

Animal Model for Endoscopic Neurosurgical Training: Technical Note

Authors

J. C. Fernandez-Miranda¹, J. Barges-Coll¹, D. M. Prevedello¹, J. Engh¹, C. Snyderman^{1,2}, R. Carrau³, P. A. Gardner¹, A. B. Kassam³

Affiliations

¹ Department of Neurosurgery, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

² Department of Otolaryngology, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

³ Saint John's Health Center, Santa Monica, CA, USA

Key words

- neuroendoscopy
- animal training model
- endoscopic techniques
- skull base
- intraventricular

Abstract



Objective: The learning curve for endonasal endoscopic and neuroendoscopic port surgery is long and often associated with an increase in complication rates as surgeons gain experience. We present an animal model for laboratory training aiming to encourage the young generation of neurosurgeons to pursue proficiency in endoscopic neurosurgical techniques.

Methods: 20 Wistar rats were used as models. The animals were introduced into a physical trainer with multiple ports to carry out fully endoscopic microsurgical procedures. The vertical and horizontal dimensions of the paired ports (simulated nostrils) were: 35×20 mm, 35×15 mm, 25×15 mm, and 25×10 mm. 2 additional single 11.5 mm endoscopic ports were added. Surgical depth varied as desired between 8 and 15 cm. The cervical and abdominal regions were the focus of the endoscopic microsurgical exercises.

Results: The different endoscopic neurosurgical techniques were effectively trained at the millimetric dimension. Levels of progressive surgical difficulty depending upon the endoneurosurgical skills set needed for a particular surgical exercise were distinguished. *Level 1* is soft-tissue microdissection (exposure of cervical muscular plane and retroperitoneal space); *level 2* is soft-tissue-vascular and vascular-capsule microdissection (aorto-cava exposure, carotid sheath opening, external jugular vein isolation); *level 3* is artery-nerve microdissection (carotid-vagal separation); *level 4* is artery-vein microdissection (aorto-cava separation); *level 5* is vascular repair and microsutures (aortic rupture), which verified the lack of current proper instrumentation.

Conclusion: The animal training model presented here has the potential to shorten the length of the learning curve in endonasal endoscopic and neuroendoscopic port surgery and reduce the incidence of training-related surgical complications.

Introduction



The introduction of the endoscope as the sole source of visualization is revolutionizing various neurosurgical fields. The endoscopic expanded endonasal approach represents a paradigm shift perhaps equivalent to the introduction of the microscope in approaching various skull base lesions decades ago [1]. Additionally, an innovative fully endoscopic approach to intraventricular and intraparenchymal tumors that uses a rod lens endoscope and parallel instrumentation via an 11.5 mm transparent conduit or endoscopic port, has been recently proposed and successfully applied [2].

When the microscope was introduced into neurosurgery, one of the questions that the skeptics posed at that time was: what do you do when an intracranial artery or aneurysm ruptures? Quot-

ing Prof. Yasargil "... *an animal model for effective vascular surgery for the brain vessels had to be developed before the full advantages of microtechniques could be utilized*" [3]. Not without reason, contemporary skeptics on fully endoscopic skull base and brain surgery raise similar concerns: can microsurgical dissection techniques be applied to resect tumors endoscopically while preserving vital neurovascular structures? Can the surgeon stop the bleeding and repair the artery? [4]. From its inception, the principles of endoscopic dissection and hemostasis are identical to those of microscopic dissection and hemostasis both following the principles of microsurgery [5]. We believe that an animal model for effective training in endoscopic neurosurgical techniques is needed to decrease the length of the learning curve in endonasal endoscopic and neuroendoscopic port surgery. The

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Correspondence

J. C. Fernandez-Miranda, MD
 Department of Neurosurgery
 200 Lothrop Street
 PUH B400
 PA 15213 Pittsburgh
 USA
 Tel.: +1/412/647 6358
 Fax: +1/412/647 1778
 fernandezmirandajc@upmc.edu

objective of this study is to present our preliminary experience with such an animal model, and to encourage the young generation of neurosurgeons to pursue proficiency in endoscopic neurosurgical techniques.

Material and Methods

20 Wistar rats in the 300–500 g range were used as models. They were anesthetized by means of a 10 mg/kg ketamine hydrochloride injection. The Institutional Animal Care and Use Committee (IACUC) at University of Pittsburgh approved this study protocol. 2 anatomic regions, cervical and abdominal, were the focus of our endoscopic microsurgical exercises. These regions were selected based on the diameter of their major vessels (carotid artery – 1 mm; aorta artery – 2–3 mm). After the skin incision was performed, the animals were introduced into the physical trainer to carry out fully endoscopic surgical procedures. The physical trainer consisted of a plastic polystyrene material box with the following dimensions: 20 cm (height), 22 cm (width), and 28 cm (length). These dimensions were appropriate to comfortably position the animal. Final surgical depth, after positioning the animal, varied as desired between 8 and 15 cm. 4 rows with paired ports of different sizes were made in the lid of the box with the purpose of simulating the human nostrils (◉ Fig. 1). The vertical and horizontal dimensions of the paired ports were: 35×20 mm, 35×15 mm, 25×15 mm, and 25×10 mm. Interestingly, a recent study on human anatomic specimens as well as patients has shown that the working area provided by the human nostrils (considering their elasticity) averaged 28 (±3)×31 (±3) mm [6]. 2 additional single ports were made for the introduction of the 11.5 mm endoscopic port employed at our institution for minimally invasive brain surgery [2]. Rod lens endoscopes (Karl Storz, 4 mm, 18 cm, Hopkins II, 0, 30, and 45 degree) attached to a high definition camera were used as the sole source of illumination and magnification. Typically, 2 surgeons performed the operations, one driving the camera, and the other dissecting the tissues. When a driving surgeon was not available, as it happened in 5 out of 20 procedures, the Armand endoscope holder (KLS Martin L.P., Jacksonville, Florida) was employed. The same endoneurosurgical instrumentation (Karl Storz, Tuttlingen, Germany) as that employed in the operating room was used to complete every animal surgery, including endosurgical scissors (straight, left curved, right curved, 45-degree up, rotatable), dissectors, forceps, endobipolar, and aspirators.

Results

Cervical region

The initial step is the dissection of the cervical subcutaneous tissue to expose the underlying muscles. The aspirator on the left hand provides countertraction, while blunt dissection is performed with the right hand instrument. The external jugular vein is encountered at this layer on both extremes of the cervical exposure. Sharp dissection is needed to dissect and isolate the external jugular vein and its tributaries from the surrounding soft tissue. Selective bipolar coagulation can be used prior to sectioning some of the tributary veins in preparation of the external jugular as a donor vessel for later microsurgical anastomosis. At the digastric area, parajugular ganglia are attached to

the vein. Precise sharp dissection is required to separate them from the jugular vein.

At the muscular layer, the sternocleidomastoid and paratracheal musculature are identified. Blunt dissection is applied to develop the intermuscular plane that serves as surgical corridor to expose the carotid sheath. Opening the carotid sheath requires precise sharp dissection in order to avoid injury to its major contents, the carotid artery and vagal nerve. Next surgical exercise consists on separation of the carotid artery from the vagal nerve (◉ Fig. 1e). This maneuver demands a combination of delicate blunt and sharp microsurgical dissection techniques. Successful completion requires complete isolation of the carotid artery from the sternal area to the carotid bifurcation with preservation of the vagal nerve.

Abdominal region

Under endoscopic visualization through the trainer, blunt dissection at the subcutaneous layer will expose abdominal musculature. A midline longitudinal incision through the muscular plane and parietal peritoneum is completed in order to enter the peritoneal cavity. The goal is to expose the major vessels located at the retroperitoneal space. A combination of blunt and sharp dissection is needed to access this space (◉ Fig. 1b, c). The visceral attachments to peritoneal walls and epiploon resemble intradural arachnoidal bands that have to be sharply and precisely dissected. Detachment of visceral structures allows for exposure of the retroperitoneal space. Soft adipose tissue is dissected sharply from the aorta, cava, renal veins, and portal system (◉ Fig. 1d). Next exercise consists on complete separation of the aorta from the cava and renal veins. This requires precise combination of blunt and sharp dissection. Renal veins and cava have thin walls that are easily torn. Venous hemostasis is achieved by gentle compression and warm saline irrigation. Adhesions between aorta and cava have to be sharply divided, preferably on the arterial side to avoid venous tearing (◉ Fig. 1f). This maneuver, however, mandates high precision to avoid arterial rupture. Once aorta and cava are completely separated, from the iliac bifurcation to the thoracic cavity, temporary aneurysm clips can be applied on the aorta. A special pistol grip clip applicator is needed. Arterial hemostatic techniques can be trained by purposely perforating the aorta. A 10/0 needle has been used to create arterial pinholes that can be sealed using selective bipolar coagulation. Scissors were used to simulate large arterial ruptures not amenable to bipolar coagulation techniques. In this circumstance, the first maneuver is proximal and distal vascular control applying temporary aneurysm clips, followed by direct arterial repair using suturing techniques. No instruments are available for endoscopic microvascular suture of a 2–3 mm diameter vessel. Micropituitary forceps were employed both as needle driver and forceps. Small arterial defects were repaired with 2–3 sutures, but larger vascular reconstructions were not achieved. The same sequence of surgical exercises can be trained using an 11.5 mm endoscopic port and parallel instrumentation, simulating intraparenchymal and intraventricular endoscopic port procedures.

Levels of difficulty: endoneurosurgical technique and related exercise

The different endoscopic neurosurgical techniques were effectively trained at the millimetric level with the animal model presented in this study. After 10 training sessions, precise team coordination, delicate sharp dissection with preservation of ves-

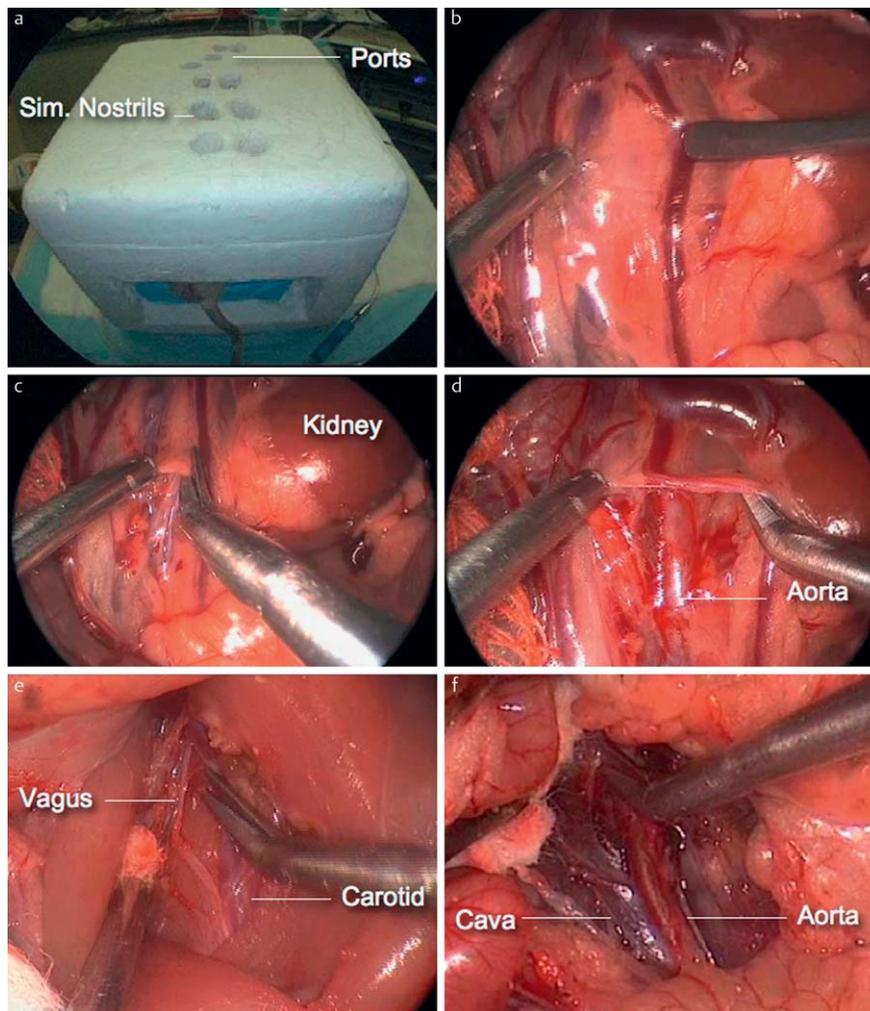


Fig. 1 **a** The physical trainer consists of a plastic polystyrene material box with 4 rows of paired ports that simulate the human nostrils and 2 additional single ports for the introduction of an 11.5 mm endoscopic port. **b** Blunt dissection is being applied to expose the major retroperitoneal vessels. **c, d** Sharp dissection and countertraction with the suction allows for precise endoscopic microdissection of vascular structures. **e** After opening the carotid sheath, the vagus nerve is sharply separated from the carotid artery. **f** A combination of blunt and sharp microdissection is used to precisely separate the aorta from the cava.

sels smaller than 1 mm, and hemostasis even in the presence of a vascular injury were possible. Levels of progressive surgical difficulty depending on the endoneurosurgical skills set needed for a particular surgical exercise could be distinguished. *Level 1* is soft-tissue dissection (exposure of cervical muscular plane, exposure of retroperitoneal space); *level 2* is soft-tissue-vascular and vascular-capsule dissection (aorto-cava exposure, carotid sheath opening, external jugular vein isolation); *level 3* is artery-nerve dissection (carotid-vagal separation); *level 4* is artery-vein dissection (aorto-cava separation); *level 5* is vascular repair and suturing (aortic rupture), which verified the lack of current proper instrumentation.

Discussion

Animal experimentation has been invaluable to progress in surgical techniques in general, and to the evolution of endoscopy in particular. Multiple animal models have been described and tested in the collective effort to train surgeons in endoscopy and to create and develop new endoscopic techniques [7]. While the most broad and large-scale efforts at developing these models have been put forth by general surgeons interested in advances in laparoscopy, no animal model for training specifically in endoneurosurgical techniques has been yet described. In this study we present our experience with a simple but rather effective animal training model. The physical trainer is self-made and

the animal widely available and easy to manage. The physical trainer does not recreate the elasticity of the nostrils or the paranasal sinus anatomy, but establishes a long distance corridor into the target that resembles the endonasal corridor and mandates delicate manipulation of microvessels under endoscopic visualization, and using endoscopic instrumentation and microsurgical techniques. The model described here has been tested both by trainees and experienced endoscopic skull base and brain surgeons, and was found to be very useful for training purposes. Importantly, the different levels of difficulty previously detailed allows for customized training. The main limitation factor is the disponibility of an endoscopic station and endoneurosurgical instrumentation in the microsurgical laboratory. However, the progressive establishment of endoneurosurgery worldwide will surely promote the development of multiple training laboratories with endoscopic capabilities.

In his autobiographic and commemorative article, Prof. Yasargil, as neurosurgeon of the century, reminded once again the imperative requirement of laboratory training to acquire expertise in all avenues of microtechniques [3]. We believe this requirement should be extended to newly developed endoneurosurgical techniques. Delicate microdissection with preservation of sub-millimetric vessels and meticulous hemostasis are absolute requirements to perform level 4 (intradural) and 5 (vascular, coronal plane) endonasal endoscopic skull base procedures [5,8], as well as intraventricular neuroendoport surgery [2]. The learning curve for this high-level endonasal and neuroendo-

scopic port surgery is therefore long and often associated with an increase in complication rates as surgeons gain experience [8]. Mastering of surgical neuroanatomy by dissecting anatomic specimens and dedicated observation of experts in the field should be the first training step. Training on live animals as part of non-survival surgeries could represent an additional training step. We believe that the animal training model presented here may shorten the length of the learning curve in endonasal endoscopic and neuroendoscopic port surgery and reduce the incidence of training-related surgical complications.

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Conflict of Interest: Amin Kassam and Ricardo Carrau are paid consultants for Stryker and Karl Storz Corporations.

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