PERIPHERAL NERVE DISORDERS AND TREATMENT STRATEGIES ACCORDING TO AVICENNA IN HIS MEDICAL TREATISE, CANON OF MEDICINE

THE WRITTEN TRANSMISSION of knowledge has played a great part in the advancement of medicine, and historical documents hold the key to a full exploration of the history of medicine. Some fields, including disciplines that deal with peripheral nerve disorders, have received little benefit from such valuable material. In particular, peripheral nerve surgery lacks perspectives from historical data. For many years, physicians have obtained positive results in the surgical treatment of peripheral nerve diseases. Relevant documents reveal that the first author who described the surgical repair of damaged peripheral nerves was Avicenna, a leading figure of the medieval era who lived in the Middle East. In his primary medical work, the Canon, he provides a description, albeit sketchy, of a suture procedure for peripheral nerve transection. This treatise influenced physicians for several centuries. In this presentation, we analyze excerpts from the Canon that concern peripheral nerve disorders and strategies for their management.

KEY WORDS: Avicenna, Canon, History of medicine, Peripheral nerve, Surgery

Peripheral nerve injuries and disorders and their management are, to some extent, as challenging for physicians now as they were in the past. The history of peripheral nerve disorders and strategies for their treatment have attracted little interest from physicians. One possible reason for this neglect may be the paucity of literature that can be found in the history of medicine, even though writings about peripheral nerves date back to the Hippocratic era. In reality, treatment methods, especially surgery for peripheral nerve diseases, have attracted the attention of physicians and surgeons since ancient times. One source of systematic writings on this subject can be found in the well-known medical book from the 11th century named Al-Qanun fi al-Tibb (the Canon of Medicine; henceforth, the Canon), which means “the law of medicine,” written by the great physician Avicenna (Fig. 1).

Avicenna, known as Ibn Sina in the Middle East, was born in 980 in Afshana, Uzbekistan, and died in 1037 in Hamadan, Iran. Avicenna is considered one of the principal mediators between the Western and Islamic worlds. His great work, the Canon, is an encyclopedic work about medicine and comprises 5 books. This work was a standard textbook in medical schools until the 16th century in the West and the 19th century in the Middle East. Gerard of Cremona translated the Canon into Latin for the first time in the 12th century. This version was published in 1473 in Milan, 1476 in Padua, and 1482 in Venice (Figs. 2 and 3). The Hebrew version was translated in 1279 in Rome and was published in 1491 in Naples (12).

The first book concerns the description of medicine, anatomy, physiology, nosology, etiology, symptomatology, health, diseases and fatal conditions, and treatment principles. The second book deals with simple drugs and their effects. Internal and external diseases of all the organs from head to foot (a capite ad calcem) are explained systematically in the third book. The fourth book considers the disorders that do not occur in a specific organ but affect the...
whole body (e.g., epidemics, fever, dermatological disorders, injuries, fractures, luxation, and intoxication); the last section of the fourth book also includes cosmetics. Complex drugs are outlined in the fifth book (19).

Studies of the history of medicine and the pertinent sections of the *Canon* have revealed that Avicenna was the first author to discuss the surgical management of peripheral nerve injury. Although the *Canon* does not include detailed information about the procedure, Avicenna emphasized the forced anatomic continuity of the nerve for proper healing after a transection injury.

Each of the 5 large books of the *Canon* is divided into treatises (*fen*), each of which, in turn, is subdivided into chapters and sections (6). Peripheral nerve disorders are considered in the first 5 sections of the fourth chapter of the fourth *fen* of the fourth book (Fig. 4).

**FOURTH FEN, FOURTH CHAPTER: NERVE AND BONE**

Avicenna begins the introductory part of this section with general information about nerve injury and some relevant symptoms. He points out that nerve injury is a serious condition and symptoms may sometimes be severe. The terminology used in the *Canon* includes some inexact definitions for today’s readers, such as spasm, confusion, or multiple swellings. Some definitions have dual meanings. We can deduce from other chapters of the book that spasm may mean either a tetanus-type muscle contraction or flaccidity/spasticity in neurological terms. Avicenna indicated an infectious state when he referred to confusion (occurring with fever) and multiple swellings (abscess). At the same time, swelling may also indicate wound edema. Similarly, swelling may be an ominous sign, or at other
times it may refer to a more benign condition. In view of these uncertain definitions and paradoxical statements, the text should basically be considered in terms of historical humoral theory. Causal relationships are not always logical in some sections of the Canon:

Human nerves are exceedingly vulnerable tissues. Since they are in relation with the brain, pain and a tormenting sense arising from their injuries are unbearable; thus, these injuries may lead to terrible consequences like spasm and confusion. Usually, spasm precedes pain in nerve injury. Swelling appears in any case even if the pain is not so terrible. The least hazardous type of nerve injury is that which occurs with fever and multiple swellings outside the wound; the patient becomes thirsty, cannot sleep well, his/her mouth becomes dry, and these symptoms are more severe if the swellings appear near the tongue. Comparable severe pain and terrible consequences may occur if the tendons are injured; in this situation, the pain is more irresistible if the wounded segment of tendon is located at a more distant site from the muscle. The pain is excruciating if the nerve swells, as happens when the nerve is exposed to cold (10, p 518a; 11, p 501).

In the next paragraph, further clinical details regarding symptoms are given, and the inflammation process after a nerve injury is outlined. Owing to the delicate nature of the nerves, Avicenna warns the reader about the application of vaporous or liquid thermal therapy after a nerve injury to prevent progressive inflammation within the nerve; these types of procedures were common in his time, according to humoral theory, which had its roots in antiquity:

If the nerve is inflamed, it will swell; the swelling may result in decay of the organs (10, p 518a; 11, p 501).

Subsequently, Avicenna gives some information about drugs that can be used for the medical treatment of nerve injuries. He mainly offers topical drugs with specifically anti-inflammatory effects:

The drugs used in nerve injury should remove the moisture from the nerve. Sometimes, swelling after nerve injury appears in a delayed fashion; in this situation, the treatment period may be prolonged (10, p 518a; 11, pp 501–502).

In the next paragraph, Avicenna classifies the main wound types in nerve injuries:

Nerve injuries are encountered mainly in two forms: either a pinprick wound caused by a sharp object, or a cleft-type [splitting and fissuring] wound. The cleft-type injury can usually be diagnosed by the naked eye, or, on rare occasions, the lesion is obscured due to its deep location in muscle, or the cleft can simply not be spotted. The cleft-type injuries occur morphologically either in longitudinal or transverse fashion. The longitudinal-type injury is more benign than the transverse one, because capillaries are commonly damaged in the latter type, which results in muscle spasm and may induce a tormenting effect on the brain, and possibly other systemic diseases which are difficult to treat would follow this type of injury. If the splitting or perforating injury to the nerve occurs in a transverse fashion, you shall most probably have to cut the nerve, and consequently the patient will calm down and symptoms will disappear (10, p 518a; 11, p 502).

In the preceding paragraph, Avicenna emphasizes the better prognosis of a longitudinal-type slash injury when compared with that of a transverse-type injury, because the longitudinal cut commonly occurs parallel to the “capillary” (the term was possibly used for “nerve fascicle” in those times), so that the majority of the nerve fascicles remain undamaged.

In the following section, Avicenna describes the tissues that may be confused with injured nerves and clarifies the likely
The first section of the fourth chapter of the fourth fen of the fourth book of the Canon is written mainly about medical treatment of penetrating wounds to the nerves, such as piercing, splitting, and transection. In this section, the nature of topical drugs is described as cold, hot, dry, and moist. Avicenna gives detailed information for each type of drug and recommends instructions for using them on specific occasions.

Do not attempt to fuse the injured nerve in the early phase; first try to relieve the pain. In order to achieve this, apply a heated fabric over the wound and let warm oil soak into it...Whenever you eliminate the pain and swelling, and you are sure that inflammatory substances do not contact the wound, begin to fuse the nerve after proper cleaning has been done (venesection, etc.) (10, pp 518a–b; 11, pp 503–504).

In the following paragraph, Avicenna refers to incomplete healing after a nerve injury. He may be describing disintegrated nerve tissue rather than neuroma formation and gives some hints on how to deal with it:

Incomplete healing of a nerve [after injury] is often seen. In particular, cold temperature and physical strikes may affect the healing process so that the wound may gain a shape like spun cotton and pain may worsen. In such a case, apply some heating oil for relieving pain, and if the nerve is visible through the wound and has a firm structure [by palpation], and the injury happened in a longitudinal fissure-like fashion, try to cover it with flesh, put some drug on it, which I mentioned before, and wrap tightly with a wide bandage (10, p 518b; 11, p 504).

In the next paragraph, Avicenna gives a proposal for repairing transection injuries to nerves; this recommendation had great significance in the history of neurosurgery:

If the fissure or transection injury occurs transversely, you must suture the nerve ends; otherwise the

edges cannot be brought face to face and shall not fuse. If you realize that waiting will culminate in an inflammation process in transverse-fashioned fissure injury, then simply cut the nerve. Cut it carefully in order to prevent further swelling and inflammation (10, p 518b; 11, p 504).

After these proposals, some medical methods and some topical drugs for care of the sutured nerves are discussed:

If a swollen nerve is exposed to cold, the condition may result in spasm and, consequently, inflammation may develop, which would attack the entire extremity. Because of that, it is not sufficient to fuse only the wound edges; you should add medical therapy until complete healing of the wound is achieved. If the incision is not wide enough, lengthen the opening at first, and observe the wound carefully to differentiate any clues that indicate inflammation, because some inflammatory substances may accumulate inside the wound and cannot escape through this narrow opening. Be sure that the wound is dry and there is no inflammation and swelling. After confirming the preferable wound condition, close the wound ends (10, p 518b; 11, p 504).

It is clear that Avicenna offers a secondary healing procedure for these types of unclean injuries. He continues with suggestions that are not so unfamiliar to current medical knowledge:

Open the bandage two or three times a day, examine the wound and wrap it again. Open the bandage on the night of the first day. If the bandage is applied at night, open it on the following morning. If the pain is not sharp in character, do not repeat examinations so frequently. It is also enough to practice these dressings two times a day (10, p 518b; 11, p 504).

The second section on peripheral nerve disorders deals with the treatment of acute and ulcerated nerve injuries. In this part, Avicenna considers medical treatment of nerve injuries. The quantity and characteristics of recommended drugs are quite astonishing. In the third section, Avicenna discusses swelling of the injured nerve. He gives highly detailed recommendations for nerve-related problems. The fourth section considers crush-type nerve injuries. Here, Avicenna recommends using only anti-inflammatory treatment. He emphasizes that if swelling is associated with this type of injury, treatment should be different from that for a crush-only injury:

When swelling and pain occur simultaneously, treat the more disturbing symptom first. ... Treatment is easier when there is only swelling. ... If the nerve is distorted by crushing, never expose it to hot or cold water (10, p 519b; 11, pp 510–511).

In the fifth section, hardening and distortions of the nerves are considered. Although Avicenna’s descriptions are not detailed, he discusses nerve entrapment syndromes and, notably, describes Tinel’s sign:
Twisting and hardening of a nerve more than usual frequently occurs from falling down or receiving a blow on the nerve. The sign of twisting and hardening of the nerve is numbness when compressing it with a finger (10, p 519b; 11, p 511).

**DISCUSSION**

The relevant sections of the *Canon* reveal that Avicenna was the first to propose surgical repair for a transection nerve injury. Scholars believe that Avicenna’s opinion concerning nerve repair, although rudimentary, remained the main protocol until the 16th century (2). Throughout past centuries, the study of the history of peripheral nerves, peripheral nerve pathology, and treatment of peripheral nerve disorders and injuries has raised a number of questions. The surgical management of the peripheral nerves has always been a challenging and complex problem. Contemporary physicians have achieved satisfactory results in the surgical management of peripheral nerves thanks to technological advancements and pioneers who made great contributions in this area. In the written history of nerve repair, the first to consider the topic was Paulus Aegineta (AD 625–690), who postulated restoration of severed nerves (1, 16). However, he did not describe the particular technique for this procedure.

In the preceding historical period, Hippocrates (460–370 BC) had introduced early knowledge about the treatment of peripheral nerve injuries in his *Aphorisms*. Section 5:18 of this book dictates that “Cold is inimical to the bones, the teeth, the nerves, the brain, and the spinal marrow, but heat is beneficial” (9, p 138). Avicenna also shared and defended this opinion. Hippocrates wrote in the same work (Section 6:19) that “When a bone, cartilage, nerve, the slender part of a jaw, or prepuce is cut out, the part is neither restored nor does it unite” (9, p 140), and (Section 7:28) “Whatever piece of bone, cartilage, or nerve is cut off, it neither grows nor unites” (9, p 142). Hippocrates’ works contain anatomic descriptions of peripheral nerves and their injuries; however, there is no mention of nerve repair.

Thus far, the relevant documents have revealed that most of the physicians of antiquity did not clearly distinguish between nerves and tendons. In addition, the medical methods that they used frequently had negative effects, which caused them to avoid attempting nerve repair procedures. Consequently, nerve surgery remained untouched for many centuries (16). The prevalent notion was that a divided nerve could not be united. Fortunately, in the following era, Herophilus of Chalcedon from the Alexandrian School (ca. 300 BC) made a critical differentiation between nerves and tendons, and he also described the spinal cord as the anatomic origin of the nerves and divided them into motor and sensory tracts (8, 13). Half a millennium later, Galen of Pergamon (AD 129–200) reassessed these findings and accepted the brain as the center of the peripheral nerves (13). Galen found that spinal root injury may cause distal paresis and suggested the application of topical drugs over the region where the root was affected (4, 6). Although there is no clear description found in Galen’s books, some scholars have acknowledged that Galen may have implied surgical repair of nerve transection in his works on wound treatment (14). In the 7th century, Paulus Aegineta postulated restoration of severed nerves; however, he recommended only closure of the wound without including primary repair of nerves. Moreover, Paulus recommended that the nerve should not be punctured by the needle (15).

There was another gap (of almost 400 years) in the history of peripheral nerve repair until Avicenna’s account, which stated that divided nerves can be sutured. Avicenna influenced his successors in an encouraging way. The “manual art of surgery,” before the introduction of the *Canon* to the Latin West, formed one of the lesser and more neglected branches of medicine. Commencing with Avicenna, the medieval Arabic physicians changed Galen’s dictum that surgery was an inferior branch of medicine. After Avicenna, there was a branching out of surgery, and the issue of purely surgical works expanded. The earliest of these writers on surgery were Roger, Roland, and the so-called “Four Masters.” Guy de Chauliac made extensive use of Avicenna’s writings (5). In Italy, the study of the *Canon* seems to have been first undertaken by surgical writers associated with Bologna and Padua. Surgical teaching in the Italian universities also drew upon practically oriented portions of the *Canon;* the use of parts of the *Canon* as a textbook of surgery is evidenced by the interest shown in Avicenna’s works by 13th century northern Italian surgical writers. The *Canon* was frequently copied in its entirety and often studied as a reference work (17).

Roger of Salerno (12th century) is widely accepted as the pioneer of the management of peripheral nerve injuries; he recommended anastomosis of the interrupted nerves, with particular emphasis on anatomic continuity (8). It is obvious that because Avicenna wrote his work approximately a century earlier than Roger, he must be considered as the pioneer of surgical nerve repair. A little later, Guglielmo da Saliceto (1210–1280) offered nerve fusion methods. Although his technique is unknown, one of his pupils, Guido Lanfranchi, practiced direct nerve suture by sewing the ends of the nerve together with the skin. The modern concept of the surgery of peripheral nerves started essentially with Gabriele Ferrara’s work (1543–1627) in Italy. He was the first to provide a precise description of suturing of the stumps of a transected nerve, which we are still practicing today (2).

Although there is currently no consensus among scholars as to whether Avicenna made a clear anatomic differentiation between the nerves and tendons/fasciae, the relevant text presented here suggests that he did. In the section of his book concerning peripheral nerve disorders, he clearly describes such a division in the principles for the treatment of nerve injury.

The medical comprehension of Avicenna was based on the Hippocratic and Galenic principles (6). His methods of treatment and drug use may be understood through considering his medical comprehension. Avicenna classified the organs according to their characteristics such as hot, cold, wet, and dry. According to this classification, Avicenna included the nerves in both the cold and dry groups:
Motor nerves, as against the normal balance, are more cold and dry in temperament while sensory nerves are colder but not drier. Sensory nerves are, perhaps, in regard to dryness nearer to the general temperament but are also too far from coldness (3, p 31).

Avicenna also classified organs as simple and compound, and he placed nerves in the “simple” category:

Nerves. These arise from the brain and the spinal cord. They are white and elastic and are easily bent but do not break. They serve sensation and movement (3, p 48).

In the treatment of nerve injury, Avicenna gives priority to cessation of pain and suggests treating the injured nerve subsequently. The most important aspect is the proposal of suturing the nerve ends after transverse cutting. Another significant issue Avicenna touches on is inflammation, which, he recommends, can be prevented by appropriate drugs. These proposals are somewhat parallel to modern neurosurgical comprehension. Drainage of inflammatory substances that have collected inside the wound, cleaning of the contaminated wound, and treating the nerve after the management of inflammation are among his principles to cure the injured nerve.

Avicenna imparts some important knowledge about emergencies, and he quotes a prescription from Galen in the second section of the fourth chapter of the fourth fen. He also quotes some prescriptions from Galen in the third section.

In conclusion, Avicenna dedicated a large part of his principal medical book, the Canon, to peripheral nerve disorders, including trauma and inflammatory diseases of the nerves. On the basis of the theory of the four humors, Avicenna recommended a great number of prescriptions for all kinds of peripheral nerve disorders. Although, he did not give a detailed description, he also recommended, for the first time, a suture procedure for transection nerve injury. As Avicenna’s Canon became influential in the West through Latin and Hebrew translations in the centuries that followed, it is likely that his opinions regarding peripheral nerve repair may well have encouraged succeeding generations of physicians.

REFERENCES

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COMMENTS
A ciduman et al. from Ankara, Turkey, have provided a well-written article that illuminates the history of peripheral nerve surgery, the Canon of Medicine, by the 11th century physician, Avicenna. I particularly enjoyed learning about the significant contribution made by this great physician to the description and management of peripheral nerve injuries. Indeed, it appears that Avicenna was an early, if not the first, authority to discuss the surgical management of the peripheral nerve. He clearly identified and described the gross pathoanatomic features of nerve injuries in continuity, including the swelling (neuraoma) that occurs in this situation. Importantly, he recognized the differential prognosis of longitudinal versus transverse nerve injuries in that the nerve may be in continuity more often in the former than in the latter case. He emphasized that nerves that were transected should be repaired. I think that all readers of the Journal who are interested in the history of neurosurgery as well as enthusiasts of peripheral nerve surgery will enjoy reading this article immensely.

Rajiv Midha
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His primary medical book, *Al-Qanun* (the *Canon*), a textbook used by all European universities, influenced physicians in the ensuing period. In this treatise, Avicenna first described a suture procedure for peripheral nerve transection. Over the years, his management strategies were practiced for a long time by physicians who obtained encouraging results in the surgical treatment of peripheral nerve disease. The details of his technique are most remarkable and awesome, especially considering the period and the few resources available at the time. The authors have provided a distinct service by reporting on Avicenna’s heritage through the description of his life and his treatise. Articles like this one, appearing in the Legacy section of *Neurosurgery*, are remarkable additions to the history of medicine.

**Enrico de Divitiis**  
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The authors have put together a most interesting article on Avicenna and his early techniques and concepts dealing with peripheral nerve injury. Until reading this article, I was unaware of Avicenna’s contribution to this subject, and I am particularly impressed that this work was done by one whom Westerners do not think of as an “operating” surgeon. The authors have also done an excellent job in ferreting out the important passages in the *Canon*, and they seem to have done the translations well. Also intriguing was reading of Avicenna’s understanding of the different types of nerve injuries and which would recover well and which would not. Avicenna appeared to be able to differentiate between the tendons and nerves, something not commonly done then. In reviewing the techniques for repair and treatment of peripheral nerve injury, his methods were clearly innovative and insightful for this period, i.e., the 11th century. However, as the authors point out so clearly, medical treatment and medications unfortunately remained a bit primitive. This presentation is clearly innovative and provides us with a new insight into the pioneering work of this great Islamic physician (and surgeon!).

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Avicenna was a pivotal figure in the development of clinical medicine. A millennium ago, he attempted to codify all medical knowledge. Eminent bibliographers, Fielding Garrison and Leslie Morton, stated that “His ‘Canon’ is one of the most famous texts ever written.” Its influence extended into the 20th century in the Near East. William Osler mentions a physician in Tehran who cited Avicenna in a consultation on a febrile patient in 1915. Avicenna’s importance can also be gauged by the number of his manuscripts in Latin and Arabic and by the incunabula found in the libraries of well-known bibliophiles such as the Biblioteca Osleriana housed at McGill University in Montreal, the Harvey Cushing collection at Yale, and the Erik Waller collection bequeathed to the library of the Royal University in Uppsala, Sweden. The authors of this article are to be commended for bringing Avicenna’s views on peripheral nerve injuries to our attention.

**Norman H. Horwitz**  
Washington, District of Columbia

Human embryonic stem cells stained with two stem cell markers, Oct4 (red) and SSEA4 (green). Credit: Rick Cohen, Ph.D., W.M. Keck Center for Collaborative Neuroscience, Rutgers, the State University of New Jersey. See Apuzzo, p 1, and Farin et al., pp 15–39.