Simulation of Cerebrovascular Circulation in the Human Cadaver for Surgical Neuroanatomy Training

Cerrahi Nöroanatomi Eğitimi için İnsan Kadavrasında Serebrovasküler Simülasyon

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ABSTRACT

OBJECTIVE: The current progress in diagnostic and screening methods and surgical equipment technologies facilitates the accessibility to numerous anatomic structures through various interventional approaches. Consequently, the exact knowledge of the anatomic locations of neurovascular structures and their interactions may ensure that the surgical intervention is planned in the most appropriate way and the structures are accessed with the least complication risk during the intervention.

MATERIAL and METHODS: A decapitated and formalin fixated whole-head of a male human cadaver kept for educational and research purposes in the Dokuz Eylul University Department of Anatomy was used in this study. Two separate reservoirs (for the arterial and the venous system) were connected to the Truno System 3 labeled perfusion pump. The reservoirs were filled with blue and red warm tap water. Colored tap water pumped on the right was emptied from the left. Continuous flow of the water in the closed-circuit arterial and venous systems was achieved. As the circulation was continuing, pterional craniotomy was performed and the dura mater was accessed and lifted under the Zeiss dissecting microscope.

CONCLUSION: We believe that this model may contribute to neuroanatomy education and provide experience for the safe and ethical performance of surgical interventions during the intraoperative period.

KEY WORDS: Cerebrovascular circulation, Simulation, Surgical neuroanatomy training

ÖZ

Günümüzde tanı yöntemleri ve cerrahi teknolojisinin gittikçe artması, intrakranyal girişimlerde pekçok anatomik yapıya ulaşılabilirliği artırmaktadır. Bu nedenle nörovasküler yapıların anatomik yerleşim ve ilişkilerinin tam olarak bilinmesi, yapılacak olan cerrahi girişimin en uygun şekilde planlanmasını ve en az komplikasyon riskiyle ulaşılmasını sağlar. Bu çalışmada, insan kadavrası üzerinde intrakranyal dolaşıma yakın bir simülasyon oluşturularak tanımlanan modelin, nöroanatomi eğitimine katkı sağlaması amaçlandı. DEÜ Tıp Fakültesi Anatomi AD'de eğitim ve araştırma amacıyla yer alan, dekapite edilmiş formalin ile fikse erişkin erkek insan kadavra baş bütünü kullanıldı. Truno System 3 marka perfüzyon pompasına arteriel ve venöz sistem için ayrı iki rezervuar bağlandı. Rezervuarlar mavi ve kırmızı renkli ılık çeşme suyu ile dolduruldu. Oluşan kapalı arterial ve venöz sistemlerde suyun devri daim etmesi sağlandı. Bu şekilde dolaşım devam ederken pterional kraniotomi yapılarak Dura mater'e ulaşıldı. Zeiss diseksiyon mikroskobu altında dura mater kaldırıldı ve Sylvian fissur, kortikal venler ve MCA görünür hale getirildi. Bu çalışmada, perfüzyon pompası ile renkli sıvı dolaştırıldığı için vasküler yapıların gözlenmesi ve girişimde bulunulması açısından hastaya yapılan cerrahi prosedüre uygunluk sağlandı. Hemodinamik olarak akışkanlığın var olması ile de anastomoz ve anevrizma onarımı gibi vasküler girişimlere de gerçeğe yakın bir deneyim oluşturdu. Bu modelin, nöroanatomi eğitimine ve intraoperatif süreçteki deneyimlerin güvenli ve etik bir şekilde oluşmasına katkı sağlayacağı kanısındayız.

ANAHTAR SÖZÜKLER: Serebrovasküler dolaşım, Simülasyon, Nöroanatomi eğitimi, İntrakranyal cerrahi, Pteryonal kranyotomi

INTRODUCTION

The current progress in diagnostic and screening methods and surgical equipment technologies facilitates the accessibility to numerous anatomic structures through various interventional approaches. Consequently, the exact knowledge of anatomic locations of neurovascular structures and their interactions ensures that the surgical intervention is planned in the most appropriate way and the structures are accessed with the least complication risk during the intervention. This experience can only be gained by using educational models based on cadavers, research animals or synthetic material before the surgical applications are performed on live patients. These educational models, which are prepared with the means in hand, have their advantages and disadvantages. The experience and knowledge to be gained from these models is directly proportional to the extent of realism that a model offers. For this reason, cadaver studies are superior to the others since the anatomic structure of the cadaver is the exact structure that will be encountered during live surgery. On the other hand, the absence of hemodynamic features in the cadaver, which are present during live surgery, is the disadvantage of a human cadaver model. This disadvantage may partly be eliminated by circulating colored fluids in the cerebrovascular structures.

MATERIAL and METHODS

The whole-head of a male human cadaver with no prominent cranial pathologies, which was kept for educational and research purposes in the Department of Anatomy of the Dokuz Eylul University Faculty of Medicine and decapitated at the C5 vertebra level followed by fixation with formalin, was used in this study. The arteries and veins were located in the decapitated cut-section, and 16-FR, 14-FR and 18-FR cannulae were placed in the in the common carotid, vertebral arteries and internal jugular veins, respectively (Figure 1). The cannulae were tied to the adjacent soft tissue and the vein lumens with silk sutures. Subsequently, two separate reservoirs (one for the arterial and the other for the venous system) were connected to the Truno System 3 labeled perfusion pump (Figure 2). The reservoirs were filled with warm tap water. At a rate equal to 60 beats per minute, the water was pumped to the arteries at a pressure of 80 mm Hg and to the veins at a pressure of 40 mm Hg, through the veins

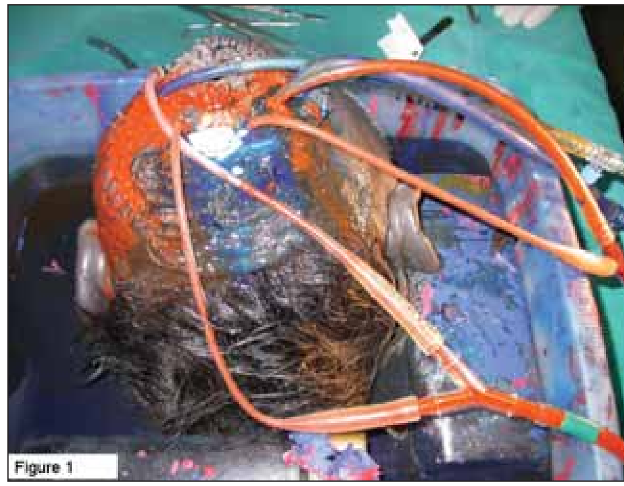

Figure 1

Figure 1: The common carotid arteries, vertebral arteries and internal jugular veins were located in the decapitated cut-section, and cannulae were placed in vessels.

Figure 2

Figure 2: Two separate reservoirs (one for the arterial and the other for the venous system) were connected to the Truno System 3 labeled perfusion pump.

on the right side. The pumped fluid was disposed through the veins on the left side and the veins were washed and the existing clots were cleaned out in this way. Meanwhile, the cut edges of the veins on the cut surface were clamped and sutured. Additionally, the cut surface was plastered with latex in order to avoid leakage. After the vein lumen was cleaned, tap water colored by red stain was poured into the reservoir connected to the arterial system and tap water colored by blue stain was poured into the reservoir connected to the venous system. A continuous flow of the water in the closed-circuit arterial and venous systems was achieved. As the circulation was continuing as described above, pterional craniotomy was performed and cranium was opened via surgical intervention (Figure 3). The dura mater was accessed and the plenitude of dural arteries was observed (Figure 4). The dura mater was lifted under the Zeiss dissecting microscope and the Sylvian Fissure, cortical veins and Medial Cerebral Artery were made visible (Figure 5). An anastomosis was applied to the medial cerebral artery branches (Figure 6).

DISCUSSION

The constant progress in surgical equipment technologies, intervention techniques and diagnostic methods necessitates better knowledge of neuroanatomy and improved surgical practice skills. The simulation models designed for this purpose should comply with ethical limitations and simulate reality as much as possible. Various materials and methods have been developed to demonstrate the vascularization of intracranial structures. Practices have been undertaken in the vascular structures of animals such as rats, cows, sheep and chickens (3,5-8,10) and up to this time, fluorescent and radio-opaque materials, silicon, gelatin, latex, acrylic or thinned polyester have been used as the colored materials injected to cadavers in order to demonstrate human vascular structures (1,4,11-14). In a study conducted in cadavers, Zhao et al. enabled radiographic imaging by adding opaque materials

Figure 3: Pterional craniotomy was performed and the cranium was opened via surgical intervention.

Figure 4: Dura mater was accessed and the plenitude of dural vessels was observed.

Figure 5: Dura mater was lifted under Zeiss dissecting microscope and the Sylvian Fissure, cortical veins and Medial Cerebral Artery were made visible.

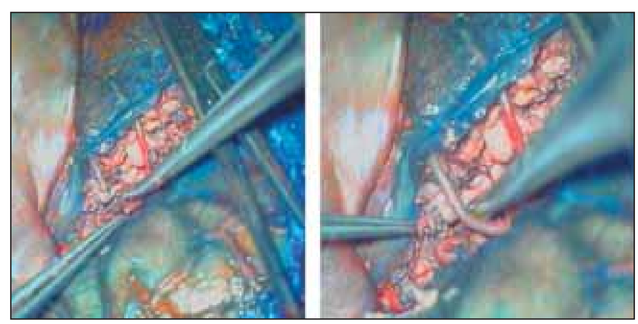

Figure 6: Medial cerebral Artery was practiced anastomosis.

into the injected colored materials. In other studies on cadavers, the vascular structure became suitable for demonstration during dissection as the lumens of these structures were wholly filled. In these studies, the vascular structures could easily be observed and their locations examined for future surgical interventions (4,11-13).

Mechanical pressure pumps have been used to achieve perfusion of fluids through the femoral or common carotid arteries for fixation of cadavers but have not been used before in a cadaver specifically for the educational purpose of simulating pulsation and vascular circulation (2,9). However, Aboud et al. used a mechanical pressure pump to simulate pulsation and vascular circulation in a cadaver for the purpose of neurosurgical education (1). They reported that their model, which was constructed by using a fresh cadaver, was convenient for the simulation of neurovascular, endoscopic and endovascular procedures. We performed our study on a cadaver fixated with formaldehyde. Although this caused a disadvantage due to the stiffness of the tissues, it was also an advantage because the tissues were durable and we could work on the model for a long time. The pterional intervention provided experience for bleeding and vascular injuries that may emerge during surgery. The cut vascular structures were sutured and this provided experience of hemostasis for actual surgical operations. Only a couple of interventions can be performed in research animals under general anesthesia whereas many interventions could be performed in our model. However, the coagulation factor was naturally out of the equation because the fluid was just made of colored water.

CONCLUSION

This study model offered advantages that rendered it superior to the studies performed on research animals since the model comprised exact human anatomical structures. Red fluid was circulated through the arteries and blue fluid was circulated through the veins and the observation of vascular structures became possible and the distinction of arterial and venous structures became easier in this way. Additionally, the intracranial surgery performed with the pterional approach offered an exact simulation of the actual surgical procedures performed for diagnosis or treatment. Since hemodynamic fluidity was present in the model, vascular interventions such as anastomosis and aneurysm repair could also be simulated. We believe that this study model, which was prepared by using a human cadaver fixated with formalin, will contribute to the teaching of neuroanatomical structures and serve to provide a secure and ethical experience for those involved in intracranial surgery.

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