3D Neuroanatomy

Visualizing and comprehending 3D neuroanatomy is challenging. Cadaver dissection is limited by low availability, high cost, and the need for specialized facilities. New technologies, including the 3D rendering of neuroimaging, 3D pictures, and 3D videos, are filling this gap and facilitating learning, but they also have limitations.

The teaching of neuroanatomy in medical education has historically been based on didactic instruction, cadaveric dissections, and intra-operative experience for students. Multiple novel 3-Dimensional (3D) modalities have recently emerged. Among these, stereoscopic anaglyphic video is easily accessible and affordable, however, its effects have not yet formally been investigated.

Data from a study suggest that a combination of multiple pedagogical resources seems to be the more advantageous for teaching neuroanatomy [1)].

The three-dimensional (3D) visualization of dural venous sinuses (DVS) networks is desired by surgical trainers to create a clear mental picture of the neuroanatomical orientation of the complex cerebral anatomy. Our purpose is to document those identified during routine 3D venography created through 3D models using two-dimensional axial images for teaching and learning neuroanatomy. Anatomical data were segmented and extracted from imaging of the DVS of healthy people. The digital data of the extracted anatomical surfaces was then edited and smoothed, resulting in a set of digital 3D models of the superior sagittal, inferior sagittal, transverse, and sigmoid, rectus sinuses, and internal jugular veins. A combination of 3D printing technology and casting processes led to the creation of realistic neuroanatomical models that include high-fidelity reproductions of the neuroanatomical features of DVS. The life-size DVS training models were provided good detail and representation of the spatial distances. Geometrical details between the neighboring of DVS could be easily manipulated and explored from different angles. A graspable, patient-specific, 3D-printed model of DVS geometry could provide an improved understanding of the complex brain anatomy. These models have various benefits such as the ability to adjust properties, to convert two-dimension images of the patient into three-dimension images, to have different color options, and to be economical. Neuroanatomy experts can model such as the reliability and validity of the designed models, enhance patient satisfaction with improved clinical examination, and demonstrate clinical interventions by simulation; thus, they teach neuroanatomy training with effective teaching styles [2)].

A study aimed to investigate if 3D stereoscopic anaglyphic video instruction in neuroanatomy could improve learning for content-naive students, as compared to 2D video instruction.

A single-site controlled prospective case control study was conducted at the School of Education. Content knowledge was assessed at baseline, followed by the presentation of an instructional neuroanatomy video. Participants viewed the video in either 2D or 3D format, then completed a written test of skull base neuroanatomy. Pre-test and post-test performances were analyzed with independent t-tests and ANCOVA.

249 subjects completed the study. At baseline, the 2D (n=124, F=97) and 3D groups (n=125, F=96)

were similar, although the 3D group was older by 1.7 years (p=.0355) and the curricula of participating classes differed (p<.0001). Average scores for the 3D group were higher for both pretest (2D, M=19.9%, SD=12.5% vs. 3D, M=23.9%, SD=14.9%, p=.0234) and posttest (2D, M=68.5%, SD=18.6% vs. 3D, M=77.3%, SD=18.8%, p=.003), but the magnitude of improvement across groups did not reach statistical significance (2D, M=48.7%, SD=21.3%, vs. 3D, M=53.5%, SD=22.7%, p=.0855).

Incorporation of 3D video instruction into curricula without careful integration is insufficient to promote learning over 2D video [3].

An interactive 3D e-learning module was developed to complement gross anatomy laboratory instruction. Incorporating such 3D modules may provide additional support for students in areas of anatomy that are spatially challenging, such as neuroanatomy. Specific anatomical structures and their relative spatial positions to other structures can be clearly defined in the 3D virtual environment from viewpoints that may not readily be available using cadaveric or 2D image modalities. Providing an interactive user interface for the 3D module in which the student controls many factors may enable the student to develop an improved understanding of the spatial relationships. This work outlines the process for the development of a 3D interactive module of the cerebral structures included in the anatomy curriculum for undergraduate medical students in their second year of study [4].

Photorealistic 3-Dimensional Models

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 the 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 the 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 platform 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 [5].

Links

http://3dneuroanatomy.com

1) Sotgiu MA, Mazzarello V, Bandiera P, Madeddu R, Montella A, Moxham B. Neuroanatomy, the Achille's Heel of Medical Students. A Systematic Analysis of Educational Strategies for the Teaching of Neuroanatomy. Anat Sci Educ. 2019 Jan 31. doi: 10.1002/ase.1866. [Epub ahead of print] Review. PubMed PMID: 30702219.

2) Karakas AB, Govsa F, Ozer MA, Eraslan C. 3D Brain Imaging in Vascular Segmentation of Cerebral Venous Sinuses. J Digit Imaging. 2018 Sep 21. doi: 10.1007/s10278-018-0125-4. [Epub ahead of print] PubMed PMID: 30242780.

3) Goodarzi A, EdM SM, Lee D, Girgis F. The effect of stereoscopic anaglyphic 3-dimensional video didactics on learning neuroanatomy. World Neurosurg. 2017 Jul 29. pii: S1878-8750(17)31219-6. doi: 10.1016/j.wneu.2017.07.119. [Epub ahead of print] PubMed PMID: 28765017.

4) Allen LK, Ren HZ, Eagleson R, de Ribaupierre S. Development of a Web-Based 3D Module for Enhanced Neuroanatomy Education. Stud Health Technol Inform. 2016;220:5-8. PubMed PMID: 27046544.

5) Spiriev T, Nakov V, Cornelius JF. Photorealistic 3-Dimensional Models of the Anatomy and Neurosurgical Approaches to the V2, V3, and V4 Segments of the Vertebral Artery. Oper Neurosurg (Hagerstown). 2023 May 24. doi: 10.1227/ons.0000000000000701. Epub ahead of print. PMID: 37235851.