Color-Coded Doppler Imaging of Normal Vertebral Arteries

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Using color-coded Doppler sonography, we studied the vertebral arteries of 42 persons without history or physical signs of vertebrobasilar disease. The intertransverse portion of the vertebral artery was visualized in all persons on both sides. Its origin was visualized in 37 persons (88.1%) on the right side and in 28 (66.7%) on the left; the atlas loop was visualized in 32 persons (76.2%) on the right side and in 36 (85.7%) on the left. Four vertebral arteries were hypoplastic. Peak systolic blood velocity ranged from 19 to 98 (mean 56) cm/sec and peak diastolic blood velocity ranged from 6 to 30 (mean 17) cm/sec. Resistive indices ranged from 0.62 to 0.75 (mean 0.69). Thus, color-coded Doppler sonography seems to be a promising noninvasive method for the evaluation of hemodynamics in the extracranial portion of the vertebral arteries. (Stroke 1990;21:1222–1225)

For many years continuous-wave Doppler sonography has been the most important tool for the noninvasive investigation of the extracranial vertebral arteries. However, the vertebral arteries cannot be visualized with this technique, making identification of the vessels difficult. With the development of duplex Doppler systems, immediate visualization of the vertebral arteries and evaluation of blood flow characteristics at different locations within them became possible. In contrast to duplex Doppler sonography, color-coded Doppler sonography provides real-time information about blood flow during B-mode imaging. The advantages of this new technique in the study of the carotid arteries have been documented, but there are no reports in the literature of the evaluation of the vertebral arteries using it.

The aim of our study is to describe the appearance of normal vertebral arteries by color-coded Doppler sonography to provide basic information for further clinical studies.

Subjects and Methods

We studied 42 persons (19 women and 23 men, mean age 62.3 years) without history or physical signs of cerebrovascular disease related to the vertebrobasilar system. We used a color-coded Doppler sonography unit equipped with a 7.5-MHz linear array transducer (Acuson 128, Mountain View, Calif.). The system analyzed returning echoes for amplitude, phase shift, and frequency shift. Amplitude data were displayed as a gray-scale or tissue (B-mode) image. Moving structures (such as blood cells) caused phase and frequency shifts. Color (red or blue) depended on the direction of blood flow with respect to the transducer and could be selected by the operator. Color shade reflected the frequency shift and depended on the velocity of the blood and the angle of the sound beam in relation to the long axis of the vessel. The system also allowed application of pulsed Doppler ultrasound with the possibility of angle-corrected velocity measurements. The sample volume was 1.5 mm.

Sensitivity of the system for detecting motion was set for each subject to slightly above the level of color noise. In addition to the color display, Doppler waveforms were obtained from all parts of the vertebral artery. We measured maximum and minimum blood flow velocities as well as resistive indices calculated as 1−(end-diastolic blood velocity/peak systolic blood velocity). All examinations were recorded on videotape and reviewed by two observers who did not perform the examination.

Each person was examined in the supine position, with the shoulders kept down and with the head turned slightly to the opposite side. At the beginning of the examination, the probe was positioned on the lateral cervical region along the long axis of the carotid artery. To identify the middle portion of the vertebral artery, the scanhead was simultaneously shifted laterally and angled until the transverse processes of the cervical vertebrae and the intertransverse portion of the vertebral artery were readily seen. The course of the vessel was then followed down to the subclavian artery and up to the base of

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the skull. To visualize the cranial portion of the vertebral artery (atlas loop), the scanhead was positioned inferior to the mastoid process in an oblique plane pointing to the subject's contralateral eye.

For further analysis, we divided the extracranial course of the vertebral artery into three segments. Segment 1 included the ostium and the proximal portion of the artery, segment 2 the intertransverse portion of the artery, and segment 3 the atlas loop (where the vertebral artery encircles the lateral mass of the atlas). Proper visualization of the segments of the vessel and sufficient display of blood flow by color were judged by the two observers by consent. Hypoplasia of a vertebral artery was diagnosed when the artery could not be visualized on the conventional B-mode image but was shown as a thin string of color by using maximum sensitivity of the color display.

Results

We examined and visualized to varying degrees 84 vertebral arteries in 42 subjects. Mean duration of the examination of both sides was approximately 15 minutes.

Segment 2 was identified by the characteristic intertransverse course of the vessel medial to the vertebral vein and by hemodynamic characteristics (high diastolic blood flow velocity). The latter was confirmed by additional spectral analysis. Segment 2 was visualized in all persons on both sides. In many cases, the vertebral vein could be seen descending parallel to the vertebral artery (Figure 1).

In segment 3 (at the C1-C2 level), the atlas loop was demonstrated as a curved vessel with a distinct color change because of the change in the direction of blood flow with respect to the transducer. Next to the atlas loop the surface of the arcus posterior of the atlas was shown as a curvilinear echo with shadowing (Figure 2). The atlas loop could be visualized in 32 subjects (76.2%) on the right side and in 36 (85.7%) on the left.

Segment 1 was well seen in all patients except for the point at which the vertebral artery emerges from the subclavian artery (Figure 3). The ostium could be visualized in 37 persons (88.1%) on the right side and in 28 (66.7%) on the left.

In 20 subjects (47.6%) all parts of both vertebral arteries, including the emergence from the subclavian artery, were demonstrated well. In eight persons (19.1%) only one part of both vertebral arteries could not be visualized sufficiently; in four the insufficiently visualized part was the origin of the left vertebral artery. In the remaining 14 subjects (33.3%) more than one part was not seen properly. Four vertebral arteries (three on the right side and one on the left) were diagnosed as hypoplastic compared with the opposite side; in two the atlas loop and the origin of the hypoplastic artery could not be visualized adequately.

Peak systolic blood velocity ranged from 19 to 98 (mean 56) cm/sec and peak diastolic blood velocity ranged from 6 to 30 (mean 17) cm/sec. Resistive indices ranged from 0.62 to 0.75 (mean 0.69).

Discussion

Considering its widespread use and excellent results in detecting carotid artery disease, it is surprising that only a few studies have been devoted to duplex sonography of the vertebral arteries. Acker-
Staff et al.\(^4\) reported that 31 of 117 vertebral arteries studied could not be identified with the duplex scanning system. Moreover, the duplex scan did not satisfactorily display the ostium of 28 vertebral arteries. In contrast to Ackerstaff et al.,\(^4\) using duplex sonography, Touboul et al.\(^7\) were able to visualize the pretransverse and intertransverse segments in all of 50 healthy subjects. The ostium was seen in 47 persons on the right side and in 30 on the left.

However, the authors paid no attention to the upper segment of the vertebral artery. They found duplex scanning to be an easily performed noninvasive method to study morphologic and hemodynamic characteristics of the vertebral arteries from their origin to the C4–C3 level. Our results are similar to those of Touboul et al.\(^7\) with respect to the proximal and intertransverse segments of the vertebral artery, but we were able to visualize the atlas loop of the vertebral artery in many of our subjects. This is important since atherosclerotic lesions may occur not only in the proximal segments of the vertebral artery, but also in the atlas loop.\(^11\)

We demonstrate that color-coded Doppler sonography allows identification and visualization of different segments of the extracranial vertebral arteries, including the proximal portion with the ostium and the upper regions where the vertebral artery encircles the lateral mass of the atlas, in a high percentage of patients. The origin of the vertebral artery from the subclavian artery is more difficult to visualize on the left side than on the right. This may be due to the deeper course of the left subclavian artery than on the right.\(^12\) Moreover, the left vertebral artery emerges directly from the aorta in 8% of cases.\(^11\) Additionally, difficulties in color-coded Doppler sonography of the vertebral arteries remained with more posterior origins and with a tortuous course in segment 1. Nevertheless, the proximal portion of the vertebral artery (i.e., the pretransverse segment in the lower cervical region) is easy to identify using color-coded Doppler sonography; this identification may be difficult using continuous-wave Doppler sonography.\(^1-3\)

Whereas the intertransverse portion (segment 2) of the
vertebral arteries cannot be assessed using the latter, color-coded Doppler sonography demonstrated it in all persons in our study.

Using color-coded Doppler sonography, the atlas loop can be identified because of its typical features (i.e., curved course of the vessel with different colors proximally and distally, close to the arcus posterior of the atlas). In obese patients with short necks, it is difficult to position the transducer probe adequately to visualize the atlas loop (segment 3) of the artery. In such cases, continuous-wave Doppler sonography may still be useful.

In conclusion, color-coded Doppler sonography is superior to other ultrasound techniques in the identification of the vertebral arteries. Therefore, this method is likely to be the screening examination of the future.

References

Key Words • hemodynamics • ultrasonics • vertebral artery
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