# RESEARCH COLLECTION ON
# ULTRASOUND VOL. 1

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Chapters from books edited by: **Philip Ainslie, Kerry Thoirs** and **Yasuhiro Honda**

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# Preface

This is the first of two volumes on the subject of ultrasound.

Since the Seventies, ultrasound imaging has been a vital diagnostic tool in hospitals and other clinical settings. It has many advantages over other techniques in terms of non-invasiveness, safety and economy and recently there have been major advances such as improvements to resolution/image quality and portability of equipment, which are increasing the scope of ultrasound still further, and enabling it to be used at point of care locations such as doctors' offices.

These books provide an extensive overview of the recent advances and current clinical applications of ultrasonography, including imaging of the breast, prostate, lungs, liver and ovaries. Topics covered include the development/application of 3D ultrasound, speckle noise reduction, ultrafast ultrasound imaging, contrast-enhanced ultrasound, Doppler ultrasound, intravascular ultrasound and the application of ultrasound during anesthesia, fetal monitoring and radiation therapy.

We believe that these books will provide essential insights into the latest techniques and applications for clinicians and imaging technicians, as well as hopefully providing the stimulus for further research.

# APPLIED ASPECTS OF ULTRASONOGRAPHY IN HUMANS

Edited by **Philip Ainslie**

# Transcranial Color-Coded Sonography

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## 1. Introduction

Transcranial color-coded sonography (TCCS) was first described in 1988 (Berland et al., 1988); it combines blood flow velocity measurements with non-invasive imaging of intracranial vessels and parenchymal structures at a high spatial resolution (Zipper & Stolz, 2002). TCCS is a combination of B-mode and pulsed wave (PW) Doppler sonography; therefore, it is possible to give a color-coded demonstration of the frequency shift or the reflected energy. Because of the addition of a B mode image to the PW Doppler function (Zipper et al., 2001), TCCD also offers a number of advantages and extensions compared to its precursor transcranial Doppler (TCD). The color-coded flow-velocity map serves as an examination tool for the presence of stenoses, occlusions, and collateral flow through the circle of Willis. This chapter reviews the role of TCCS in cerebrovascular disease and describes the principles, the use of ultrasound agents, the examination procedure and related typical pathological findings. The limitations of TCCS are also considered.

## 2. Principles of TCCS

TCCS combines gray scale imaging of intracranial parenchymal structures with imaging of intracranial vessels. Due to the presence of narrow ultrasound windows in the skull, transducers with transmission frequencies between 1.8 and 3.6 MHz are most commonly used for insonation (Baumgartner, 2003). The advantage over conventional TCD is that intracranial vascular structures can be displayed in the correct anatomical relationships to parenchymal structures, allowing angle corrected flow velocity measurements (Zipper & Stolz, 2002).

Either the frequency shift (fTCCS) or the energy of the Doppler signal (pTCCS) can be shown from the color-coding: fTCCS is dependent on the Doppler shift resulting from moving erythrocytes, providing information on flow direction and velocity; pTCCS is dependent on the integrated power of the back-scattered signal (Griewing et al., 1998). Both color-coded Doppler modes image the anatomical course of cerebral vessels, allowing estimates of insonation angles and measurement of angle-corrected velocities in defined depths and sample volumes using spectral Doppler sonography. fTCCS can be used to

identify flow direction and velocity, which allows the visual estimation of basal cerebral hemodynamics; this process facilitates the positioning of the Doppler sample volume and produces less tissue motion artifacts than pTCCS (Baumgartner et al., 1997a). Compared to fTCCS, pTCCS has a better signal-to-noise ratio, is not dependent on the angle of insonation and is not subject to aliasing (Bude et al., 1994).

## 3. Ultrasound contrast agents

Adequate bone windows need to be present in order to insonate the cerebral arteries. The temporal bone window becomes smaller and may disappear with advancing age and especially in postmenopausal women. To allow the investigation of patients with insufficient bone windows, ultrasound contrast agents (UCAs) that enhance the backscatter from blood and increase the signal-to-noise ratios can be administered to the patient. For example, the intrasound contrast agent 'Levovist' consists of transpulmonary stable microbubbles formed in a galactose suspension. This causes a signal increase of approximately 25 dB and therefore an improved signal-to-noise ratio (Riet et al., 1997). In general, current UCA are spheric particles, commonly known as microbubbles; microbubbles are typically reflective and can thus be separated from tissue. The microbubble concept comprises a gaseous component trapped by a shell structure. Currently, perfluorocarbon derivates are the gaseous component of choice, whereas phospholipids, human albumin or polymers are mainly used as shell material (Sauerbruch et al., 2009).

UCA are optimized ultrasound- scatters because of their oscillating behavior and their high reflectivity, which is about 1000fold higher in comparison to erythrocytes. The UCA mean diameter of approximately 2-4μm accounts for the strong oscillatory response at ultrasound wavelengths between 1-3.5 MHz (Sauerbruch et al., 2009). Measured flow velocities may therefore be higher when using UCA; therefore, to allow comparisons, follow-up examinations should also be performed with UCA. Although there is varying availability of UCA in different countries and a lack in studies with direct comparison of the different UCA, application of multiple small boli (e.g. in the case of Riet et al. (1997) Levovist was given in the following concentrations: 16 mL of 200 mg/mL; 10 mL of 300 mg/mL; and 8 mL of 400 mg/mL) or continuous intravenous infusion increases the length of the diagnostically useful time window (Nedelmann et al., 2009). Future research on the reliability and validity of different UCA is needed.

## 4. Examination procedure

For assessment of the cerebral arteries several acoustic windows are described: the transtemporal, transforaminal, transoccipital and transorbital windows. These examination procedures have been descrived in depth elsewhere (Baumgartner, 2003, Sauerbruch et al., 2009; Zipper et al., 2001; Zipper & Stolz, 2002) and will only be briefly overviewed here. The most common plane - to allow depiction of the circle of Willis - for the cerebrovascular exam is via the axial mesencephalic insonation plane through the temporal bone window (Nedelmann et al., 2009). The examination procedure for the temporal bone window is therefore described in this section.

Transtemporal insonation starts in B mode with an axial projection in the orbito-meatal line through the transtemporal window (Fig. 1 & 2). This projection shows the temporal axial mesencephalic or orbitomeatal scanning plane. These planes are essentially characterized in B mode by the butterfly shaped mesencephalon brain stem surrounded by an echogenic border, corresponding to the basal systems at a depth of about 5-9 cm. After identifying the mesencephalon the assessment is continued in color-coded B mode to investigate the cerebral vessels. Slight up- or downwards tilts of the transducer are necessary to follow the course of the vessel segments of the circle of Willis. Using this approach, the distal intracranial part of the internal cerebral artery (ICA) and - in most cases - the carotid siphon, the main stem (M1) and insular (M2) segments of the middle cerebral artery (MCA), the precommunicating (A1) segment of the anterior cerebral artery (ACA), and the precommunicating (P1) and postcommunicating (P2) segments of the posterior cerebral artery (PCA) can be reliably recognized and allocated in the color-coded B mode image (Baumgartner, 2003; Zipper et al., 2001; Zipper & Stolz, 2002). By convention, in fTCCS, a system setting can be chosen that codes a flow towards the probe red and away from the transducer blue; thus the ICA, M1 MCA, and P1 PCA are coded red; and parts of the carotid siphon, the A1 ACA, and the P2 PCA are coded blue (Zipper & Stolz, 2002).

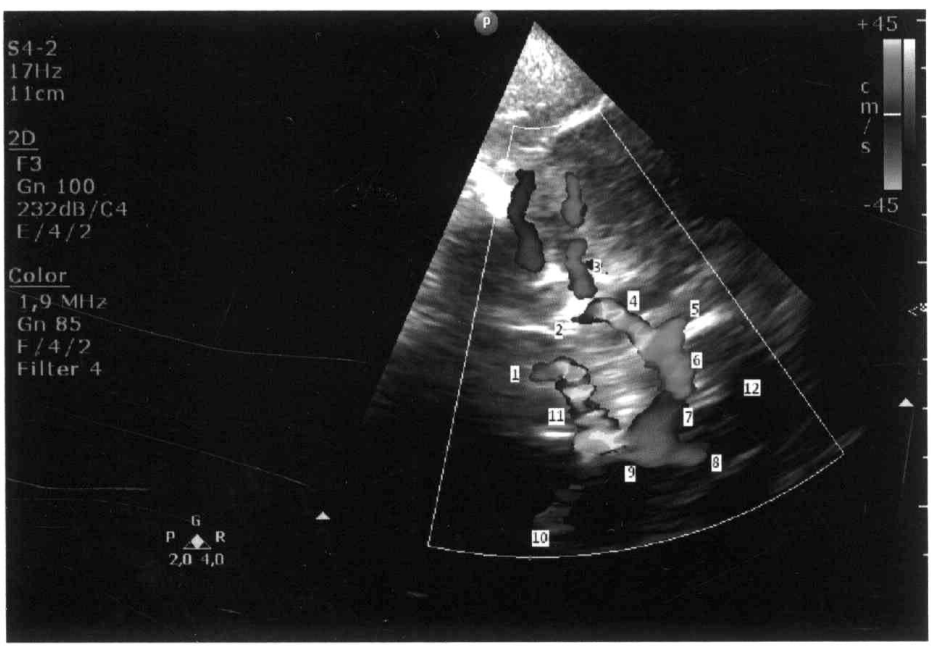


Fig. 1. Transtemporal insonation with fTCCS. Flow towards the probe is red and away from the transducer blue: (1) ipsilateral and contralateral A2 ACA, (2) ipsilateral A1 ACA, (3) ipsilateral M1 MCA, (4) ipsilateral posterior communicating artery, (5) ipsilateral P2 PCA, (6) ipsilateral P1 PCA, (7) contralateral P1 PCA (8) contralateral P2 PCA, (9) contralateral posterior communicating artery, (10) contralateral M1 MCA, (11) contralateral A1 ACA, (12) mesencephalon surrounded by both PCAs.