Dr. Albert L. Rhoton Jr: his life and contributions to Neurosurgery

RESUMO
Dr. Albert L. Rhoton, conhecido como um dos pioneiros no estudo da neuroanatomia microcirúrgica, dedicou, com muito brilhantismo, parte de sua vida à elaboração de inúmeras linhas de pesquisas nesta área do conhecimento através de estudos realizados por ele e por seu laboratório ao longo dos anos, uma vez que havia, na época, uma clara necessidade de aprofundar os conhecimentos a respeito da mesma. A fim de compreender melhor seus estudos e contribuições para a especialidade neurocirúrgica, realizou-se uma pesquisa nas plataformas MedLine/PubMed e SciELO, com os descritores “Rhoton”, “Rhoton’s lab”, “education”, “historical review”, “anatomy”, “microsurgical anatomy” e “neurosurgery” combinados entre si, resultando em seis artigos que serviram de base para a elaboração da presente revisão narrativa. A partir desta, foi possível inferir que seus trabalhos versaram, principalmente, a respeito dos temas: nervos cranianos, hipófise e sela túrcica, artérias, ventrículos, conhecimentos relativos ao estudo de base de crânio e estruturas internas do cérebro, a fim de correlacioná-los com as descobertas anatômicas e as novas abordagens cirúrgicas avançadas. Estas, possibilitaram grandes avanços na especialidade, inaugurando novas técnicas, sugerindo abordagens mais eficazes e seguras e trazendo descrições anatômicas de maior acurácia e riqueza de detalhes, graças às técnicas inovadoras de pesquisa e ilustração adotadas por seu laboratório, que facilitaram a aprendizagem médica. Além disso, é importante ressaltar que suas contribuições não foram restritas apenas ao seu país de atuação, tendo se disseminado ao redor do mundo, podendo-se destacar a América Latina e, dentro dela, o Brasil.

Palavras-chave: Rhoton; Laboratório de Rhoton; Anatomia microcirúrgica; Neurocirurgia

ABSTRACT
Dr. Albert L. Rhoton, known as one of the pioneers in the study of microsurgical neuroanatomy, has devoted, with great brilliance, part of his life to the elaboration of innumerable lines of research in this area of knowledge through studies carried out by him and his fellows at the laboratory over the years, since, at that time, there was a clear need to improve knowledge about it. In order to better understand his studies and contributions to the neurosurgical specialty, a survey was carried out on MedLine/PubMed and SciELO platforms, with the keywords “Rhoton”, “Rhoton’s lab”, “education”, “historical review”, “anatomy”, “microsurgical anatomy” and “neurosurgery” combined, which resulted in six articles that served as the basis for the elaboration of this narrative review. From this, it was possible to infer that his works dealt mainly with the following themes: cranial nerves, pituitary gland and sella turcica, arteries, ventricles, the knowledge related to the study of the skull base and internal structures of the brain, in order to correlate them to anatomical discoveries and new advanced surgical approaches. This enabled great advances in the specialty, inaugurating new techniques, suggesting more effective and safer approaches and bringing anatomical descriptions of greater accuracy and richness of details, thanks to innovative research and illustration techniques adopted by his laboratory, which facilitated medical learning. In addition, it is important to note that his contributions were not restricted only to his country of operation, having spread around the world, emphasis in Latin America, especially Brazil.

Keywords: Rhoton, Rhoton’s lab, Microsurgical anatomy, Neurosurgery
Dr Albert L. Rhon was a neurosurgeon and professor who lived in the United States between 1932 and 2016, known as a pioneer in the study of microsurgical neuroanatomy. He has devoted himself extensively to the study of this area, which, until then, was poorly explored. Dr. Rhon and his lab introduced many new research ideas, surgical techniques and approaches, and also developed better microsurgical instruments. Achievements that were only possible because of the study and teaching of anatomy in his laboratory, where more than 500 articles on the subject were produced, which were fundamental for the improvement of neurosurgical techniques.

All this development and researches have brought great benefits both to surgeons around the world and to patients undergoing neurosurgical procedures. Thus, it is extremely important to address their contributions, which are used, until today, by several neurosurgeons.1,2

**METHODS**

The present study is a narrative review of the literature and intends to address the professional trajectory of Dr. Albert Rhon Jr, highlighting his contributions to neuroanatomy and Neurosurgery. This retrospective review was produced from the research of scientific articles published until 2020, based on the Medical Literature Analysis and Retrieval System Online (MedLine/PubMed) and Scientific Electronic Library Online (SciELO).

The key words used for the search in the database were: "Rhoton", "Rhoton’s lab", "education", "historical review", "anatomy", "microsurgical anatomy" and "neurosurgery".

From the search in the databases 171 articles were obtained. Those that did not allow complete reading were eliminated, as well as those which analysis of the summary and reading of content did not fit the desired search profile. At the end, 31 articles remained for this work.
from the research of scientific articles published until 2020, based on the Medical Literature Analysis and Retrieval System Online (MedLine/PubMed) and Scientific Electronic Library Online (SciELO).

The keywords used for the search in the database were: “Rhoton”, “Rhoton’s lab”, “education”, “historical review”, “anatomy”, “microsurgical anatomy” and “neurosurgery”.

RESULTS

From the search in the databases 171 articles were obtained. Those that did not allow complete reading were eliminated, as well as those which analysis of the summary and reading of content did not fit the desired search profile. At the end, 31 articles remained for this work.

This review looks back on Dr. Albert L. Rhoton Jr.’s main contributions to neurosurgery and to the development of anatomical and microsurgical studies around the world.

DISCUSSION

**Academic Education**

Dr. Albert L. Rhoton Jr. was born on November 18, 1932 in a rural area of Kentucky, in the southeastern United States, having studied as a child at a simple school. Despite this humble beginning, Dr. Rhoton would later become one of the best known neurosurgeons in the world.

After finishing high school in Ohio, Dr. Rhoton started his studies at Ohio State University, where he earned his bachelor’s degree in science. At the end of the course, he was invited by a professor to assist a neurosurgery and then he discovered his true passion, deciding to attend to medical school. He entered the Washington University School of Medicine in Saint Louis, graduating in 1959. He began his residency in general surgery at Columbia Presbyterian Medical Center in New York and after that became a neurosurgical resident at the New York Neurologic Institute, completing his residency in 1965 at Barnes Hospital in Saint Louis.

**Contributions to the Mayo Clinic**

After his Neurosurgery residency, Dr. Rhoton joined the Mayo Clinic in Rochester, Minnesota, in January 1966. During his first year at the clinic, he performed a total of 479 neurosurgical procedures and started multiple research groups, having published 4 works that year. In 1967 he began to dedicate himself even more to studies in his laboratory, focusing mainly on cerebral microanatomy, having as main lines of research the sensitive connections of the brainstem and the innervation of the cerebral arteries.

The introduction of the microscope, in both the operation room and in his research at the Mayo Clinic laboratory, allowed a more detailed study of neuroanatomy. In 1968, Albert L. Rhoton Jr. presented a work on microsurgical anatomy and early diagnosis of acoustic neuromas at the Annual American Medical Association in New York, obtaining great success and
approval due to his extremely detailed anatomical findings. During the following years, Dr. Rhoton developed several other lines of research focusing on microsurgical anatomy, having published more than 20 articles and performed more than 3000 neurosurgical procedures during the 7 years which he remained at the Mayo Clinic.

Contributions of Rhoton’s Lab

With his departure from the Mayo Clinic, Dr. Rhoton dedicated himself to the foundation, in 1975, of the George Schrader Colter microsurgical anatomy laboratory at the University of Florida, popularly known as Rhoton’s Lab, where numerous discoveries in the field of neuroanatomy and microneurosurgery occurred. With a multidisciplinary team of neurosurgeons, laboratory directors, medical illustrators, researchers and a management team, Rhoton’s Lab has brought advances that impacted the world of neurosurgery and will continue to impact it for decades. With the financial assistance from patients, private sectors and the university itself, Rhoton was capable of giving rise to this center so respected worldwide, that, 23 years after its foundation, it was relocated to the McKnight Brain Institute.

Among the contributions of this institution, we can mention the production of instruments for microneurosurgical practices, such as Rhoton micro needle holder and Rhoton’s micro dissector, available in 14 sizes. Also noteworthy are the teaching of more than 100 researchers, most of them foreigners, the teaching of surgical dissection courses, the production of more than 500 scientific articles, in addition to an innovative work in neuroanatomical illustrations with remarkable advances in the techniques of staining, which revolutionized the way neuroanatomy and neurosurgery came to be taught. Between the 90s and the 2000s, the interest about anatomical representation in three dimensions arose, an idea that was perfected with neurosurgical endoscopy, which characterizes yet another of the great contributions of Rhoton’s Lab.

It is important to note that many of the goals achieved by Dr. Rhoton and his laboratory are due to the fact that he is always very dedicated to his work, acting patiently and clearly even with the language barrier, often encountered in the face of the great number of foreign researchers at the institution. Furthermore, despite traveling frequently, teaching classes around the world, Dr. Albert Rhoton sought, even in these periods, to be continually in contact with his students in order to instruct scientific productions, surgical practices and photographic record throughout these practices.

Focusing on the many researches carried out by Dr. Rhoton and the Rhoton’s Lab, they have made significant contributions to the advances in Neurosurgery, since they discussed topics, which were little explored at the time, but of great importance for this specialty. Among them, we can highlight it below.

Cranial nerves, pituitary and sella turcica

During the time he worked at the Mayo clinic, Dr. Rhoton started his studies on cranial nerves in primates. Then, he dedicated himself to detailing their anatomy from autopsies performed on the brain and temporal bone. Afterwards, as head of the Neurosurgery Division at the University of Florida, Dr. Rhoton focused on the study of tumors of the pituitary gland and acoustic neuromas, the second being considered one of his greatest works in the early stages of his career, since he was able to comprehend that, in these cases, the facial nerve was displaced by the tumor, being, in most cases, stretched over the anterior half of the capsule, this being one of the explanations for the damage that was usually caused to this nerve in the surgery of acoustic tumors. Thus, he suggested the existence of two regions where the VII nerve would not have been displaced markedly, which should be observed during surgery in order to maintain the pre-existing anatomical interrelation. In this way, it enabled an important advance regarding the preservation of the facial nerve in surgeries of acoustic neuromas.

Dr. Rhoton also dedicated himself to the study of the trigeminal nerve, the optic nerve and the lower cranial nerves at jugular foramen, along with his illustrators, and carried out a work of retouching the black and white illustrations existing at that time, which was extremely important to highlight essential anatomical details that were not seen in the original images. Regarding the pituitary gland and the sella turcica, touch-ups and colored illustrations were also carried out, in addition to the description of the variations of the septal insertion in the...
anterior floor of the sella turcica, of the intercavernous venous connections and of the carotid prominence, highlighting its thickness and the frequency of its defects, studies that contributed enormously to recent advances in transnasal access techniques11.

**Arteries**  
His work involving arteries was very useful for neurosurgeons who, until then, were limited to studying them from descriptions made by neuroradiologists. Dr. Rhoton adopted the technique of red latex or acrylic injection in the arteries to facilitate the dissection of the branches, allowing a better visualization of them. Thus, he did not hesitate to rename arteries and branches and suggest new segmentations based on their origin to facilitate the understanding and to assist in performing difficult procedures, as in the case of basilar aneurysms, which were greatly benefited by his project involving the upper basilar artery and its perforating branches12-14.

**Ventricles**  
Dr. Rhoton realized that, at the time, in the texts made by anatomists there were few descriptions of blood vessels related to the ventricles. Thus, he gathered the knowledge of anatomists together with the description of the vascular structures described by the radiologists and reorganized them, focusing on both microanatomy and neurosurgical techniques15,16.

His work on demonstrating the posterior aspect of the fourth ventricle resulted in the anatomical description of the cerebromedullary fissure, which enabled the emergence of the telovelar surgical approach, widely used today. Studies on the lateral ventricle have also made it possible to describe a safer surgical technique through the choroidal fissure2.

**Skull base**  
Research involving skull base anatomy also stood out in his contributions, in which he sought to improve his knowledge of the cavernous sinuses, orbit, temporal bone, jugular foramen and foramen magnum. Through cadaveric dissections, Dr. Rhoton was able to study the various surgical approaches of the cavernous sinus and adjacent regions, relating to the recent discoveries about the superior venous complex. In addition, in this region, new approaches to the lateral foramen magnum were also observed, such as the extreme-lateral, transcondylar and transcondylar fossa, the posterolateral portion of the foramen magnum through a new more in-depth study of this region. It is also important to highlight Dr. Rhoton's effort to deepen his knowledge of the jugular foramen, since, being a region of difficult access, it had been little described, which led him to seek, tirelessly, to catalog information about the region, reviewing the available surgical approaches. Regarding the studies of the orbits, it aimed, mainly, to detail the transcranial approach, the lateral surgical approach and the knowledge about the superior orbital fissure3,11,17-23.

**Internal brain structures**  
Using the fiber dissection method, Dr. Rhoton was able to expand the discoveries about the internal structures of the brain. Thus, from the development of brainstem surgeries, his research focused on this region, with the intention of finding a safe entry zone in order to cause minimal damage to the patient. In this context, not only the discoveries about the brainstem were crucial to science, but also the fiber dissection method used by him, which is still used today in several procedures, such as auditory brainstem implantation and deep brain stimulation6,11,24-28.

**New surgical methods associated with knowledge of microanatomy**  
The Rhoton laboratory sought to follow the new demands of science for safer and more effective procedures, through collaboration with numerous technologies such as endoscopic surgery, both endonasal and endoscopy-assisted surgery for aneurysms, and cerebellopontine lesions, neuronavigation system, endovascular surgery, auditory brainstem, in addition to deep brain stimulation. All projects were elaborated in detail, in order to minimize and avoid the surgical complications of these procedures2,8,29,30.
Contributions to Brazil and Latin America

The legacy of Dr. Rhoton and his laboratory for Neurosurgery is immeasurable and global, especially in the field of microsurgery and neuroanatomy. His contributions were, and still being, helpful, for a large number of patients. In his 50 years of career devoted to neurosurgery, Dr. Rhoton participated in numerous lectures, courses and conferences around the world, allowing his discoveries and innovations in Neurosurgery to influence medical practice in different regions of the planet. In relation to the Latin America and also with Brazil, his connection began in 1977, when Dr. Evandro de Oliveira visited Dr. Rhoton's laboratory in Gainesville, a visit motivated by Dr. Evandro's fascination with new discoveries about microsurgery correlated strongly with anatomical knowledge. Dr. Evandro, years after his first visit, became Dr. Rhoton's first Latin American research partner. Since that first direct contact with Latin medicine, Dr. Rhoton had 23 other research partners from Latin America (14 Brazilians, 7 Argentines, 1 Chilean and 1 Mexican), which makes it undeniable that the innovations had a direct impact on Latin American's Neurosurgery and, especially, in the Brazilian's one.6,31

CONCLUSIONS

The contribution that Dr. Albert Rhoton Jr. left for medicine is notable: he not only devised new surgical approaches and created instruments for Neurosurgery, but also proved to be a competent leader and teacher, training countless neurosurgeons. In addition, Dr. Rhoton was compared by many to Lorenzo de Medici in the Renaissance of the arts in Florence, due to his revolutionary works and illustrations relating neuroanatomy to art. Therefore it is evident that Dr. Rhoton's contributions must be remembered and admired for decades, since the impact of his innovations is immeasurable for both professionals and patients. His remarkable dedication to expanding the teaching of neuroanatomy and micro neurosurgery must never be forgotten.

REFERENCES


Luiz Severo Bem Júnior, MD, MR
Neurosurgery Residency
Hospital da Restauração Governador Paulo Guerra
Recife, Brazil
Email: luizseverobemjunior@gmail.com

Conflicts of interest: The authors have no conflict of interest to declare.

Funding statement: none.