Anatomy of the Lateral Base of the Skull: Development of a Method of Study

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Abstract:

Introduction: Surgery of the lateral base of the skull is a medical specialty still in full development. There are few centers of excellence that have the required physical and human structure to perform these procedures safely. The development of the teaching method based on dissection of cadavers in an anatomy lab is fundamental to the correct training of surgeons in this specialty. Objectives: To describe the development of a method of study of the lateral base of the skull. Methods: In this study we dissected fresh cadavers prepared with dye solution injected in the intracranial arteries and veins. We performed the classical accesses to the lateral base of the skull in such a manner to allow the establishment of a dissection route and the advantage of the anatomical part. The confection of teaching material was carried out through a digital reflex camera. Results: The training program was structured in stages: 1) Study of the teaching material developed in this research project and available in digital slides and films in the infra-structure of stage; 2) Obtain a high degree of familiarity and competence with micro-surgical instruments, using the stages of dissection of temporal bones; 3) Preparation of the anatomical parts with injection of dye; 4) Dissection under supervision following the route described in this project. Conclusions: The teaching of surgery should include dissection in an anatomy lab, which allows a reduction of the time of learning curve and better anatomical knowledge.

INTRODUCTION

Skull base surgery is a medical specialty still being developed. There are but a few centers of excellence in the world with both the human assets and the proper facilities able to safely carry out these procedures. It encompasses two medical specialties, otolaryngology and neurosurgery which, working together or independently, approach the most varied types of tumors and diseases present in this complex anatomical region.

A skull base surgeon requires a profound knowledge of this region, most specially of its complex vascular structure: arteries, veins and venous sinuses with broad anatomical variation, which are commonly involved in the disease to be treated.

The discipline of otolaryngology of the University Hospital of the Medical School of the University of Sao Paulo introduces the first program of skull base surgery in Brazil: the Internship of specialized complementation in Advanced otological and neurotological surgery, with two years duration in a full time schedule. The goal is to train otolaryngology surgeons into the proper management of diseases in this region.

Therefore, this organized and official way of training neurotologists in our country has been recently created. We can currently count on advanced image systems, which allows us to broadcast our surgeries in 3D to the operating theater itself, or to an adjacent auditorium; and we have the availability of a complete temporal bone dissection lab, which is all mandatory for the proper training of the skull base surgeon and the dissection of cadavers in the anatomy lab.
Previously described are some teaching material and study methods used to prepare the cadavers for study (1-4).

Our goals in this work have been to create a teaching method for skull base and neurotological surgeries, that allows the development of a high degree of familiarity and competence with microsurgery instruments and a set of guidelines to be used in the anatomical dissections of the lateral skull base.

METHOD

This study was developed at the General and Human Topographic Surgery Lab of the Department of Surgery of the Medical School of the University of Sao Paulo (USP), and was approved by the ethics committee for the Assessment of Research Projects from the Clinical Board of the University Hospital of the Medical School of the University of Sao Paulo (protocol 767/04).

Three heads (six sides) of fresh cadavers were prepared for dissection with the injection of a dye solution dissolved in liquid silicone. The structure of the dissection station was derived from the one utilized in the Practical Course of Temporal Bone Dissection which has been traditionally held at the department of otolaryngology of the Medical School of the University of Sao Paulo. The heads of fresh cadavers, stored in a 75% alcohol solution, were prepared for dissection with the aim of highlighting intracranial vasculature. Both the internal carotid artery and the internal jugular vein were bilaterally identified and dissected in the cervical region. The vertebral artery was also dissected and isolated in both sides. The vessels were cannulated by a catheter of the same gauge. The vessels were tied with a # 0 cotton wire in a way to fix the catheters and avoid liquid reflow. Following that, the vessels were repeatedly flushed with water with a 60 cc syringe until we could obtain a good perfusion of its contralateral counterpart. For instance, when flushing the right internal carotid artery, we must be able to see the water coming out of the left internal carotid artery and not see any blood clot inside the vessel. This stage is paramount, because inadequate flushing or clots present inside the vessels prevent dye from getting into the vessel and the subsequent filling up of the whole intracranial vascular system, specially that of the small arterial branches. After flushing, the dye is injected. Both the internal carotid and the vertebral arteries were injected through their neck portion, and the internal jugular vein was injected right after these two. The arteries were dyed red and the venous system was dyed blue. The dye had the following formula:

A) Arteries: two parts polymethyl silaxane (thinner) and one part silicone
B) Veins: one part polymethyl silaxane (thinner) for one part silicone
The catalyst (dilaurate calcium carbonate) was added before injecting the solution in

the vessel lumen, in the ratio of 10cc for each 300cc of solution. The dye (water soluble pigments) were added right before the infusion.

The photographs were taken with an SLR digital Nikon D70® of 6.5 megapixels, made up of the camera body and one adaptor in place of the lens, which was fit to the light scope of the surgical microscope. The pictures were taken with the light dividing diaphragm closed and 1 sec exposure time. The images were immediately seen in the computer monitor that was connected to the camera through a USB cable.

We performed the classic lateral skull base approach in order to determine the best dissection route to follow, in other words, to determine the best dissection map, to setup the most efficient access to the same side of the head without compromising the anatomy of the region:

1.accesses through the otic capsule: translabyrinthine access (5), transcochlear access (6)
2.accesses preserving the otic capsule: pre-sigmoid retrolabyrinthine access (7), classic middle fossa access, broad and transpetrous access (8,9), and infra-temporal access (4).

RESULTS

1- Guidemap for the dissection of anatomy specimens
Created in order to use the anatomy specimens (separated heads with intra-vascular solutions) in sequential dissections (Figures 1-6).
Side 1: Access through the otic capsule: Start with the translabyrinthine access and extend it transotically and posteriorly in transcochlear.
Side 2: Accesses that preserves the otic capsule: Start through the classical middle fossa approach, broaden and transpetrous, move on to the pre-sigmoid retrolabyrinthine and finish with the type A infra-temporal.
2- Program Structure
The training program has been setup within the two year Advanced Otologic and Neurotologic Surgery Specialized Complementation Internship Program. In order to avoid improper use of the anatomy specimens, each stage of the dissection guidemap will be assessed by one program supervisor.
Stage 1: Assessment of the teaching material prepared in this research project and available in digital slides and videoclips within the internship program.
Stage 2: Acquire a high degree of familiarity and competence with the microsurgery instruments in the temporal bone dissection stations.
Stage 3: Preparation of the anatomy specimens with the dye injection.
Stage 4: Supervised dissection according to the guide aforementioned.

DISCUSSION

The initial idea behind this research project was to create structured conditions for the preparation of teaching material, such as videos and digital photography, used in lateral skull base surgery. Notwithstanding, during the execution of the project, our goal grew bigger and, considering our experience in ear surgery, acquired in the established structure of the surgery teaching from the Ear Group of the Department of Otolaryngology of the Medical School of the University of São Paulo, we have formalized an anatomy and surgical study method for lateral skull base approaches, encompassing the classical surgical accesses to this region and enhancing the surgeon's familiarity with the specific microsurgery instruments. This method is fundamentally based on the study and the performance of surgical procedures in the anatomy lab.

The surgical procedure enhancement process may be divided in three phases (10):
1) A didactical phase in which the intern familiarizes oneself with the instruments and techniques, including experience in artificial, cadaver or animal models.
2) A training phase in which the resident performs the procedure under supervision.
3) A practical phase in which the resident performs the procedure in growing levels of independence. Competence is achieved as this phase is concluded.
It is necessary to add that these phases may be carried out, in part, within the anatomy lab with cadaver and artificial models. Besides, the learning curve, that is, the performance improvement with surgical experience, has been shown and represents the fundamental factor in the teaching of surgery (11,12).

Surgery teaching methods have focused in a combination of didactic teaching with evaluated supervision in the surgical center (13). We have seen that most medical residence programs in otolaryngology have adopted this teaching mode for surgical training. However, from both the ethical and practical views, the surgical center can not be considered the ideal place to learn surgical techniques (14).

Having a learning stage in the surgery laboratory enhances the student's performance in the Surgical Center and should be an integral part in the framework of any surgeon training center (15). The major goal of performing surgery in the cadaver is to develop the anatomical knowledge, acquire familiarity with the instruments and techniques and shorten the learning curve. The use of documentation methods, such as photographs and films, are useful not only in the preparation of teaching material but also to record, in video format, the surgeries the residents perform, for feedback and self assessment purposes. We believe that an intense teaching stage in the micro-surgery lab may help the residents to expedite the conclusion of their training.

In our institution we have a traditional course on temporal bone surgery, framed in such a way as to enhance the participant's familiarity with the microsurgery instruments, anatomical knowledge and the surgical techniques in ear and temporal bone surgery. Not only this course, but we also offer the residents and training physicians a structure that allows them to have surgical training in nose, nasal sinuses and larynx. For some years now, in our institution the resident is required to perform a minimum number of surgeries in the lab before performing surgeries in the operating theater. Such experience has proven more than adequate, allowing the resident to be more skilled before starting on his/her surgery rotations. The ear surgery teaching within the Otology Group of the Department of Otolaryngology of the Medical School of the University of São Paulo requires the students to use the anatomy lab that we keep constantly available to the residents. They are required to dissect at least ten temporal bones under supervision before starting their surgery rotations. Our experience in training otologists has allowed us to setup this formal teaching on lateral skull base surgery and neurotology with the creation of this "Specialized Complementation Internship on Advanced ear and neurotology surgery" two years ago, and our first surgeon graduated in early 2005. A teaching structure to teach the anatomy of such a complex region, as is the lateral skull base, has become very necessary, and since there is no model present in the literature, we followed the experience we have from teaching otological surgery in the lab.

We believe the efficient learning of skull base microsurgery encompasses sequentially: theoretical and practical knowledge stages. The first stage is to get acquainted with the lateral skull base approaches, because it is hard to find a medical residence program that teaches this type of surgery and, consequently, surgeons with a full grasp of this technique. Currently, this stage is carried out by specialized book and journal readings that, as we see it, should be complemented by photography and videos made within the teaching institution itself. Photography brings a better picture quality, and a static and chosen view of certain anatomical structures. This is the preferential mode used to prepare classes and courses. Movie clips are better when they are fully viewed, without editing, thus showing the whole surgical technique and the difficulties the surgeon faces at each step. Since most of our surgeries are made under the microscope, video recording is easy and of excellent quality.

Following this theoretical stage, we have the stage of familiarity with the microsurgery instruments, using temporal bone dissection stations. This method already exists, it has been well structured for years now, and it is fully accessible to residents and interns of the specialized complementary course. The temporal bone dissection lab has fully equipped temporal bone dissection stations, where the surgeon works the microscope and microsurgery instruments with the necessary frequence to acquire full familiarity with the real surgery.

Stages 3 (anatomical parts preparation with dye injection) and 4 (supervised dissection following the described guidemap) are carried out by the 1st year neurotology intern. The method used to prepare the anatomy parts proved to be efficient, easy and of low cost. Using a water-soluble liquid dye has brought great color quality and storage resistance. The difficulty in obtaining fresh cadaver heads makes imperative to have a dissection guidemap, in order to best use each head available.

We should bear in mind that the objective is the anatomical study within surgical approaches and, therefore, we use care in not doing an approach that would impair the performance of another one in sequence. This fact was taken into account when we prepared the lateral skull base study guidemap. Following this guidemap, all the lateral skull base anatomical structures are studied by the surgeon, within a surgical perspective. The surgical approaches chosen are the classic ones in this surgical specialty, from them others are derived and are easily learned when the anatomy is well understood.

CONCLUSIONS

1. The study of the lateral skull base anatomy based on this guidemap developed at our department allows the surgeon to better understand the anatomical structures present in this complex region within a surgical perspective, similar to the one he/she will find in a real surgery. Besides, it also enhances the surgeon's skill in performing many approaches to the lateral skull base.
2. Laboratory surgical practice of anatomy is very up to date. Despite ethical and legal aspects regarding cadaver dissection, it is the best material due to its intrinsic characteristics.

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Figure 1. Classic translabyrinthine approach. The opening of the dura mater in the posterior cerebral fossa has the jugular bulb (BJ) inferiorly, the Fallopian canal laterally (CF), the superior petrous sinus superiorly (SPS) and the sigmoid sinus posteriorly (SS). One can have a broad operating field only by using these anatomical limits during surgery. (AF: Acoustic-facial bundle, Cb: cerebellum).
Figure 2. Translabyrinthine approach visualizing the acoustic-facial bundle (AF) and the trigeminal nerve (Tr) in large magnification.

Figure 3. Larger magnification showing the middle ear and the facial nerve in its second and third portions. The yellow dotted line corresponds to the area that should be opened for the transcochlear approach (CO: ossicular chain, CT: chorda tympani nerve, NF: facial nerve, T: ear drum).

Figure 4. Transcochlear approach. Partial cochlear removal (CO). We notice the cochlear nerve (NC) penetrating the modiolus. The vestibular nerves (NV) may be seen under the instrument while the facial nerve (NF) is posteriorly pushed with a microspreader. The posterior transposition of the facial nerve is carried out when a tumor extends anteriorly to the petrous apex, however, even with careful handling, the facial nerve function is rarely kept normal, differently from what happens in the nerve anterior transposition (SS: sigmoid sinus).
Figure 5. Middle cerebral fossa approach. Opening the pre-sigmoid dura mater having access to the acoustic-facial bundle (AF) and pons cerebelli angle. The opening boundaries are the semi-circular canals (CSC) laterally, the petrous sinus superiorly (SPS) and sigmoid sinus (SS) (postero-superiorly) and the jugular bulb inferiorly (BJ).

Figure 6. Access through transpetrous middle fossa. Petrous apex and posterior fossa exposed (CO: cochlea, CI: internal carotid artery, FP: posterior cerebral fossa, V2 and V3: trigeminal nerve).