Evaluating normal variant cerebrovascular circulation using Ultrasound and MRI

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Introduction

The Circle of Willis is the major source of blood supply to the brain.[a] It connects the circulation in the right and left hemispheres with the circulation in the anterior and posterior hemispheres. Located at the base of the brain, a complete circle of Willis is the most important source of collateral circulation in the presence of extracranial carotid or vertebral artery disease. It is complete in approximately 50% of the population.[b] Various medical imaging modalities are used to image the circle of Willis with MRI and ultrasound being two relatively common and non-invasive techniques.

Methods

A mid-range ultrasound scanner (UF-850XTD by TeraRecon Inc., San Mateo, CA / Fukuda Denshi Co. Ltd., Tokyo, Japan) was used to evaluate the cervical arteries and the circle of Willis. The 2.5 MHz phased array transducer was used to evaluate the intracranial circulation via the temporal and occipital windows. A 6-9 MHz Linear transducer was used to evaluate the cervical carotid and vertebral arteries.

A cerebral MRI had been done a few years prior, however the results were not known during the ultrasound examination. This examination was relatively low resolution with 1mm thick sagittal acquisitions, a matrix size of 256 x 256 pixels, and a pulse sequence not optimized for vascular imaging. However, through advanced processing using the Aquarius Workstation (TeraRecon, Inc., San Mateo, CA), it was possible to extract meaningful images for comparison with the ultrasound examination.

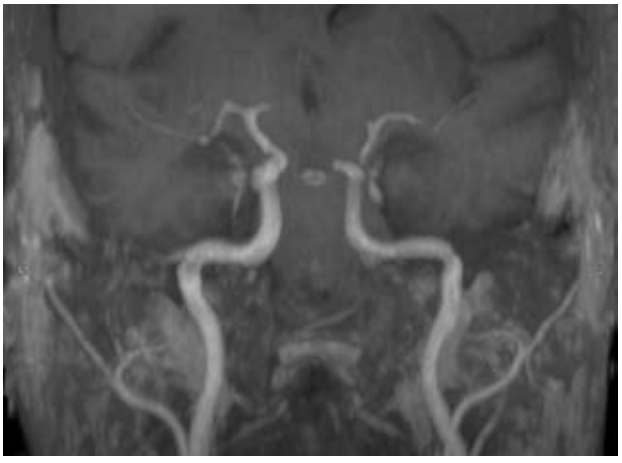

Figure 1: Coronal slab Maximum Intensity Projection MRI showing normal carotid arteries bilaterally.

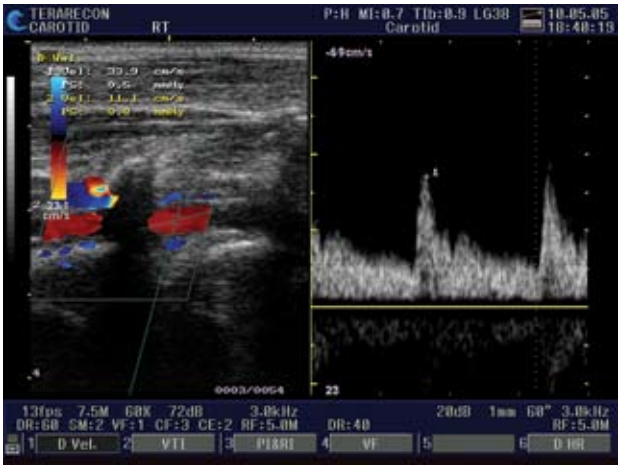

Figure 2: Right vertebral artery with normal flow pulsatility.

Results

The cervical ultrasound examination demonstrated normal carotid arteries bilaterally, which was consistent with the former MRI (Figure 1 and 1A). The right vertebral artery appeared larger in caliber with normal flow (Figures 2 and 2A). The left vertebral artery appeared smaller in caliber with increased flow pulsatility (Figure 3 and 3A). The MRI showed a left vertebral artery that had a diminutive signal (Figure 6).

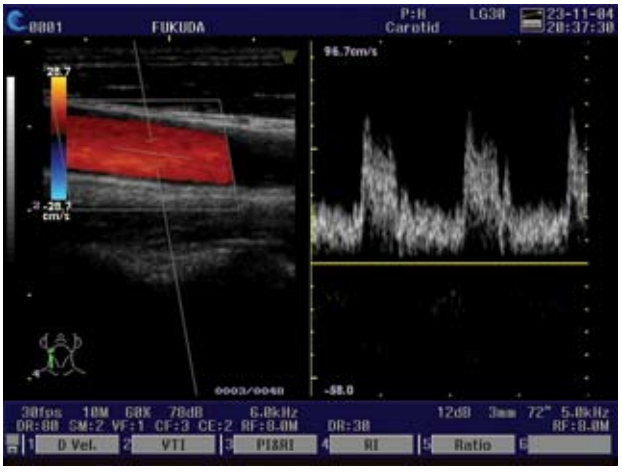

Figure 1A: Color Doppler image of the common carotid artery shows widely patent vessel with normal spectral Doppler flow.

Figure 2A: Diameter measurement of right vertebral artery is 0.35 cm.

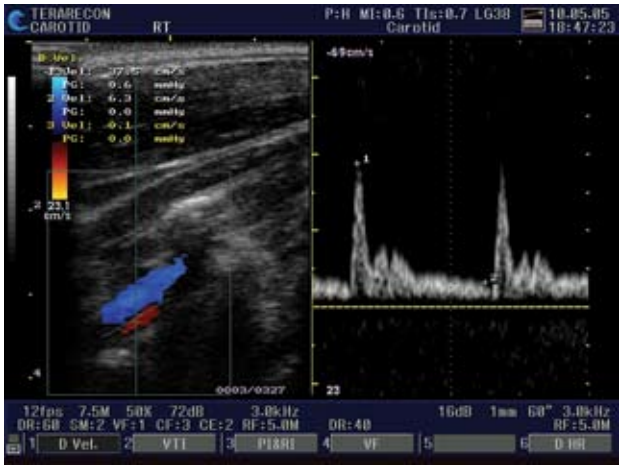

Figure 3: Left vertebral artery displaying increased flow pulsatility.

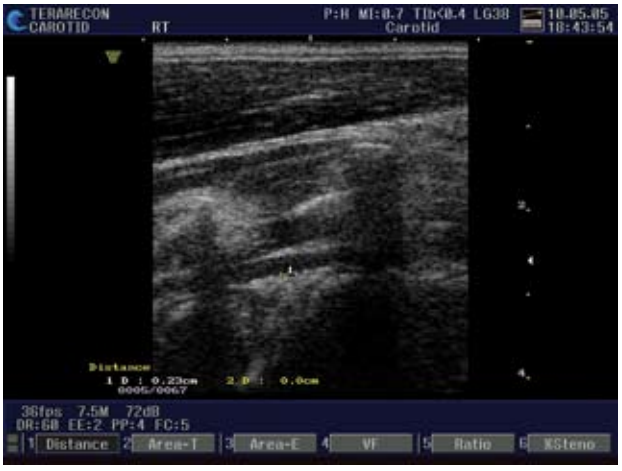

Figure 3A: Diameter measurement of left vertebral artery is 0.23 cm

Figure 4: Color Doppler ultrasound of right vertebral artery showing large caliber with normally directed flow.

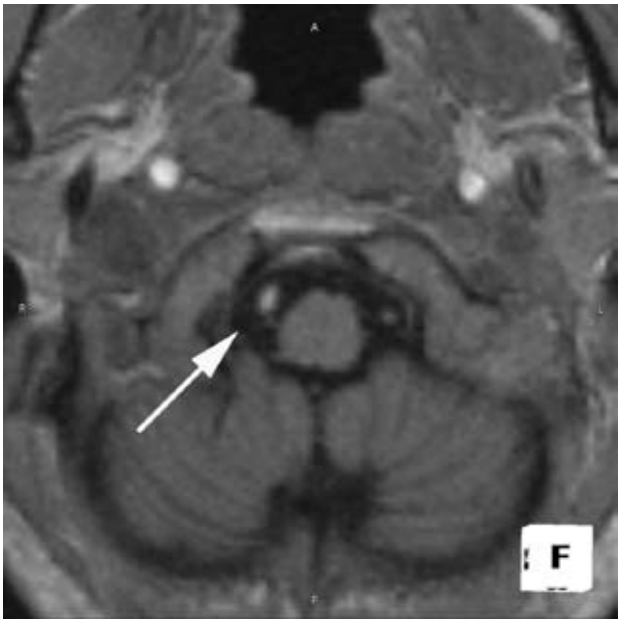

Figure 5 Cerebral MRI showing patent right vertebral artery

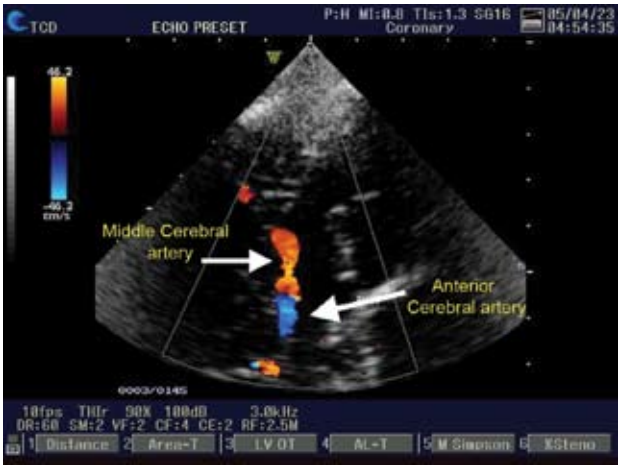

Figure 7 Transcranial Color Doppler image demonstrates a normally directed MCA (red) and ACA (blue) on the right side

The transcranial ultrasound examination demonstrated normal flow patterns in the middle and anterior cerebral arteries bilaterally (Figure 7); however there appeared to be a direct connection between the bilateral posterior cerebral arteries and the terminal internal carotid arteries. Upon evaluation of the posterior circulation, the intracranial left vertebral artery was not located while the right vertebral artery appeared widely patent with normal flow patterns. At the level of the basilar artery origin, the right vertebral artery appeared to turn sharply towards the left side and continued towards the base of the brain.

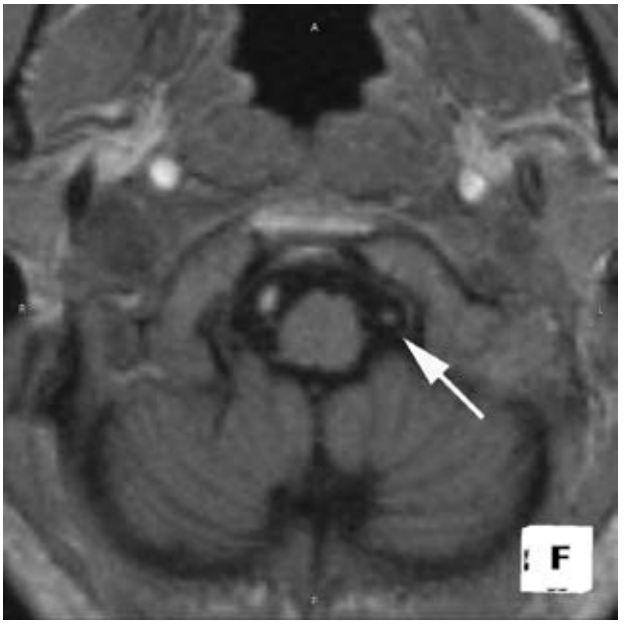

Figure 6 Cranial MRI showing diminutive signal from the left vertebral artery

The final interpretation of the ultrasound exam was fetal origin of the posterior cerebral arteries with a dominant right vertebral artery. The ultrasound examination was unable to clearly identify the left intracranial vertebral and basilar arteries.

The MRI which had been performed a few years prior was retrospectively re-evaluated and found to confirm most of the ultrasound findings. It clearly showed the normal intracranial right vertebral artery (Figure 8), a diminutive left vertebral artery (Figure 6), and the fetal origins of the posterior cerebral arteries (Figures 9, 10 and 11). The distal intracranial vertebral arteries appeared to directly connect to the posterior cerebral arteries, bilaterally (Figure 12).

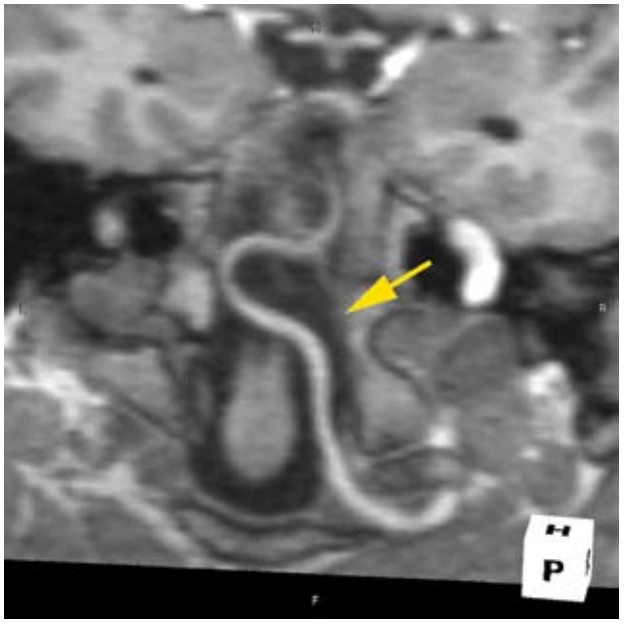

Figure 8 Slab Maximum Intensity Projection of right vertebral artery

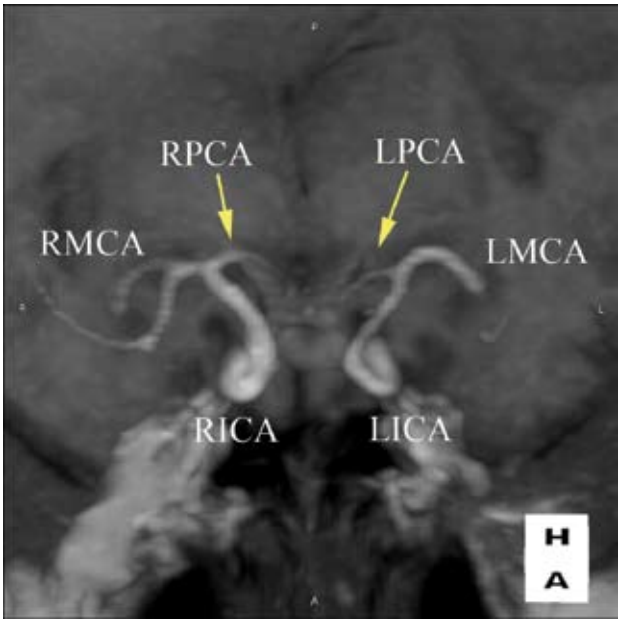

Figure 10 Coronal / Anterior Oblique Slab MR Maximum Intensity Projection demonstrating bilateral fetal original of the posterior cerebral arteries

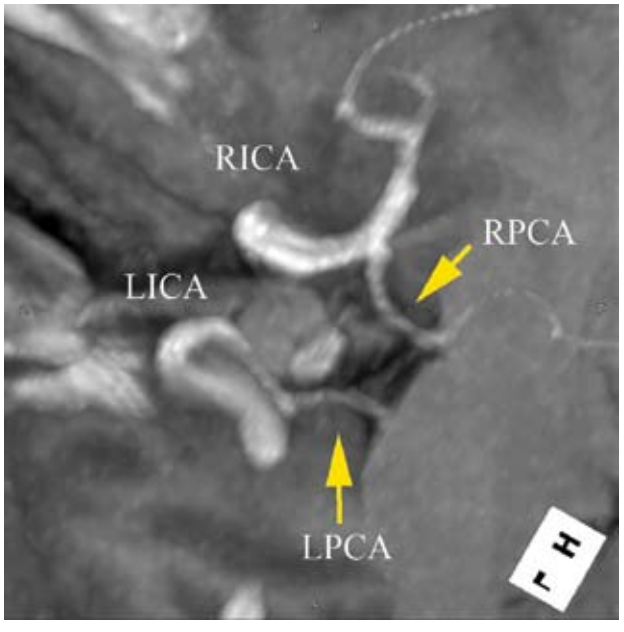

Figure 9 Oblique Slab MR Maximum Intensity Projection demonstrating bilateral fetal origin of the posterior cerebral arteries

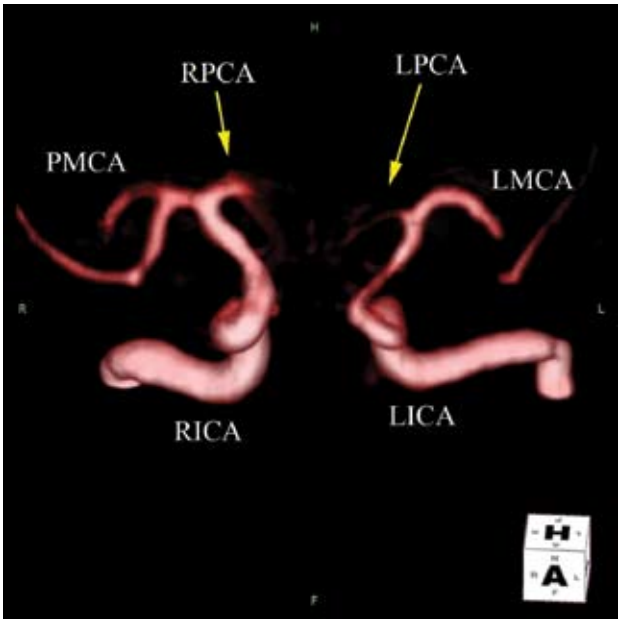

Figure 11 Coronal / Anterior Oblique 3D Volume Rendering demonstrating bilateral fetal original of the posterior cerebral arteries

Figure 12 Both intracranial vertebral arteries appear to be connecting directly to the posterior cerebral arteries (arrows)

Conclusion

The application of transcranial color Doppler ultrasound was in this case able to demonstrate bilateral fetal origin of the posterior communicating arteries, a normal variant of the circle of Willis. The incidence of unilateral posterior communicating artery origin of the fetal type has been reported to be around 15%, and hence we can expect the incidence of bilateral origin of the posterior cerebral arteries to be significantly lower. Embryologically, the posterior cerebral arteries originate from the internal carotid arteries. Later in fetal development, the posterior cerebral arteries attach themselves to the apex of the basilar artery leaving behind the smaller posterior communicating arteries. However, when the posterior cerebral arteries remain attached to the internal carotid arteries (like in this case), this results in the fetal origin of the posterior communicating arteries. Bilateral fetal origin implies near 100% dependence on the carotid arteries for cerebral blood supply, with minimal or no dependence on the vertebral arteries for the same, rendering the subject less well-equipped with potential collateral pathways should flow-limiting carotid stenosis or occlusion develop.

With the advent of procedures such as trans-cranial Doppler as demonstrated herein, ultrasound is now a very useful modality to evaluate the major arteries comprising the circle of Willis and the major cervical vessels that are its source. When used in conjunction with other non-invasive modalities like CT and MRI, a definitive diagnosis can be obtained in the majority of the cases without subjecting the patient to more invasive, time consuming and costly arteriography or cerebral angiography. These non-invasive diagnostic tools in the hands of trained medical professionals will allow the best possible quality of care for physicians and their patients.

a Baumgartner RW, Baumgartner I, et al.: Transcranial color-coded duplex sonography in the evaluation of collateral flow through the circle of Willis. Am J Neuroradiol 18:127-33, 1997.

b Hoksbergen AW, Legemate DA, et al.: Collateral variations in circle of Willis in atherosclerotic population assessed by means of transcranial color-coded duplex ultrasonography. Stroke. 31:1656-60, 2000.