

TOS History

150 AD: Galen, the Greek anatomist and court physician to Marcus Aurelius, first describes the cervical rib in human dissections.

1500's: Andreas Vesalius, who is responsible for the revival of Galen's work (which had fallen into disfavor in the Dark Ages), again describes the cervical rib in human cadavers.

1742: Francois-Joseph Hunauld describes and categorizes supernumerary ribs in humans, including the cervical rib.

1821: Sir Astley Cooper first describes arterial thoracic outlet syndrome in a young woman with arm ischemia, and demonstrates the relationship between a cervical rib and compression of the subclavian artery.

Sir Cooper was one of the leading surgeons of his day, publishing seminal work on the repair of inguinal hernias, and becoming renowned as a vascular surgeon. He was named sergeant surgeon to Kings George IV and William IV, and to Queen Victoria, and founded the famous medical school at Guy's Hospital in London.

1831: Henry Mayo in London reports the first subclavian artery aneurysm due to thoracic outlet syndrome, caused by an exostosis of the first rib.

1853: John Hilton, a British surgeon, describes gangrene of the arm in a patient with compression of the subclavian artery caused by an exostosis of the first rib.

In 1849, Dr. Hilton became a full surgeon at Guy's Hospital in London, and Professor of Anatomy and Surgery in the Royal College of Surgeons in 1860. Dr. Hilton performed one of the first recorded surgeries for an internal hernia with bowel strangulation, and was the first to use internal sphincterotomy for the treatment of anal fissure. The 'White Line of Hilton' he described is still a widely-recognized anatomic landmark for colorectal surgeons.

1860: W. H. Willshire notes the relationship between a cervical rib and paresthesias of the upper extremity.

1861: Richard Holmes Coote at St. Bartholomew's Hospital in London performs the first surgical resection of a cervical rib, with relief of arterial TOS.

1875: Sir James Paget in London first describes spontaneous thrombosis of the subclavian-axillary vein in young individuals with arm swelling.

Sir Paget is widely regarded as one of the two founders of modern pathology, along with Rudolf Virchow in Germany. He established himself as a famous surgeon in London by mastering the major English, French, German, Dutch, and Italian medical literature, and by applying a strict scientific discipline to the study of human physiology as it applied to

surgery. In the field of pathology, Sir Paget's work was groundbreaking. Sir Paget established the scientifically rigorous use of the microscope in the study of human infection and tumors. Following Paget, the microscope became the essential and indispensable scientific tool of pathology. Paget published *Lectures on Surgical Pathology*, one of the two landmark works in pathology. He served as surgeon extraordinary to Queen Victoria and surgeon in ordinary to the Prince of Wales, and was elected president of the Royal College of Surgeons.

1884: Leopold von Schroetter in Vienna independently describes spontaneous thrombosis of the subclavian-axillary vein in young individuals.

Von Schroetter was an internist and laryngologist in Vienna. He developed the first modern lecture hall, with an accompanying laboratory. At the age of 78, he attended the Crown Prince of Germany.

1884: A. P. Gould describes the first case of stroke resulting from arterial thoracic outlet syndrome. Additional cases were reported by Symonds in 1927, Yates in 1928, Smith in 1941, Hoobler in 1942, Fields in 1986, and Al-Hassan in 1988.

1903: F. Bramwell describes neurovascular compression in the presence of a normal first rib, without a cervical rib.

1905: John Benjamin Murphy of Chicago was the first surgeon to resect a cervical rib that was associated with a subclavian artery aneurysm.

Dr. Murphy is still known for numerous surgical innovations, including Murphy's button (to join two segments of bowel), the Murphy's sign (for the diagnosis of cholecystitis), Murphy's tympani, and the Murphy test (for diagnosis of kidney disease). Dr. Murphy pioneered end-to-end anastomoses of hollow viscera and blood vessels, championed early appendectomy in cases of appendicitis (despite strong opposition from the Chicago medical establishment), and introduced therapeutic pneumothorax for pulmonary tuberculosis.

1907: Dr. William Keen at Thomas Jefferson University in Philadelphia publishes a review of 42 cases of resected cervical ribs, and describes a clinical definition and surgical treatment for this disorder.

Dr. William Williams Keen was the first surgeon in America to remove a brain tumor and have the patient survive for 30 years. Dr. Keen served as a surgeon in the Civil War, and utilized his experiences to publish *Gunshot Wounds and Other Injuries of the Nerves*, the seminal book in its field. After the Civil War, Dr. Keen traveled to Europe to study with famed physicians Duchenne in Paris and Virchow in Berlin. Dr. Keen returned to Thomas Jefferson University in Philadelphia as professor of surgery, where he performed the first successful brain tumor removal, performed the first ventricular puncture for the treatment of hydrocephalus and increased intracranial pressure, and developed the technique of cervical nerve root section for the treatment of spasmodic torticollis. In

1887, Dr. Keen revised and reedited the American edition of Grey's anatomy, and in 1906 he became the editor of the multivolume *Surgery, Its Principles and Practice*. Dr. Keen had a long professional relationship with Harvey Cushing, whose contribution to this work created a sensation in the world of medicine, and established the discipline of neurosurgery as a distinct field.

In 1893, Dr. Keen assisted in removing a sarcoma from the mouth of President Grover Cleveland, an operation which was kept secret for more than 15 years, until after the President's death. In 1921, Dr. Keen attended Franklin Delano Roosevelt after he contracted polio. Dr. Keen was the president of the American Medical Association in 1900, was the first surgeon to receive an honorary fellowship in the American College of Surgeons, was elected an honorary fellow of the Royal College of Surgeons in England and the Legion of Honor in France, and received honorary degrees from seven North American universities and four international universities.

1908: J. B. Roberts describes numerous anatomic forms of the cervical rib and the surgical importance of each form.

1910: Dr. Thomas Murphy in Australia performs the first resection of the first rib, with complete relief of symptoms at three month follow-up.

1912: Thomas Wingate Todd at Manchester University describes the potential causes of neurovascular compression in the thoracic outlet in a series of scientific papers outlining the anatomy and anatomical variations of the thoracic outlet. Dr. Todd's anatomic dissections included descriptions of cervical ribs, anatomic variations of the first rib and scalene muscles, and the position of the clavicle with shoulder movements. Dr. Todd also postulated that the gradual descent of the shoulder girdle with aging causes narrowing of space between the clavicle and rib, contributing to neurovascular compression.

In 1912, Dr. Todd became Professor and Chairman of Anatomy at what is now Case Western Reserve University Medical School in Cleveland. Dr. Todd built the Hamann-Todd Osteological Collection, the world's largest collection of human and anthropoid skeletons. He also publishes *The Atlas of Skeletal Maturation* in 1937, and initiated the Brush study in 1926, both of which are widely-accepted tools for the evaluation of human skeletal growth and maturation.

1918: William Halsted publishes a number of papers describing subclavian artery aneurysms caused by cervical ribs.

Dr. Halsted was one of the pioneers of modern surgical technique in the United States, using aseptic technique and novel wound closure techniques to advance the safety and efficacy of surgery. He performs the first emergency blood transfusion, the first radical mastectomy, the first nerve block, the first inguinal hernia repair, and invents the surgical glove. Dr. Halsted was named the first surgeon-in-chief of the Johns Hopkins Hospital, and was the first professor of surgery at Johns Hopkins Medical School. He created

subspecialty divisions in the surgery department, and the radiology department at Johns Hopkins, and became renowned for training surgical residents, many of whom went on to create surgical residency programs at institutions throughout the United States, and thus spread the prodigious influence of Dr. Halsted. Dr. Halsted was also the captain of the first American 11-player football team in 1870.

1919: John Sebastian Bach Stopford and E. D. Telford at Manchester University Medical School describe compression of the lower trunk of the brachial plexus by a normal first rib, and report results from 10 patients following resection of the first rib.

John Sebastian Bach Stopford trained under Thomas Wingate Todd, and wrote numerous scientific papers on the traumatic disruption of nerves, the regeneration of injured nerves, the autonomic nervous system, and the compression of peripheral nerves, most notably that caused by cervical ribs. Dr. Stopford's monograph on the circulation of the pons and medulla is regarded as a classic publication. Later in his career, Dr. Stopford served as the Chair of Anatomy, the Dean of the medical school, and the Vice-Chancellor of the University. Dr. Stopford was appointed M.B.E. and K.B.E., was knighted in 1941, was awarded honorary degrees in science and law at the University of Cambridge and other universities, and was awarded Honorary Fellowships in the Royal College of Surgeons and the Royal College of Physicians.

1920: AA Law demonstrates the existence of several soft tissue bands that clinically simulate the presence of a cervical rib by causing neurovascular compression.

1927: Adson and Coffey at the Mayo Clinic suggest the mechanism of the anterior scalene muscle causing upper extremity neurovascular compression in patients with cervical ribs, and first demonstrate that scalenotomy could relieve symptoms of neurovascular compression without resection of the cervical rib. This procedure becomes popular for several decades, although the recurrence rate is very high (around 60%)(1).

Dr. Alfred Washington Adson created and headed the Section of Neurological Surgery at the Mayo Clinic. He was a pioneer in American surgery, was a founding member and president of the Society of Neurological Surgeons, and was president of the Minnesota State Medical Association and the Minnesota State Board of Medical Examiners.

1929: Naffziger and Grant first introduce the concept of neurovascular compression in the thoracic outlet due to scalene muscle anomalies, without the presence of a cervical rib. They perform the first scalenotomies for relief of these symptoms, but do not publish their findings until 1937 and 1938.

Dr. Howard Christian Naffziger, who trained under eminent surgeons William Halsted and Harvey Cushing, became one of the most esteemed neurosurgeons of his time. He created the division of Neurosurgery and served as Chairman of the Department of Surgery at University of California San Francisco, was elected president of the American College of Surgeons, and was Chairman of the committee that established the American Board of Neurological Surgeons.

Francis Clark Grant trained under eminent neurosurgeons Charles Frazier and Harvey Cushing. Dr. Grant succeeded Dr. Frazier as Professor and Chairman of Neurosurgery at the School of Medicine and the University Hospital at University of Pennsylvania. He published over 200 papers in his lifetime, and refined or developed several neurosurgical procedures and instruments.

1931: Telford and Stopford propose that the variable distribution of sympathetic fibers in the brachial plexus could explain the variable degrees of vascular disturbance seen in patients with symptomatic cervical ribs.

1935: Renowned surgeons Alton Ochsner, Mims Gage and Michael DeBakey at LSU publish a comprehensive study of patients with symptoms of neurovascular compression in the thoracic outlet in the absence of a cervical rib, for which they coin the term, "Scalenus Anticus Syndrome". They credit Naffziger with first recognizing the utility of this approach in patients without cervical ribs, in his series of scalenotomies beginning in 1929, and suggest the term "Naffziger Syndrome".

Dr. Alton Ochsner was named Chairman of Surgery at Tulane Medical School at the young age of 31, and founded the world-famous Ochsner clinic at Charity Hospital in New Orleans, which remains one of the pre-eminent surgical teaching programs in the country. Dr. Ochsner was the first to report the link between cigarette smoking and lung cancer, and he trained some of the most prominent surgeons of the time, including Dr. Michael DeBakey.

Dr. Michael DeBakey is one of the most renowned cardiovascular surgeons in the world. After volunteering for military service in World War II, Dr. DeBakey created the concept that became the Mobile Army Surgical Hospital (M*A*S*H unit) that had stellar success during the Korean War. Dr. DeBakey was one of the first cardiothoracic surgeons to perform coronary bypass surgery, was the first man to perform carotid endarterectomy, and made numerous other contributions and innovations in cardiovascular surgery, including work on the Dacron artificial graft, the heart-lung machine, and the artificial heart.

1937: Telford and Stopford demonstrate the mechanism of neurovascular compression by a normal first rib, and publish a report on six patients who were relieved of symptoms of TOS by first rib resection(2).

1938: Adson performs the first scalenectomy, or resection of the entire anterior scalene muscle. This procedure was performed intermittently over the next several decades, until Sanders introduces a more refined technique in 1979.

1943: Murray Falconer and L.G. Weddell describe several military recruits with neurovascular compression caused by heavy backpacks and assuming the "military" position, with the shoulders thrust backwards. They believe that this neurovascular compression is caused by compression of the neurovascular bundle between the normal

clavicle and first rib on assumption of an unusual posture, even in the presence of normal anatomy, and coined the term “costoclavicular syndrome”. Dr. Falconer publishes a second paper with Dr. Franklin W. P. Li, describing an additional 11 patients who underwent first rib resection with good results. Several of these patients had been previously treated for carpal tunnel syndrome, without relief.

Dr. Falconer was one of the strongest proponents for the use of surgical ablation in the treatment of temporal lobe epilepsy. He performed a fellowship under pioneer neurosurgeon Alfred Adson at the Mayo clinic in 1937, and was named first Director of Neurosurgery at Guy’s Hospital in 1949. Dr. Falconer developed the renowned program at this institution for the treatment of temporal lobe epilepsy, and over his career helped to elucidate the pathology, and developed and refined the surgical criteria and techniques for treatment of these patients.

1944: R. L. Swank first describes the differences between upper and lower brachial plexus involvement in thoracic outlet syndrome.

1945: I.S. Wright describes four patients with numbness and paresthesias that spread from their fingertips to involve their entire arm, without pain. One of these patients develops gangrene. Symptoms in all patients are caused by sleeping with their arms over their heads. Wright proposes the term "Hyperabduction Syndrome", which he feels is a result of the axillary artery and brachial plexus being stretched under the coracoid process and pectoralis minor tendon on hyperabduction.

1953: Lord performs the first claviclectomy to relieve compression at the costoclavicular interval. This procedure is disfiguring and causes a significant alteration in function, and never becomes popular.

1956: R. M. Peet and colleagues first use the term “Thoracic Outlet Syndrome” to unify all the upper extremity neurovascular compression syndromes.

1962: O. Theron Claggett, the president of the American Association for Thoracic Surgery, and one of the premiere thoracic surgeons of the mid-twentieth century, re-introduces the first rib resection, after decades of disappointing results from scalenotomy alone. In his presidential speech to the American Association for Thoracic Surgery, Claggett recounts an extensive history of TOS, and proposes first rib resection by the posterior approach. This approach eventually falls out of favor because it requires a fairly radical soft-tissue dissection, and because it leads to disruption of the posterior shoulder girdle musculature, which is now felt to be important in the stability of the shoulder girdle.

1960’s: Supraclavicular and infraclavicular approaches for first rib resection are used by various surgeons, but are not widely accepted.

1966: Dr. David Roos performs the first transaxillary first rib resection. Dr. Roos demonstrates and categorizes numerous soft tissue anomalies in the thoracic outlet. His

transaxillary approach goes on to achieve wide acceptance, due to a less radical soft-tissue dissection than previous approaches, and to improved visualization of the muscular and fibrous anomalies that are known to exist in the thoracic outlet.

1972: D. Silver recommends tenotomy of the pectoralis minor in selected cases of first rib resection.

1979: Dr. Richard Sanders introduces supraclavicular scalenectomy in patients who have had prior first rib resection for post-traumatic TOS, and who develop recurrent symptoms. Due to the great success of this approach, Dr. Sanders utilizes this scalenectomy in patients with TOS due to neck trauma.

1989: Dr. Erdogan Atasoy performs transaxillary first rib resection combined with supraclavicular scalenectomy.

Present: Current leaders in the field include Harold Urschel (who has performed over 5,000 TOS surgeries) at Baylor University, Dr. Richard Sanders (who has performed over 2,000 TOS surgeries), Dr. David Roos (who has performed over 2,400 TOS surgeries) Dr. Charles Brantigan and Dr. Stephen Annest in Denver, Colorado, Dr. Samuel Ahn and Dr. Hugh Gelabert at UCLA, Dr. Erdogan Atasoy at the University of Louisville, Dr. A. Lee Dellon and Dr. Julie Freischlag at Johns Hopkins University, Dr. Robert Leffert at Harvard Medical School, and Dr. Susan Mackinnon at Washington University in St. Louis.

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