Reflections on the contributions of Harvey Cushing to the surgery of peripheral nerves

Historical vignette

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By the time Harvey Cushing entered medical school, nerve reconstruction techniques had been developed, but peripheral nerve surgery was still in its infancy. As an assistant surgical resident influenced by Dr. William Halsted, Cushing wrote a series of reports on the use of cocaine for nerve blocks. Following his residency training and a hiatus to further his clinical interests and intellectual curiosity, he traveled to Europe and met with a variety of surgeons, physiologists, and scientists, who likely laid the groundwork for Cushing’s increased interest in peripheral nerve surgery. Returning to The Johns Hopkins Hospital in 1901, he began documenting these surgeries. Patient records preserved at Yale’s Cushing Brain Tumor Registry describe Cushing’s repair of ulnar and radial nerves, as well as his exploration of the brachial plexus for nerve repair or reconstruction. The authors reviewed Harvey Cushing’s cases and provide 3 case illustrations not previously reported by Cushing involving neurolysis, nerve repair, and neurorrhaphy. Additionally, Cushing’s experience with facial nerve neurotization is reviewed. The history, physical examination, and operative notes shed light on Cushing’s diagnosis, strategy, technique, and hence, his surgery on peripheral nerve injury. These contributions complement others he made to surgery of the peripheral nervous system dealing with nerve pain, entrapment, and tumor. (DOI: 10.3171/2010.11.JNS10804)

Key Words • brachial plexus • Harvey Cushing • history • nerve repair

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Harvey Cushing10

Pre-Modern Peripheral Nerve Surgery

The history and evolution of peripheral nerve surgery has not been well researched and documented until recently. The origins of peripheral nerve surgery can be traced back to Hippocrates as early as the 4th century BC.5,4,16,26,27 The first account of the differentiation of nerves from tendons traces back to the 3rd century BC when Herophilus (335–280 BC) traced peripheral nerves back to the spinal cord and differentiated motor and sensory nerves.5,24,26 As Galen was trained in the Hippocratic School, he too proposed that divided nerves could not be repaired and thus influenced many surgeons’ views on peripheral nerve repair for centuries to come.5,16,27

From the 7th century onward, a host of individuals were involved in advancing our understanding of peripheral nerve surgery. Paul of Aegina, Avicenna, Roger of Salerno, Guglielmo da Saliceto, and Guy de Chauliac are universally accepted as the pioneers in this field.2,4,16 While Paul of Aegina (AD 625–690) made references to nerve suture in his work, the first clear reference to the suture repair of a severed nerve is attributed to the Persians; Rhazes (850–932) and Avicenna (980–1037) recommended epineural end-to-end neurorrhaphy with sutures.4,16,26 Guy de Chauliac (1330–1368), the father of French surgery, sutured epineural tissue to allow the least intervention of nonnervous substance between the nerve endings.3,4,16

Modern Peripheral Nerve Surgery

A turning point in the field of peripheral nerve surgery occurred with the arrival of Gabrielle Ferrara11 (1543–1627) who is largely considered the father of modern peripheral nerve surgery.5,4,16 Within Ferrara’s surgical preparation and technique, we are able to see many of the same surgical principles used today.

Despite Ferrara’s work, the enthusiasm for nerve repair was dampened because the return of physiological function did not immediately follow an anatomically successful nerve repair. This thought process began to change in 1795 with the work of Cruikshank5 and Haigh-ton,13 who reported that anatomical continuity of severed
nerves could be restored and that the reunited nerve could regain function. This observation was based on the principle that the return of function occurred in a delayed fashion to allow for the fibers to regenerate and restore continuity.16

The above contributions, as well as the greater understanding of nerve anatomy and physiology in the 1800s due to the works of Schwann,23 Nissl,18 Waldeyer,29 and Waller30 among others, constructed the foundation to allow for rational approaches to nerve repair. Peripheral nerve surgery became a realistic possibility, and a wide array of techniques for nerve coaptation was introduced by Rawa20 and Philipeaux and Vulpian,19 among others. It was not until 1873 that a giant step forward was made when Heuter described the epineural suture method favored today and provided data demonstrating adequate return of function with this suture technique.3,16,26,27

In 1878, Albert of Austria is reported to have used allografts from an amputated leg to replace a median nerve segment resected along with a sarcoma. Robson21 is generally credited with having performed the first successful nerve autograft in 1889, having bridged a 6-cm gap in the median nerve with a popliteal nerve graft obtained from an amputated limb. Three years after the graft was sutured in place, the functional result was judged as “perfect.” The first report of successful neurotization was by Drobnik in 1879 when he anastomosed the peripheral facial nerve and the central end of the external zygapophyseal joint.16,17,22 Even at the turn of the 20th century, with the development of nerve repair and reconstruction techniques, peripheral nerve surgery was still in its infancy.

Cushing’s Involvement With Peripheral Nerve Surgery

When Drobnik first accomplished neurotization in 1879, Harvey Cushing was a mere 10 years old. Cushing entered Harvard Medical School in 1891 and later began his position as Assistant Resident in Surgery to Dr. William Halsted at The Johns Hopkins Hospital from 1896 until 1900. During this 4-year period, he remained under the influence of Halsted and developed a growing interest in using cocaine for local nerve blocks. Cushing published a case report of cocaine utilization for a brachial plexus block for a humerus amputation at the shoulder due to sarcoma.2 He later published a case series of local nerve blocks with cocaine in 1898.6 Although Cushing’s clinical interests grew while at The Johns Hopkins Hospital, he believed his intellectual outlook was still somewhat restricted. Consequently, Cushing took a 14-month hiatus from The Johns Hopkins Hospital to travel to Europe and meet with a variety of surgeons, physiologists, and scientists. It was during this 14-month period that Cushing worked with Kocher, Horsley, Sherrington, Robson, and Kronecker. These scholars likely laid the groundwork for Cushing’s growing interest in peripheral nerve surgery, as he returned in 1901 and began documenting a series of peripheral nerve surgical cases. Furthermore, the rudimentary techniques available at the time for intracranial surgery made cranial explorations highly risky. Therefore, Cushing may have advanced his surgical methods on the peripheral nervous system as a passageway to operate on the CNS.

The following have been derived from a review of Harvey Cushing’s patient records preserved at Yale’s Cushing Brain Tumor Registry. These records demonstrate that Cushing was not only the father of modern intracranial surgery but also carried an interest in peripheral nerve surgery. Unless otherwise stated, each case is included in Cushing’s own words. None of the cases included below has been previously reported by Cushing.

Illustrative Cases

Case 1

Diagnosis: Musculo-spiral paralysis (old fracture of humerus with division of neuroma). Histopathological diagnosis was fibro-myxoma of the nerve.

History of present illness: Twenty-seven-year-old male who about six years ago had a right arm and upper third of the humerus caught in the belt system in a compound, comminuted fracture accompanied by the nerves which has caused inability to extend the right hand.

Physical examination: At junction of middle thirds of humerus, there is a large amount of callous and at outer side a cord is felt which causes shooting pain down the back of hand when pressed.

Wrist, drop of right hand; interossei and extensors are atrophied; sensation impaired on back of radial side of hand.

Dr. Cushing: The present condition of paralysis has existed for a period of seven years. Patient states that his right arm was caught in a revolving shaft and broken in six places. The arm was first put in a splint and a plaster-of-Paris dressing, upon the removal of which a month later a nonunited fracture was found to be present in the lower third of the forearm. This was operated upon and the bones sutured. The result, considering the nature of the injury, is a very satisfactory one. The paralysis probably has existed since the injury for the patient noticed that he could not extend his wrist and that there was an area of numbness on the back of the hand and forearm extending up to the elbow. This condition has remained ever since the original injury. In the midhumeral region there is a palpable thickening and slight deformity of the bone and lying over it at the outer portion at the site of the musculo-spiral groove is a tender nodule the size of a chestnut, thick under the finger elicits contractions of the trapezius muscle. In the forearm itself there is marked atrophy of the extensor group of muscles including the supinator longus and extensors of the wrist and fingers. There is neither atrophy nor loss of power in the extensors of the elbow or wrist of the interossei and lumbricals muscles. One curious phenomenon is noticeable, namely, that when the patient closes the hand as though to make a fist the hand extends slightly upon the wrist which looks as though some power must be present in these muscles, although they cannot separately and voluntarily be moved. Electrical reaction shows a complete absence of response in the muscles of the forearm supplied by the musculo-spiral. There is no response whatsoever to galvanic current.

Operation: Dr. Cushing

Anesthesia: Chloroform

June 20, 1905

Suture of Musculo-Spiral Nerve
An incision was made along the outer side of the arm in the course of the musculo-spiral nerve. The neuroma, which could be palpated before the operation and manipulations of which cause contraction in the lower part of this trapezius muscles, was easily exposed. It, however, lay in the midst of a dense cicatricial mass which evidently corresponded with the old humeral fracture. The operator searched for a long time at this situation but was unable to locate the central end of the peripheral part of the nerve. Consequently, it was necessary to enlarge the incision down toward the elbow and to locate the musculo-spiral between the group of flexor muscles and the supinator longus. It was here easily found and then traced upward toward the neuroma. This part of the nerve became greater thinned out and was so small that, although it had been exposed at the earlier dissection, it had not been recognized as the peripheral stump. By stretching the central end of the musculo-spiral, it was possible to elongate the nerve almost two inches, and this corresponding with the gap between the two inches. There were a few fibers which passed through the neuroma and supplied the musculo-spiral. This was demonstrated not only by electrical reaction, but also by a mechanical stimulus of the neuroma which would lead to these contractions. It is possible that the fibers passing through the neuroma and transmitting these impulses may have been divided. An effort, however, was made to move them and the central stump, after cutting off the neuroma, was split for a distance of about 5 cm, one portion being used with the peripheral stump, the conical point of which had been cut off and the lower portion was left in contact with a few branches to the trapezius mentioned above. … Stimulation of the peripheral stump before suture was made gave no contraction whatsoever of the musculo-spiral distribution of the forearm. The only response which was obtained was a response in the adjoining brachialis anterior and biceps muscles. After this suture was made, the wound was reclosed in layers to prevent any dead spaces and to lessen as much as possible the resultant scar.

The macroscopical appearances of the peripheral nerve, even where it was not thinned out, were quite different from those of the intact central stump proximal to the neuroma. The nerve was very soft, of a peculiar dusty-bleish color, which has been noticed oftentimes hereetofore to characterize the completely degenerated peripheral sections. There was also in the central end of the nerve a neuroma lying about 3 cm above the larger neuroma. This was split an anastomosed into the central end of the nerve [Fig. 1].

Dr. Cushing
June 28

Patient has had an uneventful convalesence. First dressing today. The wound healed without reaction. Suture removed. There has been no change in preexisting conditions. Flexion extension of the elbow are possible as before. Patient thinks that the numbness on the back of the hand is less than it had been before the operation.

Case 2

Diagnosis: Rupture of brachial plexus (left)
Complaint: Paralysis of left arm; history of present illness

Ten months ago (about two months after he came to this country while working in the coal mine, digging coal) an upright gave way and a large flat piece of slate came down on him in such a manner that his lower jaw was fractured and his head stretched from the left shoulder. For almost a month, he laid unconscious but rallied later on. In the remaining nine months, the fractured jaw has united. There is, however, total loss of sensation in the whole arm up to the shoulder.
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Rupture brachial plexus-suture by anastomosis of VII root

The brachial plexus was exposed without dividing the clavicle. The entire supraclavicular portion of the plexus with the exception of the branch to the suprascapular muscles and the portion of the plexus below and under the clavicle were tied up in dense scar. With great difficulty and only after destructi
tive dissection of the V and VI roots freed from the scar and it was apparent that there had been some continuation of fibers, the chief cicatricial formation was at the point of view of these two roots. On following down the line of vertebra, no root whatsoever could be found opposite the next vertebra. The next inferior root arched from the vertebra still further below, toward, and downward, as shown in the diagram here. This was taken to be the VIII. Just below this root was the stump of a nerve, which the operator regarded as the avulsed branch of the VII root of the plexus. This was brought up underneath the VIII root and was sutured to the lower part of the VI, as shown in the diagram [Fig. 2]. The stump of this nerve was amputated and preserved for microscopical examination.

The wound was closed with great care after hemostasis had been assured. All the parts were sutured back in position as accurately as possible. No drainage was used.

November 5, 1905—The left arm, in comparison with the right, shows atrophy.

November 25, 1905—Wound was entirely healed. Arm freed from bandages and allowed to hang in a sling. Treatment of the arm with galvanism and daily massage began.

Special note
Dr. Cushing

December 15, 1905

Faradism given the same response as formerly. To galvanism, response from all the muscles about the shoulder, forearm, and hand is sharp and very much like the normal. There is no change in the measurement of the arm above and below the elbow. The general appearance of the skin, forearm, and hand is not as dusky and cyanotic. The mottled color having gone. No sweating of the hand, temperature is more near/like that of the opposite side. Vaso-motors are active. Muscles, especially the biceps, are still flabby. The deltoid holds the humerus up in position better. Pectoralis show some power in holding arm to side. Sensory stimuli are appreciated in the arm down to elbow. The left pupil and left palpebral fissure are smaller and narrower than on the right side.

Special note
Dr. Cushing

May 25, 1906

Since operation, 205 days ago; with supraclavicular galvanic simulation, there is a pilo-motor reflex with production of goose-flesh and erection of fine hairs over his left chest, back, and shoulder as low down as to the line of sensory anesthesia. The line is very accurately marked out in this way. The arm below this line, although the skin is in perfect condition, has a dusky hue with dilatation of all the subcutaneous veins. The radial pulse is much smaller than on the right and the arm branches markedly when elevated. The dusky appearance and dilatation of veins does not return quickly when it is once more allowed to sag or hang down. The axilla is moist, but the arm and hand, below the level of anesthesia, have dry skin with no sweating. No atrophic changed observable by the fingernails.

The pupils are still equal, right being almost double size of left. The marked difference in the size of palpebral openings. There is no paralysis of scapular muscles, wing of scapula being held firmly to chest, head of humerus is held well up in glenoid cavity and does not sag as much as formerly.

Case 3

Diagnosis: Ulnar nerve paresis

September 23, 1926

Dr. Cairns

A female laboratory technician of 30 reenters the hospital complaining of weakness, atrophy and paralysis of the left hand, more particularly in the ulnar nerve distribution. In March 1925, following a hypodermic prick there was swelling and inflammation of the left forearm with numbness over the ulnar nerve distribution and motor paralysis of the muscles supplied by the ulnar nerve. It was incised about two weeks after the infection and since then she has had violent urticarial attacks. Her medical history shows an unusual susceptibility to infection. She returns because during the past year there has been a slowly progressive loss of sensation in the other fingers of the hand and an atrophy of the ulnar muscles as well. Physical examination is essentially negative except for hypotension, eruptions on the face, sinus arrhythmia, and an early systolic whiff. There is complete loss of sensation over the ulnar side of the palm and wrist and little finger and paralysis and contracture of the little finger [Fig. 3].

Operative note

October 2, 1926

Anesthesia: Ether-Miss Way [the preparer of the anesethe
sia]

Procedure: Neurolysis for Infection of Unknown Origin occurring in the Depth of the Tissues of the Left Arm.
With the patient’s arm in the position shown in the accompanying sketch [Fig. 4] a long incision was made finally reaching from near the external condyle 2/3rds of the distance down the arm. So soon as the scar in this situation was excised the most curious blue fascial sheaths were brought into view. It was suggested by Mr. Cairns that this might have been due to the mercurochrome which had been used. The flexor carpi ulnaris was identified and drawn outward as shown in the accompanying sketch [Fig. 4]. Finally in the midst of the scar the ulnar nerve was brought into view, though before it was cleared of its enveloping scar the nerve both distally and proximally was fully exposed. It was fortunate that this was done; otherwise the branch to the flexor carpi ulnaris would have been divided. Whether any branches to the flexor sublimis group were divided is difficult to tell.

A fairly dense mass of scar tissue which enveloped the nerve was finally broken open and the nerve freed. The wound was then closed carefully in successive layers by fine silk sutures.

October 4, 1926
Dr. Cairns

Wound dressed by Dr. Cushing. Some overriding of the edges of the incision, nearer the upper end than the lower. At this part the wound was reopened and some fresh stitches inserted. Arm and forearm enclosed in starch casing.

October 8, 1926
Dr. Cairns

For the first time since onset of ulnar palsy there has been sensation in the ulnar side of the hand: momentary flashes of a burning, rather painful sensation in little and ring fingers. Also has pain up forearm when she passively extends the little fingers. Never had this operation before. Starch casing is very comfortable indeed. Objectively there is no change in anesthesia which is still complete over ulnar distribution of hand. In connection with the peculiar greenish color of the muscles noted at this last operation the patient states that when the infected area was opened at the first operation the surgeon noted a peculiar green color of the tissues. In subsequent treatment mercurochrome was injected locally into the tissues of the forearm. The patient was discharged “improved.”

Discussion

During his career, Harvey Cushing (1869–1939) demonstrated a keen interest in and contributed much to the field of peripheral nerve surgery. Cushing performed peripheral nerve procedures during the early part of his career when intracranial surgery was associated with significant risks due to the infancy of surgical and anesthetic techniques and the lack of reliable methods to control intracranial pressure during surgery. At this time, peripheral nerve surgery provided an opportunity for Cushing to be involved in the treatment of the nervous system without accepting the higher risks of brain surgery. Later in his
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career, acceleration of his competency in intracranial surgery allowed him to limit his practice to brain surgery.

The 3 newly described cases highlight Cushing’s use of a broad armamentarium of peripheral nerve19 and brachial plexus19 reconstructive techniques. Other cases of ruptured brachial plexus were reported by Cushing and in the majority of these, scar tissue was removed from the operative site and appropriate nerve roots anastomosed.28 Interestingly, one of these patients with plexus avulsion chose to have his entire upper limb amputated due to its dysfunction.28 Of the technique of peripheral nerve repair, Cushing stated:

...the procedure is a delicate one, and the probability of success will depend largely upon the delicacy with which the nerves are handled, upon the accurate approximation of the never stumps with the least possible suture material and that placed only in the nerve sheath, upon absolute hemostasis, and upon the care with which the tissues lining the wound are handled, since it is of the utmost importance that there be a minimum of cicatricial formation. It is inconceivable, however, that the divided ends of each individual nerve fiber should once more unite in the process of regeneration by perfect coaptation.9

Interestingly, Cushing also explored facial reanimation procedures. In 1903, he published a report of a patient who developed a facial palsy after a gunshot wound with an exit site behind the ear.9 Cushing performed a facial to spinal accessory nerve neurotization, a first of its type in the US.9,25 Silk suture on fine curved intestinal needles was used to unite the perineurium of these aforementioned nerves. By day 112, the patient stated “when I wish to laugh straight, I help it out with my shoulder.” On day 287, Cushing noted “volitional control of individual groups of muscles has returned and can be affected without associated shoulder movements or contraction in the other facial muscles.” Throughout this patient’s treatment, Cushing used daily electrical treatments.

Cushing also advanced our understanding of patients with peripheral nerve pain, entrapment, and tumors. While a trainee of Halsted, Cushing also developed an interest in local anesthesia.7,10 Cushing published a case series of local nerve blocks with cocaine,8 including a regional nerve block at the shoulder due to sarcoma.25 In 1902, Cushing studied the systemic responses following section of nerves of the upper limb during amputations.8

Cushing also made early observations on neurogenic thoracic outlet syndrome and the role of a cervical rib, elongated transverse process, and a fibrous band to result in lower trunk or C-8/T-1 nerve dysfunction.28 This patient was a 19-year-old woman with weakness in the arm and intrinsic muscles of the hand with atrophy of these later muscles, intense pain, and loss of sensation over the ulnar aspect of the arm. Following removal of the rib via a posterior cervical triangle approach, Cushing described the patient as “entirely relieved” from her intense pain with improvement in her sensation.

It is likely that his early interest directly or indirectly influenced his teacher Halsted, his student Howard Naffzinger, and other luminaries (including Alfred Adson, Alton Ochsner, and Michael DeBakey)—all of whom subsequently helped define and refine the pathoanatomy and treatment of this condition. Finally, in addition to Cushing’s pioneering work related to intracranial tumors, specifically those affecting cranial nerves such as acoustic neuromas, he also performed a tumor resection from the brachial plexus.5

Conclusions

This review illustrates Harvey Cushing’s interest in and contributions to the management of conditions affecting the peripheral nervous system.

Disclosure

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

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