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The Learning Curve in Skull Base Surgery Part 1–From Historical-Philosophical Concepts to Microsurgical Lab Training

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Abstract

The learning curve reflects surgeons' experience in managing several patients with the same disease. In skull base surgery, the professional's place on the curve could be related to the number of times the same procedure was performed. Where does curve begin? What amount of training is necessary prior to its application in surgical settings? What were the results of the first few skull base tumor surgeries performed by a surgeon who goes on to produce excellent results, and how is reflected in the start of their learning curve? The only way for neurosurgeons to improve their results from the start is with prior training in the microsurgery laboratory. This learning technique is essential to maximize the chance of success of a neurosurgical procedures, minimizing the morbidity rate to which patients are subjected by less experienced neurosurgeons. This article is divided in two parts, and its purpose is to show how training in the microsurgical laboratory fits into the construction of knowledge about skull base surgery, based on authors' experience and reflections. This first part discusses the technical, psychological, and philosophical aspects of medical knowledge, primarily addressing those training in skull base surgery, the principles of some selected philosophical currents, and their influence on the development of current medical knowledge.

Keywords

- skull-base
- learning curve
- microsurgical laboratory

This paper, divided in two parts, is a tribute to Professor Evandro de Oliveira, MD, PhD. (1945 - 2021).

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Introduction

The learning curve, as applied to the surgical sciences, could reflect one's experience in managing several patients treated surgically for the same pathology.[1] In skull base surgery, the surgeon's place on the curve could be related to the number of times the same procedure was performed, for example, in treating vestibular schwannoma. Alternatively, the procedure's execution within a subgroup of the disease, or even the surgical approach, such as in the middle fossa, used to treat a small vestibular schwannoma.

We should first consider the ethical challenge encountered at the base of this curve when residents, young surgeons, and even more experienced professionals take on technically challenging procedures that are new to them. Where should this curve begin? What amount of training is necessary prior to its ascent? What were the results of the first few skull base tumor surgeries performed by a surgeon who goes on to produce excellent results, and how should this be reflected in the start of their learning curve?

Similarly, what are the results of young neurosurgeons employing their first extended endoscopic approaches for tumor resection at the anterior skull base? Or the outcome of aneurysm surgeries? How did their first neural or vascular anastomoses go? Or their first petroclival meningiomas? Many more examples could be cited.

However, with regard to a large number of neurosurgical procedures, perhaps the only way for neurosurgeons to improve on their results from the start of their career is training in the microsurgery laboratory.[2–5] This learning technique is essential to maximize the chance of success of a neurosurgical procedure. Furthermore, to minimize the morbidity rate to which patients are subjected to by less experienced neurosurgeons, this dictum should be heeded: "A neurosurgeon's first surgery should commence only after they have completed their 100th corpse dissection." Combined with training in neurosurgical microanatomy, the development of manual dexterity and practice of novel surgical techniques on animal models or in virtual reality are essential to maximize good outcomes.

Moreover, in-depth knowledge of microsurgical anatomy acquired in the laboratory alone is no guarantee of good results for patients and their families. In the training of a skull base surgeon, other areas of knowledge, along with technical training, are the foundation for optimal patient management and should be included in a professional's education.[6]

Surgeons undertaking a procedure for the first time will clearly be further along in their learning curve if they practice on corpses and experimental animals first. Justifying poor performance in surgery by noting that a professional is at the start of their education is unacceptable. Of course, complications arise in surgery and their likelihood, however small, is inherent to any procedure even when performed with the most experienced hands. However, the probability of such complications should be minimized by first attaining a solid knowledge of neurosurgical microanatomy. This paper will discuss examples of this knowledge at length, as well as the education they trace.

This article is divided in two parts. The first part discusses the technical, psychological, and philosophical aspects of medical knowledge, primarily addressing those training in skull base surgery, the principles of some selected philosophical currents, and their influence on the development of current medical knowledge. The second part addresses the foundations of neurosurgical training and their effect on surgery education, proposing a guide to microsurgical laboratory training, not only to understand anatomy but also to develop surgical skills. After this, training in the microsurgery laboratory and the challenges of being a neurosurgical assistant will be explored. Then, regarding cognitive skills, we will address the multidisciplinary aspect and the need for a comprehensive knowledge of the areas related to neurosurgery. As for affective skills, we will discuss the significance of their development and their direct results on patients and colleagues. While this article focuses on the work of neurosurgeons, it could be applied to any medical specialty in skull base surgery, such as ear, nose, and throat (ENT) or head and neck surgery.

Why We Think That Way? The Development of Scientific Knowledge

The type of medicine most widely practiced today is allopathic or conventional medicine. Diseases are considered to be caused by external insults or by dysfunction of an internal organ or system, and treatment is oriented toward their causes and symptoms. Other approaches to dealing with diseases include those that regard it as originating in a mental or spiritual disorder, or from phenomena for which there is no physical or biological explanation. These approaches include homeopathy, traditional Indian medicine and Ayurveda, traditional Chinese medicine and acupuncture, folk medicines, faith healing, shamanism, and intuition.

There is no doubt that the decisions we make today about, for example, the best way to treat a skull base meningioma, have their origins in the 7th century BCE with the pre-Socratic philosophers. This may seem like a useless or tenuous assertion, but they were the first scholars to reject gods and demons in their explanations of reality.

Three philosophers in particular are noteworthy for having built frameworks, which, despite seemingly having no relation with neurosurgery today, are the basis of our professional conduct: René Descartes, Baruch Spinoza, and Immanuel Kant (►**Fig. 1**). One of the world's greatest philosophers, René Descartes, sought the foundation of truth in his works, and "Discourse on the Method" is his proposal. Descartes starts from methodical doubt, which is the simple act of doubting everything; this principle is based on the fact that our ideas come from our senses, and so are uncertain and unstable. Some, however, present themselves to the human spirit, with clarity and stability, and occur to all people in the same way, regardless of how they experience senses, which means they reside in everyone's minds and are innate. The first of these innate ideas is the Self. The statement "I think, therefore I am" leaves us with no doubt about

Fig. 1 René Descartes (1596–1650), Baruch Spinoza (1632–1677), and Immanuel Kant (1724–1804).

our existence. The second is the dual nature of man, that is, the mind-body dualism; for Descartes, the universe consists of "thinking substance," or mind, and matter, the is latter capable of being explained by physical and mathematical laws. Mind and matter are only united in humans. Thus, Descartes proclaims, correct reasoning is to "never accept anything as true if it cannot be seen clearly and distinctly as such." As for the third idea, he proposes to "conduct my thoughts in such order that, by commencing with objects the simplest and easiest to know, I might ascend little by little, and, as it were, step by step, to the knowledge of the more complex." This method is the cornerstone of today's medical knowledge and decision-making in medical practice. Evidence-based medicine can be considered the ultimate refinement of this philosophy. Criticisms of this method, however, are also part of this refinement, which is why they shall be addressed here, when discussing current microsurgical recommendation for vestibular schwannoma management.

The philosophy of Baruch Spinoza is considered a response to Descartes's dualistic philosophy, which made the world impossible to understand, in his opinion. He found out that through Descartes's philosophy it would be impossible to explain the relationship between God and the world, or between the spirit and the body. In response, Spinoza deduced a complete metaphysical system, which presents the world as a perfectly intelligible whole. As irrelevant as this philosophy may seem, we must consider that, when treating a patient, it is not only the Cartesian aspects that are involved, but also an intelligence that is often intuitive and irrational and seems to be closer to reality, where moral and religious factors can influence decisions. Regarding ethics, Spinoza manages to unite three systems of ethics in a harmonious unit. These three systems, according to Will Durant,[7] are the ethics that consider all men to be equally precious, reciprocate evil with good, preach in politics an unlimited democracy (like Christianity and Buddhism), accept the inequality of men, and appreciate the risks of combat and dominance (along with Nietzsche and Machiavelli) and, finally, consider that only the informed and mature minds can judge when love or power should rule. This type of philosophical approach within neurosurgery tends to value the experience of neurosurgeons and their ethics, and not only decision-making based on scientific aspects, as Descartes postulates. This could be exemplified in patients with skull base diseases with a clear indication for surgical treatment, but who have strong negative feelings regarding a procedure in which the surgeons don't feel confident. Sometimes, the best approach is to understand the patients' humanity and reschedule the procedure for later.

A third philosopher who exerts a great deal of influence on the way we practice medicine is Immanuel Kant, whose ideas dominated the 19th century thinking and still inform mature philosophical discourse today. Kant postulated that we have a completely distorted notion of reality because our knowledge is restricted by what we can sense. Therefore, reason and logic are recent constructions originating in a fragile and deceptive part of the self. Science, as we are capable of knowing it, would thus be naïve, as it concerns "things in themselves, in their full external and incorrupt reality,"[7] and not the sensations, perceptions and concepts of those who merely observe phenomena. A definitive concept of reality would, for this reason, be a mere hypothesis from our point of view. Kant asserts that what brings us closer to reality is our moral sense, the inevitable feeling that an act is either right or wrong when confronted with temptation, which is inherent to every human being. This could not come from our sense-based reasoning, but instead must derive from a more vivid and immediate feeling, which suggests a transcendental, physical, and metaphysical perception of a given phenomenon. To answer the question of "what truly exists?", Kant tries to reconcile realism with idealism, and rationalism with empiricism.

Although the Cartesian method is generally accepted as our guide to professional decision-making, in practice, the Kantian viewpoint and its more complex considerations of patients and ourselves should instead guide the practice of medicine. This argument alone should encourage the skull base surgeon in training to go well beyond just technical training.

Learning Curve Growth Patterns

According to Charles Handy, the normal pattern of acquiring knowledge and experience can be seen as a steep upward curve that eventually slows, peaks, and begins to decline (►**Fig. 2A**). The secret to professional and personal success, for Handy, is to start a new curve as the current one descends. As he puts it, "what leads you to success is probably not what will keep you there." Considering the many areas of knowledge we encounter in our lives, such as technical, personal, and emotional knowledge, a single curve could not represent

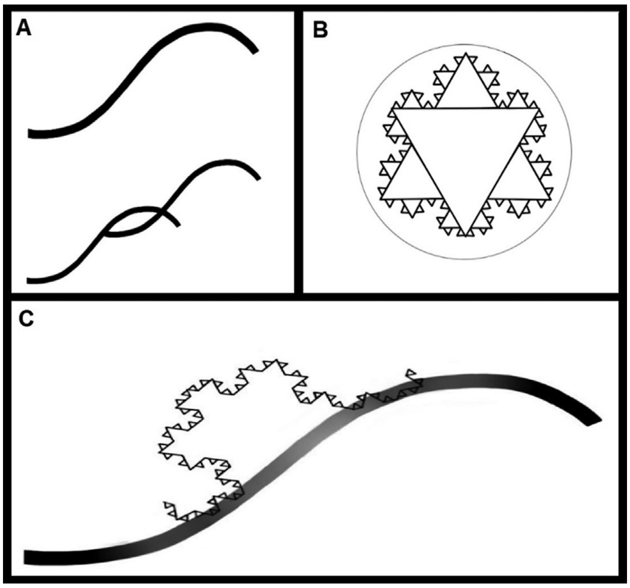

Fig. 2 Learning curves, based on Traynelis[8]: (A) Handy curve; (B) Koch snowflake model; (C) Handy-Koch superposition.

our relation to it all.[6] These infinite aspects of knowledge may create the perspective of a more chaotic pattern, like the Koch snowflake model (►**Fig. 2B**), in which knowledge is represented as a triangle from which each can became a new branch of knowledge, indefinitely. Combining the Handy and Koch models, we can represent an infinite number of curves, with emerging branches, some more or less developed, as the multiple aspects of one's knowledge should be represented (►**Fig. 2C**).

If we consider skull base surgery training, each curve represents the affective, cognitive, and psychomotor knowledge to be developed by neurosurgeons in training. In a more advanced phase of training, surgeons may choose to branch off and seek a subspecialty. Likewise, the path of knowledge they take can branch into new techniques, such as temporal bone drilling or microvascular anastomoses.

Evidence-Based Medicine and Skull Base Surgery

Evidence-based medicine is a recent development, having emerged in Canada in the 1980s. It is based on a decision-making process that relies on the bibliographical analysis of a given subject. A critical evaluation is conducted and externally validated by asking "to what extent do the results published in the literature serve the population I am treating?".

Although there is not yet enough data with a high degree of clinical and epidemiological evidence on which to base most treatments in neurosurgical practice, a critical analysis of class I studies should be undertaken to recommend certain surgical modalities and discard others. For example, microsurgery, embolization, radiosurgery, and surveillance are four possible courses of treatment that are widely accepted by the neurosurgical community and require little analysis to qualify the internal validity of their results. The well-known international subarachnoid aneurysm trial (ISAT) study,[8] which compared embolization versus microsurgery in the treatment of intracranial brain aneurysms, is a class I study, meaning it was prospective, comparative, double-blind, and randomized. However, its internal validity, the results that derive from a large use of neurointervention procedures, cannot be extrapolated to provide external validity over the surgical results, which have historically been excellent. Clearly, we are moving toward a multidisciplinary approach that joins the work of neurosurgeons and interventional radiologists in such a way that debates concerning the selection of one technique among several options are increasingly rare, or maybe redundant. The same is true of radiosurgery increasingly replacing microsurgery in the management of skull base tumors and several other conditions. Therefore, any surgeon training in skull base techniques should be aware that all assertions based on studies must be interpreted with a critical view, and should not be accepted without personal evaluation.

To discuss how to evaluate the best course of treatment for a disease using evidence-based medicine, along with its advantages and criticisms, let's use the following disorder as an example. The management of vestibular schwannomas has become a controversial topic. Although it is met with dogmatic responses in many neurosurgery centers, as well as arbitrary flowcharts and archaic habits of treatment, in some others it prompts a thorough evaluation to determine the best course of treatment in light of clinical and epidemiological evidence, because it is recognized that this disorder raises several questions for which there are still no answers.

In 2017, the Congress of Neurological Surgeons published a series of systematic reviews on vestibular schwannomas,[9–11] and the questions asked were remarkably varied. What is the best surgical approach for preserving facial and vestibulocochlear nerve function? Does the tumor's size influence the choice of approach? Should intracanalicular tumors be resected? Should surgery be the first therapeutic option for patients with type 2 neurofibromatosis (NF2)? Another part of the study addressed issues related to radiosurgery, such as what are the best radiosurgery devices, techniques, and follow-up exams. Similarly, Systematic Review and Evidence-Based Guidelines on Hearing Preservation Outcomes in Patients with Sporadic Vestibular Schwannomas were produced. A large number of studies were evaluated in these works, and their conclusions always noted that there were large amounts evidence available to support decision making.

Increasingly, neurosurgeons choose more conservative management options not because they want the best outcomes for their patients in light of the literature but, often, because they have not developed enough with educational methods before trying to manage certain illnesses.[12] They may lack the necessary perspective that surgical experience should provide. As with skull base diseases, in which intervention procedures and radiosurgery have been increasingly indicated, radiosurgery has been replacing surgery indiscriminately as the first choice of treatment for all patients, even those with vestibular schwannomas or skull base

Grade	Tumor
T1	Purely intracanalicular
T2	Intrameatal or extrameatal
T3a	Filling the cerebellopontine cistern
T3b	Reaching the brainstem
T4a	Compression of the brainstem
T4b	Compression of the brainstem with dislocation of the fourth ventricle

Fig. 3 Hannover classification for vestibular schwannomas.

meningiomas. However, this is not always the best option for the patient. Microsurgical technique remains superior to many new technologies and less invasive approaches.[13]

To gain the experience that provides results comparable to those of well-established skull base surgeons, and results that are comparable or superior to those achieved with less invasive techniques, young professionals must have a broad education. This should include, but not be limited to, training in microsurgery and anatomy laboratories, accompanying senior colleagues with recognized expertise and watching their routine before, during, and after surgery, watching surgical videos of the specialties they are pursuing, and, when finally undertaking their first surgeries, having all the necessary resources at their disposal, such as an ultrasonic aspirator, a surgical microscope, and other appropriate microsurgical instruments, followed by intraoperative neurophysiological monitoring.

Data from pioneers in skull base surgery should help motivate the current generation of young physicians to start on a path of improving their skills with training to improve patients' outcomes.[6,14–20] Given the ongoing evolution of neurosurgical science, it is expected that the first cases of a young surgeon should bear results at least similar to those of surgeons with decades of experience. Likewise, many complications encountered by the older generation of surgeons will mostly not be repeated by the younger generation thanks to this evolution.[12] Our work in Brazil illustrates this well. In the past 8 years, all of our vestibular schwannoma patients have been managed by a team composed of an otologist (JL), two neurosurgeons (GRI and FB), and a neurophysiologist. Both surgeons trained for over a year in microsurgical laboratories. In our series of 93 cases of vestibular schwannomas, the main objective was to preserve facial nerve function, and the secondary objective was total resection of the tumor. Following this strategy, facial nerve preservation with complete tumor resection was achieved in all T1, T2, and T3 neurinomas (Hannover classification – ►**Fig. 3**). For some of the T4 tumors, near total resection based on intraoperative neurophysiological changes was chosen instead.

Hearing was preserved in half of the patients with T1 and T2 tumors. We used retrosigmoid approaches with most patients, and translabyrinthine in patients without any

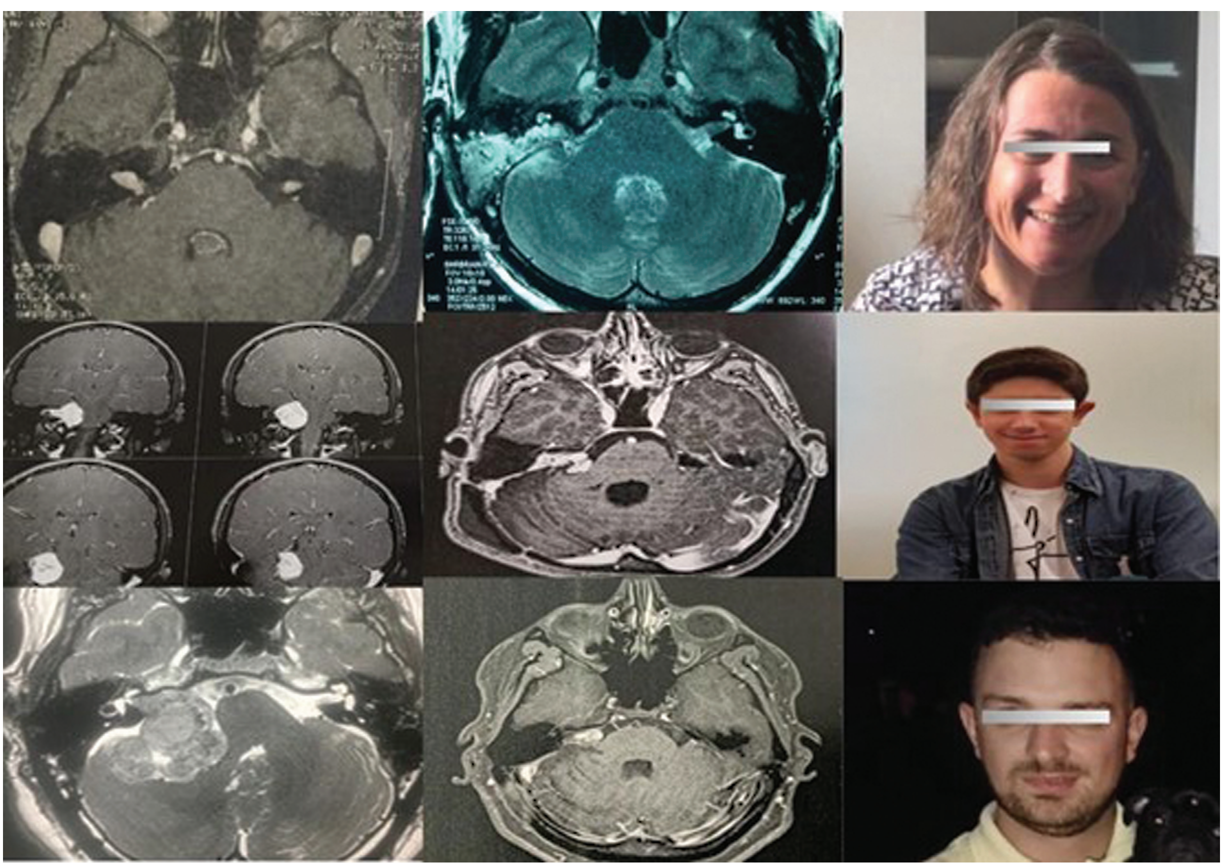

Fig. 4 Pre- and postoperative exams of three cases of vestibular schwannomas, with their respective postoperative preserved facial mimic. The main objective was to preserve facial nerve function, even if some residual tumor must be left, guided by intraoperative neurophysiological monitoring.

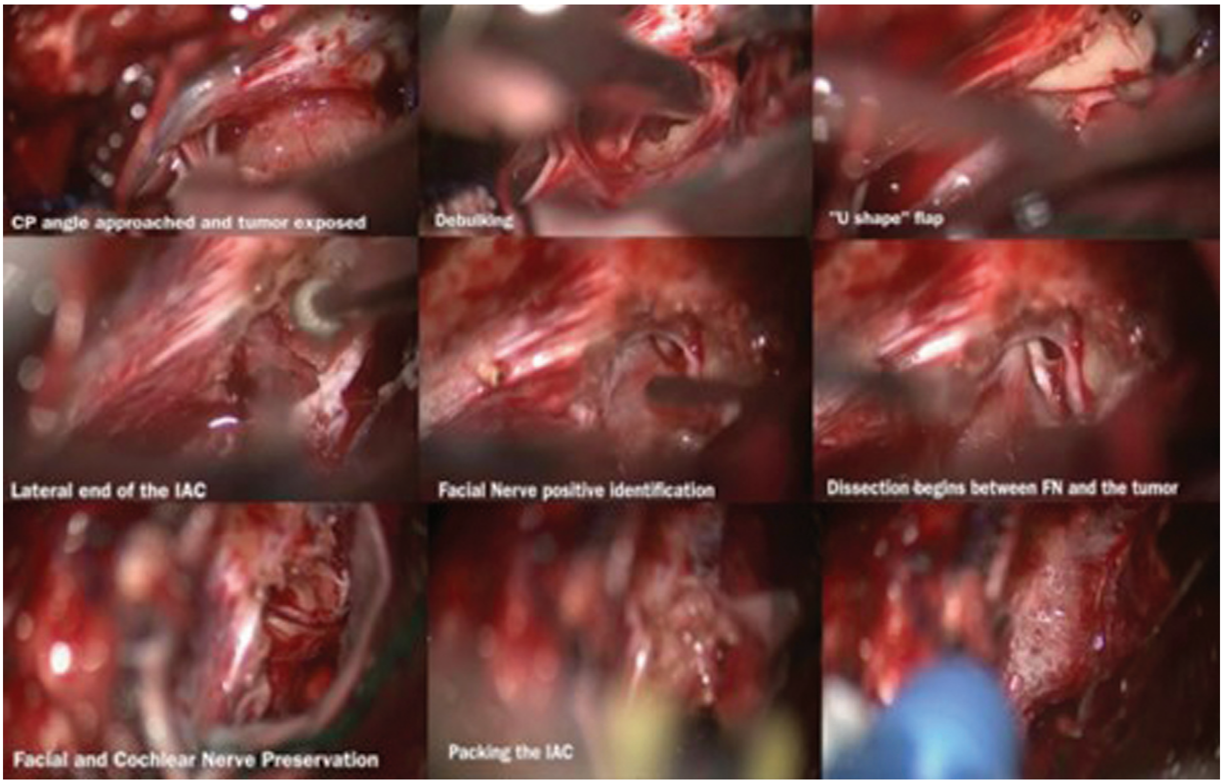

Fig. 5 Step-by-step approach to the internal acoustic canal: applying knowledge from microanatomy laboratory training in the operative room.

viable hearing who had small tumors extending to the fundus of the meatus. For cases that presented with complete facial paralysis, we opted for early facial hypoglossal anastomosis, 3 months after surgery at most. Except for one patient with venous infarction after resection of a T4 tumor, there were no deaths in this series.

So far, our methodology for managing patients with vestibular schwannoma has not grown to statistically significant numbers, and we have no clinical-epidemiological evidence based on prospective randomized studies. However, this work has been highly satisfactory for our patients. Several case series and reports have shown improvement in facial paralysis indexes over the years.[6,12,14–21] While, in our series, we have seen improvement in the extent of tumor resection over the years, the rate and severity of facial paralysis remained low since the beginning. ►**Figs. 4–9** illustrate some cases of cerebellopontine angle tumors in our series. We have been following another 46 patients with serial magnetic resonance imaging (MRI). Most of them are elderly patients with asymptomatic intrameatal tumors.

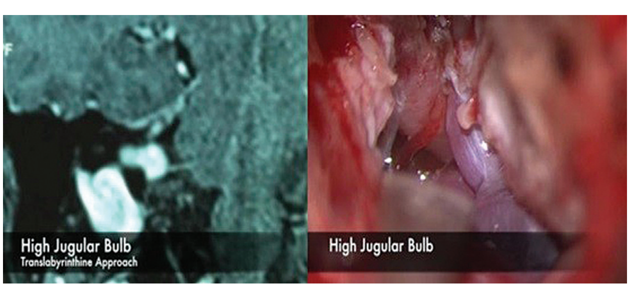

Fig. 6 A case of a high jugular bulb in a cerebellopontine angle approach: the importance of microanatomy knowledge to prevent unexpected situations in surgery.

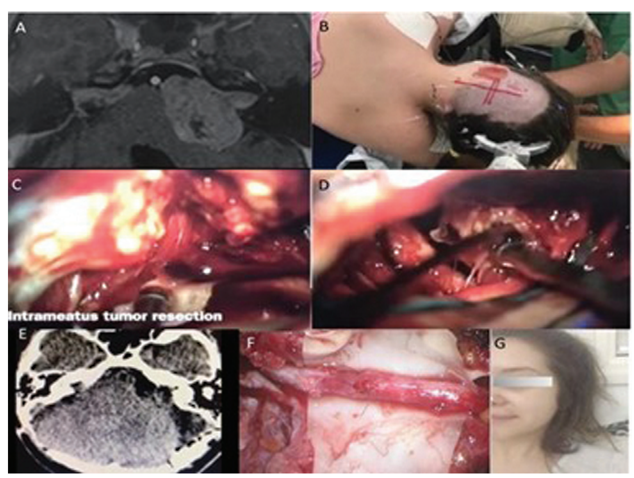

Fig. 7 A case of a grade IVB vestibular schwannoma. (A) Gadolinium-enhanced T1-weighted axial image showing left-sided vestibular schwannoma compressing brainstem and dislocating the fourth ventricle; (B) patient's surgical positioning: ¾ prone position with shoulder retraction; (C) opened internal acoustic canal; (D) tumoral resection; (E) early postoperative computed tomography (CT) scan showing gross total tumor resection and opened internal acoustic canal; (F) intraoperative hypoglossal-facial nerve anastomosis; (G) postoperative facial motricity preservation.

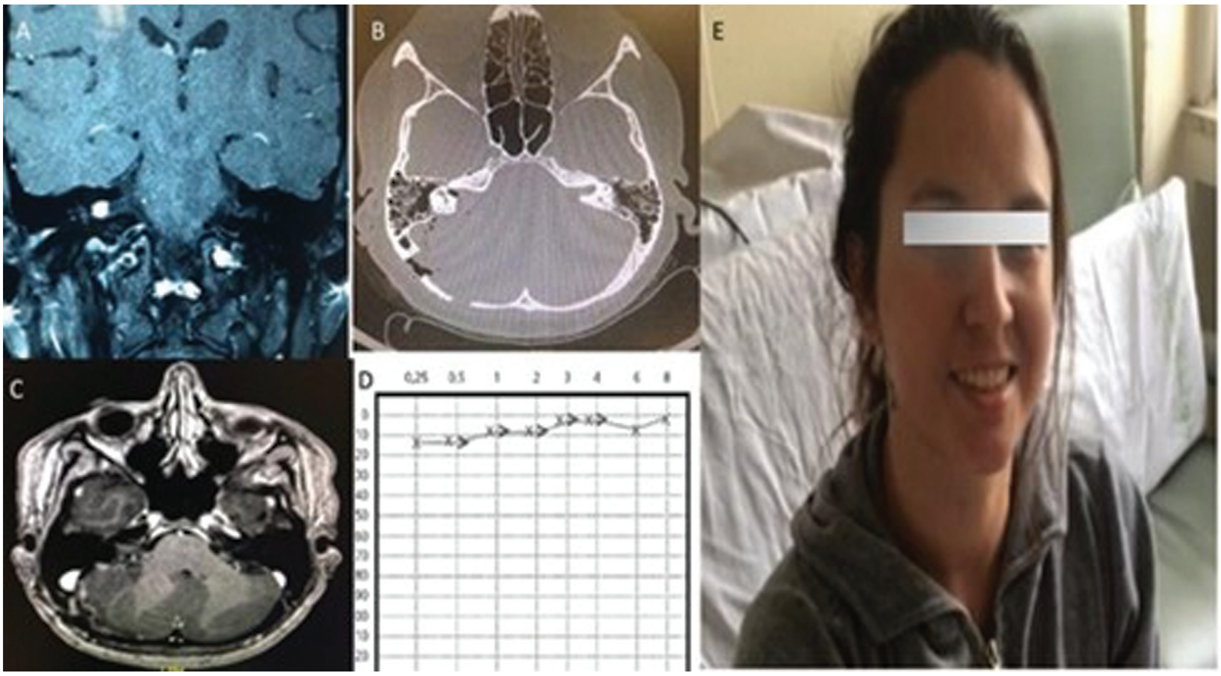

Fig. 8 Intracanalicular vestibular schwannoma (grade I). (A) Gadolinium-enhanced T1-weighted sagittal image showing a small lesion within the internal acoustic canal; (B) early postoperative computed tomography (CT) scan showing the opening of the internal acoustic canal; (C) gadolinium-enhanced T1-weighted axial image showing complete tumoral resection; (D) postoperative audiometry showing hearing preservation; (E) postoperative facial motricity preservation.

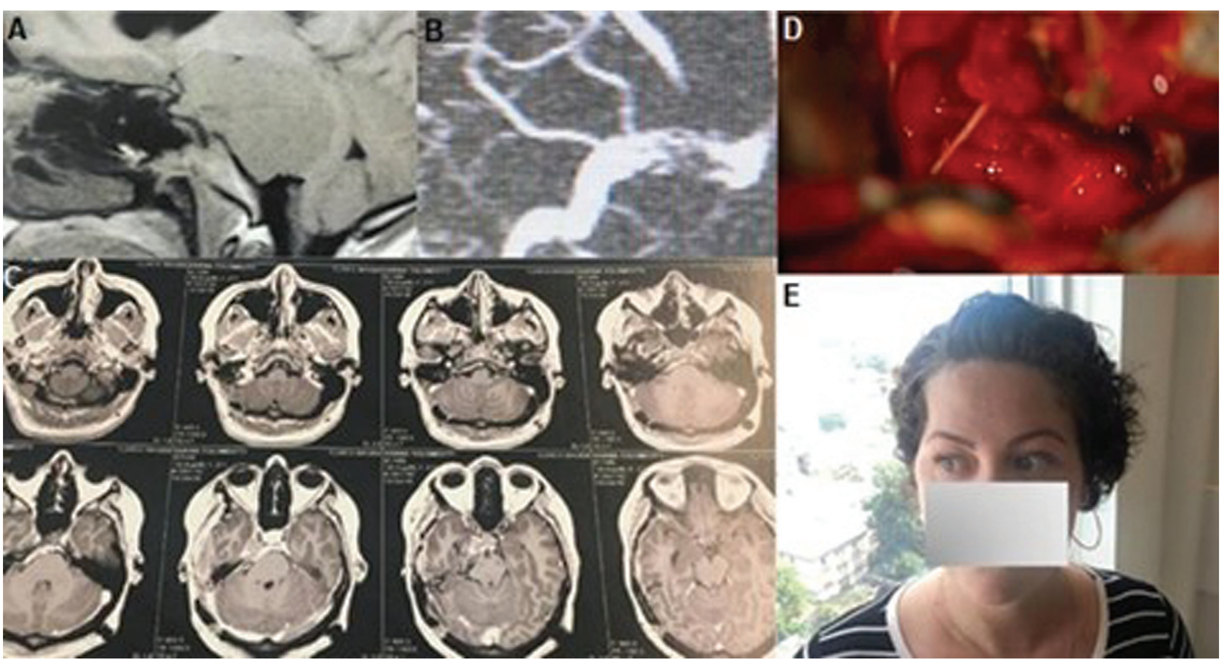

Fig. 9 Sphenopetroclival meningioma. The patient had lower cranial nerves palsies and hemiparesis. (A) Sagital T1-weighted image showing tumor interface with brainstem; (B) brain venography showing Labbé vein in its usual position. Based on that, a posterior petrosal approach was performed; (C) gadolinium enhanced T1-weighted postoperative image, showing near total ressection; (D) intraoperative image showing the IV cranial nerve. Near total resection without ophtalmoparesis was achieved. Residual tumor left in the cavernous sinus; (E) asymptomatic patient in a 6-years follow-up. Annual magnetic resonance imaging (MRI) with no tumor growth.

Final Considerations

In the first part of this article, we've tried to briefly demonstrate the construction of western knowledge and the steps that skull base surgeons, in the beginning of their careers, must take when evaluating the medical literature using evidence-based medicine. We emphasize that for uncommon diseases, including most of the skull base ones, the best approach is rarely based on rigid statistical data, but rather on the patients' expectations and surgeons' experience, knowledge, and empathy levels at that particular point of their career.

Note

Some small parts of this article were published previously in Portuguese by the senior author, * but with a different focus on the learning curve. Following the Brazilian Association for Technical Standards (ABNT) and copyright rules (lei número 9.610), these parts are identified by quotation marks.

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Conflict of Interests

The authors have no conflict of interests to declare.

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