



Research Article

Vascular Silicone Injection of Fresh Cadaveric Cow Cranium: Alternative Training Model For The Human Brain

Necati TATARLI¹, Hikmet Turan SÜSLÜ¹, Davut CEYLAN², Aşkın ŞEKER³, Hakan KARABAĞLI⁴, Ender KÖKTEKİR⁴, Selçuk ÖZDOĞAN¹, Tufan HIÇDÖNMEZ¹

¹Dr. Lütfi Kırdar Kartal Education and Research Hospital, Department of Neurosurgery, İstanbul, Turkey ²Sakarya University School of Medicine, Department of Neurosurgery, Sakarya, Turkey ³Marmara University Institute of Neurological Sciences, Department of Neurosurgery, İstanbul, Turkey ⁴Selçuk University School of Medicine, Department of Neurosurgery, Konya, Turkey

Summary

Background: Anatomical and physiological variations of the human brain's vascular system can be observed via silicone injection of the arterial and venous systems. As a novel method, the injection of a fresh cadaveric cow cranium with silicone is an alternative to using the human brain for microanatomical studies.

Objective: To report on an improved method for the colored silicone injection of a fresh cadaveric cow cranium using a silicone injection technique.

Methods: Five fresh cow crania were injected as an alternative to human brains for microanatomical dissection, in which the preparation consisted of the irrigation of the major vessels and the injection of colored silicone. Cannulation of the internal carotid arteries and the internal jugular veins with catheters was performed, and the vasculature was irrigated with water (major arteries and veins). The fixation of the specimen with either formaldehyde or alcohol, and the colored injection of the arteries and veins with red and blue silicone, respectively, was then performed.

Results: The silicone injections resulted in the deeper penetration of the colored solutions into the small cerebral vessels and mesenchymal structures of the fresh cadaveric cow crania. Of the five injected specimens, four exhibited successful injections, while one had suboptimal results.

Conclusion: Silicone injection of the cadaveric cow brain, based on the anatomical and physiological assessment of the vasculature of the specimen for microanatomical studies, is suggested as an alternative to using human brain specimens.

Key words: Cadaver, cow cranium, dissection, silicone injection, microneurosurgical training, resident training

Taze İnek Kranium Kadavrasının Vasküler Silikon İnjesiyonu: Eğitim Modeli Olarak İnsan Beynine Bir Alternatif

Özet

Arka plan: İnsan beyin damar sisteminin anatomik ve fizyolojik farklılıkları, arteriyel ve venöz sistemlerin silikon enjesiyonu ile görülebilir. Yeni bir yöntem olarak, taze inek kranium kadavrasının silikon injesiyonu, mikroanatomik çalışmalar için insan beyninin silikon enjesiyonuna bir alternatiftir.

Amaç: Amacımız, silikon enjesiyon tekniği kullanarak taze inek kranium kadavrasının renkli silikon enjesiyonu için geliştirilmiş bir metot bildirmektir.

Yöntem: İnsan beynine alternatif olarak mikroanatomik diseksiyonlarda kullanılmak üzere beş adet taze inek kraniumu, injekte edildi. Hazırlık, majör damarların yıkanması ve renkli silikon injeksiyonunu içerir. Sırasıyla internal karotis arter ve internal juguler venlerin kateterle kanülasyonu, ana arter ve venlerin su ile yıkanması, kraniumun alkol veya formaldehit ile fikse edilmesi, kırmızı ve mavi silikon ile arter ve venlerin renkli injeksiyonu uygulandı.

Bulgular: Silikon injeksiyonları, taze inek kranium kadavrasında, küçük beyin damarlarının ve mezenkimal yapıların içine renkli solüsyonların derin penetrasyonunu sağladı. İnjektasyon yapılmış beş kraniumun dördünde başarılı olundu. Birinde ise suboptimal sonuçlara varıldı.

Sonuç: Mikroanatomik çalışmalar için kraniumun damarlarının anatomik ve fizyolojik değerlendirilmesi temelinde, silikon injekte edilmiş inek kranium kadavrası, insan beyin kadavrasına bir alternatif olarak önerilmiştir.

Anahtar Kelimeler: Kadavra, inek kraniumu, diseksiyon, silikon injeksiyonu, mikronöroşirürji eğitimi, asistan eğitimi

INTRODUCTION

Neurosurgical training, neuroanatomical research, and novel neurosurgical techniques depend on the detailed study of cadaveric specimens^(3,4,7,10). The colored injection of the arterial and venous systems of cadaveric human crania provides precise anatomic details of the cerebral vasculature essential for microanatomical studies^(1,2,7,8,10). In the neurosurgical literature, there have been many reports of microneurosurgical laboratory training models with silicone injected cadaveric human brains^(1,2,3,5,7,8). However, the silicone injection procedure of fresh cadaveric cow crania has not been thus far reported in the neurosurgical literature.

Here, we describe the novel technique for the colored silicone injection of fresh cadaveric cow crania for training models. The present model of a fresh cadaveric cow cranium with silicone satisfies our aim to familiarize the residents of neurosurgery, in the earlier years of their residency program, with similar microneurosurgical techniques used in cranial approaches.

MATERIAL AND METHODS

This laboratory model was designed in the Dr.Lütfi Kırdar Kartal Education and Research Hospital, and developed at the Marmara University, Institute of Neurological Sciences, Prof. Albert Rhoton Neuroanatomy Laboratory as an

innovation of the previously designed model of fresh cadaveric cow brains.

Five fresh cadaveric cow crania, obtained from a local butcher, were injected and preserved for anatomical dissection. The study material consisted of fresh cadaveric crania from 2-3 year-old cows, and was kept in the refrigerator at 4 C° for 6-10 hours after the specimen was obtained.

Cannulation, Irrigation, and Fixation

The fresh cadaveric cow crania were fixed in formaldehyde, and were then separated at the neck to provide isolation of the blood vessels for cannulation. The jugular veins, carotid arteries, and vertebral arteries were isolated and dissected for silicone injection.

The cervical vessels were identified and dissected to isolate 1.5 to 2 cm of each vessel from the surrounding soft tissue, and silastic tubes of appropriate size were inserted in each of the internal carotid arteries (ICAs) and internal jugular veins (IJVs). The vertebral arteries (VAs) were then identified and dissected from the foramina transversaria; however, the VAs could not be cannulated due to the small lumen. The stumps of the vessels were secured with 2-0 silk suture; while disposable polypropylene pipette tips were connected to the silastic tubing of each blood vessel and the ends of the tubing were clamped using polypropylene tube clamps. The connector tips were cut to the

size of each silastic tube. Next, all of the cannulated vessels were flushed repeatedly with tap water using a 50-cc syringe to remove the clots and insure a smooth flow. The arterial system was irrigated before the venous system, because venous congestion may lead to increased resistance and decreased arterial flow.

After the water irrigation protocol, the ICAs were injected first, followed by the IJVs, using fixation solution. Then, the catheters were closed to maintain the fixation solution within the vasculature for 48 to 72 hours. The cranium was then partially immersed in a closed container with a mixture of 10 % formaldehyde and 10 % ethyl alcohol for as long as the specimen remained in use, and kept refrigerated at 4 C°. After the fixation was complete, the catheters were opened and the vessels were flushed again with room-temperature water to reassess the vascular permeability before the colored silicone injection.

Colored Silicone Injection of the Arterial and Venous Systems

The silicone (3110 RTV silicone rubber) was prepared, and the mixtures were thinned at ratios of the two materials: for arteries, thinner 2:silicone 1; and for veins, thinner 1 : silicone 1 (the thinner used was polydimethylsiloxane). Then, the red or blue pigment was added, in which a higher concentration of pigment provided the vasculature with vivid color. The approximate concentration of the pigment was an amount that was enough to eliminate the transparency of the cup; then, the catalyst for each solution was added immediately before the injection (1/3 – 1/2 tube for 100–150 ml of solution; more catalyst equals faster curing of the silicone).

The colored silicone was injected manually according to the following guidelines: for arteries, internal carotid, 50ml each x 2 = 100 ml; and for veins, internal jugular 75 ml each x 2 =150 ml. The ICAs were injected first with 50 cc of the red silicone;

as soon as the flow could be seen coming out of the contralateral ICA, this vessel was clamped and steady pressure was applied through the ipsilateral ICA to promote the flow into the posterior communicating arteries (PComAs), toward the vertebrobasilar system. The venous system was then injected with the blue silicone solution. A larger volume of silicone is needed for this injection, because of the larger volume of the venous system; therefore, 75 cc of blue silicone was attached to the catheter of the IJV, and the venous system was filled until the flow out of the contralateral IJV was seen. Both Foley catheters were then clamped, and the procedure was repeated with the contralateral IJV. After the injection of both IJVs, the catheters were closed and the balloons in each catheter were inflated to encourage the further flow of latex into the venous system.

The specimen was kept in a plastic bag in a bucket in an inverted position for 48 hours, without being submerged in ethanol, to avoid any interference with the silicone curing process. The hardening of the silicone left in the cups can be used to indicate the degree of curing in the injected specimen. Each silastic tube was cut at the point of entry into the vessels, after confirmation of the curing process.

RESULTS

Among the five injected specimens, four had successful injections (anterior and posterior vascular systems colored), while one had suboptimal results (anterior vascular system colored, posterior vascular system not colored). The colored silicone injections resulted in the deeper penetration of the colored solutions into the small cerebral vessels and mesenchymal structures in the successful injections. Silicone casts are sometimes insufficient in creating the forms of the veins when clots are present.

The VAs could not be cannulated due to the small lumen; however, the anterior and posterior vascular systems were colored by

the ICA and IJV cannulations. One specimen had a failure in the color injection in the posterior vascular system due to the failure of the removal of clots and debris during irrigation of the

vasculature. Adequate water irrigation was the most important factor for the colored posterior vascular system, without VA cannulation.

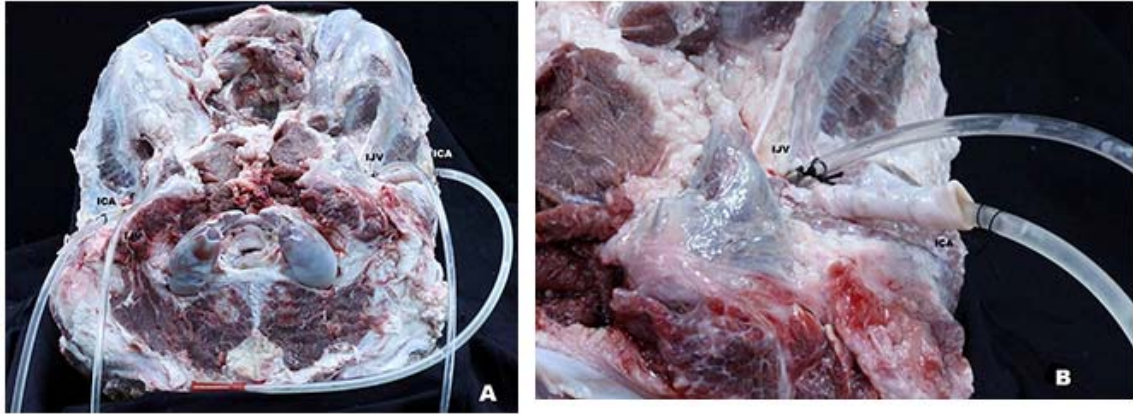


Figure 1 A, B: The great vessels of the neck have been isolated and dissected from the surrounding tissues. These great vessels have been cannulated with appropriately sized tubing (internal carotid artery: ICA, internal jugular vein: IJV).



Figure 2: Irrigation with tap water results in the expulsion of clotted blood from the contralateral vessel.

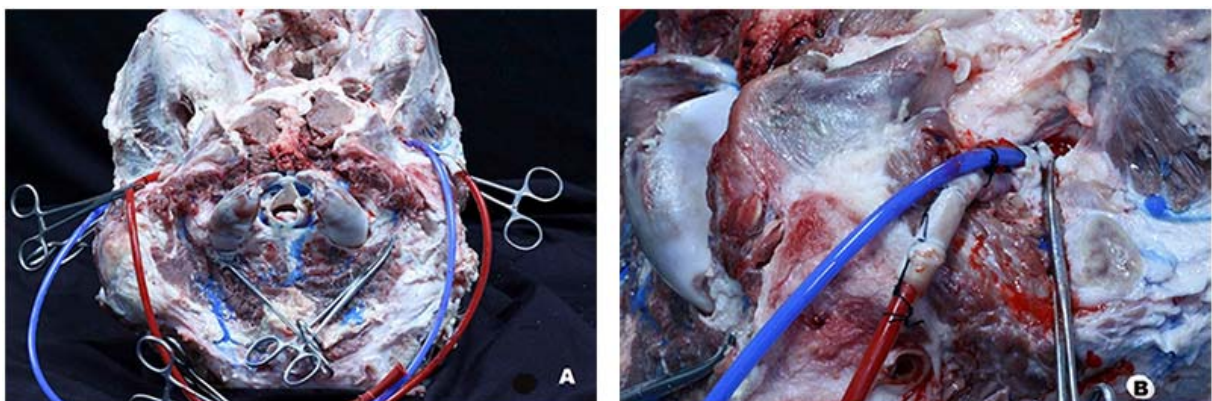


Figure 3 A, B: The final specimen should have colored silicone in the intracranial circulation.

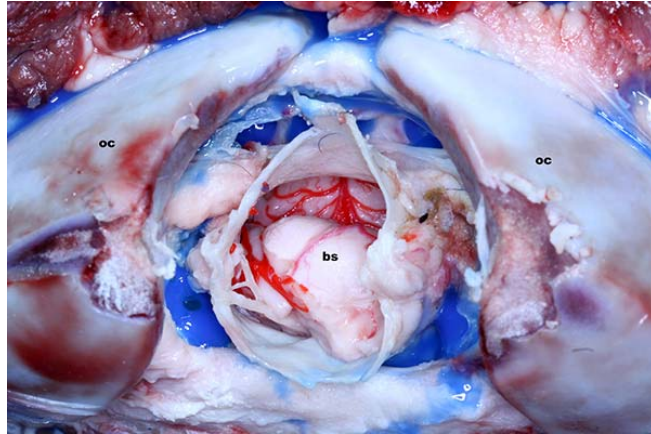


Figure 4: The VAs cannot be cannulated due to small lumina. However, the anterior and posterior vascular systems are colored by ICA and IJV cannulation (brainstem: bs, occipital condyle: oc).

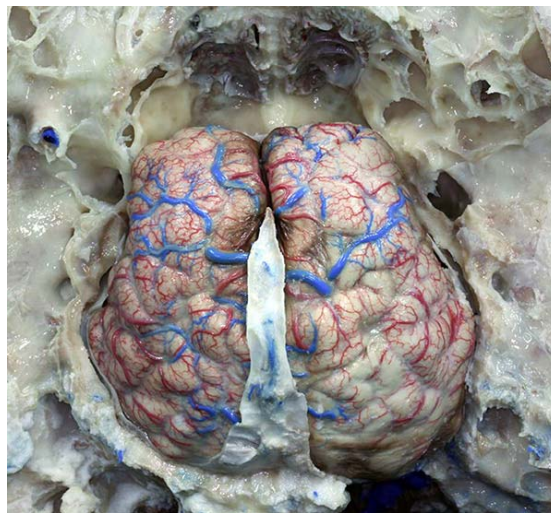


Figure 5: Specimen showing the cerebral vessels and cerebral hemispheres.

DISCUSSION

Selective injection of the cerebral vasculature was first documented by Thomas Willis during the 17th century⁽⁶⁾. Willis described, for the first time, details of the arterial system of the brain. By selectively ligating different parts of the “circle”, he demonstrated that blood flow could still reach the contralateral hemisphere through the anastomotic connections of the *circulus arteriosus*.

The colored injection of the cerebral vasculature is now commonly performed to improve the quality of the anatomical detail of cadaver specimens for

microneurosurgical research, education, and laboratory training^(1,2,5,7,8,9). With modern microsurgical techniques, the color injection is necessary to provide anatomical detail similar to that of the human brain anatomy in the operating room. Few reports in the literature specifically address the techniques for the colored injections of cadaveric human specimens, and disagreement regarding the optimal injection techniques remains^(1,2,3,5,9). Our injection method relies on a physiological assessment of the flow in the arterial and venous systems of fresh cadaveric cow crania for microneurosurgical training models.

The arterial system is irrigated before the venous system, because venous congestion may lead to increased resistance and decreased arterial flow. The venous system has a high capacitance, and irrigation without previous arterial flushing can result in the congestion of the venous sinuses and intracranial veins, which increases resistance within the arterial system, prevents adequate removal of clots and debris, and decreases the effective dilation of distal arteries. The irrigation sequence should be followed by completing the ICAs first, and the IJVs second. The irrigation should be continued until the water flow is clear, which ensures that clots and debris have been removed. The amount of irrigation used, usually 2 to 4 L, depends on the amount of clots and debris within the vasculature.

The regulation of the water flow by selective vessel clamping during water irrigation helps to dilate portions of the arterial system, and to open potential anastomoses of the human brain. During the irrigation of both ICAs, the catheter is intermittently clamped to promote the flow through the PComAs into the vertebrobasilar system of the human brain. Similarly, during the irrigation of one VA, it is important to clamp the contralateral VA to promote the flow into the basilar artery and through the PComAs into the carotid system of the human brain. The VAs could not be cannulated due to the small lumen in our specimens. However, the anterior and posterior vascular systems of cow brains are colored by ICA and IJV cannulation through the PComAs.

Practice on a cadaveric cow cranium has several advantages over the use of a human brain: the preparation of the model is simple; the material is cheap, convenient to manage, easy to obtain, and requires neither a specific facility for maintaining living animals nor anesthesia; and the cow cranium costs only \$30. Junior residents can practice microneurosurgery on fresh organic tissue in their early residency

period, and they learn how to use microneurosurgical instruments (bipolar cautery tools, hook, suction tube, microscissors, etc.) under the operating microscope in a three-dimensional surgical field that simulates real-life surgery. The use of cadaveric cow material raises no ethical objections. The use of the silicone injected cow cranium is easily accessible, repeatable surgical training model that mimics silicone injected human brains, and helps to improve the surgical skills of neurosurgical trainees.

The differences between the anatomy of cow and human brains are negligible in terms of microneurosurgical handling. However, one must remember that the training model is not an anatomical study of the cow's brain in the context of veterinary medicine; and, except for its microneurosurgical similarities to corresponding structures in the human brain, the brain's actual anatomy is not the subject of the training model.

CONCLUSION

In this study, a training model alternative to the cadaveric human brain using silicone to study the neuroanatomical details of the system has been reported. This model is based on an assessment of the physiology of flow within the cerebral vasculature during the different stages of the neurosurgical procedure, and has led to superior results in the preparation of cadaveric specimens for neuroanatomical dissection.

Conflict of interest

There is no conflict of interest.

Acknowledgements

We have no financial relationship to this work, nor have we received any other form of financial support, government or company grants, or research support. We are not employees of a company, consultants for a company, stockholders of a company, or members of a speakers' bureau.

Correspondence to:

Necati Tatarlı

E-mail: necatitatarli@yahoo.com

Received by: 24 August 2014

Accepted: 18 December 2014

The Online Journal of Neurological Sciences (Turkish) 1984-2015

This e-journal is run by Ege University

Faculty of Medicine,

Dept. of Neurological Surgery, Bornova,
Izmir-35100TR

as part of the Ege Neurological Surgery

World Wide Web service.

Comments and feedback:

E-mail: editor@jns.dergisi.org

URL: <http://www.jns.dergisi.org>

Journal of Neurological Sciences (Turkish)

Abbr: J. Neurol. Sci.[Turk]

ISSNe 1302-1664

6. Poulhes J. Preparation of anatomic pieces in plastic materials. *Presse Med.* 1953; 61(16):327
7. Rhoton AL Jr: Operative techniques and instrumentation for neurosurgery. *Neurosurgery* 2003; 53(4): 907-34
8. Rhoton AL Jr: Cranial Anatomy and Surgical Approaches. Schaumburg, Lippincott Williams & Wilkins, 2003, pp.295-301
9. Sanan A, Abdel Aziz KM, Janjua RM, van Loveren HR, Keller JT. Colored silicone injection for use in neurosurgical dissections: anatomic technical note. *Neurosurgery* 1999; 45(5): 1267-71
10. Turan Suslu H, Ceylan D, Tatarlı N, Hicdonmez T, Seker A, Bahri Y, Kılıç T. Laboratory training in the retrosigmoid approach using cadaveric silicone injected cow brain. *Br J Neurosurg.* 2013; 27(6): 812-4

REFERENCES

1. Alvernia JE, Pradilla G, Mertens P, Lanzino G, Tamargo RJ. Latex injection of cadaver heads: technical note. *Neurosurgery* 2010; 67(2 Suppl Operative): 362-7
2. Groen RJ, Grobbelaar M, Muller CJ, van Solinge G, Verhoof O, du Toit DF, Hoogland PV. Morphology of the human internal vertebral venous plexus: a cadaver study after latex injection in the 21-25-week fetus. *Clin Anat.* 2005; 18(6): 397-403
3. Hicdonmez T, Hamamcioglu MK, Parsak T, Cukur Z, Cobanoglu S. A laboratory training model for interhemispheric-transcallosal approach to the lateral ventricle. *Neurosurg Rev.* 2006; 29(2): 159-62
4. Hicdonmez T, Hamamcioglu MK, Tiryaki M, Cukur Z, Cobanoglu S. Microneurosurgical training model in fresh cadaveric cow brain: a laboratory study simulating the approach to the circle of Willis. *Surg Neurol* 2006; 66(1): 100-4
5. Peng TH, Ding HM, Chen SH, Tang ML, Hong L, Tan JG, Wang AP, Xu DC. Demonstration of three injection methods for the analysis of extrinsic and intrinsic blood supply of the peripheral nerve. *Surg Radiol Anat.* 2009; 31(8): 567-71