JNS

HISTORICAL VIGNETTE

A brief retrospective of the history of neurosurgery in Croatia

Bruno Splavski, MD, PhD,[1] and Kenan I. Arnautović, MD, PhD[2,3]

[1]University of Applied Health Sciences, Zagreb, Croatia; [2]Semmes Murphey Neurologic and Spine Clinic, Memphis, Tennessee; and [3]Department of Neurosurgery, University of Tennessee Health Science Center, Memphis, Tennessee

The beginnings of neurosurgery in Croatia date to the end of the 19th century when Teodor Wickerhauser performed the first craniotomy in the country in 1886. Exactly 60 years later, in 1946, Danko Riessner founded a separate neurosurgical ward in Zagreb and is therefore considered the founder of Croatian neurosurgery. His main scientific contribution was a paper on the shifting of brain masses, published in 1939. The Department of Neurosurgery at the University of Zagreb was founded in 1974 as one of the first institutions of its kind in Southeast Europe. Finally, the Croatian Neurosurgical Society was founded in 1992 to promote the neurosurgical profession and science at the national level. This historical vignette aimed to provide a brief chronology of the most important events and notable people in the history of Croatian neurosurgery, as well as to commemorate its founders and highlight its development from the beginning to its current state of proficiency and expertise.

https://thejns.org/doi/abs/10.3171/2023.8.JNS231309

KEYWORDS Croatia; founding fathers; history; neurosurgery

The history of Croatian neurosurgery illustrates the country's close connection to the sphere of Western medicine, a link that has been instrumental since neurosurgical procedures were first established in Croatia. In this brief retrospective and historical vignette, we present a summary of the most notable people and a chronology of the most important events in the history of Croatian neurosurgery. These seminal people and events are highlighted to commemorate the founders of Croatian neurosurgery and to remember its development from humble beginnings to its current state of proficiency and expertise.

Brief Background on Croatia

Croatia is a country at the crossroads of Central and Southeast Europe, with its seaboard along the eastern coast of the Adriatic Sea. It was first recognized as an independent country in 879 AD during the reign of Duke Branimir. Tomislav became the first Croatian king in 925 AD, which elevated the country to the status of a kingdom and lasted about 200 years until Croatia entered a union with Hungary in 1102. In 1527, as Croatia was confronted with imminent conquest by the Ottoman Empire, the Croatian Parliament elected Ferdinand I of Austria to the Croatian throne, thus incorporating Croatia into the Habsburg Monarchy, which became the Dual Austro-Hungarian Monarchy from 1867 until the end of World War I. In October 1918, the State of Slovenes, Croats, and Serbs, newly independent from Austria-Hungary, was proclaimed in Zagreb, which then merged with Serbia in December 1918 to form the Kingdom of Yugoslavia. The kingdom lasted until the end of World War II, after which the Socialist Republic of Croatia became a founding member and constituent part of the Socialist Federal Republic of Yugoslavia. This federation lasted until October 1991, when Croatia declared its independence from Yugoslavia. The subsequent war that led to the dissolution of Yugoslavia was fought over the next 4 years (1991–1995). In the time following the war, Croatia continued to develop and became a member of the European Union in 2013.

Croatia borders Slovenia to the northwest, Hungary to the northeast, Serbia to the east, and Bosnia and Herzegovina and Montenegro to the southeast; it shares a maritime border with Italy to the west and southwest (Fig. 1). The country spans 21.851 square miles (56.594 km^2) and has a population of 3.9 million, with Zagreb as its capital and largest city, which is populated by roughly 790,000 citizens. Zagreb is also the major political, administrative, economic, industrial, cultural, academic, and scientific center of the country. The University of Zagreb, founded in 1669, is the largest university in the country and is the oldest continuously operating academic institution in

ABBREVIATIONS EANS = European Association of Neurosurgical Societies; WFNS = World Federation of Neurosurgical Societies.

SUBMITTED June 7, 2023. **ACCEPTED** August 31, 2023.
INCLUDE WHEN CITING Published online November 10, 2023; DOI: 10.3171/2023.8.JNS231309.

FIG. 1. A map of Croatia depicting its borders with neighboring countries. The World Factbook 2021. Washington, DC: Central Intelligence Agency, 2021. Figure is available in color online only.

Southeast Europe. The university's School of Medicine was established in 1917 and is the oldest medical teaching institution in the Slavic South. There are three other regional centers in the country with highly developed academic and medical structures: Split, Rijeka, and Osijek. Together, these form the four medical centers of excellence that provide healthcare and neurosurgical services. In addition, there are hundreds of healthcare institutions in Croatia, including 75 hospitals employing more than 6500 medical doctors, of whom just more than 100 are neurosurgeons. Croatia has a universal healthcare system, which can be traced back to the Hungarian-Croatian Parliament Act of 1891 that provided a form of mandatory insurance for all state employees, factory workers, and craftsmen.

The Croatian Academy of Sciences and Arts (*Hrvatska akademija znanosti i umjetnosti* [HAZU]) in Zagreb is the most well-known scientific institution at the national level. It has promoted language, culture, arts, and science (including medicine) since its inception in 1866.

Development of Neurosurgical Practice in Croatia

Predecessors and Humble Beginnings of Neurosurgical Activity in Croatia

The preliminary stages of neurosurgical activity in Croatia came before the end of the 19th century, when Teodor Wickerhauser (1858–1946), who became a primary physician-surgeon in 1890, established modern training in surgical practice and antiseptic principles in operating rooms in Croatia[1] (Fig. 2A). In 1894, he created an external ward at the newly built public general hospital Sisters of Mercy (*Sestre milosrdnice*) in Zagreb, which included 400 beds and services for surgery, otorhinolaryngology, ophthalmology, and dermatology-venereology.[2] The single ward was later divided between surgery-gynecology and other surgical diseases, and it was considered the most innovative facility in this part of Europe, with separate antiseptic and septic operating theaters for surgery; patients were assigned to the infirmary quarters according to the surgery type.[3,4] In 1895, the Austro-Hungarian emperor, Franz Joseph I of Austria (1830–1916), visited the new hospital and was impressed by both its size and modernity, proclaiming it as one of the most advanced hospitals in the monarchy.[5]

Wickerhauser was a dedicated surgeon and renowned educator who instilled in his students a strong work ethic and the enthusiasm needed for establishing various modern surgical disciplines in Croatia[3] (including neurosurgery, to some extent, 6 decades later). Although he did not use surgical rubber gloves, he introduced new antiseptic rules of surgical performance, which became generally accepted practice by surgeons in operating theaters worldwide.[1] With his mental discipline and expertise, he set the standard for surgical wards in hospitals throughout the country, always trying to pass on the acquired knowledge to younger generations, and is considered the father of modern Croatian surgery.[2] He was esteemed not only by his fellows but also throughout country, becoming an honorary member of the Yugoslav (now Croatian) Academy of Sciences and Arts in 1914.[4] He authored the very first paper on craniotomy in Croatia in 1886, describing the surgical management of a boy with an epidural hematoma caused by a complicated temporal bone fracture with bleeding from the middle meningeal artery.[2]

In 1917, Wickerhauser was one of the founding fathers of Zagreb University School of Medicine, together with his surgical trainees Dragutin Mašek (1866–1956) and Miroslav Čačković Vrhovski (1865–1930), the latter of whom later became his successor.[2,6] Three founding professors held the first session of the Professors' Choir in May of 1918, at which they elected Čačković Vrhovski as dean and Mašek as vice dean of the medical faculty.[2]

Čačković Vrhovski published on the surgical treatment of a depressed skull fracture of the frontal bone along with generalized epileptic seizures in the *Croatian Medical Herald* in 1898. He successfully performed these operations with morphine and chloroform anesthesia. He also reported on a lethal gunshot wound to the brain in 1900 and projectile wounds to the head in 1917. Not only was he the first dean of Zagreb's medical school, but also he became a leading Croatian surgeon and radiologist.[5] Additionally, he was president of the Croatian Medical Association from 1923 to 1924 and editor-in-chief of the *Croatian Medical Herald* in the years 1898–1904, 1915–1918, and 1923–1924. The *Herald* was started in 1877 as the first official medical bulletin in the Croatian language in the Kingdom of Croatia and Slavonia, a constitutional part of the Austro-Hungarian Monarchy at that time.

In 1922, Aleksandar Blašković (1882–1953) performed the first transnasal pituitary surgery in 6 patients at the Sisters of Mercy Hospital in Zagreb,[7,8] which he accomplished just a decade and a half after Hermann Schloffer

FIG. 2. A: Teodor Wickerhauser (1858–1946), the founder of modern Croatian surgery. Nasta Rojc, *Portrait of Theodor Wickerhauser*, Zagreb, 1950. Oil on canvas, 55.5 × 46.5 cm. Courtesy of The Croatian Museum of Medicine and Pharmacy. **B:** Danko Riessner (1907–1973), the founder of Croatian neurosurgery. © Miroslav Krleža Lexicographic Institute, published with permission. **C:** Ivan Jelicic (1929–2012), the first president of the Croatian Neurosurgical Society. **D:** Djuro Vranković (1927–2021), the founder and first chair of the Department of Neurosurgery, Osijek University Hospital Centre. **E:** Josip Paladino (b. 1950), the president of the Croatian Neurosurgical Society for three consecutive terms (1998–2001, 2001–2005, and 2005–2009). Panels C–E © Bruno Splavski, published with permission. Figure is available in color online only.

(1868–1937), from Innsbruck, Austria, reported the first successful resection of a pituitary tumor via a transsphenoidal approach, using a superior nasal route via a transfacial lateral rhinotomy incision with local anesthesia provided by cocaine.[9–12] Renowned Nobel Prize laureate Emil Theodor Kocher (1841–1917), a professor of surgery at the University of Bern, Switzerland, was among the first to perform resection of a pituitary adenoma in 1909 by modifying an approach to expand visualization within the sella.[13] Oskar Hirsch (1877–1965), of Vienna, Austria, demonstrated the first complete endonasal transseptal transsphenoidal procedure in 1910, via a sublabial approach, which soon became a classic operative method that was embraced by Harvey Cushing the same year,[14–16] although Cushing eventually abandoned it for a safer transcranial approach, which became the prevalent pituitary surgery procedure in the decades that followed.[11]

Blašković was up-to-date with the current trends of hypophyseal surgery at that time; however, he turned his attention and dedicated his entire professional career to urology, becoming a founding father of modern Croatian urology.[5] He was also the two-time president of the Croatian Medical Association (Association of Physicians of the Kingdom of Croatia and Slavonia) between 1920 and 1923 and 1925 and 1927; it was established in 1874 as one of the first national professional organizations of physicians in this part of Europe.

Ante Šercer (1896–1968) was the first surgeon in Croatia to operate on a series of 10 pituitary adenoma patients via a transnasal (transseptal) approach according to Hirsch's standards. He published his experiences in a 1927 article titled, "When and how to operate pituitary tumors."[8,37] He was a world-recognized otolaryngologist and a prolific author of many internationally peer-reviewed scientific articles, including one about a cerebellar abscess that appeared in the *Croatian Medical Herald* in 1928. He was also an academician and dean of the Zagreb School of Medicine from 1936 to 1937 and from 1943 to 1945.[17] Šercer is credited with helping lay the foundation of the Faculty of Medicine in Sarajevo, Bosnia and Herzegovina, in 1944, in which about 160 students were enrolled that year.[18,19]

During a difficult period of World War II (1941–1945), a puppet state of the Independent State of Croatia was created by the Axis forces, and a highly oppressive political regime was imposed. Consequently, Croatian neurosurgery became mainly nonfunctional except in the capital city of Zagreb, where only the basic management of military head and spinal injuries was performed.

Establishment of Croatian Neurosurgery

Danko Riessner (1907–1973) was a practicing surgeon at Sisters of Mercy Hospital in Zagreb. After completing his neurosurgical training in Berlin, Germany, he set up a separate neurosurgical ward in 1946 in Zagreb, with 50 beds at Rebro Hospital. He is considered the founder of Croatian neurosurgery (Fig. 2B).[20] He possessed a vast understanding of neurosurgery and a superb operative technique, based on the modern surgical convention established by Wickerhauser more than half a century earlier. Riessner is credited with further developing the neurosurgical profession in this part of Europe.[21] His key scientific input to the field was an article on shifting brain masses due to subdural hematoma, which was published in 1939, as well as a paper on the surgical treatment of late posttraumatic epilepsy, which appeared in 1943.[21] In the *Croatian Medical Herald*, he published an article on neurofibromatosis type 1 (von Recklinghausen's disease) in 1936, two articles on intracranial hemorrhages and another on operative management of trigeminal neuralgia in 1940, and a paper on traumatic brain injury management in 1952.[38–43]

Matija Kožić (1915–1981), educated abroad, was the first Croatian specialist in neurosurgery and the founder in 1974 of the Department of Neurosurgery at the University of Zagreb, one of the leading institutions of its kind in Southeast Europe. In 1954, he published the first reports on spinal injury and cervical intervertebral disc degenerative disease in Croatia in the *Croatian Medical Herald*.[44]

He also published the first Croatian articles on brain tumors and the surgical management of hydrocephalus and epilepsy.[21] He further improved the quality and organization of neurosurgical service.

The procurement of the device for CT imaging of the head (EMI CT brain scanner) in 1976 at the University Hospital Centre in Zagreb was a groundbreaking event, which was significant for the further development of Croatian clinical neurosciences in general and neurology and neurosurgery in particular. It began operation just 2 years after it was initially deployed in 1974 at Atkinson Morley Hospital in Wimbledon, London, United Kingdom.[22]

Croatian Neurosurgery During the Homeland War (1991–1995)

Wartime has played a key role in the development of the neurosurgical profession in Croatia. Because of the number and severity of brain and spinal injuries during war, as well as the limitations imposed by warfare on frontline medicine, neurosurgeons examined different methods and models and devised special protocols for the management of projectile war injuries to the brain and spine. The skill and knowledge gained from wartime experiences significantly improved the progress of surgical treatment of injuries sustained during peacetime and strongly influenced the overall advancement of the neurosurgical profession at a national level.

The clinical condition of the wounded depends mainly on the mechanism of injury, including the speed and kinetic energy of the projectile, the anatomical location of the injury, and the existence of associated injuries to other organs.[23] Despite the noticeable evolution in understanding the mechanisms of injury and aggressive modern surgical and medical treatment, the morbidity and mortality from life-threatening wartime brain and spinal injuries remained high because of the various interdependent factors influencing one's prognosis.[24–27]

Croatian Neurosurgery After Gaining State Independence

Croatia became an officially recognized independent state by the international community in January 1992, after severing its ties with the Yugoslav Republic in October 1991 by proclamation of the Croatian National Assembly. Shortly afterward, Croatian neurosurgeons also severed ties with the Yugoslav Association of Neurosurgeons, with which they had been affiliated since 1946. Consequently, the Croatian Neurosurgical Society was founded in 1992 to promote the neurosurgical profession nationally.[21] Ivan Jelicic (1929–2012), then head of the Department of Neurosurgery at the University of Zagreb School of Medicine, was elected its first president (Fig. 2C). He was the first Croatian neurosurgeon who trained abroad in Zürich, Switzerland, with renowned neurosurgeon M. Gazi Yaşargil,[28] who introduced the surgical microscope to the field of neurosurgery and was considered one of the most important neurosurgeons of the second half of 20th century.[29–33] Jelicic was the first neurosurgeon in Croatia to use the microsurgical technique for intracranial aneurysms, about which he published a book, written in Croatian, in 1985.[45] He is consequently regarded in the country as the founder of cerebrovascular surgery via microneurosurgical methods.[21]

TABLE 1. Timeline of the most important events in Croatian neurosurgical history

Year	Achievement
1886	Surgical management of epidural hematoma (by T. Wickerhauser)
1886	Surgical management of depressed skull fracture (by M. Čačković Vrhovski)
1922	1st transnasal pituitary surgery (by A. Blašković)
1927	Surgical series of 10 cases of pituitary adenoma (by A. Šercer)
1943	Surgical treatment of late posttraumatic epilepsy (by D. Riessner)
1946	1st separate neurosurgical ward (by D. Riessner)
1974	1st department of neurosurgery
1985	1st book on cerebrovascular surgery in Croatian (by I. Jelicic)
1992	Croatian Neurosurgical Society founded
1996	1st Congress of the Croatian Neurosurgical Society
2004	Stereotactic radiosurgery established

After the war ended, Croatian neurosurgery benefited from the wartime experience gained in handling brain and spinal injuries sustained in military combat, as well as the enormous skills and enthusiasm of neurosurgical personnel nationwide. In conjunction with Croatia's rapid economic development and social progress, the profession soon attained the same level of standards as the most developed neurosurgical services in the European Union.

Lastly, the first radiosurgical ward in Southeast Europe was established in 2004 within the Department of Neurosurgery of the University of Zagreb School of Medicine upon obtaining modern devices and equipment for stereotactic radiosurgery (Gamma Knife). It is still in operation today.

A timeline of the most important events in Croatian neurosurgical history is depicted in Table 1.

Neurosurgical Curriculum for Residents in Croatia

An authorization and a decision for the implementation of specialist training in neurosurgery are initiated by the Minister of Health of the Republic of Croatia, in accordance with the proposal of the National Commission for Specialist Training of Doctors of Medicine.

Modern neurosurgical residency training in Croatia lasts for 6 consecutive years (72 months). After completion of training, residents must pass a specialist's examination to become board-certified neurosurgeons. At present, two institutions in Croatia (Department of Neurosurgery, University of Zagreb School of Medicine; and Department of Neurosurgery, Sisters of Mercy University Hospital Centre, Zagreb) offer full neurosurgical residencies.

The curriculum for the residency program consists of the following requirements: general surgery, including the basics of surgical technique and traumatology (3 months);

anatomy of the central and peripheral nervous systems and surgical approaches (2 months); neuropathology (1 month); neurology and neurophysiology with neurorehabilitation and endocrinology included (6 months); radiology and radiotherapy (1 month); microbiology with laboratory diagnostics (1 month); anesthesiology, rheumatology, and intensive care medicine (1 month); general vascular surgery (1 month); pediatric surgery excluding pediatric neurosurgery (1 month); ear, nose, and throat (otorhinolaryngology) (1 month); experimental surgery and basics of microsurgical technique (1 month); neurotraumatology (10 months); oncological surgery (10 months); vascular neurosurgery (10 months); spinal surgery (10 months); surgery of peripheral and autonomous nervous systems (2 months); pediatric neurosurgery (6 months); endoscopic neurosurgery (3 months); stereotactic and functional neurosurgery (3 months); radioneurosurgery (3 months); and postgraduate neurosurgical professional course (3 months). During their entire residency, residents are required to maintain a logbook of completed neurosurgical procedures (operations), which has to be updated regularly.

When the residency training program in Croatia is compared with resident training in the United States, some insignificant differences remain. According to the American Board of Neurological Surgery training requirements, 7 years (84 months) of neurosurgical residency training must be completed and consists of the following: 54 months of core clinical neurosurgery, including 12 months as chief resident during the last 2 years of training, 3 months of basic neuroscience (e.g., neurology, neuro-otology, neuroradiology, or neuropathology) within the first 18 months of training, 3 months of critical care relevant to neurosurgery patients within the first 18 months of training, a minimum of 6 months of structured education in general patient care (e.g., trauma, general surgery, neurosurgery, orthopedic surgery, otolaryngology, or plastic surgery), and 21 months spent in one program; 30 months of electives in areas such as neuropathology, neuroradiology, research, additional neurosurgery, or possibly areas of special interest such as complex spine surgery, endovascular or pediatric neurosurgery, or clinical and nonclinical neurosciences; and 6–12 months in an outside rotation, which may be counted toward the core 54 months of neurosurgery training.

All US postgraduate training must be under the ultimate direction and supervision of the resident's neurosurgery program director.

Current Rank and File of Croatian Neurosurgery

The World Federation of Neurosurgical Societies (WFNS) was founded in Brussels, Belgium, in 1955, and its first elected president was the famous British neurosurgeon Sir Geoffrey Jefferson (1886–1961).[34,35] This was a momentous step forward in the establishment and improvement of the neurosurgical profession on a global level, which was followed by the founding of the European Association of Neurosurgical Societies (EANS) in Prague, in then Czechoslovakia, in 1971, by delegates from 18 national societies present at the 4th European Congress of Neurosurgery.

TABLE 2. Comprehensive tally of the current rank and file of Croatian neurosurgery

	No. of Neurosurgeons	No. of Residents	Total
University Hospital Centre Zagreb	16	4	20
University Hospital Centre Sisters of Mercy Zagreb	12	6	18
Dubrava University Hospital, Zagreb	9	2	11
Children's Hospital Zagreb	2	1	3
University Hospital of Split	7	2	9
Clinical Hospital Centre Rijeka	6	2	8
University Hospital Centre Osijek	7	4	11
General Hospital Zadar	3	0	3
General Hospital Varazdin	3	1	4
General Hospital Dubrovnik	2	1	3
General Hospital Dr. Josip Bencevic Slavonski Brod	2	1	3
Pula General Hospital	2	0	2
Private practice	8	0	8
Retired	20	0	20
Total	99	24	123

The Croatian Neurosurgical Society became a full member of the EANS and WFNS at the 10th WFNS Congress held in Acapulco, Mexico, in October 1993.[21] The decision to accept the society was granted unanimously during the meeting of the EANS Management Board, headed by its president, Mario Brock (b. 1938), from Germany.

The first regular annual meeting of the society was held in Osijek in April 1993. On that occasion, the first anniversary of the establishment of the independent Department of Neurosurgery of Osijek University Hospital Centre was marked by Djuro Vranković (1927–2021), the doyen and one of the founding fathers of Croatian neurosurgery, becoming its first chair (Fig. 2D).

The first congress of the society was held in Zagreb in November 1996 and was dedicated to traumatic brain injuries and projectile war wounds to the brain and spine. Velebit Iveković (1934–1998), a renowned neurosurgeon and grandson of a famous Croatian painter, Oton Iveković (1869–1939), was elected president of the society, a post he retained until his death in 1998.

The first congress was followed by seven consecutive congresses held triannually until the last one, which was organized in Split in May 2017. The prearranged 9th congress of the society, intended for 2020, was not held because of the restrictions imposed by the COVID-19 pandemic. The event was rescheduled for and held in October 2023.

Josip Paladino (b. 1950), among the most prominent Croatian neurosurgeons, was elected president of the society in 1998. He held this position for three consecutive terms (1998–2001, 2001–2005, and 2005–2009) (Fig. 2E). Paladino was essential in introducing stereotactic radio-

FIG. 3. Modern-day institutions and operating rooms in Croatia. **A:** The complex of University Hospital Centre Zagreb, the site of the main neurosurgical facility in Croatia (Department of Neurosurgery, University of Zagreb School of Medicine). **B:** The main administrative building of Sisters of Mercy University Hospital Centre in Zagreb, the second institution offering neurosurgical residencies at the national level. **C:** The old building of Osijek Hospital with a neurosurgical ward occupying the left wing. It was among the most modern hospital facilities in Southeast Europe when built in 1936. **D:** The modern building of Osijek University Hospital, which is for emergency patients and outpatients. **E:** The modern-day operating room of the Department of Neurosurgery of Sisters of Mercy University Hospital Centre in Zagreb is equipped with an up-to-date neurosurgical armamentarium. All panels © Bruno Splavski, published with permission. Figure is available in color online only.

surgery into national neurosurgical practice in Croatia in 2004.

During the 30 years of the society's existence, the general progress of neurosurgical expertise across the country has flourished. A host of neurosurgical hubs across the country have been established, along with several centers of excellence in the regional capitals of Zagreb, Split, Rijeka, and Osijek, which are equipped with up-to-date diagnostic and surgical gear and staffed with remarkably educated personnel. A comprehensive tally of the current rank and file of Croatian neurosurgery as of March 24, 2023, broken down by centers and neurosurgical staff, is depicted in Table 2. This tally of nearly 100 neurosurgeons (including 20 who are retired) for a country of 3.9 million people seems to be slightly high. However, the country is geographically stretched and the distances among large neurosurgical centers are great (Fig. 1). Therefore, it is not always easy for patients to reach these centers in time; hence the increased number of neurosurgeons dispersed all over the country.

The society, departments, and individual neurosurgeons have retained and formed new professional relations with their colleagues from other countries of the former Yugoslavia, as well as from the entire region of Southeast Europe, through numerous symposia, scientific meetings, and personal mutual collaboration. Leading Croatian neurosurgeons were among the founding fathers of the Southeast Europe Neurosurgical Society (SeENS), which was

established in Zagreb in 2012 to improve neurosurgical care, training, and research in Southeast Europe by promoting expertise exchange and cooperation among neurosurgeons in the region.[36] The relations between academic neurosurgery departments and other national science faculties with internationally recognized expertise are also very well established.

Hospitals in the Republic of Croatia are categorized into four categories: national/university hospitals, county hospitals of regional significance, county hospitals, and local hospitals. Neurosurgical service is mainly offered in national/university hospitals (Fig. 3A–D).

Private health institutions, including a few neurosurgical ones, are also present in the Croatian health system. They most often rent premises owned by the state and must meet certain criteria set forth by the Croatian Ministry of Health, which includes a minimum threshold to accommodate patients and a minimum range of neurosurgical services.

Today, the neurosurgical profession and its practice in Croatia has attained the same level of standards as most developed Western countries, which ensures its further success and advancement in accordance with the principles of modern neuroscience (Fig. 3E).

Conclusions

The growth in neurosurgical practice and expertise on the national level in Croatia was slow but steady during the country's past and recent history. This growth has relied mostly on a few skilled personalities who created modern neurosurgery as one of the most advanced and exquisite medical professions in the country through their determination, devotion, and enthusiasm. Hence, surgical innovations, professional pride, creativity, and dedication remain the hallmarks of the history of neurosurgery in Croatia. This extraordinary discipline is ensured to have a bright future in Croatia, allowing Croatian neurosurgeons to keep pace with scientific and professional advances in the field worldwide.

Acknowledgments

Andrew J. Gienapp (Department of Neurosurgery, University of Tennessee Health Science Center, Memphis, Tennessee, and Children's Foundation Research Institute, Le Bonheur Children's Hospital, Memphis, Tennessee) provided language, technical, and copy editing; preparation of the manuscript, tables, and figures for publishing; and publication assistance.

References

1. Zec P. Reflexions on the occasion of Wickerhauser's 75th anniversary. *Lijec Vjesn*. 1933;55(10):543-544.
2. Thaller L. Teodor Wickerhauser. *Lijec Vjesn*. 1933;55(10): 466-471.
3. Florschutz V. Dr. Teodor Wickerhauser and his school. *Lijec Vjesn*. 1933;55(10):465-466.
4. Sušec T. Professor Teodor Wickerhauser. Historical review. *Acta Clin Croat*. 2006;45(2):120.
5. Ružić B, Katušić J, Spajić B, et al. History of urology at the Sestre Milosrdnice University Hospital Center. *Acta Clin Croat*. 2018;57(suppl 1):9-20.
6. Dugački V, Regan K. The establishment of medical school in Zagreb in World War I. Article in Croatian. *Acta Med Hist Adriat*. 2015;13(suppl 1):97-120.
7. Fatović Ferencić S, Gnjidić Z. Sellar region surgery in Croatia in the first half of 20th century. *Croat Med J*. 2006;47(2): 310-317.
8. Gnjidić Z, Kovac D, Petric V, Sajko T, Talan-Hranilović J. 80 years of hypophyseal surgery at the Sestre Milosrdnice Hospital. Article in Croatian. *Lijec Vjesn*. 2002;124(11-12): 389-393.
9. Lindholm J. A century of pituitary surgery: Schloffer's legacy. *Neurosurgery*. 2007;61(4):865-868.
10. Liu JK, Das K, Weiss MH, Laws ER Jr, Couldwell WT. The history and evolution of transsphenoidal surgery. *J Neurosurg*. 2001;95(6):1083-1096.
11. Kanter AS, Dumont AS, Asthagiri AR, Oskouian RJ, Jane JA Jr, Laws ER Jr. The transsphenoidal approach. A historical perspective. *Neurosurg Focus*. 2005;18(4):e6.
12. Schmidt RF, Choudhry OJ, Takkellapati R, Eloy JA, Couldwell WT, Liu JK. Hermann Schloffer and the origin of transsphenoidal pituitary surgery. *Neurosurg Focus*. 2012; 33(2):E5.
13. Gautschi OP, Hildebrandt G. Emil Theodor Kocher (25/8/1841-27/7/1917)—a Swiss (neuro-)surgeon and Nobel Prize winner. *Br J Neurosurg*. 2009;23(3):234-236.
14. Hirsch O. Endonasal method of removal of hypophyseal tumors with report of two successful cases. *JAMA*. 1910;55: 772-774.
15. Lanzino G, Laws ER Jr. Key personalities in the development and popularization of the transsphenoidal approach to pituitary tumors: an historical overview. *Neurosurg Clin N Am*. 2003;14(1):1-10.
16. Liu JK, Cohen-Gadol AA, Laws ER Jr, Cole CD, Kan P, Couldwell WT. Harvey Cushing and Oskar Hirsch: early forefathers of modern transsphenoidal surgery. *J Neurosurg*. 2005;103(6):1096-1104.
17. Oreskovic M. Prof. Ante Sercer MD (April 12, 1896–November 25, 1968). Article in Croatian. *Lijec Vjesn*. 1970;91(11): 1246-1247.
18. Dugacki V. The first medical school in Sarajevo (1944-1945). Article in Croatian. *Lijec Vjesn*. 1999;121(6):216-218.
19. Masić I. Establishment of the first medical faculty in Bosnia and Herzegovina. Article in Bosnian. *Med Arh*. 2004;58(4): 253-256.
20. Rasulic L. Neuroscience and neurosurgery in Southeast Europe. *Int Neurosci J*. 2015;1(1):52-68.
21. Splavski B. A brief review of the history of global and Croatian neurosurgery. *J Appl Health Sci*. 2023;9(1):61-69.
22. Beckmann EC. CT scanning the early days. *Br J Radiol*. 2006;79(937):5-8.
23. Vrankovic D, Splavski B, Hecimovic I, Glavina K, Dmitrovic B, Mursic B. Analysis of 127 war inflicted missile brain injuries sustained in north-eastern Croatia. *J Neurosurg Sci*. 1996;40(2):107-114.
24. Splavski B, Vranković D, Sarić G, et al. Early surgery and other indicators influencing the outcome of war missile skull base injuries. *Surg Neurol*. 1998;50(3):194-199.
25. Vranković D, Hećimović I, Splavski B, Dmitrović B. Management of missile wounds of the cerebral dura mater: experience with 69 cases. *Neurochirurgia (Stuttg)*. 1992;35(5): 150-155.
26. Splavski B, Vranković D, Sarić G, Blagus G, Mursić B, Rukovanjski M. Early management of war missile spine and spinal cord injuries: experience with 21 cases. *Injury*. 1996; 27(10):699-702.
27. Splavski B, Sisljagić V, Perić L, Vranković D, Ebling Z. Intracranial infection as a common complication following war missile skull base injury. *Injury*. 2000;31(4):233-237.
28. Stienen MN, Serra C, Stieglitz LH, Krayenbühl N, Bozinov O, Regli L. UniversitätsSpital Zürich: 80 years of neurosurgi-

cal patient care in Switzerland. *Acta Neurochir (Wien)*. 2018; 160(1):3-22.
29. Kriss TC, Kriss VM. History of the operating microscope: from magnifying glass to microneurosurgery. *Neurosurgery*. 1998;42(4):899-908.
30. Mavrogenis AF, Markatos K, Saranteas T, et al. The history of microsurgery. *Eur J Orthop Surg Traumatol*. 2019;29(2): 247-254.
31. Uluç K, Kujoth GC, Başkaya MK. Operating microscopes: past, present, and future. *Neurosurg Focus*. 2009;27(3):E4.
32. Yaşargil MG. A legacy of microneurosurgery: memoirs, lessons, and axioms. *Neurosurgery*. 1999;45(5):1025-1092.
33. Yaşargil MG. Personal considerations on the history of microneurosurgery. *J Neurosurg*. 2010;112(6):1163-1175.
34. Scoville WB. The World Federation of Neurosurgical Societies. A brief history. *Surg Neurol*. 1977;7(4):185-188.
35. Walker AE. The evolution of the World Federation of Neurosurgical Societies. *Acta Neurochir (Wien)*. 1988;94(3-4): 99-102.
36. Rasulić L, Rotim K, Sajko T. The sense and sensibility of SeENS in Sarajevo 2015: building bridges of knowledge and understanding. *J Neurol Surg A Cent Eur Neurosurg*. 2015; 76(suppl 2):i.
37. Šercer A. Kada i kako operirati tumore hipofize. *Med Pregl*. 1927;12:480-482.
38. Riessner D, Zülch KJ. Uber die Formveränderungen des Hirns (Massenverschiebungen, Zisternenverquellungen) bei raumbeengenden Prozessen. *Dtsch Z Chir*. 1939;253(1-2): 1-61.
39. Riessner D. Prilog operativnoj terapiji posttraumatske kasne epilepsije. *Lijec Vjesn*. 1943;2:35-37.
40. Riessner D. Intrakranijalna krvarenja. *Lijec Vjesn*. 1940;62: 306-311.
41. Riessner D. Intrakranijalna krvarenja. *Lijec Vjesn*. 1940;62: 350-351.
42. Riessner D. Prilog operativnom liječenju neuralgije trigeminusa. *Lijec Vjesn*. 1940;61:192-195.
43. Riessner D. Liječenje kraniocerebralnih provreda. *Lijec Vjesn*. 1952;75(5-6):89-94.
44. Kozic M. Oper tivna terapija ishialgije. *Lijec Vjesn*. 1954; 76(9-10):580-584.
45. Jelicic I. *Cerebrovaskularna Kirurgija*. Školska Knjiga; 1985: 1-263.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: both authors. Acquisition of data: both authors. Analysis and interpretation of data: both authors. Drafting the article: both authors. Critically revising the article: both authors. Reviewed submitted version of manuscript: both authors. Approved the final version of the manuscript on behalf of both authors: Arnautović. Administrative/technical/material support: both authors. Study supervision: both authors.

Correspondence

Kenan I. Arnautović: Semmes Murphey Neurologic and Spine Clinic, Memphis, TN. kenanarnaut@yahoo.com.