Virtual modeling and interactive virtual reality display of unusual high-riding cervical aortic arch

Sarv Priya, Prashant Nagpal
Department of Radiology, University of Iowa Hospitals, Iowa City, IA, USA

ABSTRACT

A cervical aortic arch is a rare vascular malformation that is characterized as a high positioned aortic arch, above the clavicle. The knowledge of its branching pattern is essential to characterize the entity further accurately. Noninvasive cross-sectional imaging, including computed tomography angiography or magnetic resonance angiography, is the imaging methods of choice. Due to highly complex anatomy, three-dimensional (3D) images help in providing improved anatomical visualization. Virtual reality is a relatively new computer-generated simulation technique that allows the interactive display of high-resolution models using a wearable headset and interactive controllers. We describe a rare form of a cervical arch and briefly discuss the latest methods of improved visualization using 3D virtual reality displays and smartphones.

Keywords: Cervical aortic arch, computed tomography angiography, three-dimensional imaging, three-dimensional model, virtual reality, volume-rendered

INTRODUCTION

A cervical aortic arch is a rare vascular anomaly that is characterized by a high-riding aortic arch that extends above the medial ends of clavicles.[1] Three-dimensional (3D) imaging helps with a better understanding of the anatomy, branching patterns, and relationship with surrounding structures. Recently, virtual reality (VR) models have been used to describe complex cardiovascular diseases providing an interactive and intuitive display. VR is a computer-generated image simulation technique that allows the interactive display of the image models. These models are viewed using a wearable handset and can be manipulated by interactive controllers. In this work, we describe an unusual branching pattern of the cervical aortic arch and briefly discuss advanced visualization methods including virtual reality and smartphone display.

Videos are available on: www.annalspc.com

Access this article online

Quick Response Code:

Website: www.annalspc.com

DOI: 10.4103/apc.APC_188_19

CLINICAL SUMMARY

An 18-year-old female with 22q11 deletion syndrome presented for biopsy of thyroid nodules. She had a known diagnosis of a cervical arch, which was asymptomatic and had no prior cross-sectional imaging. A computed tomography angiography (CTA) was performed to evaluate this vascular anomaly before performing a thyroid biopsy. CTA revealed a complex right-sided cervical arch. The arch was extending high into the neck and reached the level of the hyoid bone [Figure 1]. The arch then coursed inferiorly on the right side and was highly tortuous in its course. The descending aorta was to the right of the spine in the proximal-most portion, which encircled the trachea and crossed to the left of the spine [Figure 1]. The arch branching pattern was also unusual. The left common carotid artery (CCA) arose as the first branch from the ascending aorta. The right CCA

How to cite this article: Priya S, Nagpal P. Virtual modeling and interactive virtual reality display of unusual high-riding cervical aortic arch. Ann Pediatr Card 2021;14:122-4.

Address for correspondence: Dr. Sarv Priya, Department of Radiology, University of Iowa Hospitals, 200 Hawkins Drive, Iowa City, IA 52242, USA.
E-mail: sarv-priya@uiowa.edu

Submitted: 20-Nov-2019 **Revised:** 21-Feb-2020 **Accepted:** 18-Sep-2020 **Published:** 19-Nov-2020

was absent, and there was the separate origin of right internal and external carotid arteries from the right arch itself. The left subclavian artery (LSCA) arose as an aberrant last branch with a Kommerell's diverticulum from the left-sided descending aorta [Figure 1]. Imaging findings suggested Type A cervical arch (Haughton's classification) with vascular ring formation. The vascular ring was completed by the segment of ascending aorta anteriorly, tortuous aortic arch on the right, retroesophageal contralateral descending aorta posteriorly, and ligamentum arteriosum on the left.

Virtual reality 3D imaging was performed to better understand the anatomy and highlight the same for the physician performing thyroid biopsy. The models provided an immersive experience with an interactive display of spatial orientation of the vascular anomaly as well as its relationship with the airway [Figure 2 and Supplementary Video 1]. Due to the absence of any symptoms from her cervical aortic arch, no surgical intervention was suggested, and she successfully underwent fine-needle aspiration of her thyroid nodules without complications.

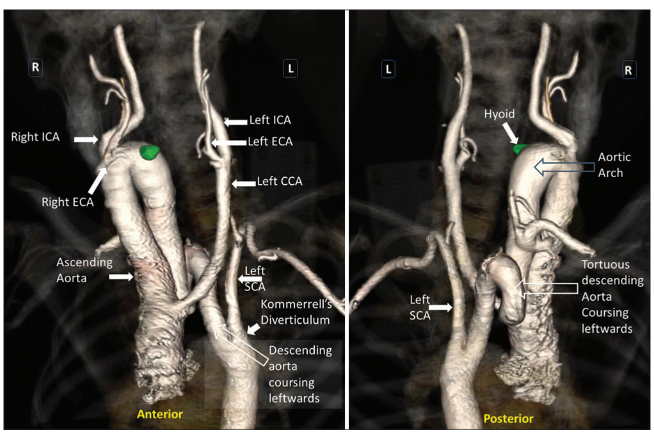

Figure 1: Anterior and posterior views of volume-rendered model. Volume-rendered three-dimensional models displaying aortic arch branching pattern. Anterior view shows separate origin of right external and internal carotid artery and aberrant left subclavian artery arising from diverticulum. Posterior view shows the tortuous descending aorta crossing from right to left side. Hyoid bone is seen in green color

DISCUSSION

The cervical aortic arch is defined as an arch reaching above the medial end of the clavicle and is commonly seen on the right side.[1] It is an unusual anomaly that results either due to abnormal persistence of second or third aortic arches or due to failure of caudal migration of the fourth aortic arch.[2] Cervical aortic arch is commonly associated with 22q11 deletion syndrome and other cardiac anomalies.[2] Clinically, it can be asymptomatic, or patients can present with dysphagia/dyspnea. Cervical arch may be complicated by aneurysm formation, dissection, or coarctation.[3] Imaging using computed tomography or magnetic resonance imaging plays a vital role in the characterization of the vascular anomalies and their complications.[4] The branching pattern is very complex, and many variations have been described. Haughton *et al.* classified the anomaly in five different types [Supplementary Table 1].[5] More recently, Zhong *et al.*, in their review of 35 patients with cervical arch, proposed a new classification system as they found that they were unable to categorize three patients according to Haughton classification. They classified cervical arch anomalies into two groups based on the presence/absence of vascular rings and the relationship of descending aorta to the aortic arch [Supplementary Table 2].[6] They mentioned this new scheme to be more intuitive and better in making surgical decisions.

ADVANCED VISUALIZATION

Static 3D volume-rendering is available on most 3D software platforms. It helps in quick understanding of the anatomy. However, it lacks depth perception and is not intuitive. Virtual reality (VR) is a technique that allows the interactive display of the image models in a fully immersive environment with the ability to manipulate images in real time. This technique allows interactive visualization of volume-rendered data or segmented patient-specific models in a virtual environment. Many commercially available VR software are available. We used free, open-source Slicer software for segmentation and VR viewing.[7]

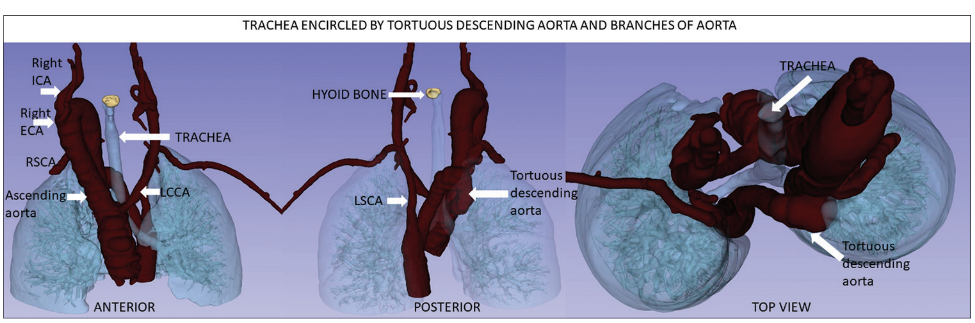

Figure 2: Virtual reality model. Anterior and posterior view of the virtual reality model shows aortic arch branching pattern and relationship of arch branches with airway. Top view of the model shows arch branches encircling trachea

Routinely acquired diagnostic axial CTA images were uploaded into the Slicer software. Images were cropped and interpolated to get isotropic voxels. Delineation and segmentation of vascular and bronchial tree were performed using threshold growing and seed-based algorithm based on Hounsfield units. After that, the model was hollowed (isolating the blood pool) by the creation of a 2 mm shell using the Hollow tool. For VR viewing, head-mounted virtual reality glasses (Windows HP Mixed reality glasses) were used along with their interactive handheld controllers. VR allows real-time interaction (magnification/slicing) with multiple viewing angles [Supplementary video 1]. The virtual reality glasses/controllers used for the index case are inexpensive (approximately 250 dollars). This technique and hardware allow enhanced 3D experience without the need for expensive commercial software. In addition, no modification in CTA acquisition technique with respect to radiation or contrast dose is required for creating virtual models. This can be an excellent tool for a better understanding of intracardiac anatomy in complex cardiovascular malformations.[8,9] Such 3D models can also be uploaded as interactive cine clips onto a smartphone [Supplementary Video 2] or on a website (supplementary 3D model), providing an easy method of sharing with the clinical team, trainees, or patients for treatment planning or education purposes.

CONCLUSION

Cervical arch anomalies are rare vascular malformations that can be noninvasively imaged by CTA or MRA. Interactive virtual reality images can provide a more intuitive display of these complex anomalies, thus helping with pretreatment planning and better patient understanding. These virtual reality images can also be displayed/stored on smartphones to enhance sharing for better patient communication and education.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Guha S, Grover V, Aiyer P, Dhull J. A unique case of right cervical aortic arch with anomalous left common carotid artery and absent right common carotid artery. Ann Med Surg (Lond) 2016;9:58-60.
2. Priya S, Thomas R, Nagpal P, Sharma A, Steigner M. Congenital anomalies of the aortic arch. Cardiovasc Diagn Ther 2018;8:S26-44.
3. Chen HY, Chen LK, Su CT, Chen SJ, Lin CH, Tsai YF, *et al.* Left cervical aortic arch with aneurysm and obstruction: Three-dimensional computed tomographic angiography and magnetic resonance angiographic appearance. Int J Cardiovasc Imaging 2002;18:463-8.
4. Nagpal P, Khandelwal A, Saboo SS, Bathla G, Steigner ML, Rybicki FJ. Modern imaging techniques: Applications in the management of acute aortic pathologies. Postgrad Med J 2015;91:449-62.
5. Haughton VM, Fellows KE, Rosenbaum AE. The cervical aortic arches. Radiology 1975;114:675-81.
6. Zhong YL, Ma WG, Zhu JM, Qiao ZY, Zheng J, Liu YM, *et al.* Surgical repair of cervical aortic arch: An alternative classification scheme based on experience in 35 patients. J Thorac Cardiovasc Surg 2020;159:2202-13.
7. Fedorov A, Beichel R, Kalpathy-Cramer J, Finet J, Fillion-Robin JC, Pujol S, *et al.* 3D Slicer as an image computing platform for the Quantitative Imaging Network. Magn Reson Imaging 2012;30:1323-41.
8. Priya S, Ashwath R. Highly atypical double barrel outlet to aorta in double inlet left ventricle, double outlet right ventricle. J Cardiovasc Comput Tomogr. 2020 Sep-Oct;14(5):e63-e65.
9. Priya S, Nagpal P, Sharma A, Pandey NN, Jagia P. Imaging spectrum of double-outlet right ventricle on multislice computed tomography. J Thorac Imaging 2019;34:W89-99.

Supplementary Tables

Supplementary Table 1: Haughton's classification of cervical aortic arch

Types	Cervical arch branching pattern
Type A	Absent one common carotid artery, separate origin of internal and external carotid arteries (ipsilateral to arch) and contralateral descending aorta with aberrant subclavian artery (Case described in current case report)
Type B	Both common carotid arteries present with contralateral descending aorta
Type C	Bicarotid trunk and contralateral descending aorta
Type D	Normal branching pattern with ipsilateral descending aorta
Type E	Right-sided arch and right descending aorta with an aberrant left subclavian artery

Supplementary Table 2: Zhong's *et al.* alternative classification of cervical aortic arch

Types	Cervical arch branching pattern
Type A	Cervical Arch without vascular ring
Type A1	Left sided arch with ipsilateral descending aorta
Type A2	Mirror image pattern of Type A1
Type B	Cervical Arch with vascular ring (retroesophageal aortic segment/subclavian artery)
Type B1	Right sided arch, ipsilateral descending aorta and aberrant left subclavian artery
Type B2	Right-sided arch with contralateral descending aorta
Type B3	Left-sided arch with ipsilateral descending aorta and aberrant right subclavian artery
Type B4	Left-sided arch with contralateral descending aorta