Perspectives in Medicine (2012) 1, 334—343

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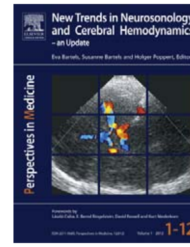
Bartels E, Bartels S, Poppert H (Editors):
New Trends in Neurosonology and Cerebral Hemodynamics — an Update.
Perspectives in Medicine (2012) 1, 334—343

journal homepage: www.elsevier.com/locate/permed



Transcranial sonography of the cerebral parenchyma: Update on clinically relevant applications

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KEYWORDS
Transcranial ultrasound;
Stroke;
Parkinsonism;
Substantia nigra;
Basal ganglia;
Electrode position control

Summary Transcranial B-mode sonography (TCS) is a neuroimaging technique that displays the brain parenchyma and the intracranial ventricular system through the intact skull. Sophisticated TCS systems can currently achieve a higher image resolution of echogenic deep brain structures than MRI under clinical conditions. The different imaging principle of TCS allows visualization of characteristic changes in several neurodegenerative diseases that can hardly be visualized with other imaging methods, such as substantia nigra hyperechogenicity in Parkinson's disease (PD), and lenticular nucleus hyperechogenicity in atypical Parkinsonian syndromes. The intracranial ventricular system and a midline shift due to space-occupying brain lesions (e.g., intracerebral hematomas) are reliably assessed with TCS. The present paper reviews recent studies on diagnostic TCS applications that, as a result, can be recommended for routine use in clinical practice. These applications include the bedside monitoring of space-occupying lesions in acute stroke patients, the early and differential diagnosis of PD, and the postoperative position control of deep brain stimulation electrodes. Novel technologies such as in-time fusion of TCS with MRI scans, automated detection of intracranial target structures, and improved 3D-image analysis promise an even wider application of TCS in the coming years.

Introduction

Transcranial B-mode sonography (TCS) is a neuroimaging technique that displays the brain parenchyma and the intracranial ventricular system through the intact skull. Its different imaging principle allows visualization of characteristic changes in several neurodegenerative diseases that can hardly be visualized with other imaging methods, such as substantia nigra (SN) hyperechogenicity in Parkinson's disease (PD) [1,2]. While TCS has been performed in children already in the 1980s and 1990s of the last century [3,4], the clinical application of TCS in adults has developed only subsequently since the TCS imaging conditions are much more difficult in adults because of the thickening of temporal bones with increasing age [5]. In the 1990s first studies showed that TCS allows the visualization of major parenchymal structures, as well as lesions (mainly tumors and bleeding) from the lower brainstem up to the parietal lobe [6—10], and well reproducible measurements of the whole ventricular system [11]. Due to the technological advances of the past decade a high-resolution imaging of deep brain structures is meanwhile possible in the majority of adults [2,12,13]. Present-day TCS systems can achieve a higher image resolution in comparison not only to former-generation systems, but currently also to MRI under clinical conditions (Fig. 1) [13]. A sophisticated clinical high-end TCS system was shown to gain an in-plane image

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2211-968X
doi:10.1016/j.permed.2012.02.014

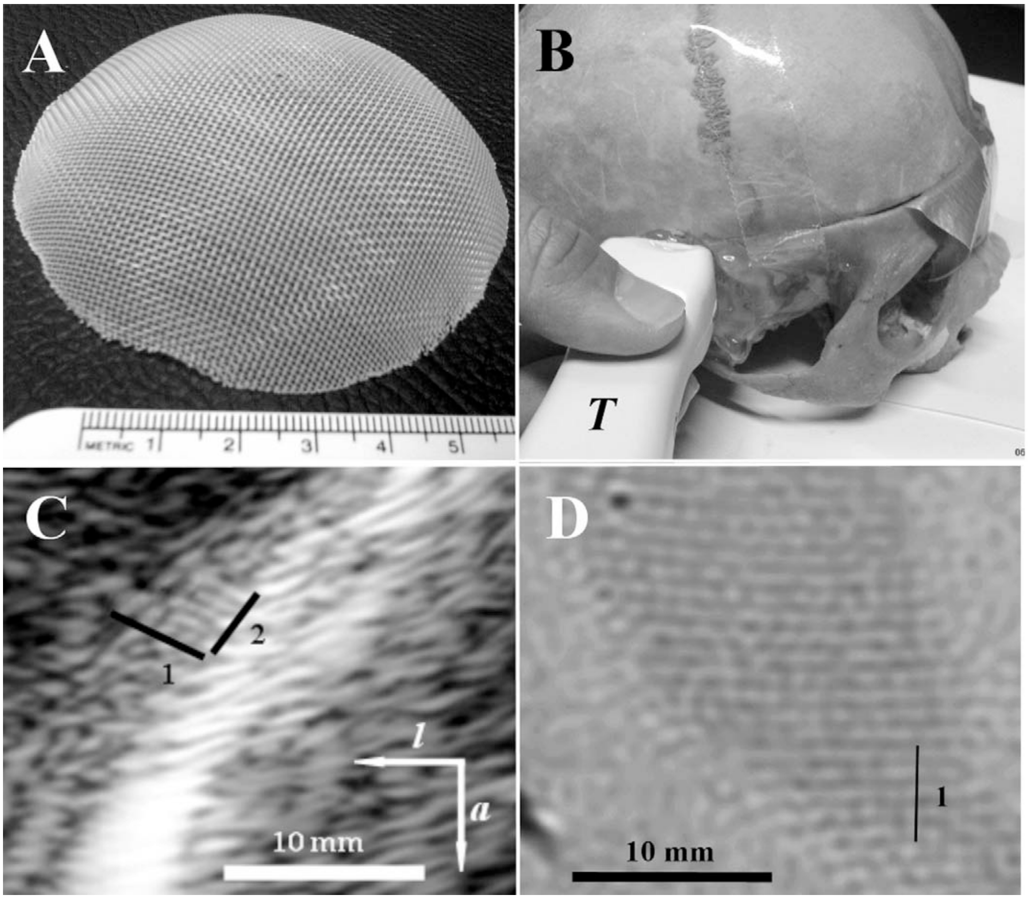

Figure 1 Comparison of transcranial sonography (TCS) and MRI with respect to image resolution of the network structure of a kitchen strainer placed within a human skull phantom filled with ultrasound gel. (A) Photograph of the kitchen strainer consisting of polyamide threads forming a 1.1 mm × 0.8 mm network. (B) The transducer (T) was placed at preauricular position for TCS. (C) Using a contemporary TCS system, the network structure of the intracranially located strainer could be clearly visualized (*a* = axial direction, *l* = lateral direction, 1 = bar indicating five threads with 1.1 mm distance, 2 = bar indicating five threads with 0.8 mm distance). (D) With MRI, simulating clinical conditions, the network structure was not visualized (1 = bar indicating five threads with 1.1 mm distance) [13].

resolution of intracranial structures in the focal zone of about 0.7 mm × 1.1 mm [13]. Beside high image resolution, contemporary TCS systems also offer high mobility, and TCS images of good quality are meanwhile obtained with distinct hand-held TCS systems [14]. Further advantages of TCS are its non-invasiveness, low costs, high acceptance by the patients, and relative independence from movement artefacts. This has promoted the development of a number of clinical TCS applications especially in patients with movement disorders, and in patients who need bedside assessment. An important milestone was the establishment of consensus guidelines on TCS in movement disorders [1], which was triggered by an activity of the European Society of Neurosonology and Cerebral Hemodynamics (ESNCH) in 2004. The use of ultrasound contrast agents offers an improved assessment on TCS of patients with acute stroke [15—17], with brain tumors [18], and inflammatory brain disorders [19], but is still on an experimental level and will be reviewed in another chapter of this serial.

The present paper reviews TCS studies without contrast agent application published in the past decade that assessed novel TCS applications, which can be, as a result, recommended for clinical use. These applications include the monitoring of space-occupying lesions in acute stroke patients, the early and differential diagnosis of PD, and the postoperative position control of deep brain stimulation (DBS) electrodes.

TCS system settings and scanning procedures

For TCS, a contemporary high-end ultrasound system, as applied also for transcranial color-coded cerebrovascular ultrasound, equipped with a 2.0- to 3.5- (1.0- to 5.0-) MHz transducer can well be used. It has to be considered that certain measurements, e.g., of the size of a hyperechogenic area are dependent on the applied ultrasound system and the individual system settings. System parameters, such as the width of ultrasonic beam, the line density, and even the age of the probe influence the image resolution. Therefore, reference values need to be obtained (and ideally updated for the same probe every 2—3 years) separately for each ultrasound system. The following system settings are recommended: penetration depth 14—16 cm,