Ultrasound examination of carotid and vertebral arteries

Abstract Ultrasound is the most widespread diagnostic procedure in obstructive disease of the arteries supplying the brain. The combined non-invasive information on morphology and function makes duplex ultrasound the procedure of choice in screening and follow-up of carotid artery disease. This review deals with all relevant aspects of color duplex ultrasound of the carotids and the vertebral arteries. After a short introduction into the clinical background, the paper focuses on aspects of examination technique. In the main part of the review the relevant ultrasound findings in carotid artery disease are discussed. The different methods for grading stenoses of the internal carotid artery are explained in detail. Other relevant pathologies, such as vertebral artery disease, dissection and aneurysms, are briefly mentioned. The clinical value of ultrasound in the work-up of carotid and vertebral artery disease is briefly discussed in comparison with other imaging procedures.

Keywords Carotid arteries · Vertebral arteries · Color duplex ultrasound · Stroke

Introduction

Stroke is one of the leading causes of death in industrialized countries [1, 2]. Approximately one-third of acute cases have a fatal outcome. In many patients, survival means prolonged and often irreversible disability. The paralysis following a brain attack frequently leads to complete dependence on nursing care and permanent speech disorders that impair the stroke victim’s ability to communicate.

Four-fifths of all ischemic events are heralded by arteriosclerosis. The large majority of pathological changes affect the extracranial arteries that supply the brain and are especially prevalent at the carotid bifurcation. Over the past years, numerous multicenter studies have investigated the merits of surgical interventions to repair carotid stenoses (e.g. ECST, NASCET, ACAS) [3, 4, 5, 6, 7]. All studies have proposed limits defining the respective degree of stenosis above which a clinically favorable outcome of surgery can be expected. When specific inclusion criteria were applied, both symptomatic and asymptomatic patients benefited from surgical therapy. The two randomized studies (NASCET, ECST) on the efficacy of carotid thrombendarterectomy (TEA) in symptomatic patients [3, 4, 5, 6, 7, 8, 9] showed that patients with high-grade carotid artery stenoses, defined as a diameter reduction of between at least 70–80%, who were treated with surgery achieved a greater benefit than the group receiving conservative treatment. Even asymptomatic patients with carotid stenoses of at least 60% diameter reduction can benefit from carotid surgery. The ACAS study [8, 10] showed that surgery initially led to a significant risk reduction (absolute 5.8%, relative 55%). However, more recent meta-analyses indicate that carotid TEA reduces the absolute risk in asymptomatic patients by only approxi-
mately 2% [4]. While stent-supported percutaneous transluminal angioplasty (PTA) of the carotid artery has gained importance in recent years [11, 12, 13, 14, 15, 16, 17], the long-term results have not yet been verified in randomized studies.

The extracranial distribution of most vascular lesions makes them accessible to detection by ultrasound imaging. The examination aims at determining nature, localization, and extent of the vascular lesions. Many of the above-mentioned therapeutic studies of the past were followed by a great number of diagnostic studies comparing the results of ultrasound and invasive angiographic procedures, since all the data from the large multicenter studies had been based solely on the angiographic estimation of the degree of stenosis [18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31].

The carotid arteries are a classic area of application for diagnosis by Doppler ultrasound. Before the advent of duplex technology, diagnosis was based on the analysis of continuous wave (CW) Doppler waveforms, including direct examination of the carotid artery and the indirect evaluation of the periorbital arteries using compression tests. Color duplex ultrasound allows for the simultaneous visualization of vascular lesions in the gray-scale image (plaque, stenosis, occlusion) and the associated abnormalities in flow in the color-encoded image (intraspecial velocity increase, poststenotic flow disturbances, lack of flow signal due to occlusion). After demonstration of pathological findings by color duplex, hemodynamic quantification of the pathology is achieved by analysis of Doppler spectral wave forms.

**Examination technique**

Before starting an ultrasound examination of the neck arteries, the patient's relevant neurologic history must be taken. The ultrasound examination should be conducted according to a standardized method, regardless of the clinical center. The patient is placed in the supine position with the head slightly extended. The examiner can either sit on the patient’s right side, as in abdominal sonography, or behind the patient’s head. The advantage of sitting by the patient's side is that it provides a spatial orientation identical to that of most other types of ultrasound examinations. It is also helpful when working in small quarters. For examination of specific vessels, the patient is told to turn the head to the opposite side. It is best to scan the left side of the neck first so that the patient can watch the initial part of the examination on the screen. The patient is told not to speak, but to breathe quietly and evenly. Swallowing should be avoided to prevent artifacts due to the motion of the laryngeal bones and soft tissue.

Duplex ultrasound of the carotids should always be conducted with linear transducers (5–7.5 MHz). After optimization of the gray-scale image, the PRF and color gain should be adjusted so that the color pixels completely fill the vessel of interest at least in systole. There should be no extraluminal color bleed. The flow image in non-stenotic vessel sections should be free of aliasing (no red-to-blue color shift). For more rapid orientation, imaging should start in the color duplex mode and can then be supplemented by quantitative analysis of Doppler spectral wave forms.

Some authors recommend the use of power Doppler for detection of carotid stenoses [32, 33], because they think it is easier to ascertain the degree of carotid stenosis due to the more complete filled-in part of the visualized lumen with color pixels. In individual situations, the use of intravenously administered ultrasound signal intensifiers is a similarly sensible way to improve the intravascular signal [34] and is particularly helpful for differentiating high-grade stenosis from an occlusion. The extent to which the B-flow method may become important in the detection and quantification of carotid stenoses is the subject of ongoing studies.

In order to quickly assess the anatomical and topographical situation, examination of the carotid vessels begins by continuous imaging from caudal to cranial in transverse section. Most lesions can already be identified in the transverse survey, whereby vessels are better defined in the longitudinal section. Examination of the carotid arteries starts by imaging the common carotid artery and the carotid bifurcation in transverse section, then identifying the arteries in the longitudinal image. Relevant diagnostic images will simultaneously define the outer and inner vessel walls and perfused lumen, which underscores the importance of optimizing the gray-scale and color images. While doing so, the examiner monitors the color flow pattern for evidence of abnormalities. Afterwards, Doppler spectra are recorded in the longitudinal scan plane in order to confirm the color findings. Nevertheless, representative, angle-corrected spectra including velocity measurements should always be recorded as a general rule. The hallmarks for distinguishing the internal carotid artery from the external carotid artery are listed in Table 1.

CW Doppler ultrasound relies on the visualization of vessels connecting the internal and external carotid systems (and the periorbital arteries in particular) using compression tests. By contrast, these vessels are less important in color-flow Doppler ultrasound. Basically, the retrobulbar portion of the ophthalmic artery can be demonstrated by placing the transducer over the closed eye. To better control the transducer and relieve pressure on the eye, one edge of the transducer can rest against the glabella. In practice, this indirect method of Doppler sonography is hardly ever necessary when color Doppler is used.