Transcranial Doppler (TCD) ultrasonography has been used since 1982, when Aaslid et al. introduced a transcranial Doppler device with a pulse sound emission of 2 MHz that could penetrate the skull successfully and accurately measure both blood flow direction and velocity in the basal cerebral vessels and in the circle of Willis. During the last several years TCD has become accepted as a tool for measuring physiological parameters of blood flow in the major intracranial arteries and as well as for evaluating several intracranial vascular pathological processes.

Through selected acoustic windows such as the cranial foramina and thin regions of the skull, a complete transcranial Doppler (TCD) TCD ultrasonography examination samples the following arteries: ophthalmic, intracranial carotid, middle, cerebral, anterior, and posterior cerebral, posterior cerebral, intracranial vertebral, and basilar arteries, through selected acoustic windows such as cranial foramina and thin regions of the skull.

Various procedures for the performance of TCD ultrasonography examinations have been described. However, the core principles underlying TCD ultrasonography examination techniques, however, are widely agreed upon (1–5).

We summarize here—This chapter summarizes the TCD ultrasonography examination procedures used routinely in our laboratory. The techniques described have been efficient and reliable in our hands. Additional technical innovations, such as improved probe
sensitivity allowing insonation of the straight sinus and other components of the venous circulation, the development of microbubble ultrasound contrast media enabling early detection of blood-brain barrier disruption, and enhanced sampling through the temporal window, B-mode, and color flow imaging, and embolus detection are discussed in elsewhere other chapters. [UP]

[H2] Laboratory Setup[

[H3] Examination Room[/H3] Features of the Room

[UP] The laboratory suite should be situated in a tranquil environment so that ambient noise does not interfere with the examiner’s ability to detect audio signals from insonated vessels. Dimmer control allows adjustment of overhead lighting to meet the contrasting demands of patient observation and the probe positions, and monitoring the video data display monitoring. A generous amount of space in the examination room facilitates the maneuvering of patients who are confined to wheelchairs or stretchers. [UP]

[H3] Examination Room, Tables and Chairs[/H3]

[UP] The examination table should comfortably support recumbent patients. A height-adjustable table has the advantages of enabling the safe transport of patients to and from transport on and off safely at a low elevations, while allowing the examiner to select a higher position for comfortable execution of probe manipulations. Examination is generally performed in a higher position with the technician seated in a firm, tall stool at the head of the supine patient. The technician may prefer a swivel stool with a wheeled base that allows for easy maneuvering to examination positions on either side of the patient. The examination room should
also be furnished with a cushioned chair for the posterior circulation portion of the examination, for when the patient will be asked to assume a seated position with the head tilted forward. —The TCD ultrasonography examination used in the assessment of vasospasm after SAH is usually conducted in the intensive care unit. In such circumstances, ultrasonography examination is performed at the bedside but the examiner must contend with a critically ill and sometimes uncooperative patient, head dressing, intracranial bolt, post-surgery drainage, intravenous lines and pumps or background noises from the monitors, any of which pose limitations to the TCD ultrasonography examination.

Examination Room

Equipment

TCD ultrasonography transcranial Doppler instruments have evolved rapidly during recent years. Older machines have maintained their utility because the type of information obtained — data from the Doppler spectrum — was displayed quite well on the early units. The newer units improved ergonomic features of the probe and color display, and are programmable, with storage, post-processing and trending capabilities. These newer instruments also offer the capability to perform bilateral simultaneous studies, and enhanced software for evaluation of CO₂ responses, and embolus detection. Newer devices include TCD mapping systems which automatically generate three-dimensional images of vascular trees as the study is performed, and color-coded B-mode transcranial sonographic systems which allow noninvasive and direct visualization of the cerebral vessels and brain parenchyma.
Because the insonation angle represents the most important technical variable affecting Doppler velocity, these newer devices enable a better documentation and discrimination of the spatial relationship of the basal cerebral arteries and angle-corrected measurements of the blood flow velocities, since the insonation angle represents the most important technical variable affecting Doppler velocity. In conventional TCD ultrasonography applications, the angle of insonation is assumed to be less than 30 degrees. Correction for the angle of insonation, a cosine function and insignificant at small angles, becomes of importance at a large angle of insonation. [UP]

The optimal instrument used for TCD ultrasonography examinations depends upon the needs of the particular laboratory. For instance, if most of the studies are to be performed in the ICU, for example, an intensive care unit, a portable TCD ultrasonography unit that can be easily maneuvered into different positions would be useful. If, however, many of the studies will include carotid and transcranial evaluation of patients with cerebrovascular diseases, an instrument that can perform both of these evaluations may prove to be the most economical. [UP]

In standard clinical TCD ultrasonography instruments, the examiner positions the handheld transducer. In three-dimensional TCD mapping systems, the transducer is anchored to a headpiece placed over the patient’s head, and a computerized readout of probe position and sample depth allows calculation of the intracranial position of sample volumes. A microprocessor integrates data acquired during systematic alterations of probe alignment to generate multiplanar images of blood flow. Three-dimensional TCD mapping systems have been demonstrated to successfully insonate vessels through the temporal window at
rates comparable with those of hand-held systems, and may be more accurate in identifying the posterior cerebral artery (PCA) and supraclinoid internal carotid artery (ICA) (7).

Each uses a pulsed Doppler system with a low-frequency (1- to 2 MHz ultrasonic signal) that provides adequate penetration through thin areas of the cranium. Higher frequencies such as the 3 to 10 MHz probe frequencies ordinarily employed in extracranial ultrasound examination do not penetrate bone and soft tissue sufficiently to allow insonation of intracranial vessels. A hand-held transducer, which operates as both transmitter and receiver, is range gated and directionally sensitive. Range gating provides depth discrimination, allowing the technician to position the sample volume and to take measurements at selected sites 25 to 100 mm from the transducer. Directional resolution allows for separation and assessment of flow directions distinguishing signals moving toward and away from the transducer.

The ultrasound beam is optimally focused to a discrete sample volume. The sample volume size varies with the depth being sampled and between instruments, and is approximately 3 to 6 mm x 3 to 6 mm. Such sample dimensions ordinarily exceed the cross-sectional area of the small cerebral arteries so that all of the velocities within the lumen are sampled. This results in a broadened spectral waveform appearance similar to that seen in continuous-wave Doppler studies of the extracranial circulation. Ultrasound gel optimizes coupling of the patient’s skin and the transducer surface. A high-pass filter within the receiver removes signals produced by arterial wall thumps and probe position movements. A microprocessor then carries out fast Fourier transform analysis of the signal, enabling real-time spectral display. On a video console, the spectral analyzer exhibits velocity along the y axis, and...
varies the brightness of the display to reflect the amplitude or intensity of the signal. Several different TCD systems combining these elements are commercially available.

This chapter focuses on standard examination with a standard TCD device. More complex examination techniques using advanced instruments are discussed in other chapters.

Data Acquisition and Storage

TCD instruments generally contain a microprocessor that analyzes the spectral signal to derive such measures as peak velocity, mean velocity and pulsatility, and may display values for these measures on the video monitor. Hard copy records of waveforms and accompanying data derivations may be made using any of several available storage media, including Polaroid photographs, thermal paper copies, or videocassette tapes. Hard copies enable review of these records when interpreting the study at a later date. Data may be stored directly on optical disk as well. A standardized form should be developed for the recording of data by the technician. This form may be used to prepare reports in a uniform fashion, and to enter data into computerized files should the compilation of a database be desired.

Patient Orientation

A short explanation of the purpose, method, and noninvasive nature of the TCD examination reassures the patient, a worthy end in itself as well as a means of minimizing stress-related fluctuations in cerebral blood flow. If information on the referral note is incomplete, it is...
helpful to ask the patient if he or she has recently experienced any neurologic symptoms to determine the clinical questions the referring physicians wishes the study to address.

### Patient Dress

Eyeglasses should be removed and hats, scarves and other headgear placed aside. A towel is draped over the top of the patient’s garments to prevent excess gel from falling onto a shirt or blouse. Patients who have recently had craniofacial surgery or injuries, (e.g., a patient who has had a saccular aneurysm clipped and is undergoing TCD evaluation for vasospasm) may have surgical dressings or suture lines that obstruct access to acoustic windows. Sterile ultrasound gel should be used when attempting to place the probe in such vicinities.

### Extracranial Circulation

Because flow dynamics in the feeding cervical vessels strongly influence the intracranial circulation, many patients have extracranial duplex carotid studies performed before TCD examination. TCD findings are most accurately interpreted when extracranial perturbations of flow are recognized and taken into account.

### Vascular Anatomy

The aim of a TCD study is the comprehensive assessment of blood flow velocities in the basal cerebral arteries. As an examination proceeds, the interpreter gradually constructs a mental map of the arterial network at the base of the skull, integrating serially obtained data concerning individual vessel segments into a coherent image of blood flow velocity about the circle of
Willis. A thorough understanding of the standard anatomy and common variants of the circle of Willis is a prerequisite to the performance and interpretation of TCD studies.  

**Standard Anatomy**

The ICA arises at the bifurcation of the common carotid in the midcervical region ([cite](Figure 2.1)[cite]). In its extracranial course, the ICA is bereft of branches. The ICA enters the skull in the carotid canal and courses anteromedially in the petrous portion of the temporal bone. Passing through the foramen lacerum, the petrous segment of the ICA becomes the cavernous segment. The ICA travels medially within the cavernous sinus, angles sharply forward along the lateral margin of the sphenoid sinus, and then turns rostrally, forming an S-shaped double curve that led Moniz to christen the ICA in this region the carotid siphon, an important target for TCD examination. The ICA pierces the dura mater medial to the anterior clinoid process, giving rise to its short supraclinoid segment, the source of three important branches: the ophthalmic artery (OA), the posterior communicating artery (PComA), and the anterior choroidal artery ([15,16]). The OA is the first supraclinoid branch of the ICA, running forward into the orbit through the optic foramen. The branches of the OA often participate in rich anastomotic connections with branches of the external carotid artery. Consequently, the OA may serve as an important channel for collateral flow from the external carotid to the ICA circulations. The ICA bifurcates into two major terminal branches, the anterior cerebral artery (ACA), which travels anteromedially, and the middle cerebral artery (MCA), which courses laterally. ([UP])

The ACA nourishes the anterior, superior, and medial portions of the frontal lobes and the medial surface of the cerebral hemispheres extending as far back as the splenium of the corpus callosum. The artery has been divided into a proximal (A1) segment, running from the ACA...
origin to its junction with the anterior communicating artery (AComA), and distal, postcommunicating (A2 through A5) segments, which are superoposteriorly around the corpus callosum. In different series of cadaver studies the median intraluminal diameter of the A1 segment ranged from 1.6 to 2.1 mm and its median length measured 12.7 to 13.5 mm (17–21).