Manipulation of Volume Data to Manufacture Vascular Replicas

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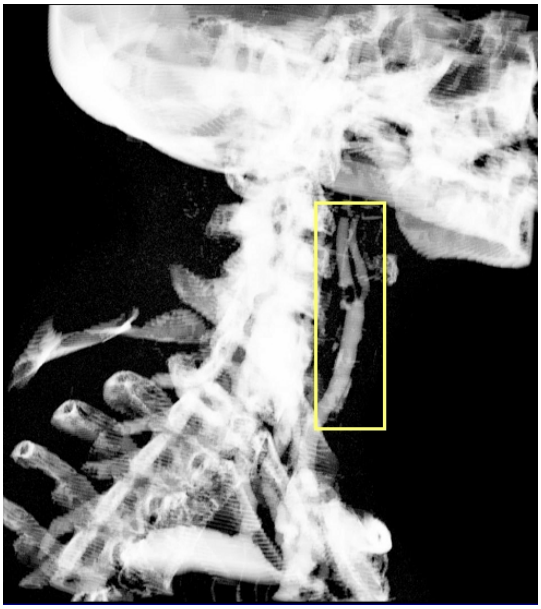
Abstract

There are three reasons to create physical replicas of human anatomy: (1) to be able to better visualize the shape of a single organ, or a section of anatomy; (2) to be able to visualize the spatial relationships in three-dimensions; and (3) to use accurate replicas to practice or rehearse otherwise high-risk clinical procedures in the laboratory. This paper describes a project to fabricate a carotid artery. It discusses the gathering of data, the conversion to a volume, and the subsequent conversion to a manufacturable form.

Methods

This project was to validate that we could create a replica of a patient's carotid artery and validate that the dimensions and scanned images were the same. Our original input was Computed Tomography (CT) slice data, 0.62 mm thick in DICOM format ([1], [2], [3]). From that data, we assembled a volume in the VOX file format. This contained the same information as the original data, but was cast as a 3D volume instead of a series of 2D slices.



This volume was then displayed and interacted with using the San Diego Supercomputer Center's (SDSC) Volume Explorer (vx) software ([4]), shown here to the right. The volume was cropped and the desired range of scalar values was determined. This was passed to our Volume Surface (vs) software ([5]), where a triangle-surface file in the STL file format was produced. We used this to fabricate the artery on SDSC's Z Corporation Z402C machine ([6]). The Z402C manufactures parts a layer-at-a-time from plaster-like powder.

This prototype was then coated with an epoxy and lacquered to seal and smooth some of the surface artifacts. This is shown in the photograph below, left.

We subsequently made a silicone mold so that we could eventually create a clear elastic silicone replica of the prototype using the lost wax technique. The silicone mold is shown to the right.

Results

CT resolution was the gating limitation. In addition, there may have been artifacts created from pulsatility on the patient's scan as well as the degree to which we modified the prototype surface (epoxy, lacquer, flame-polishing).

Conclusions

This project's novelty is based upon multidisciplinary methods: the manipulation of the volume data to view it and create the necessary 3D screen display, the fabrication steps, the molding methods, and the medical use of the model. Creating vascular replicas from live patients offers a promising device to help physicians determine how best to treat a difficult lesion, what tools to choose, as well as providing students an additional method of learning anatomy and physiology. Even at this early stage the process is fairly inexpensive and can be accomplished in less than a week. While static 3D models in the operating room provide biomodelling "maps" of vessel geometries, replicas can not only serve this function, but can be placed into a pulse simulator for examination and hands-on practice in the laboratory.

References

[1] Kerber CW, Heilman CB, Zanetti PH. Transparent Elastic Arterial Models. I. A brief technical note. *Biorheology* 1989; 26(6):1041-1049

[2] Lermusiaux P, Leroux C, Tasse JC, et al. Aortic Aneurysm: Construction of a Life-Size Model by Rapid Prototyping. *Annals of Vascular Surgery* 2001;131-5

[3] D'Uroso PS, Thompson RG, Atkinson RL, et al. Cerebrovascular Biomodelling: Technical Note. *Surg Neurol* 1999; 52:490-500

[4] Mike Bailey, "Interacting with Direct Volume Rendering", *IEEE Computer Graphics and Applications*, Volume 21, Number 1, January/February 2001, pp. 10-12.

[5] Mike Bailey, "Manufacturing Isovolumes", *Proceedings of the International Workshop on Volume Graphics*, Swansea, UK, March 24-25, 1999, pp. 133-146.

[6] Dave Nadeau and Mike Bailey, "Visualizing Volume Data Using Physical Models", *Proceedings of IEEE Visualization 2000*, October 2000, pp. 497-500.