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Japanese Neurosurgeons and Microsurgical Anatomy: A Historical Review

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Abstract

Research in microneurosurgical anatomy has contributed to great advances in neurosurgery in the last 40 years. Many Japanese neurosurgeons have traveled abroad to study microsurgical anatomy and played major roles in advancing and spreading the knowledge of anatomy, overcoming their disadvantage that the cadaver study has been strictly limited inside Japan. In Japan, they initiated an educational system for surgical anatomy that has contributed to the development and standardization of Japanese neurosurgery. For example, the Japanese Society for Microsurgical Anatomy started an annual educational meeting in the middle of 1980s and published its proceedings in Japanese every year for approximately 20 years. These are some of the achievements that bring worldwide credit to Japanese neurosurgeons. Not only should Japanese neurosurgeons improve their educational system but they should also contribute to the international education in this field, particularly in Asia.

Key words: microsurgical anatomy, Japanese neurosurgeons, Rhoton's laboratory, microsurgical anatomy seminar, education of the surgical anatomy

Introduction

Microscopic neurosurgery emerged in the 1960s, and advances in neurosurgery have accelerated with the development of surgical technology. With its emergence, studies on microsurgical anatomy were also initiated in the late 1960s, to address the necessity of precise anatomical knowledge of the brain. In Japan, microneurosurgery started in the 1970s, approximately 10 years later. Many Japanese neurosurgeons were curious for knowledge of microsurgical anatomy to improve the safety of their surgery; however, it was difficult to study the subject, owing to legal and religious prohibitions. Cadaveric specimens were and continue to be strictly limited for use by surgeons in study and research because of these prohibitions. Their thirst for knowledge of anatomy impelled them to travel abroad, although they did not receive any support. The main laboratories where Japanese neurosurgeons have studied include those of Dr. Rhoton at the University of Florida (UF) and Dr. Fukushima at the Duke University. Japanese neurosurgeons have contributed to major advances in neurosurgery for the last 40 years in the field of microanatomy. Their achievements have not only spread knowledge worldwide through textbooks and academic articles but also after returning to Japan they have established an educational system for anatomy and contributed to the development and standardization of Japanese neurosurgery. For example, in 1986, they initiated one of the first societies in the world devoted to microsurgical anatomy seminars, the Japanese Society for Microsurgical Anatomy (formerly the Japanese Microsurgical Anatomy Seminar); the Society has conducted annual meetings for the past 30 years, publishing educational textbooks as proceedings. In this article, the authors review the contributions of Japanese neurosurgeons to the worldwide development of microsurgical anatomy and their establishment of the educational system for this field in Japan. The authors also discuss the future prospects for anatomical research and the roles that Japanese neurosurgeons should play.

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I. Dawn of microsurgical anatomy and Dr. A. L. Rhoton Jr.

Dr. A. L. Rhoton, Jr. always says that microsurgical anatomy is the roadmap for applying microsurgical techniques to surgeries and this makes them more accurate, safer, and gentle. When he was undergoing training as a young neurosurgeon, he did not see a facial nerve preserved during the surgical removal of an acoustic neurinoma.[1,2] He realized that he needed more precise study on anatomy through the operating microscope. Therefore, when he worked at the Mayo Clinic as an instructor, he began his anatomical study with a Japanese colleague, Dr. S. Kobayashi from Shinshu University, Nagano, Japan, and published a paper titled "Nervus intermedius" in 1968 (Fig. 1).[3] To the best of our knowledge, this was the first article on microsurgical anatomy, and he established this field as a research field of neurosurgery, which was most directly related to the surgeries.

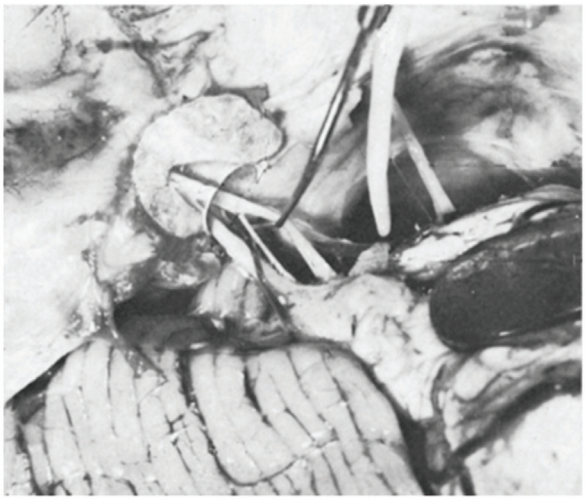

Fig. 1 The figure of the left internal auditory canal from Dr. Rhoton's first paper on microsurgical anatomy (from Rhoton et al.,[3] with permission).

II. Dr. Rhoton's laboratory at UF and contribution of Japanese fellows

In 1972, Dr. Rhoton moved to UF as a chairman of the Department of Neurological Surgery, and began his research on microsurgical anatomy in earnest.[1,2,4] He established an anatomical laboratory perfectly simulating the operation room with all surgical instruments and a microscope; here he devised new research methods. He initiated the infusion of red and blue silicone into arteries and veins, respectively, and painted the outlines of anatomical structures on monochrome photographic paper. The photographs became clearer around 1980 because the arachnoid membrane of the cadaveric specimens had been removed from the specimens before the photographs were taken (Fig. 2). Later, some of these research methods were shared with several other laboratories.

Dr. Rhoton has conducted research with more than 100 research fellows from all over the world for approximately 45 years to explore and clarify the detailed anatomy of the brain. Various research themes have been taken up by Dr. Rhoton with the development of modern neurosurgery. The main themes include (1) the facial nerve and temporal bone, (2) arteries and their perforating arteries, (3) the relationships between the cranial nerves and the vessels, (4) the ventricles, (5) venous systems, (6) the anatomy of skull base surgery, and (7) endoscopic anatomy. The results of these studies have been published as textbooks and articles in well-known journals such as *Journal of Neurosurgery*, and precise anatomical knowledge has been disseminated worldwide. The figures in papers from Dr. Rhoton's laboratory were

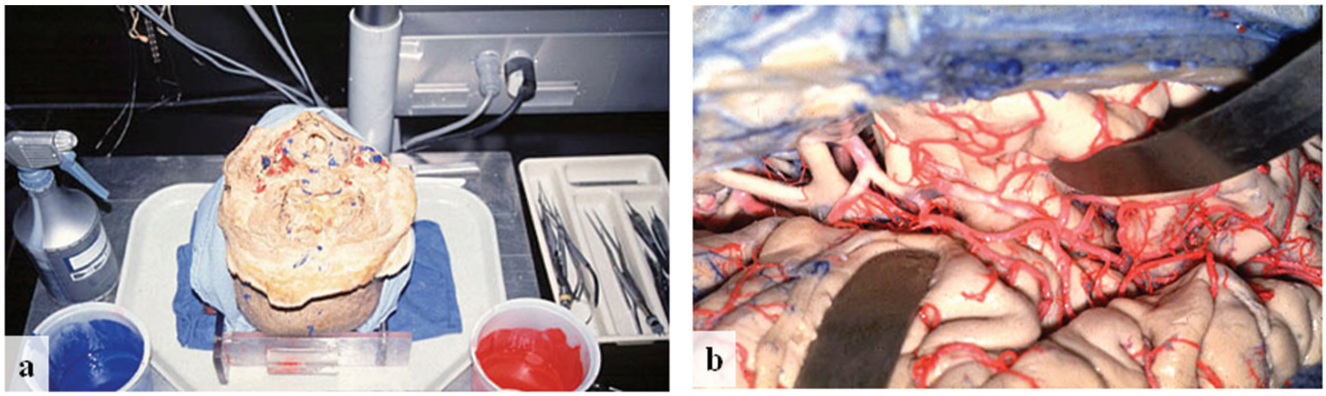

Fig. 2 Research methods devised at Dr. Rhoton's laboratory for microsurgical anatomy. a: Infusion of dye. A cadaveric specimen (head) into which *red* and *blue* dyes have been infused into the arteries and veins, respectively. b: Dissection of a specimen under the operating microscope; the specimen is dissected following the trans-Sylvian approach.

black and white initially, then in color, and now are available as three-dimensional images. After collecting all the knowledge from his laboratory, Dr. Rhoton published a book titled "RHOTON–Cranial Anatomy and Surgical Approaches," often called "RHOTON" or "the Rhoton book."[1] "RHOTON" has been translated from English into Portuguese and Chinese and is widely considered to be the bible of neurosurgeons worldwide (Fig. 3); the Japanese version is currently being prepared. The foreword of the book contains a list of 75 research fellows who worked with him, of whom more than one-third are Japanese, which exceeds the number of American fellows.

Fig. 3 Original textbook "RHOTON" and the Portuguese and Chinese versions (from Rhoton,[1] with permission).

The first Japanese research fellow in Dr. Rhoton's Neuro-Microanatomical Laboratory at UF was Dr. N. Saeki from Chiba University, who studied perforating arteries from the basilar artery tip and published an article on the subject in 1977.[5] Every year since the late 1970s, for more than 40 years, one or two Japanese neurosurgeons have studied and published articles in many different areas, and greatly contributed to the RHOTON textbook with their research results.[1] To date, 39 Japanese students have studied under Dr. Rhoton and published 45 original English papers on microsurgical anatomy as first author.[6–50] Although we cannot discuss all the articles and textbooks here, we would like to introduce five that were selected for the cover of the *Journal of Neurosurgery*, one of the oldest and most popular neurosurgical journals (Fig. 4).[7,9,13,32,48]

III. Anatomical education in Japan and international dissemination

Approximately 30 years ago, the Japanese Society for Microsurgical Anatomy (formerly the Japanese Microsurgical Anatomy Seminar) was established.

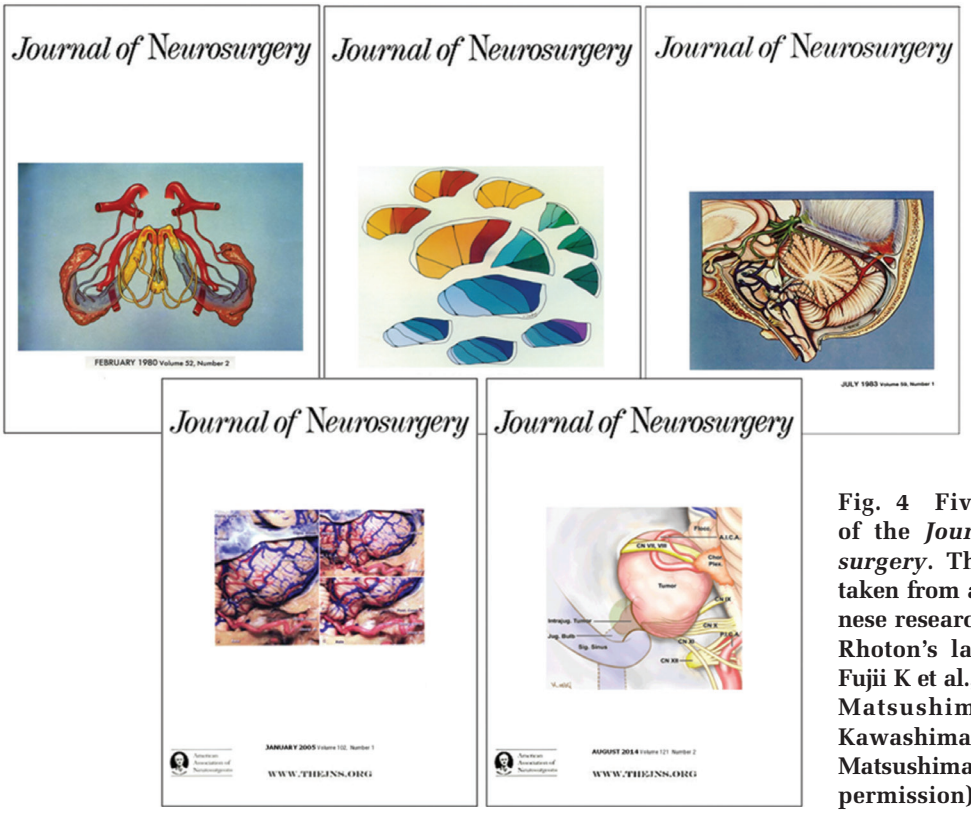

Fig. 4 Five front covers of the *Journal of Neurosurgery*. The figures were taken from articles by Japanese research fellows at Dr. Rhoton's laboratory (from Fujii K et al.,[7] Gibo H et al.,[9] Matsushima T et al.,[13] Kawashima M et al.,[32] and Matsushima K et al.,[48] with permission).

At that time it was very difficult for Japanese neurosurgeons to obtain enough anatomical knowledge for their surgeries because there were very few textbooks or videos on microsurgical anatomy, even in English. Some English papers, which were gradually appearing in English-language journals, were the only sources of anatomical knowledge. Many Japanese neurosurgeons were eager to obtain anatomical knowledge, preferably in Japanese. Under these circumstances the first meeting of the Japanese Society for Microsurgical Anatomy was conducted at the Kyushu University in Fukuoka in 1986, when Dr. Rhoton attended the retirement ceremony of late Dr. K. Kitamura, Kyushu University. Dr. Rhoton's previous research fellows assembled and presented lectures on various areas they had studied at UF (Fig. 5A). In 1988, Dr. S. Kobayashi, then the president of the Japanese Congress of Neurological Surgeons, organized the second meeting in Nagoya with the 8th annual meeting of the Congress, with the aim of further disseminating this practical knowledge. Thereafter, the annual meeting of the Japanese Society for Microsurgical Anatomy was held with the annual meeting of the Japanese Congress every year for 20 years until 2007. The meeting of the Anatomical Seminar made a great contribution to neurosurgical education in Japan. Several neurosurgeons interested in microneuroanatomy joined the organizing committee over time, and the annual meeting became large. It was a great success, sometimes with over 800 participants at one meeting.

The proceeding of the annual meeting of the Society, "Surgical Anatomy for Microneurosurgery," was published in Japanese after each meeting following the second one in 1988, and 20 volumes of the proceedings were published through the 21st meeting (Fig. 5B).[51–70] The fact that more than 3000 copies of vols. 1–4 were purchased by Japanese neurosurgeons shows the role they played in Japanese neurosurgical education and development, as practical anatomy textbooks in Japanese. They were finally discontinued in 2008, as many Japanese textbooks with color illustrations had appeared.

For the education of young neurosurgeons, a video series on microsurgical anatomy was also produced as a collaborative project by the Japan Neurosurgical Society and the University of Florida from 1992 to 1993 (Fig. 6). Nine of Dr. Rhoton's fellows visited UF again and produced educational video tapes on 10 topics.[71–80] These gave more three-dimensional perspectives of specimens than that were available from photographs. Further, some Japanese fellows published Japanese textbooks on microsurgical anatomy.[81,82]

As knowledge of microsurgical anatomy became generally known in Japan with the appearance of many textbooks and surgical videos, the annual meeting of the society had to be modified to meet the needs of the neurosurgeons. The meeting became one of the plenary sessions of the annual meeting of the Japanese Congress in 2008, as recommended by Dr. S. Miyamoto, the president of the 28th Japanese Congress, and the organizing committee members.[83] This session was organized as a more advanced one intended for certified practitioners, and a more basic anatomical meeting was initiated for young neurosurgeons. The lectures of the advanced session have been published in the supplement of the *Japanese Journal of Neurosurgery*.[83]

Fig. 5 The Japanese Society for Microsurgical Anatomy (formerly the Japanese Microsurgical Anatomy Seminar). a: Dr. Rhoton and the lecturers in the first meeting of the Society. b: Proceedings of the 20 annual meetings of the Society (from SciMed Publications, with permission).

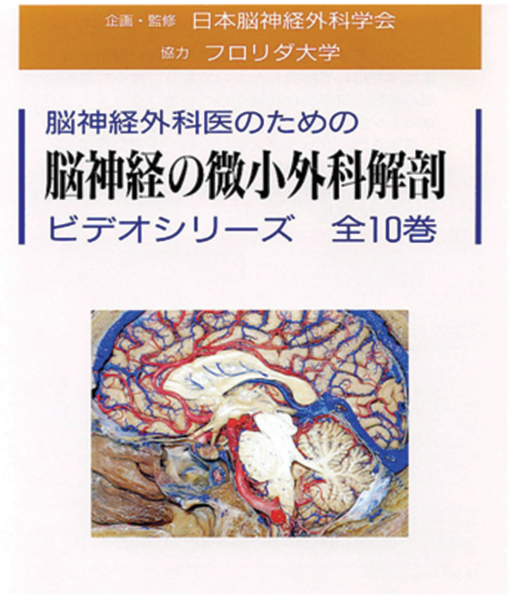

Fig. 6 Neurosurgical Educational Video Journal, a series of 10 volumes on microsurgical anatomy co-produced by the Japanese Neurosurgical Society and the University of Florida.

The demand for anatomical seminars increased internationally. The first meeting of the international seminar was held in October 2002 in Matsumoto, Japan, as one of the satellite symposia of the 61st annual meeting of the Japan Neurosurgical Society. Dr. E. Timurkaynak (Ankara, Turkey), and Dr. E. de Oliveira (Sao Paulo, Brazil), previous research fellows of Dr. Rhoton, held the international meeting thrice in Turkey and once in Brazil, inviting Dr. Rhoton as copresident and several experts from all over the world as speakers. These international seminars contributed to the professional development of many neurosurgeons not only in the host countries but also in neighboring countries.

IV. Other foreign research laboratories and Japanese neurosurgeons

In the 1990s, studies in microsurgical anatomy had begun in other institutions. The main laboratories in the United States where the Japanese neurosurgeons studied microsurgical anatomy were those of Drs. T. Fukushima and Al-Mefty. Japanese neurosurgeons who studied under Dr. T. Fukushima performed useful research projects on cadavers. With Dr. Fukushima's great experience of skull base surgeries, most were practical and employed his surgical techniques. To date, 11 Japanese neurosurgeons have published 30 original papers in English as first authors and 9 of these are concerned solely or mainly with microsurgical anatomy.[84–92] They also published the Fukushima Manual of Skull Base Dissection, which was originally used during his dissection course.[93] Some of his students published textbooks on skull base dissection.[94–96] All of them contributed to education in skull base surgery not only in Japan but also in many other countries. In Dr. Al-Mefty's laboratory, venous projects associated with skull base surgeries were mainly performed.[97,98] Beyond these projects, some Japanese neurosurgeons published original English papers on microsurgical anatomy in other laboratories.[99]

V. Research and dissection courses in Japan

Though many Japanese neurosurgeons traveled abroad to study microneurosurgical anatomy, some studies were performed in Japan and a few original papers have been published in English. To overcome the difficulties of using cadaveric specimens, researchers used parts of removed brain tissues, dry skulls, and resected skull base blocks as materials for their studies.[100–109]

In addition to anatomical meetings and publications in Japanese, several dissection courses, albeit small and/or semi-closed, have been held in conjunction with the education of medical students at several universities since the early 1990s. To the best of our knowledge, the first such courses were held in 1993 at Osaka city and Kobe universities. They were offered mainly for training in skull base surgeries. Recently, instead of cadaveric specimens, realistic life-size skull models have been used in some dissection courses.

Discussion

Studies in microsurgical anatomy have been performed mainly in the United States, where many Japanese neurosurgeons have traveled for study, subsequently playing important roles in describing anatomy, developing neurosurgical approaches, and disseminating their knowledge in the world. Their strong desire to obtain anatomical knowledge just after the appearance of the operative microscope in Japan led to this activity. In addition, they made great efforts to educate young neurosurgeons and disseminate their anatomical knowledge in Japan, by establishing the Japanese Society for Microsurgical Anatomy, holding its annual meetings, and publishing the proceedings in Japanese and in videos. We are not aware of the existence of such a continuous educational society elsewhere in the world. The reasons why Japanese neurosurgeons have been deeply involved in this research field even in foreign countries include (1) strong and urgent desire to perform their surgeries accurately and safely, (2) strict limitations on use

of cadaveric specimens for study, and (3) a small number of operative cases experienced by any single surgeon, owing to the surplus of certified neurosurgeons. Besides, it may be pointed out that Japanese surgeons have the patience to perform anatomical research, a tedious and dirty enterprise requiring handling cadaveric specimens.

Given that not only many papers but also many textbooks including the RHOTON textbook have been published, some may say that research on microsurgical anatomy is complete. However, with the development of surgical technology and the appearance of new surgical treatments, anatomical research must be advanced in order to support them. Several studies of less invasive surgeries including neuroendoscopic and neuroendovascular surgery have been reported.[43–46] Use of new technology such as computer technology is also a frontier in anatomical studies. Dr. Kakizawa employed computer-graphical anatomy to develop a computational simulation system for education.[40]

The study of anatomy is enlightening for all young neurosurgeons. The educational system and materials should be further improved. There are two educational methods: classroom lectures and dissection courses using cadaveric specimens. Given that each method has merits and demerits, both should be improved. For the former, both the basic anatomical meeting and the advanced session in the annual meeting of the Japanese Congress should be continued. For the latter, a limited number of neurosurgeons can attend the courses and the regions they can study are mainly those of the skull base, because of the quality of the autopsied specimens. Preparation also demands much time and labor. However, it must not be forgotten that there are practical knowledge and techniques that can be learned only from the dissection of cadaveric specimens. In the near future, we should hold dissection courses in which the sulci, gyri, ventricles, and dissecting fibers can be studied. Dissection courses for skull base surgery and those for the neural structures of the brain including the ventricles should be organized periodically and more frequently and in more places, with modest course fees so that many young neurosurgeons can participate repeatedly in the courses. To organize such courses, we must quickly resolve the problems, including legal barriers.

With respect to education in microsurgical anatomy outside Japan, classroom lectures and cadaver dissection courses have been held in other countries. However, they are too few for the neurosurgeons in the world. Japanese neurosurgeons who have studied microsurgical anatomy should contribute to education abroad, particularly to developing countries in Asia. Following Dr. Rhoton, the authors hope that research and education in microsurgical anatomy will make surgeries worldwide accurate, safe, and gentle.

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Conflicts of Interest Disclosure

The authors declare no conflicts of Interest. All authors who are members of The Japan Neurosurgical Society (JNS) have registered online self-reported COI disclosure statement forms through the website for JNS members.

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