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Surgical Neurology International

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SNI: Neurovascular

Editor
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Technical Notes

Handmade models for aneurysm surgery: A useful tool for training

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Received : 12 October 2022
Accepted : 26 November 2022
Published : 09 December 2022

DOI
10.25259/SNI_941_2022

Quick Response Code:

ABSTRACT

Background: Aneurysm surgery is considered difficult by young and trainee neurosurgeons. This is due to difficulty in understanding orientation of aneurysm complex (proximal and distal vessels, aneurysm neck, and fundus) in relation to the surrounding structures (skull, brain, vessels, and nerves) after head is rotated, extended, and fixed on the head frame. Virtual three-dimensional (3D) imaging studies and 3D-printed models help young neurosurgeons but are not accessible to most of the centers due to need for resources (human and equipment). Authors used handmade 3D models of aneurysm complex to train young neurosurgeons before and during surgery to make them understand steps to treat it.

Methods: RadiAnt DICOM viewer software (2022.1.1, 64-bit, *Medixant*, Poznan, Poland) was used for acquiring 3D Volume Rendering Technique images to make aneurysm models preoperatively. Twisted 20 Gauze galvanized iron wires were used for making proximal and distal branches and Epoxy Putty (*M-seal, Pidilite*® industries, Mumbai, India) was used to make smooth surfaces of the vessels, aneurysm necks, and fundi. Models were used in operating room (OR) before and during surgery to help surgeons and trainees get oriented to the aneurysm complexes.

Results: Handmade models, oriented as per patients' head position, were useful to make surgeons and trainees to understand projection of various components of the aneurysm complex in relation to adjacent structures, especially skull base, during both preoperative planning and in OR even before completion of the dissection.

Conclusion: Handmade models of aneurysms are inexpensive tool and can help trainee neurosurgeons to plan and execute surgical management of aneurysms.

Keywords: Aneurysm, Cerebrovascular, Epoxy putty, Handmade models, Volume rendering technique

INTRODUCTION

Aneurysm clipping is considered complex and difficult especially by trainee and young neurosurgeons.[2] Reasons for it are difficulty in understanding orientation of aneurysm complex (proximal and distal vessels, aneurysm neck, and fundus) (AC); inability to visualize morphology by looking at axial, sagittal, and coronal images alone; and variations in anatomies of involved vessels in the aneurysm complex and last but not the least: position of head in operation room (OR) fixed in head frame in rotation and extension. Advancements in radiology techniques have helped significantly but still digital subtraction angiography (DSA) and MR angiography fail to reveal orientation of AC in relation to the skull (skull base in aneurysms of circle of

Willis).[1,4,11,14,15] Recent use of three-dimensional (3D) printers and volume rendering technique (VRT) images has addressed the issue, but still their use is limited due to underutilization of VRT and unavailability of 3D printers at most of the centers due to paucity of resources (both human and equipment).[7,12]

Authors use handmade 3D models of AC to plan and execute aneurysm surgeries along with training trainees and young neurosurgeons and report the technical details of the same.

TECHNIQUE

As per protocol, patients with intracranial aneurysms planned for craniotomy and clipping underwent computed tomography angiography (Somatom Definition Flash, 256 Slice, Siemens, Germany). DSA too was done whenever required in cases of unsatisfactory visualization of AC, blister aneurysm was suspected, or cross flow assessment was required. Digital CT angiogram DICOM files were acquired and 3D VRT images were processed using RadiAnt DICOM Viewer (2022.1.1, 64-bit, Medixant, Poznan, Poland).

VRT images of the AC were acquired on desktop/laptop as per our earlier report.[12] Handmade models of the AC were made by twisting twin 20-Gauze galvanized iron wires to make proximal and distal vessels [Figure 1a]. VRT images were rotated and seen in different projections to simulate the twisted iron wires to copy directions and angulations as close to the images as possible [Figure 1a]. Epoxy Putty (*M-seal, Pidilite*® industries, Mumbai, India) (EP) was prepared by mixing the two components of the putty and then used to cover the wires to make the relative calibers of the vessels, aneurysm necks, and fundi [Figures 1a-c]. Settling time of EP is approximately 45 min before which it can be shaped as close to the VRT images. We also used available fabric color to make it appear as it would appear in the surgical field [Figures 1 and 2]. Usual time to make the AC was approximately 10–15 min. Once ready, it was used for surgical planning in conjunction with CT VRT [Figures 2a-d] and DSA VRT [Figure 2b and d], whenever available. The model was made available in the OR for intraoperative assistance during the surgery. During dissections close to AC, model was positioned as per patient's head position to identify various components of the aneurysm and predicts the residual unexposed components deep within the surrounding structures [Figures 1a and b; 2a and c]. It used to help young neurosurgeons intraoperatively in carrying out safe dissection and identifying various components of the AC and clip reconstruction of the vessels.

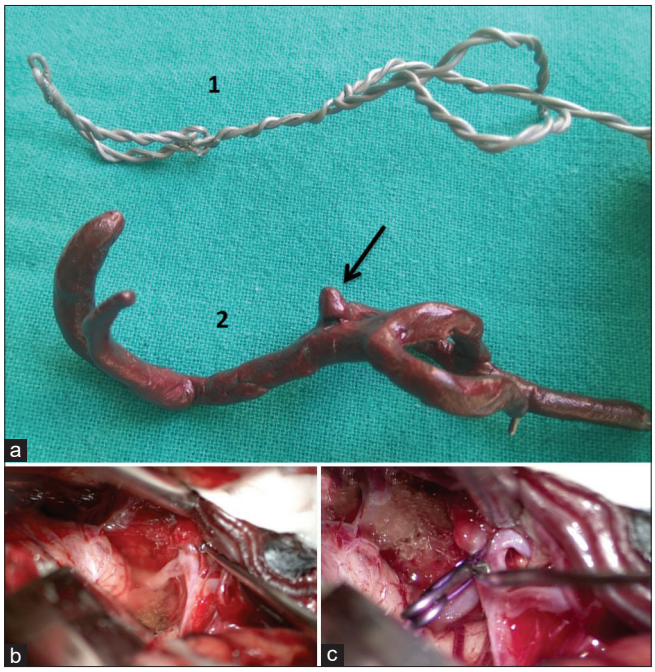

Figure 1: (a) Shows twisted galvanized iron wire skeleton of right middle cerebral artery bifurcation aneurysm (1) which was covered buy epoxy putty to depict aneurysm (arrow) and (2) the model was colored dark red by fabric color. (b) Surgically exposed right sylvian fissure through pterional approach showing proximal and distal branches of aneurysm complex. (c) Surgical field showing clipped aneurysm and proximal and distal branches of aneurysm complex.

DISCUSSION

Cerebrovascular anatomy is taught by two dimensional images of line diagrams which are available in textbooks in the early part of medical training. Cadaver dissection and cadaver dissection images are also part of the curriculum when basic anatomy is taught in the medical schools. Detailed neuroanatomy by two-dimensional images of the

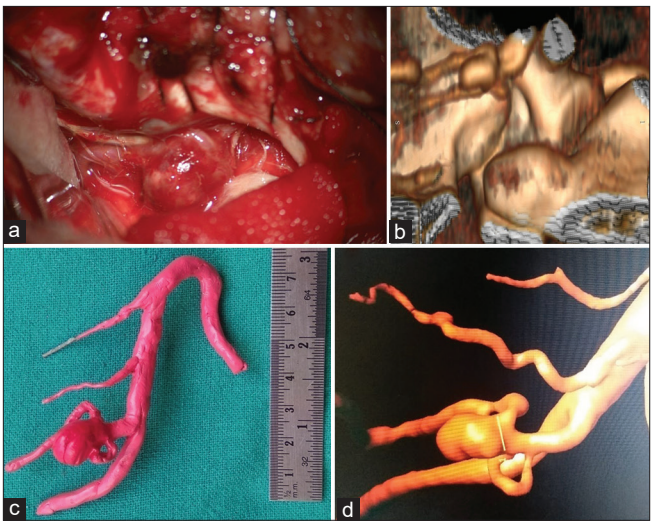

Figure 2: Surgically exposed left posterior inferior cerebellar artery aneurysm using left para-median suboccipital craniotomy (a). Same aneurysm seen on edited CT volume rendering technique (VRT) image (b), handmade model (c), digital subtraction angiography VRT, and (d) positioned similar to patient's head.

line diagrams and cadaver dissection images has become part of the neurosurgical training.[10] Despite having a good concept of neurovascular anatomy, head rotation and extension for most of the aneurysm surgeries make it difficult, especially for a young neurosurgeon or trainee, to visualize AC in the surgical field. High-resolution digital images are being used in recent years after advancements in information technology around the world.[10] Facility of cadaver dissection for neurosurgical training, though not available uniformly at many centers, is very important. Despite all these training methods, anatomical variations in cerebrovascular anatomy are quite common and patient-specific anatomy is a must for planning and execution of surgical clipping of aneurysms.[18,23]

Advancements in imaging techniques such as CT, MRI, and DSA can provide 3D Multi-Planer Reformation (MPR), which can reveal AC in three axes, are very useful for assessing AC.[9,21] However, MPR images are 2D images and its morphology needs to be imagined by the observer, which is difficult in the early part of neurosurgical career. Advanced DSA equipments, nowadays, can provide excellent quality of virtual 3D images of the AC which can be seen in detail by rotating it in different directions.[21] However, these images fail to show bony anatomy in relation to AC with similar clarity. VRT images of MR angiography too does not reveal bony structures with the AC. Various authors have shown role of 3D CT angiography and 3D DSA in planning and surgery of aneurysms.[8,11] Ishida *et al*.[11] have used three-dimensional imaging software (TOSHIBA Xtension V2.01) for reconstructing aneurysms, in which they used to study clip positions and not for preoperative planning or intraoperative assistance which may be due to less advanced technology available in 2001. VRT of CT is still underutilized for aneurysm surgeries in neurosurgery despite being used in other disciplines such as craniofacial surgery and thoracic surgery.[3,4,14,20]

Virtual 3D VRT images of CT for aneurysms are editable and are helpful in preoperative planning of craniotomy, knowing appearance of AC in relation to the adjacent bony structures in a particular head position of the patient which can be made available in the OR on a laptop. These images are rotatable and can be seen from various directions.[23] However, a handmade model of AC, a replica of what was seen in the 3D VRT images, is a real physical model available during planning and in the OR is more appropriate for trainees and young neurosurgeons for detailed planning and surgical dissection once these were positioned according to the head positions of the patients. During planning, these models can be placed in the skull base for better understanding. Brain shifts and brain retractions does affect the components of AC, but these were discussed during planning and were taken into consideration while dissecting around AC. Relative proportions of various components of AC were important, not the size of the AC, which were made approximately 2–3 times bigger than the real AC found in the surgical field to make it convenient to prepare and depict details.

The use of 3D printers is increasing, nowadays,[5,7,13,17,19,25] which was also used by the authors for couple of years, but it required dedicated trained manpower for running and maintaining the equipment, took an average of 8–12 h to make a model, was difficult to print thin vessels, and needed supervision of neurosurgeon involved in the management of the patient. Modern equipments and technology are able to give much better qualities of models, but are still out of reach due to lack of resources at most of the centers around the world.[6,17] Augmented reality is also emerging for various aspects of neurosurgery but still in infancy.[16,22]

Limitations

AC model is made based on appearance of VRT images and all the deficiencies of CT VRT are associated with it especially inability to show thin vessels and perforators and blister aneurysms.[24,26] VRT of DSA may be used to make it more effective whenever it is available. Making an AC model is an artwork, which depends on one's creativity and may not be easy for everyone. However, making proper orientation of proximal and distal vessels in relation to neck and some part of fundus, which too should be directed correctly, is important and may not be difficult even for a person with average creativity or skills. More than making a model, the process of making it is much more useful, as it allows the maker to know the AC in great detail, to an extent that even without model; the maker is able to visualize it in the surgical field.

CONCLUSION

Handmade models of aneurysm complex may be an important tool for preoperative planning and intraoperative assistance in aneurysm surgeries, especially for trainees and young neurosurgeons. It is safe and inexpensive and can be used even at resource limited settings.

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

Financial support and sponsorship

Publication of this article was made possible by the James I. and Carolyn R. Ausman Educational Foundation.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Sharma V, Garg M, Bhaskar S, Tiwari S, Bhatia PK, Jha DK. Handmade models for aneurysm surgery: A useful tool for training. Surg Neurol Int 2022;13:571.