Photorealistic 3-Dimensional Models of the Anatomy and Neurosurgical Approaches to the V2, V3, and V4 Segments of the Vertebral Artery

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BACKGROUND: The vertebral artery (VA) has a tortuous course subdivided into 4 segments (V1-V4). For neurosurgeons, a thorough knowledge of the 3-dimensional (3D) anatomy at different segments is a prerequisite for safe surgery. New technologies allowing creation of photorealistic 3D models may enhance the anatomic understanding of this complex region.

OBJECTIVE: To create photorealistic 3D models illustrating the anatomy and surgical steps needed for safe neurosurgical exposure of the VA.

METHODS: We dissected 2 latex injected cadaver heads. Anatomic layered dissections were performed on the first specimen. On the second specimen, the two classical approaches to the VA (far lateral and anterolateral) were realized. Every step of dissection was scanned using photogrammetry technology that allowed processing of 3D data from 2-dimensional photographs by a simplified algorithm mainly based on a dedicated mobile phone application and open-source 3D modeling software. For selected microscopic 3D anatomy, we used an operating microscope to generate 3D models.

RESULTS: Classic anatomic (n=17) and microsurgical (n=12) 3D photorealistic models based on cadaver dissections were created. The models allow observation of the spatial relations of each anatomic structure of interest and have an immersive view of the approaches to the V2-V4 segments of the VA. Once generated, these models may easily be shared on any digital device or web-based platforms for 3D visualization.

CONCLUSIONS: Photorealistic 3D scanning technology is a promising tool to present complex anatomy in a more comprehensive way. These 3D models can be used for education, training, and potentially preoperative planning.

KEY WORDS: Photogrammetry, Surface scanning, Anatomy, Neurosurgery, Vertebral artery, Augmented reality, Virtual reality

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The approaches to the vertebral artery (VA) and especially the segments V2-V3-V4 (Model 1) have long been a challenge to skull base surgeons.[1-5] Most importantly, the vessel has a complex course which may also vary at the craniovertebral junction depending on the position of the head (Model 2).[1-5] Second, there is an associated venous plexus around the artery, which is contained in a periosteal sheath along the foraminal (V2) and craniocervical segment (V3) of the VA that necessitates special consideration. In the suboccipital region, the VA is also surrounded by the same venous plexus, which some authors call suboccipital cavernous sinus.[6] Another important point is the complex multilayered musculofascial and neurovascular anatomy of the suboccipital and anterolateral neck region, respectively. A correct anatomic knowledge of fascial planes between the deepest layer of muscles in the region of the craniovertebral junction and the VA periosteal membrane may prevent troublesome bleeding from the VA plexus and hence increase surgical safety.[1,5,7-9] On the other hand, the anterolateral surgical corridor to the V2 and V3 segments crosses critical neurovascular structures at different levels, with accessory nerve, jugular vein, common carotid, external and internal carotid arteries, vagus, glossopharyngeal and

ABBREVIATIONS: AR, augmented reality; **DICOM,** Digital Imaging and Communications in Medicine; **SLS,** structured light scanning; **VA,** vertebral artery; **WebGL,** Web Graphics Library.