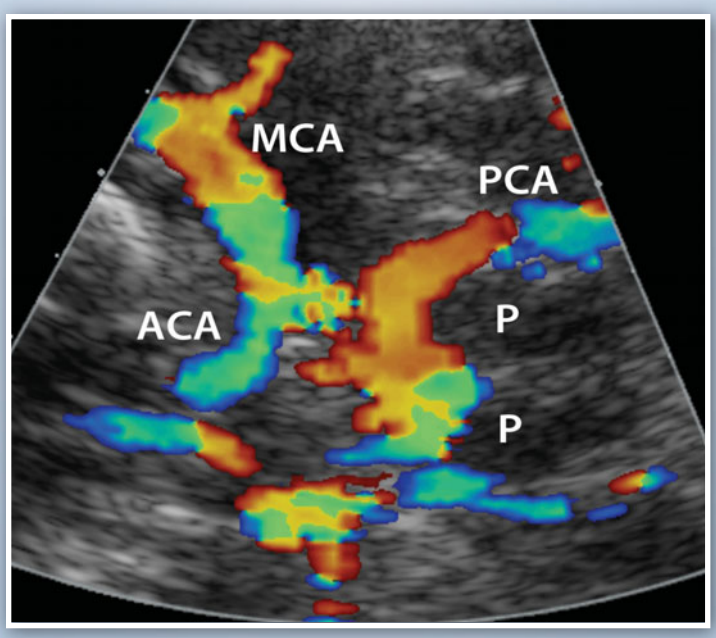
AIUM Practice Guideline for the Performance of a

Transcranial Doppler Ultrasound Examination for Adults and Children

Guideline developed in conjunction with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU).



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The American Institute of Ultrasound in Medicine (AIUM) is a multidisciplinary association dedicated to advancing the safe and effective use of ultrasound in medicine through professional and public education, research, development of guidelines, and accreditation. To promote this mission, the AIUM is pleased to publish, in conjunction with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU), this *AIUM Practice Guideline for the Performance of a Transcranial Doppler Ultrasound Examination for Adults and Children*. We are indebted to the many volunteers who contributed their time, knowledge, and energy to bringing this document to completion.

The AIUM represents the entire range of clinical and basic science interests in medical diagnostic ultrasound, and, with hundreds of volunteers, the AIUM has promoted the safe and effective use of ultrasound in clinical medicine for more than 50 years. This document and others like it will continue to advance this mission.

Practice guidelines of the AIUM are intended to provide the medical ultrasound community with guidelines for the performance and recording of high-quality ultrasound examinations. The guidelines reflect what the AIUM considers the minimum criteria for a complete examination in each area but are not intended to establish a legal standard of care. AIUM-accredited practices are expected to generally follow the guidelines with recognition that deviations from these guidelines will be needed in some cases, depending on patient needs and available equipment. Practices are encouraged to go beyond the guidelines to provide additional service and information as needed.

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I. Introduction

The clinical aspects contained in specific sections of this guideline (Introduction, Indications, Specifications of the Examination, and Equipment Specifications) were developed collaboratively by the American Institute of Ultrasound in Medicine (AIUM), the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU). Qualifications and Responsibilities of Personnel, Written Request for the Examination, Documentation, and Quality Control and Improvement, Safety, Infection Control, and Patient Education vary among the organizations and are addressed by each separately.

A transcranial Doppler (TCD) ultrasound examination is a noninvasive technique that assesses blood flow within the circle of Willis and the vertebrobasilar system.

II. Indications

A. Indications for a TCD ultrasound examination of adults include but are not limited to:

1. Detection and follow-up of stenosis or occlusion in a major intracranial artery in the circle of Willis and vertebrobasilar system, including monitoring of thrombolytic therapy for acute stroke patients.[1–3]
2. Detection of cerebral vasculopathy.[4,5]
3. Detection and monitoring of vasospasm in patients with spontaneous or traumatic subarachnoid hemorrhage.[2,6]
4. Evaluation of collateral pathways of intracranial blood flow, including after intervention.[7]
5. Detection of circulating cerebral microemboli.[3]
6. Detection of right-to-left shunts.[2,8]
7. Assessment of cerebral vasomotor reactivity.[2,3]
8. As an adjunct in the confirmation of the clinical diagnosis of brain death.[2–4,9,10]
9. Intraoperative and periprocedural monitoring to detect cerebral embolization, thrombosis, hypoperfusion, and hyperperfusion.[2,11]
10. Evaluation of sickle cell disease to determine the stroke risk.[12–17]
11. Assessment of arteriovenous malformations.[4]
12. Detection and follow-up of intracranial aneurysms.
13. Evaluation of positional vertigo or syncope.[18]

B. Additional applications in children include but are not limited to:

1. Assessment of intracranial pressure and hydrocephalus.[19,20]
2. Assessment of hypoxic ischemic encephalopathy.[4,5]
3. Assessment of dural venous sinus patency.[4,5]

III. Qualifications and Responsibilities of Personnel

See www.aium.org for AIUM Official Statements including *Standards and Guidelines for the Accreditation of Ultrasound Practices* and relevant Physician Training Guidelines.

IV. Written Request for the Examination

The written or electronic request for an ultrasound examination should provide sufficient information to allow for the appropriate performance and interpretation of the examination.

The request for the examination must be originated by a physician or another appropriately licensed health care provider or under the physician's or provider's direction. The accompanying clinical information should be provided by a physician or another appropriate health care provider familiar with the patient's clinical situation and should be consistent with relevant legal and local health care facility requirements.

V. Specifications of the Examination

Cerebral blood flow velocities and the resistive index can be variable and are affected by age, the arterial carbon dioxide level, and cerebral and systemic perfusion and thus are influenced by the state of patient arousal, the effect of mechanical ventilation and suctioning, and the presence of systemic shunts, cardiac disease, current fever, or anemia. It is important to perform examinations when patients (especially children) are awake, quiet, and calm. If possible, examinations should not be performed if the patient has been sedated or anesthetized earlier the same day.

A. Infants With an Open Fontanelle

Depending on the size of the child, sector, curvilinear, or linear transducers with gray-scale and Doppler frequencies from 5 to 10 MHz should be used. Duplex ultrasound is preferred over nonimaging Doppler methods for more precise localization and insonation within the targeted vessels when imaging through the fontanelles.

In infants, open fontanelles provide acoustic windows to the intracranial circulation. The internal carotid vessels and the branches of the circle of Willis can be interrogated through the anterior fontanelle in coronal and sagittal planes (although the middle cerebral artery [MCA] may be better interrogated via a transtemporal approach; see below).[4] For basic assessment of global cerebral arterial flow and waveform analysis, interrogation of the pericallosal branch of the anterior cerebral artery (ACA) on sagittal imaging via the anterior fontanelle is the simplest, most reliable approach. The superior sagittal sinus can be evaluated through an open sagittal suture. Imaging of the posterior circulation can be performed via the foramen magnum or via the posterolateral fontanelle located just posterior to the mastoid process.[21,22]

When assessing for elevated intracranial pressure, interrogation of the pericallosal branch of the ACA both before and after gentle compression of the anterior fontanelle can be performed.[23,24] Care should be taken to minimize the degree and duration of compression.

B. Adults and Children After Fontanelle Closure

Either transcranial spectral Doppler sonography, power M-mode Doppler sonography, or transcranial color-coded duplex sonography (TCCS) should be performed with the patient supine. If velocity reference standards have been previously acquired with nonimaging TCD methods (and thus not angle corrected), velocity measurements with imaging methods (TCCS) should not be angle corrected to allow comparison with reference values.[5,25] It should be noted that velocities obtained with duplex imaging equipment may be lower than those obtained with nonduplex imaging equipment. Therefore, stroke risk cut points obtained with imaging equipment may need to be lowered.[26–28] However, if validated reference values for angle-corrected TCCS velocities exist in an ultrasound laboratory, and a sufficient length of a vessel is visualized during TCCS to allow angle correction, then angle-corrected velocities can be obtained.[29]

In adults, a TCD examination requires the use of lower-frequency transducers to adequately penetrate the calvarium to produce useful gray-scale images and Doppler signals. A 2- to 3-MHz transducer or multifrequency transducer with 2- to 3-MHz spectral Doppler capability is commonly required.[4] For children or small adults, adequate imaging may be possible at higher frequencies.

Representative views should be obtained of each of the distal internal carotid arteries (ICAs), the ACA, MCA, and posterior cerebral artery (PCA) in the circle of Willis, and the vertebrobasilar system. Any abnormalities should be evaluated and documented. Both the left and right sides of the circulation should be interrogated, unless the examination is performed to follow up a known abnormality of a specific vessel.

After fontanelle closure, the two available acoustic windows are the temporal bone and the foramen magnum. The transtemporal window is the thinnest portion of the temporal bone (the pterion) located cephalad to the zygomatic arch and anterior to the ear (Figure 1).

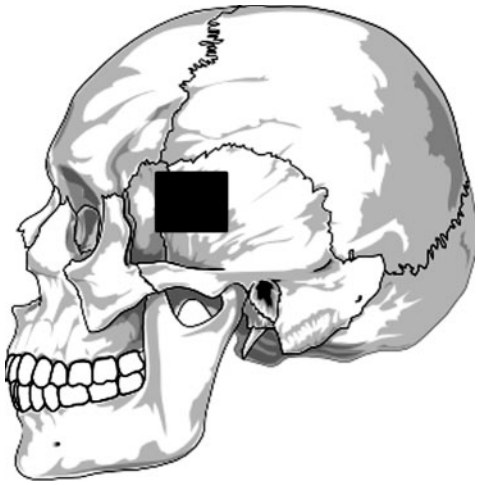

Figure 1. Location of the pterion.

On gray-scale images, the hypoechoic heart-shaped cerebral peduncles and echogenic star-shaped basilar cistern are the reference landmarks for the circle of Willis (Figure 2).[30,31]

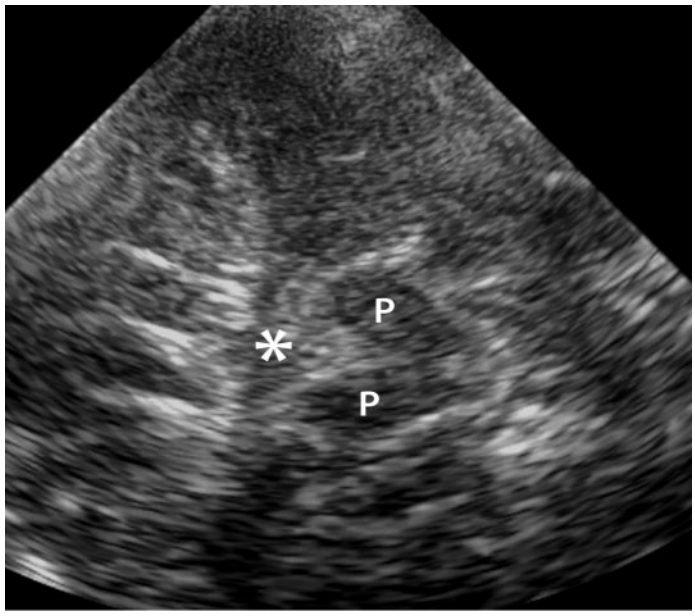

Figure 2. Transtemporal gray-scale image showing the cerebral peduncles (P) with the echogenic basilar cistern (*) located just anteriorly.

Anterior and lateral to the cistern is the MCA, which should be insonated using color and spectral Doppler ultrasound (Figure 3).[4]

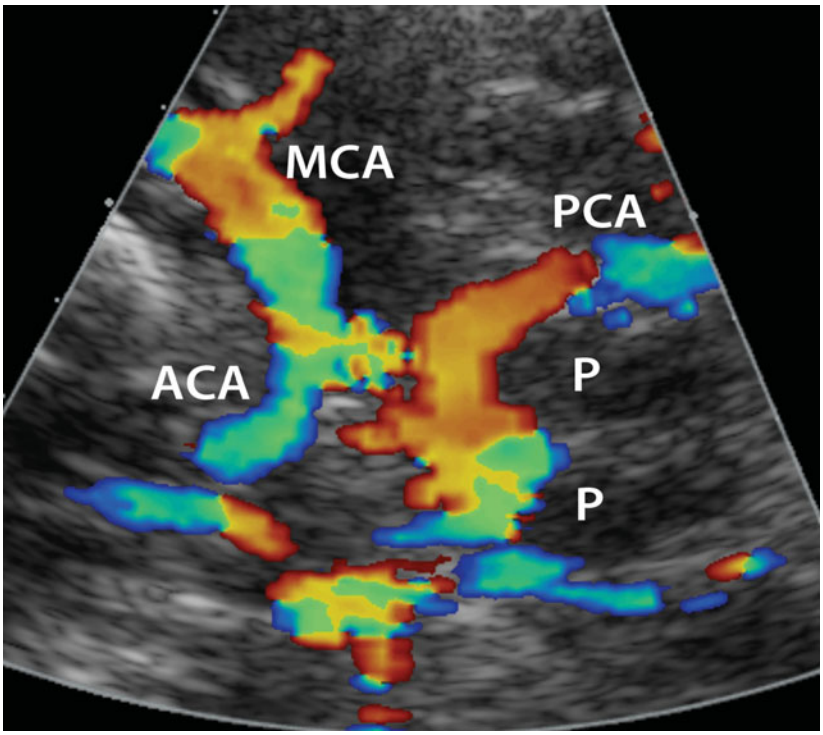

Figure 3. Transtemporal color Doppler image of the circle of Willis showing the MCA with flow directed toward the transducer. The ACA flow is directed away from the transducer. The PCA is seen coursing around the cerebral peduncles (P).

Depending on the clinical indication, the MCA should be interrogated at 2- to 5-mm intervals from its most superficial point below the calvarium to the bifurcation of the A1 segment of the ACA and the M1 segment of the MCA.[32] Flow in the MCA is directed toward the transducer. The ACA should be interrogated distal to the bifurcation. Flow in the ACA should be away from the transducer (Figure 3). The PCA is found located immediately anterior to the heart-shaped cerebral peduncles and has forward flow toward the transducer in the P1 segment, whereas flow in the more distal P2 segment is directed away from the probe.

The foramen magnum can be used to study the vertebral and basilar arteries. The patient should be turned to one side and the neck flexed so that the chin touches the chest. The transducer is placed over the upper neck at the base of the skull and angled cephalad through the foramen magnum toward the nose.[31] For imaging Doppler studies, the reference landmark is the hypoechoic medulla. The vertebral arteries should be interrogated at 2- to 5-mm intervals. On TCCS, the vertebral arteries have a V-shaped configuration as they extend superiorly to form the basilar artery. Flow in the vertebral and basilar arteries is directed away from the transducer and should be interrogated up to the distal end of the basilar artery.

In patients with suspected carotid stenosis or occlusion, a transorbital examination of the ophthalmic arteries and carotid siphons can be performed.[33,34] These images must be performed at reduced power settings with a mechanical index not to exceed 0.23 to prevent ocular injury.[35]

In patients with subarachnoid hemorrhage and signs of vasospasm, a submandibular approach can be used to sample the distal ICA in the neck to calculate mean flow velocity ratios between the MCA and ICA, the so-called hemispheric or Lindegaard index.[36] Both approaches are performed with 2-MHz spectral Doppler ultrasound without angle correction.

Doppler waveform analysis of the cerebral arteries should be performed. In children with sickle cell disease, this analysis should include the time-averaged maximum mean velocity according to the Stroke Prevention Trial in Sickle Cell Anemia criteria.[4,14–17] In adults, either the mean flow velocity or peak systolic velocity and pulsatility and resistive indices should be recorded. The velocity is obtained at 2- to 5-mm intervals along the entire course of the vessel. Velocity can be measured either by an automatic tracing method or by manual placement of cursors.

Angle-corrected TCCS velocities have typically not been used for studies such as pediatric sickle cell evaluation, but this technique has been recommended for some studies such as adult stroke evaluation if TCCS angle-corrected reference values are validated for a specific group of patients.[5,25,29,37] The use of angle correction thus depends on the clinical information needed and the reference standards used in clinical decision making. The written report should indicate whether angle correction was used.

VI. Documentation

Adequate documentation is essential for high-quality patient care. There should be a permanent record of the ultrasound examination and its interpretation. Images of all appropriate areas, both normal and abnormal, should be recorded. Variations from normal size should be accompanied by measurements. Images should be labeled with the patient identification, facility identification, examination date, and side (right or left) of the anatomic site imaged. An official interpretation (final report) of the ultrasound findings should be included in the patient's medical record. Retention of the ultrasound examination should be consistent both with clinical needs and with relevant legal and local health care facility requirements.

Reporting should be in accordance with the *AIUM Practice Guideline for Documentation of an Ultrasound Examination.*

VII. Equipment Specifications

A TCD examination should be performed with a real-time imaging scanner with Doppler capability using a 1- to 5-MHz transducer that can penetrate the temporal bone and foramen magnum or a nonimaging Doppler instrument (TCD or power M-mode Doppler) with 2-MHz pulsed Doppler capability. Doppler images and/or data are obtained at 2- to 5-mm intervals with a 3- to 6-mm gate. Color or spectral Doppler ultrasound should be used to locate the intracranial vessels in all cases. The color gain settings should be maximized so that a well-defined vessel is displayed. The Doppler setting should be adjusted to obtain the highest velocity in all cases. The Doppler power output should be as low as reasonably achievable.

VIII. Quality Control and Improvement, Safety, Infection Control, and Patient Education

Policies and procedures related to quality control, patient education, infection control, and safety should be developed and implemented in accordance with the AIUM *Standards and Guidelines for the Accreditation of Ultrasound Practices.*

Equipment performance monitoring should be in accordance with the AIUM *Standards and Guidelines for the Accreditation of Ultrasound Practices.*

IX. ALARA Principle

The potential benefits and risks of each examination should be considered. The ALARA (as low as reasonably achievable) principle should be observed when adjusting controls that affect the acoustic output and by considering transducer dwell times. Further details on ALARA may be found in the AIUM publication *Medical Ultrasound Safety*, Second Edition.

Acknowledgments

This guideline was revised by the American Institute of Ultrasound in Medicine (AIUM) in collaboration with the American College of Radiology (ACR), the Society for Pediatric Radiology (SPR), and the Society of Radiologists in Ultrasound (SRU) according to the process described in the AIUM *Clinical Standards Committee Manual.*

Collaborative Committee: Members represent their societies in the initial and final revision of this guideline.

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