The Microneurosurgical Training Model for Intrinsic and Extrinsic Brain Tumor Surgery Using Polyurethane Foam and Fresh Cadaveric Cow Brain: An Experimental Study

Adnan Altun[1] *and Cengiz Çokluk*[2]

OBJECTIVE: **To evaluate the feasibility of an experimentally designed brain tumor model consisting of polyurethane foam and fresh cadaveric cow brain for the surgical training of the technique for tumor ablation.**

METHODS: **A laboratory-training model was created for microneurosurgical intervention of intrinsic brain tumor ablation covering microdissection of the brain tissue and opening of the pia mater, dissection and separation of the sulcal and cisternal structures, and dissection and removal of the tumor tissue. The left front parietal lobe was used as the area of interest for this experimental study. One-centimeter cube polyurethane foam was injected 2-cm deep inside the brain tissue using a plastic injection tube. After 5 minutes, the model was ready to use under the operating microscope for dissection, separation, and removal of the tumor tissue. The compatibility of the training model also was evaluated as poor, acceptable, and perfect.**

RESULTS: **Ten stripped fresh cadaveric cow brains were used in this experimental feasibility study. The compatibility of the model was evaluated as poor, acceptable, and perfect in 1, 6, and 3 subjects, respectively.**

CONCLUSIONS: **In intrinsic brain tumor ablation, surgical manipulations of sulcal, cisternal, and fissural dissection must be undertaken while preserving vital neural and vascular structures. We believe that our model holds promise in developing the technical skills of neurosurgeons in training.**

INTRODUCTION

Brain surgery is unforgiving. Unlike some other disciplines, the learning curve is a matter of life or death in arguably all microneurosurgical interventions. To safely perform brain surgery, one must master the use of the operating microscope, handling of the microneurosurgical instruments, the microsurgical techniques required for safely opening neurobiological membranes, delicate neurovascular dissection, and effective tumor ablation. These objectives must be fulfilled in laboratory training models before a neurosurgeon in training attempts to undertake such interventions on a live patient.[1-4] There are a number of laboratory training models developed to accustom the trainee to microsurgical equipment and techniques, including dissection and suturing of the rat external carotid artery, separation of the abdominal vena cava of rats, suturing fine plastic materials with microsurgical instruments under the operating microscope, and drilling cadaveric bone materials resembling cranial base bones.[1-3,5-7]

To perform an intrinsic brain tumor ablation, pial structures must be pertinently opened, surrounding neurovascular tissues must be carefully dissected and retracted, and tumor must be removed while sparing the surrounding, uninvolved brain tissue with appropriate and exacting use of microsurgical instruments including bipolar forceps, microdissector, and suction tip.[4,8]

In this experimentally conducted study, a microneurosurgical training model simulating intrinsic brain tumor ablation was developed using polyurethane foam, fresh cadaveric cow brain, and microsurgical instruments. Structurally, the fresh cadaveric cow brain represents brain tissue whereas the polyurethane foam injected inside represents the tumor.[9,10] The components of this model are readily available and accessible. Its feasibility is evaluated and discussed along with a review of the relevant literature.

Key words
- Brain tumor dissection
- Interhemispheric fissure
- Microneurosurgery
- Operating microscope
- Training of microsurgery

Abbreviations and Acronyms
MRI: Magnetic resonance imaging

From the [1]*Department of Neurosurgery, Medical Faculty, Karatay University, Konya; and* [2]*Department of Neurosurgery, Medical Faculty, Ondokuzmayis University, Samsun, Turkey*

To whom correspondence should be addressed: Adnan Altun, M.D. [E-mail: draaltun@hotmail.com]

Citation: World Neurosurg. X (2019) 4:100039. https://doi.org/10.1016/j.wnsx.2019.100039

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery-x***

Available online: ***www.sciencedirect.com***

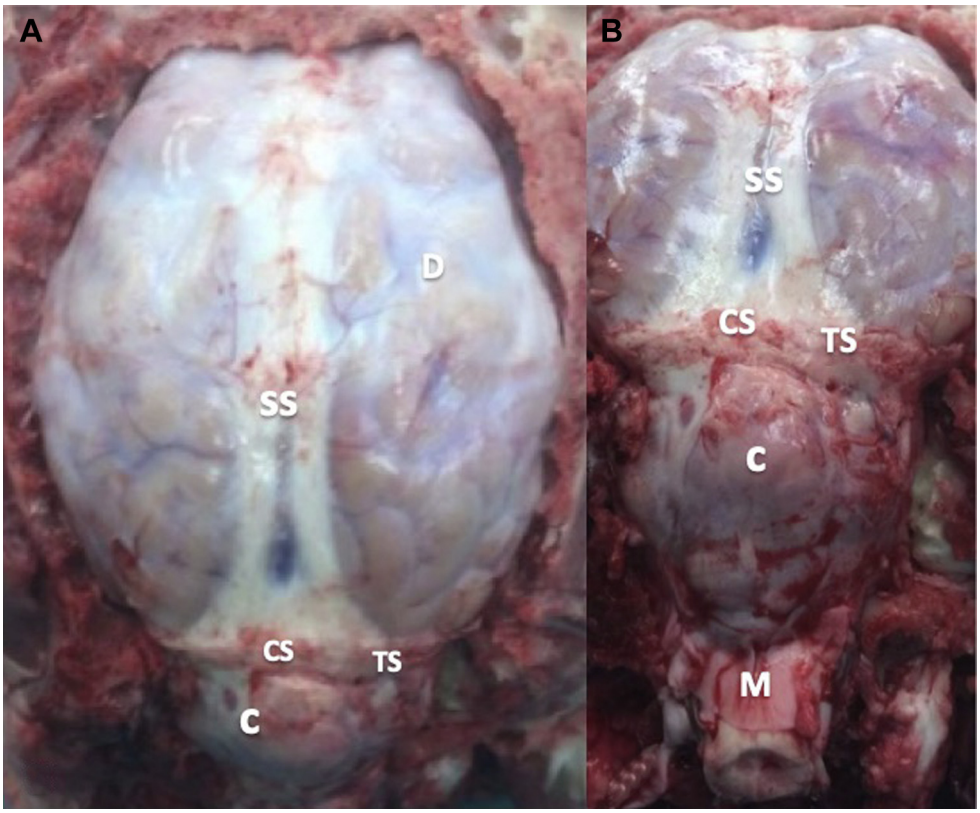

Figure 1. (**A**) Cranial view of the cow brain. D, dura mater; SS, sagittal sinus; CS, confluence sinus; TS, transverse sinus; C, cerebellum. (**B**) Posterior view of the cow brain. SS, sagittal sinus; CS, confluence sinus; TS, transverse sinus; C, cerebellum; M, spinal cord.

MATERIALS AND METHODS

The training model has 2 components, cadaveric cow brain and polyurethane foam. Surgeries were performed under the operating microscope. The training aims to accomplish the following steps: opening pia mater, microdissecting the brain tissue, dissecting and separating the sulcal and cisternal structures, and dissecting and removing the tumor tissue.

Setup

Two neurosurgeons, who are also authors of this study, conducted the experiment. The first neurosurgeon is a very experienced one, specializing in tumor surgery with a reputation of tackling difficult and high-risk brain tumors that are daunting to many others. The second neurosurgeon is a seasoned veteran, confident in a diverse array of neurosurgical interventions. The third neurosurgeon is a recently certified one with a brief history of solo clinical experience. Experiments were carried out via operating microscope (Zeiss, Oberkochen, Germany) and microsurgical instruments. All instruments in direct contact with the model were bought for training purposes and not used in contact with patients for biohazard and legal issues.

The senior author constructed all experimental models (Figure 1). A total of 12 cow brains were used and into each brain and 4 polyurethane injections representing 4 different types of brain tumors were made (Figure 2). While the foams were setting, each region was injected with magnetic resonance imaging (MRI) contrast medium (gadopentetic acid [Magnevist]; Bayer Schering Pharma AG, Berlin, Germany). Afterwards, MRI scanning was carried out (Figure 3). Each model came with an MRI sequence for operative planning. The details of the injections and relevant training goals are as detailed to follow.

Intrinsic Brain Tumor Model

The left frontoparietal lobe is designated as the area of interest. One-centimeter cube polyurethane foam is injected 2 cm deep inside the brain tissue using a plastic injection tube. Within 5 minutes, foam expands and sets in.

Training Goal. Under the operating microscope, a sulcal and cisternal dissection technique is used before incising the pial structures. The tip of the aspirator, bipolar forceps, and microdissector are pertinently used to access, isolate, and remove polyurethane mass that acts as the tumor (Figure 4).

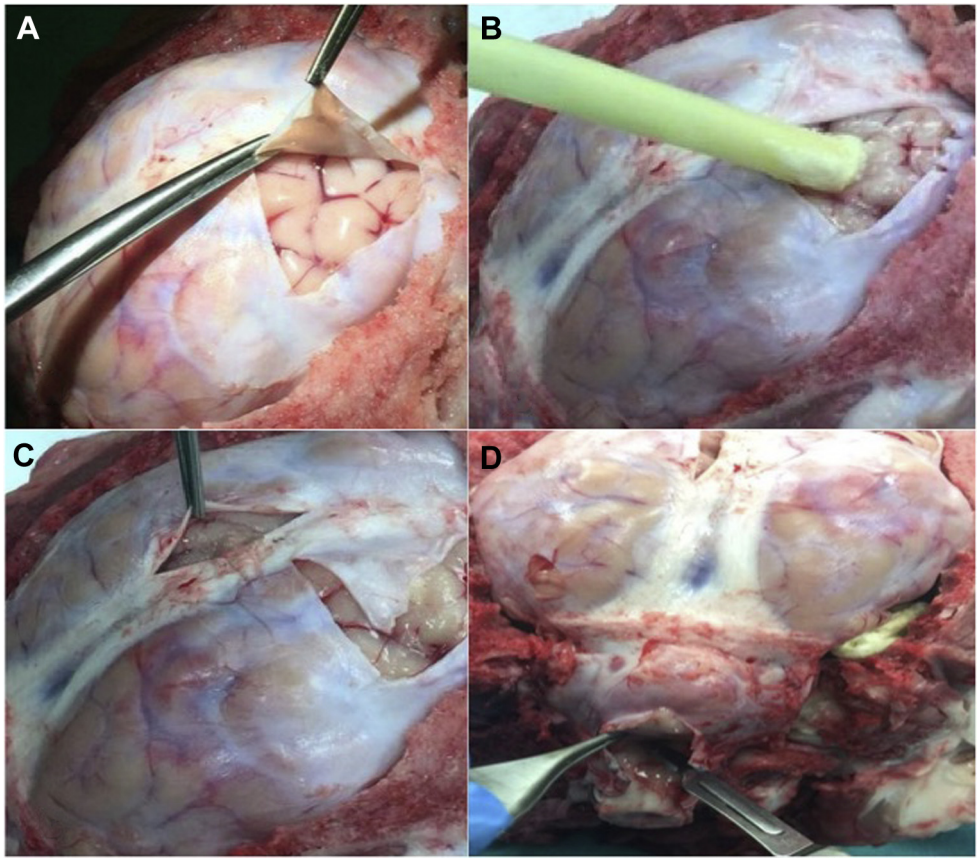

Figure 2. Polyurethane injections representing 4 different types of brain tumors. (**A**) Dura was opened on the left frontoparietal lobe. (**B**) Polyurethane foam is injected 2 cm deep inside the brain tissue using a plastic injection tube. (**C**) Dura was opened on the interhemispheric fissure, right to the sagittal sinus. (**D**) Fourth ventricle was opened for injection of polyurethane foam.

Interhemispheric Extra-Axial Tumor Model

For this model, the same amount of foam is injected inside the anterior interhemispheric fissure, right anterior to the corpus callosum.

Training Goal. The mass is accessed via the interhemispheric fissure exposure by using distraction and distortion techniques and tumor is removed, preserving the surrounding neural and vascular structures (Figure 5).

Fourth-Ventricle Tumor Model

To simulate a tumor located inside the fourth ventricle, the same amount of polyurethane foam is injected via a cannula introduced through cisternae magna.

Training Goal. Tumor is removed through the rhomboid fossa by using trans-sulcal and cisternal dissection (Figure 6).

Cerebellopontine Tumor Model

For the cerebellopontine angle tumor model, the cadaveric brain is placed on the table with its caudal surface facing up. The seventh and eighth cranial nerves are identified using microdissection and same amount of foam is injected between them.

Training Goal. The brain is placed with its lateral side facing up, and sulcal cisternal dissection, separation, and distortion techniques are exercised using various sizes of suction tips, microbayonet, microdissector, and microscissors, while avoiding damage to the neurovascular structures (Figure 7).

The senior neurosurgeon operated on 2 models to set the time scale. Afterwards, the veteran and novice brain surgeons operated on 5 brains, conducting 20 simulated tumor ablations in total. The senior surgeon evaluated the time taken for each procedure was noted and the performance of the trainees (Figure 8). Thus, compatibility and educational value of this model for preparing a neurosurgeon for a live surgery were assessed.

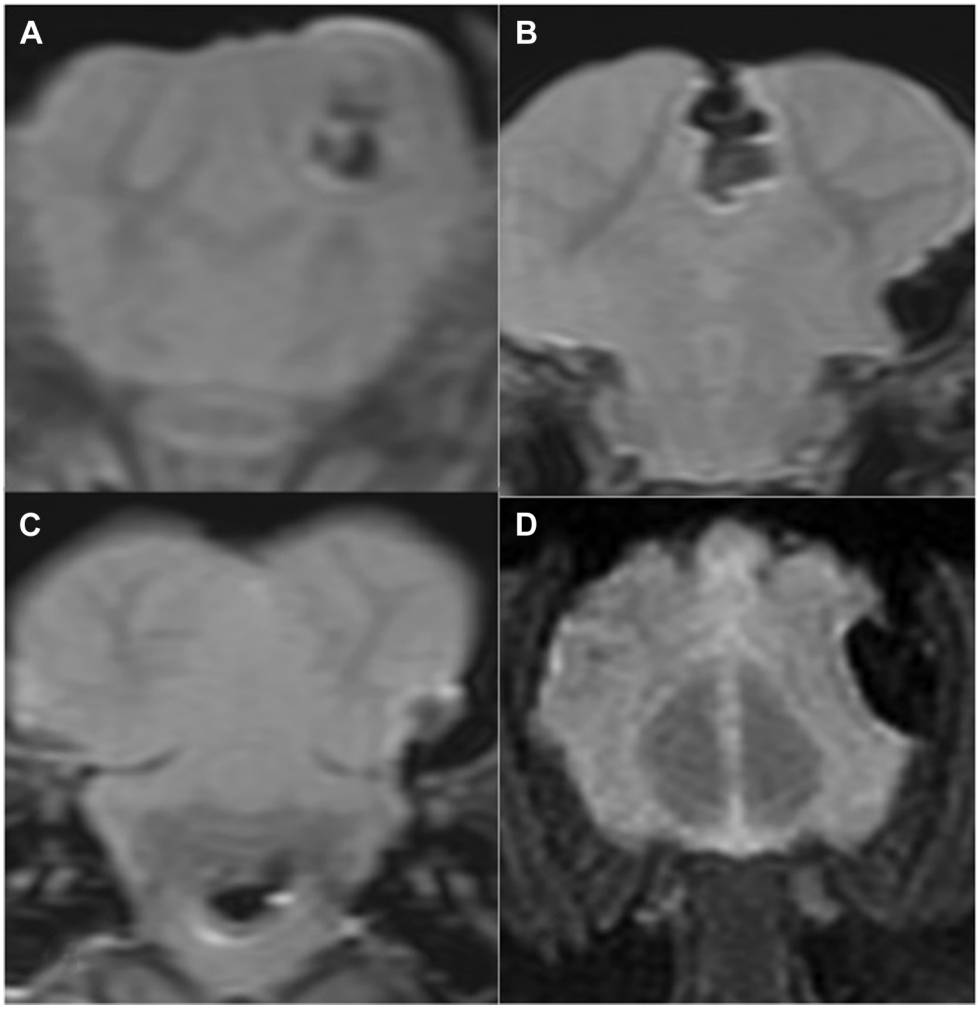

Figure 3. (**A**) Axial contrast series for intrinsic brain tumor model. (**B**) Axial contrast series for interhemispheric extra-axial tumor model. (**C**) Axial contrast series for fourth ventricle tumor model. (**D**) Axial contrast series for cerebellopontine tumor model.

RESULTS

Microscissor, micro-bayonet, and the tip of the metallic aspirator were used in the dissection of brain spaces. The sharp edge of the microscissor was used to cut and open the arachnoid membrane. Our experiences revealed that the arachnoid membrane of the cow brain is more delicate and thinner than that of the human brain. To avoid neural damage, caution must be exercised while cutting the arachnoid open. Cotton paddies and the blunt corner of the microsurgical instruments can be used to separate the brain tissue from the cisternae, sulci, and fissures. A basic microsurgical technique is efficient in separation of the brain tissue without any pia mater injury. The middle cerebral artery is easy to identify and dissect in the sylvian cistern. In contrast, dissection of the venous structure is difficult in cadaveric cow brain specimens. The identification and separation of the interhemispheric fissure is easier in comparison with sylvian cistern. The sulcal dissection of the brain hemisphere is also important. The careful and delicate dissection and separation is necessary to open the sulcus.

The suitability of the experiment for training model was evaluated as bad in 1 (10%) of the fresh cadaveric cow brains. The suitability was found as good in 6 (60%) of the procedures. In the remaining 3 (30%) brain dissections, the suitability of the experiment was evaluated as perfect.

DISCUSSION

Before performing a real surgical intervention, the training of microneurosurgical techniques is a crucial step for

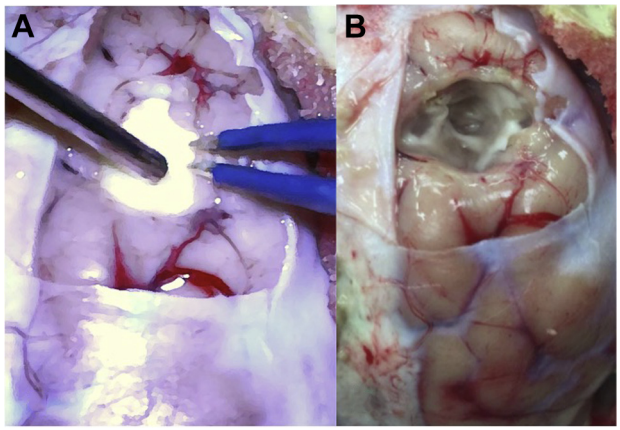

Figure 4. (**A**) Performing microsurgical operation to the intrinsic brain tumor model under the operating microscope. (**B**) Surgical field after tumor model removal.

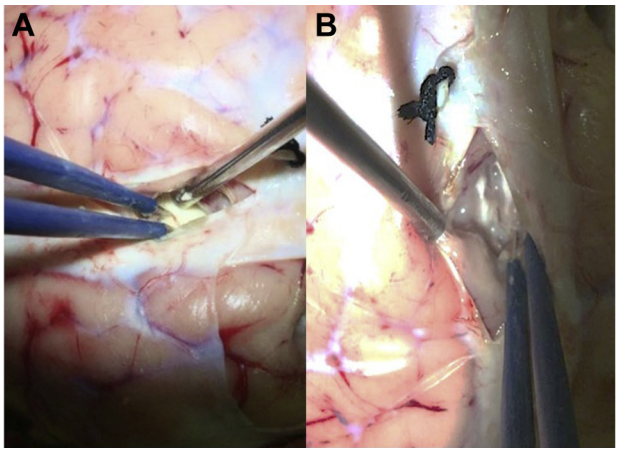

Figure 5. (**A**) Interhemispheric extra-axial tumor ablation under the operating microscope. (**B**) Surgical field after tumor model removal.

neurosurgeons.[1] During the training process, surgeons should familiar themselves with regional neuroanatomy and surgical instruments in the laboratory setting.[1] Moreover, it is imperative to repeat the surgical techniques several times on appropriate models to seamlessly execute and complete a real surgery.[1,4] In addition, it should allow room for the trainee to develop his or her own abilities and create integrated surgical techniques.[1-3,5-7] In experimental practice, vascular end-to-end, end-to-side, side-to-side anastomoses, and sylvian fissure dissection in the rat models may be use as a model for microsurgical training.[2,3,5-7] In this newly proposed model, using fresh cadaveric cow brain with polyurethane foam and real surgical instruments, including an operating microscope, is suggested as a training model for intrinsic brain tumor surgery.

In their study, Kamp et al.[4] introduced an experimental model in which they injected agar solution of various consistencies into a sheep brain. After injection, the brain was refrigerated overnight in −4°C for the solution to set. The model requires thawing before use. They proposed solutions of various consistencies to mimic malignant, metastatic, and infiltrative lesions.[4]

Our model uses cow brain, which provides closer resemblance to human brain. Polyurethane foam is injected into fresh specimen and requires only 5 minutes to set. The foam's expansion and seeping into weak spots in glial substance mimics invasive and displacing characteristics of malignant tumors.

An appropriate and successful model should have some similarities with the real represented clinical counterpart. Also, it's desirable that the model is cheap and readily available. It should not necessitate intricate preparation and should allow for repetitive interventions. Although live brain surgery models with brain size comparable with humans seem to represent a real human surgery the best, they are expensive, not readily available, and on top of that, the sacrifice a large number of large animals for this purpose would be ethically questionable. In contrast, a cadaveric cow brain costs almost nothing, can be obtained effortlessly from a butcher or slaughterhouse, can be used with no preparation required, and operated on repeatedly with no ethical concerns whatsoever.

Nevertheless, there are some differences between the human and cow brain. The human brain weighs 1200−1500 g, about twice that of the cow brain. Human brain has more sulci and gyri and has a rounded shape rather than the elongated cow brain. Other than that, all mammal brains have more similarities than differences. The location of the interhemispheric sulcus and the arachnoid membrane location have the same characteristic features between human and cow brain. In this experimental model, similar microsurgical instruments were used during dissection, separation, and distraction of the brain. Microscissor, the tip of the microaspirator, and micro-bayonet were used in the dissection and separation of the neural and vascular structures.

Microdissection is the mainstay of brain surgery. Radiodiagnostic images are used commonly to pinpoint the location of tumors and aneurysms. Once the location of the lesion is ascertained, an operative corridor is opened via microdissection around or through the sulci, cisterns, and parenchyma, and the lesion is ablated. Repetitive training of the sulcal and cisternal dissection and navigation in laboratory models is crucial in safe surgical intervention. This experimental study demonstrates that cow brain is a suitable model for training of the brain tissue, sulcal, and cisternal dissection.

Ten fresh cadaveric cow brains were used in this experimental feasibility study. The suitability of the experiment for training model was evaluated as bad in 1 (10%) of the fresh cadaveric cow brains. The suitability was found as good in 6 (60%) of the procedures. In the remaining 3 (30%) brain dissections, the suitability of the experiment was evaluated as perfect.

One drawback of this model is that the injected foam does not invade the brain tissue the way a malignant intrinsic brain tumor does. Although the foam expands after injection and mimics the mass and displacement effects of tumors, it can be dissected from

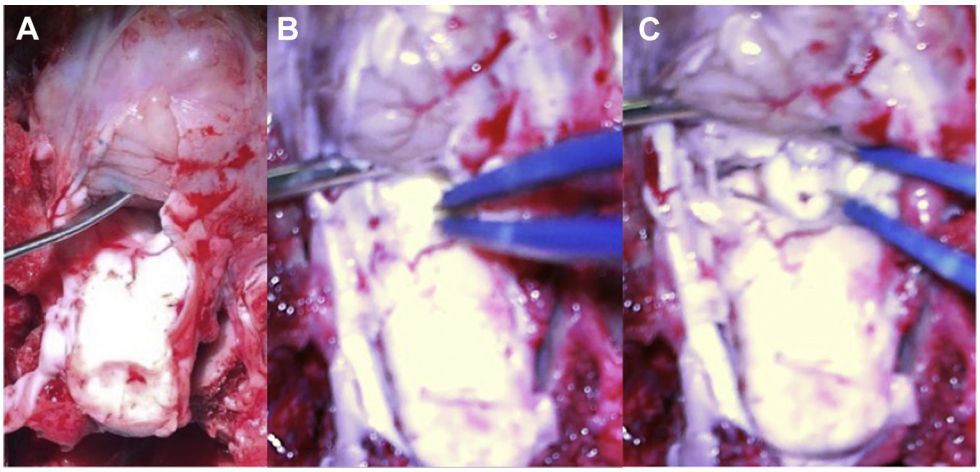

Figure 6. (**A**–**B**) simulated microsurgical fourth ventricle tumor model ablation under the operating microscope. (**C**) Surgical field after tumor model removal.

the brain tissue much easier than any malignant tumor would allow. In contrast, it represents the behavior of an interhemispheric extra-axial tumor almost authentically. Polyurethane foam is easily placed and mimics the effects of olfactory groove and parafalcine tumors along with expansion and pressure effects. Dissection must be commenced while preserving critical neurovascular structures. Likewise, this model is very suitable for fourth-ventricle tumor models, for such tumors expand occupying the rhomboid fossa, and during their ablation pons and bulbus must be preserved and cerebellar pedicles and aqueduct, which are distorted and displaced by the tumor, must be recognized. The cerebellopontine angle is one of the most difficult regions of neurosurgery. In this tight spot, not only the brain substance but also cranial nerves must be preserved as well. In our model, the foam is injected posterior to the seventh cranial nerve and removed in a manner similar to a live surgery, the tumor is mobilized carefully from the brain stem, preserving neural structures.

CONCLUSIONS

In conclusion, performing dissection and separation of the neurovascular structures on training models before real procedures on humans is sine-qua-non in practice and training of neurosurgery. The cow sulcus and cistern training model is feasible, as shown in

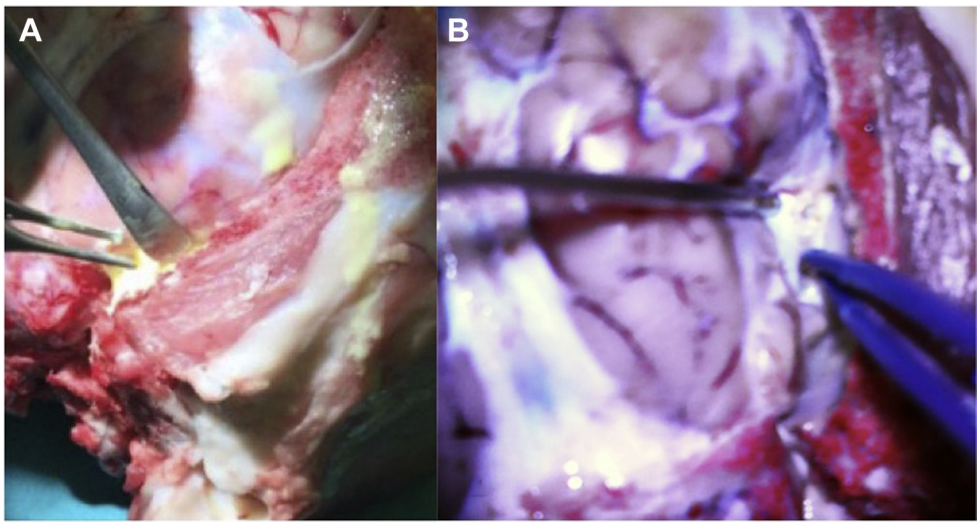

Figure 7. (**A**–**B**) Simulated microsurgical cerebellopontine tumor model ablation under the operating microscope.

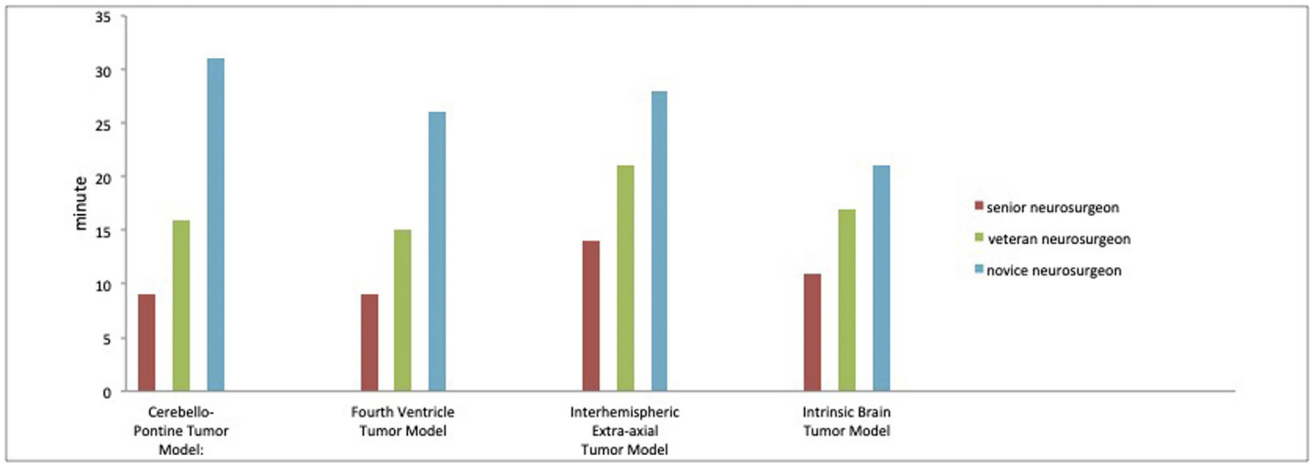

Figure 8. Performance chart displaying the time neurosurgeons spent for each intervention.

this experimental study. We believe that this training model will contribute to the practical microneurosurgery in the protecting of neurovascular tissue and adequately performing of the microsurgical intervention.

DECLARATION OF COMPETING INTEREST

The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REFERENCES

1. Cokluk C, Aydin K. Maintaining microneurosurgical ability via staying active in microneurosurgery. *Minim Invasive Neurosurg*. 2007;50:324-327.
2. Altunrende ME, Hamamcioglu MK, Hıcdonmez T, Akcakaya MO, Bırgılı B, Cobanoglu S. Microsurgical training model for residents to approach to the orbit and the optic nerve in fresh cadaveric sheep cranium. *J Neurosci Rural Pract*. 2014;5:151-154.
3. Spetzger U, von Schilling A, Brombach T, Winkler G. Training models for vascular microneurosurgery. *Acta Neurochir Suppl*. 2011;112:115-119.
4. Kamp MA, Knipps J, Steiger HJ, et al. Training for brain tumour resection: a realistic model with easy accessibility. *Acta Neurochir*. 2015;157:1975-1981.
5. Yadav YR, Parihar V, Ratre S, Kher Y, Iqbal M. Microneurosurgical skills training. *J Neurol Surg A Cent Eur Neurosurg*. 2016;77:146-154.
6. Belykh E, Byvaltsev V. Off-the-job microsurgical training on dry models: Siberian experience. *World Neurosurg*. 2014;82:20-24.
7. Turan Suslu H, Ceylan D, Tatarlı N, et al. Laboratory training in the retrosigmoid approach using cadaveric silicone injected cow brain. *Br J Neurosurg*. 2013;27:812-814.
8. Kiran NAS, Furtado SV, Hedge AS. How I do it: anterior clinoidectomy and optic canal unroofing for microneurosurgical management of ophthalmic segment aneurysms. *Acta Neurochir*. 2013;155:1025-1029.
9. Hincke MT, Nys Y, Gautron J, Mann K, Rodriguez-Navarro AB, McKee MD. The eggshell: structure, composition and mineralization. *Front Biosci (Landmark Ed)*. 2012;17:1266-1280.
10. Nakano T, Ikawa NI, Ozimek L. Chemical composition of chicken eggshell and shell membranes. *Poultry Sci*. 2003;82:510-514.

Received 12 January 2019; accepted 20 May 2019
Citation: World Neurosurg. X (2019) 4:100039.
https://doi.org/10.1016/j.wnsx.2019.100039
Journal homepage: ***www.journals.elsevier.com/world-neurosurgery-x***
Available online: ***www.sciencedirect.com***