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COVER PICTURE

Sir Charles Bell (1774–1842) and his contributions to early neurosurgery

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Abstract The renowned surgeon, neuroanatomist, and artist Sir Charles Bell not only impacted the lives of his peers through his creative endeavors and passion for art, but also sparked noteworthy breakthroughs in the field of neuroscience. His empathetic nature and zest for life enabled him to develop an early proclivity for patient care. As a result of his innovative findings regarding sensory and motor nerves and the anatomical makeup of the brain, he accepted some of the most prestigious awards and received an honorable reputation in society. Bell is recognized for his diligence, perseverance, and his remarkable contributions to surgery. The present review will explore his contributions to the discipline now known as neurosurgery.

Keywords Anatomy · Brain injuries · History of medicine · Neurosurgery

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Introduction

> The public, who are so ready to determine on the merits of our profession, and even the patients who are to suffer, are surprisingly ignorant both of the Surgeon's motives for what he does, and the propriety of the methods he puts in practice. He is continually operating in secret as a matter of necessity. The most sensible give the decision up to him; so that he is answerable to his own conscience, and to that alone.
>
> Sir Charles Bell

Sir Charles Bell's intellect and drive manifested at an early age (Fig. 1) [5]. Born in Edinburgh in 1774 to Rev. William Bell, he demonstrated a keen interest in knowledge acquisition, and with the help of his brother, an anatomist and surgeon, he gained a vast understanding of medicine [4, 6]. At the age of five, Bell mourned the death of his father, leaving him and his two brothers alone with their mother [4, 6]. His mother was sensitive and spiritual and instilled in her boys understanding and compassion for others. Ultimately, she nurtured Bell's passion for art [4, 6, 7].

Bell graduated from high school with distinction and continued to excel at the University of Edinburgh where he used his gift of art to depict accurate anatomical figures for his medical professors and wrote his first publication entitled *A System of Dissection Explaining the Anatomy of the Human Body*. In his publication, Bell portrayed his artistic talents to display his vast knowledge regarding human anatomy [7]. Immediately, the university commended Bell for his exceptional attention to detail in his artistic depictions, and colleagues demanded that his demonstrations be published. His innovated designs deemed him as one of the most influential authors of his time.

Fig. 1 Painting of Sir Charles Bell by John Stevens

As a result of his reputation, Bell was elected to the College of Surgeons and was later offered work at Edinburgh's only hospital, the Royal Infirmary. In 1802 and 1803, the third and fourth volumes of his publication *Anatomy of the Human Body* were published [7]. However, in an attempt to avoid competition with his elder brother and jealousy from the staff at the University of Edinburgh, Bell moved to London in 1808 where his geniality and passion enabled him to excel far above the city's most noble physicians [6]. On his journey, he carried the manuscript of his first publication, *Essays on the Anatomy of Expression in Painting*, in which he outlined the anatomical and psychological nature of facial expressions for artists [6, 7].

Bell reveled in outstanding accolades for his work [4]. His most eminent accomplishment, however, was his work as a surgeon at the Middlesex Hospital beginning in 1814 [4, 7]. During the Battle of Waterloo in 1815, Bell cared for and operated on injured soldiers, portraying the brutality and gore in much of his anatomical artwork including neurological injuries [4, 6, 7, 9]. At the battle, Bell operated on the wounded until "his clothes were stiff with blood and his arms powerless with the exertion of using the knife"[9]. Bell's highest accolade was his book *An Idea of a New Anatomy of the Brain*, which has been described by some as the "Magna Carta of neurology" [7]. In 1826, Bell was granted the Royal Society's first ever medal, and in 1831, he was awarded knighthood by King William IV (1765–1837) for his accomplishments [5, 7, 9]. Bell experienced significant strides in neurology, surgery, and anatomy.

Neuroanatomical contributions

His precise drawings vividly depicted various anatomical structures to better explain the preferred surgical methods of his time (Fig. 2) [5]. Bell was one of the first physicians to study details of neuroanatomy and apply this knowledge to the clinical and surgical setting and thus was an early pioneer of neurology.

Central nervous system

Information regarding the brain was readily available prior to the work of Bell, but before him, many structures and functions had yet to be discovered. In his publication titled *Idea of a New Anatomy of the Brain*, Bell highlighted the differences between the cerebrum and cerebellum [4, 9] and stated that bundles of distinct nerves span the body and conjoin at a single filament [5, 7]. He claimed that each portion of the brain serves a specific function. He reiterated that not all portions of the brain drive sensibility and that various nerves convey distinct, yet specific, functions.

In regard to the spinal cord, he claimed that the anterior portion controls motor function, while the posterior portion helps to elicit a sensory response [5]. Prior to Bell, the different areas of the spinal cord controlling sensory and motor modalities were not fully understood. Although they serve distinct functions, Bell found that two sets of nerves from a

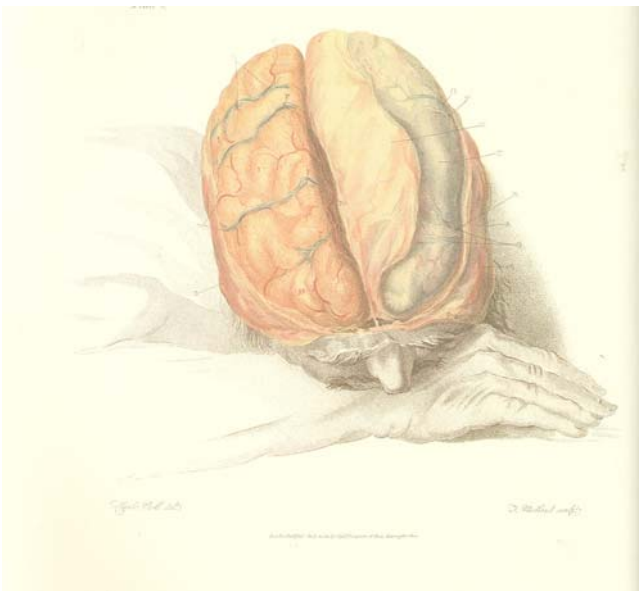

Fig. 2 Painting from Bell's *The Anatomy of the Brain, Explained in a Series of Engravings*

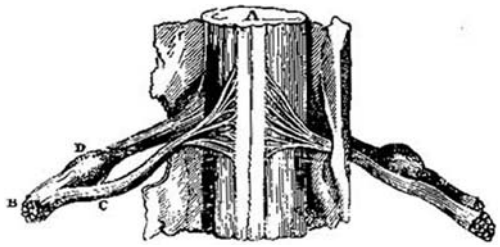

Fig. 3 Illustration of the anterior and posterior roots of the spinal cord as illustrated in Bell's *An Exposition of the Natural System of the Nerves of the Human Body*, London, 1824

single side of the spinal column gather into the same bundle. In his 1811 *A New Anatomy of the Brain*, Bell supported his notion with groundbreaking observations during vivisection: "On laying bare the roots of the spinal nerves, I found that I could cut across the posterior fasciculus of nerves, which took its origin from the posterior portion of the spinal marrow without convulsing the muscles of the back; but that on touching the point of the knife, the muscles of the back were immediately convulsed." [8, 11]. From his observations, Bell inferred that the function of the posterior roots of the spinal nerve differed from that of the anterior roots (Fig. 3) [11]. He found that disturbance of the ventral roots of the spinal nerves induced cramps, while agitation of the dorsal roots rendered no symptoms [7]. Bell recognized that in order for a nerve to relay multiple functions, its roots must connect to corresponding, yet different, areas of the brain or spinal cord [11]. He perceived the nerves of sensation as "entering" the brain and regarded nerves of motion as "passing out" from the brain (Fig. 4). In this work, he stated that the anterior root elicited contraction of the muscles, and through further experimentation, he determined that the posterior root served a

Fig. 4 Illustration from Bell's work on the peripheral nerves demonstrating the details of the nerves of the neck and thorax

sensory function [10]. Bell's work (1811) together with that of Francois Magendie (1822) regarding the motor and sensory modalities of the ventral and dorsal roots became known as the Bell–Magendie law [4, 7, 9, 11, 12].

Peripheral nervous system

In 1821, Bell expounded upon the long thoracic nerve, which innervates the serratus anterior muscle and is now named after him (external respiratory nerve of Bell), and made detailed dissections of the facial nerve [4]. Bell proved that the abducens and hypoglossal nerves served as motor nerves to the eye and tongue, respectively [12]. Bell went on to discover that the sensory nerves originate in the gray matter of the cerebrum, spinal cord, and medulla oblongata, while the motor nerves originate in the white mater. He helped to explain the fundamentals of the sympathetic nervous system and found that the visceral nerves aid not only in motion and sensation, but also in secretion. He discovered that sympathetic nerves anastomose with motor and sensory nerves and that respiration is an involuntary action [5].

Clinical contributions

While working in London, Bell operated on patients with facial paralysis, and it is he who is accredited for distinguishing peripheral from central facial paralysis [4, 12]. Bell described cases of cervical dystonia [3]. His findings and presentation in 1829 of three patients regarding the innervation and paralysis of the seventh cranial nerve provided insight into the condition now known as Bell's palsy [4, 6]. Bell also noted that the eyeball corresponding to the side of paralysis rotated upward as the patient attempted to close their eyes. He witnessed an identical rotation of the eyeball in normal individuals, calling it the palpebraloculogyric reflex, which is now known as Bell's phenomenon [4, 12]. Bell also made clinical descriptions of trigeminal nerve injury [4, 12]. He experimented with the portio minor and found that it served only a motor function while the portio major serves only a sensory function [11]. Interestingly, in 1830, he described a cystic tumor of the cerebellopontine angle presenting as anesthesia of the maxillary and mandibular divisions of the trigeminal nerve in a female patient.

Neurosurgical contributions

As a surgeon and neurologist, Bell should be regarded as a founder of neurosurgery as exemplified by both his depictions and operations of the nervous system. With his keen understanding of medicine, Bell proposed proper surgical protocol for the efficient treatment of his patients. In 1815, he highlighted the dangers of bone exposure during surgery

and stated that exposure should be minimized to avoid irritation, inflammation, and further retraction. Prior to operating on a patient, the surgeon, according to Bell, must evaluate the "local and constitutional symptoms of the disease." Bell's "neurosurgical" instruments included a scalpel, probes, quill, sponges, small and large trephines, rasp, forceps, saws, and elevators [1]. Bell believed that trepanation should be performed for preventing depressed bone fragments from irritating the meninges, for removing dead bone, and for evacuating epidural blood (Fig. 5). Also, he delved into the clinical evaluation of concussions. He claimed that a concussion may dampen sensation, as the compression on the brain reduces blood supply and diminishes sensibility [1]. He performed craniotomies for epidural hematoma as exemplified by the following:

> I find a man who has fallen from a great height lying comatose, with a very feeble pulse. He is trepanned, and a coagulum of blood is found under the skull (above the dura), an inch in depth. The coagulum is cleaned away; the man considerably revives. [10]

Although Bell's colleagues rarely analyzed disease through dissection, Bell used dissection to distinguish the differences between concussion, compression, and inflammation of the brain. He recommended the use of adhesive straps in the event that the scalp is cut from the skull. In his 1821 publication, *Illustrations of the Great Operations of Surgery: Trepan, Hernia, Amputation, Aneurysm, and Lithotomy*, he depicted and discussed methods of craniotomy [1]. He characterized diseased calvaria as being separated from the pericranium in the event that the pericranium is yellow or white in color. As a surgeon, Bell used the term "puffy tumor of the scalp" to describe a direct blow to the scalp, causing danger to the patient. He posited that blood located between the bone and the dura mater is a direct result of blood seeping through small vessels in the event of perturbed dura mater (Fig. 6) [2]. Although not having performed an operation, he described a patient with a ruptured middle cerebral artery [11]. In addition, Bell expounded upon the three types of tumor of the skull. The first was a fungus excrescence from the dura mater, while the second was a state of protrusion caused by effusion of blood. The third source of tumor was fungus cerebri, which he advocated excising. Lastly, Bell advised that the pericranium not be left exposed for a lengthy time so as to prevent the bone from being "deprived of its nourishing vessels" [1].

Fig. 5 Painting by Bell illustrating a patient with skull fracture following removal of fragments via trepanation (*Illustrations of the Great Operations of Surgery: Trepan, Hernia, Amputation, Aneurism, and Lithotomy*. London; Longman, Hurst, Rees, Orme, and Brown, 1821)

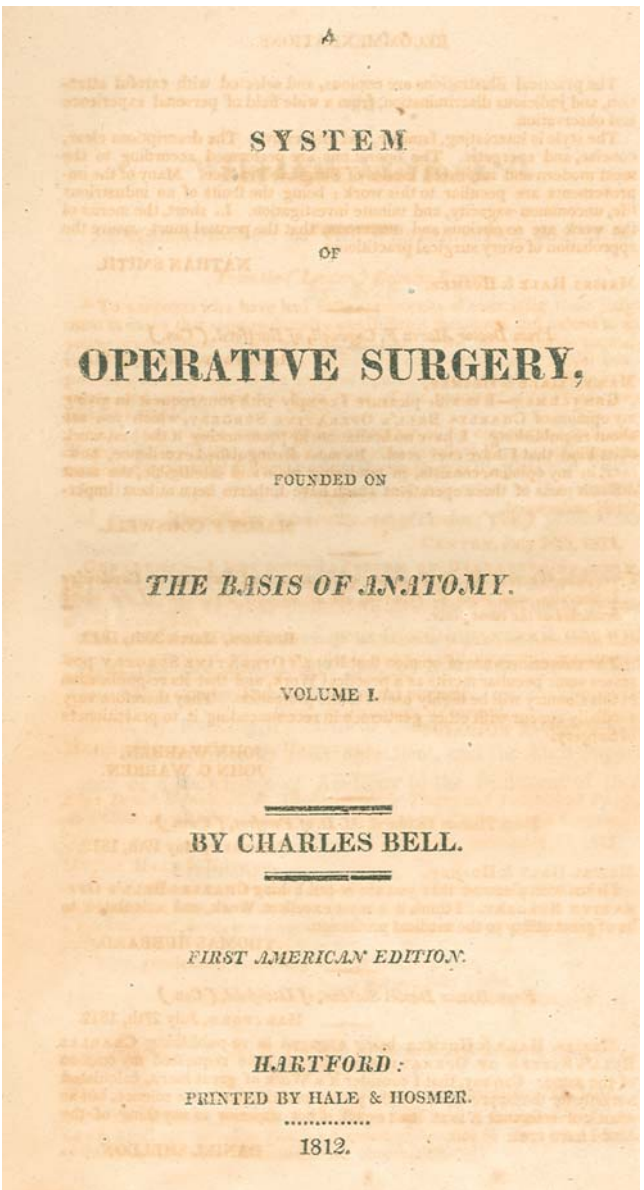

Fig. 6 Cover page of Bell's *A System of Operative Surgery Founded on the Basis of Anatomy*. Hartford, Hale & Hosmer, 1812

Conclusion

In 1836, Bell left London for Edinburgh for, as he put, "London was a good place to live in but not to die in." After achieving vast success as an artist, scientist, and physician, Bell passed away on April 28, 1842, at the age of 68 [4, 6]. Bell's early advances in anatomy, physiology, and surgery ultimately instilled in him an interest in neurology and the nervous system, sparking his vast successes and his remarkable reputation as an innovative surgeon [5]. It is such contributions to neuroanatomy and surgery on which our current discipline of0020neurosurgery is based.

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