



Training in Brain Retraction Using a Self-Made Three-Dimensional Model

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A hollow brain model was created using soft urethane. A tube passing through the hollow was attached for use as a water inlet and manometer. Water sufficient in quantity to realize the intended initial pressure was infused through the tube. The brain model was retracted with a brain spatula and the surgical corridor was opened. By measuring local force with a sensor set on the brain spatula, the model could be used for training in brain retraction. At the same time, the water column of the manometer was measured and the relationship with the force of the brain spatula was investigated. A positive correlation between the water column and local force was confirmed. This indicated that it was possible to use this model without a force sensor for the same training using water column measurements.

INTRODUCTION

Brain retraction is a basic technique used in craniotomy. To obtain an effective surgical field without damaging the tissue, the position of the spatula, the direction of retraction, and the amount of strength applied must be appropriately gauged (2, 6, 15, 17, 18). However, it is not easy for a neurosurgeon with little surgical experience to master the techniques involved in applying the spatula in an appropriate manner. The relative degree of strength to be applied can only be gauged on the basis of practical experience. In the past, it was necessary to acquire these skills in the course of practical experience; however, in recent years, there has been increasingly less opportunity for on-the-job training because of various restrictive and ethical factors (4, 11) as well as wider use of endovascular treatments.

In contrast, simulation has been practiced for many years in fields such as aviation and rail transport and has subsequently become widely used in different medical fields. The growing popularity of three-dimensional (3D) printing has also resulted in an increase in reports used in conjunction with surgical simulation and training using solid models.

We have developed and created our own brain model that to measure force in a gentle manner for use in brain retraction training. We created prototypes of models for pterional, lateral suboccipital, and frontal interhemispheric approaches. This detailed study is concerned with the model for the pterional approach.

METHODS

Developing a Solid Model

Developing Data for 3D Printers. Contrast-enhanced computed tomography (CT) images of a representative left middle cerebral artery aneurysm were obtained. The CT scanner was a definition FLASH CT manufactured by Siemens (base matrix, $512 \times 512 \times 512$; slice thickness, 0.8 mm). The Digital Imaging and Communication in Medicine (DICOM) data were visualized in three dimensions using the 3D visualization application Amira.

The right frontotemporal area was trimmed and the skull, brain, and arteries were extracted by means of thresholding on the basis of the absorption values. In the case of the brain, we separately developed a mold shaped into the interior and exterior parts. These were separately converted into standard triangulated language (STL) data (Figure 1A–C).

3D Modeling. The STL data were forwarded to an UP! Plus 3D Printer (manufactured by Beijing Tiertime Technology, Beijing). This device creates 3D models by injecting

Key words

- Brain
- Neurosurgery
- Retraction
- Three-dimensional printer
- Three-dimensional printing
- Training

Abbreviations and Acronyms

ABS: Acrylonitrile-butadiene-styrene
CT: Computed tomography

DICOM: Digital Imaging and Communication in Medicine

STL: Standard triangulated language

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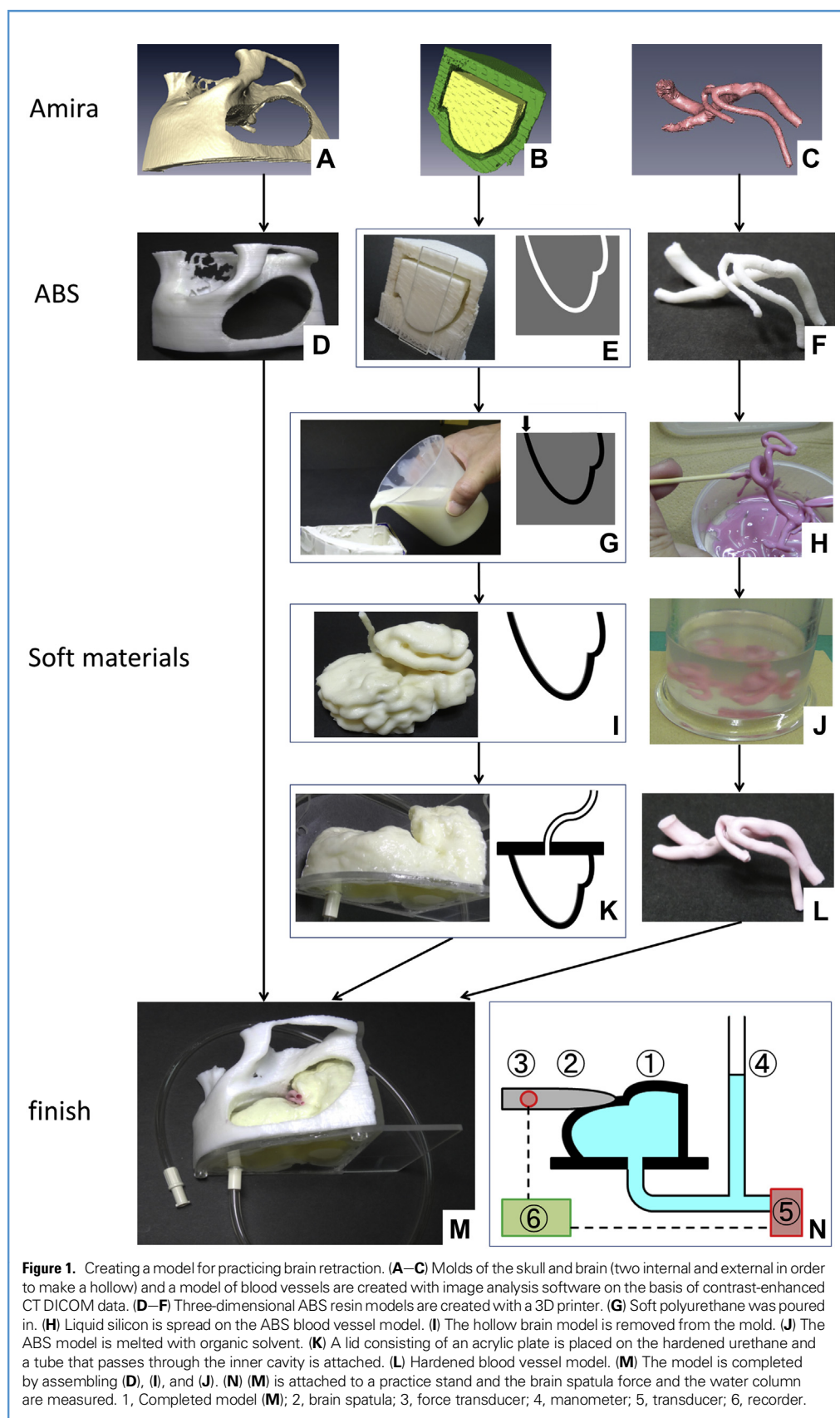


Figure 1. Creating a model for practicing brain retraction. (A–C) Molds of the skull and brain (two internal and external in order to make a hollow) and a model of blood vessels are created with image analysis software on the basis of contrast-enhanced CT DICOM data. (D–F) Three-dimensional ABS resin models are created with a 3D printer. (G) Soft polyurethane was poured in. (H) Liquid silicon is spread on the ABS blood vessel model. (I) The hollow brain model is removed from the mold. (J) The ABS model is melted with organic solvent. (K) A lid consisting of an acrylic plate is placed on the hardened urethane and a tube that passes through the inner cavity is attached. (L) Hardened blood vessel model. (M) The model is completed by assembling (D), (I), and (J). (N) (M) is attached to a practice stand and the brain spatula force and the water column are measured. 1, Completed model (M); 2, brain spatula; 3, force transducer; 4, manometer; 5, transducer; 6, recorder.

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