Legacy of Syriac-Aramaic Scholars in Transmitting Neurosurgical Knowledge Between Antiquity and the Middle Ages

Jaafar Basma[1], Christos Anagnostopoulos[4], Sylvain El-Khoury[5], Antoine Courban[6], Andrew J. Gienapp[1,2], Kenan Arnautovic[1,3]

Key words
- History
- Hunayn Ibn Isshaq
- Middle Ages
- Neurosurgery
- Syriac scholars

From the [1]Department of Neurosurgery, University of Tennessee Health Science Center, [2]Neuroscience Institute, Le Bonheur Children's Hospital, and [3]Semmes-Murphey Clinic, Memphis, Tennessee, USA; [4]Department of Neurosurgery, Korgialenio-Benakio Red Cross Hospital, Athens, Greece; [5]Department of Ophthalmology, University Medical Centre, Mainz, Germany; and [6]Department of Anatomy and Epistemology, Université Saint-Joseph, Beirut, Lebanon

To whom correspondence should be addressed: Jaafar Basma, M.D. [E-mail: jbasma@uthsc.edu]

Citation: World Neurosurg. (2021) 152:71-79. https://doi.org/10.1016/j.wneu.2021.06.024

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

The link between ancient Greek medicine and the Arabic translation period in the 9th century cannot be understood without studying the contributions of Syriac scholars. With their mastery of Greek and the related Semitic languages of Syriac and Arabic, they initiated a scientific translation process with methods that prevail to this day. In this paper, we reviewed Hunayn Ibn Isshaq's *Ten Treatises on the Eye* to elucidate the original contributions of the Syriac physicians to the field of neurologic surgery. We analyzed the oldest known diagram of orbital anatomy along with Hunayn's genuine ideas on the optic nerve anatomy and pathology, optic chiasm, afferent pupillary reflex, and papilledema and venous congestion. We also reviewed the neurosurgical elements found in the *Syriac Book of Medicines* including the thought process in localizing neurologic deficits based on clinical experience and anatomic dissections and the earliest recorded description of brachial plexus pathology.

INTRODUCTION

Common belief holds that the Middle Ages in Europe (spanning between the fall of Rome in the 5th century A.D. to the beginning of the Renaissance era in late 15th century A.D.) were a dormant time when it came to scientific contributions, leading to the Western depiction of the period as the "Dark Ages." However, scientific knowledge (including medical and neurosurgical) needed to be preserved in order for it to reemerge in Europe after more than a millennium and regain a comparable status with its ancient Hellenistic heritage. It was in the East where the torch was carried to distant cities and nations and, most challengingly, beyond foreign languages.

In order to overcome religious dogma and national and ethnic prejudices that were prevalent at the time, the universality of science required a translation method that was objective, accurate, and legible while also not negating the creativity and originality of the authors. Syriac-Aramaic scholars of the Middle East in particular played a crucial role in initiating the translation movement between Greek, Syriac, and Arabic[1] (Figure 1). These scholars were at the geographic, historical, and cultural fringes of the Greek, Arab, and Persian cultures, as well as the ancient Egyptian, Mesopotamian, and Levantine civilizations (Figure 2). They were thus able to preserve countless medical treatises written during antiquity, which were later translated into Latin. For instance, much of what we know of Galen of Pergamon is not based on ancient Greek or Latin texts but rather later Latin translations of Arabic—and by extension Syriac—books.[1,2]

Many of these Syriac scholars were renowned physicians and scientists, in addition to being professional translators who added their own discoveries and theories to their fields. Specifically, the Syriac contribution to neurosurgery has not been previously studied in the literature. In this article, we review the important but commonly overlooked legacy of the Syriac scholars in preserving, simplifying, and adding to the neurosurgical knowledge between antiquity and the Middle Ages. Unfortunately, many of the original Syriac books were lost and have been incorporated into later Arab and Latin commentaries. We thus focused on 2 surviving Syriac manuscripts with neurosurgical content: the *Ten Treatises on the Eye* and the *Syriac Book of Medicines*.

BRIEF HISTORICAL BACKGROUND

Aramaic, an ancient Semitic language, has been the lingua franca of the Middle East since Assyrian dominance and continued to be the dominant language during later Greek and Roman control. (Aramaic was the native tongue of Jesus of Nazareth and early Christians.) In the Middle Ages, the Aramaic language and alphabet evolved into "Syriac" with each region retaining its own local dialect.

Pagan temples and schools were progressively closed with the rise of Christianity in the Eastern Roman Empire, including that of Alexandria in the 5th century A.D. and the Academy of Athens in 529 A.D. Furthermore, following the Council of Chalcedon in 451 A.D., the Nestorian Schism occurred and the Syriac Nestorian Christian school of Edessa was closed in 489 A.D. These events led to an exodus of Greek philosophers and Nestorian Christian scholars to the eastern border of the Empire with Persia, where they established the schools of Nisibin and Gundishappur under Sassanid protection

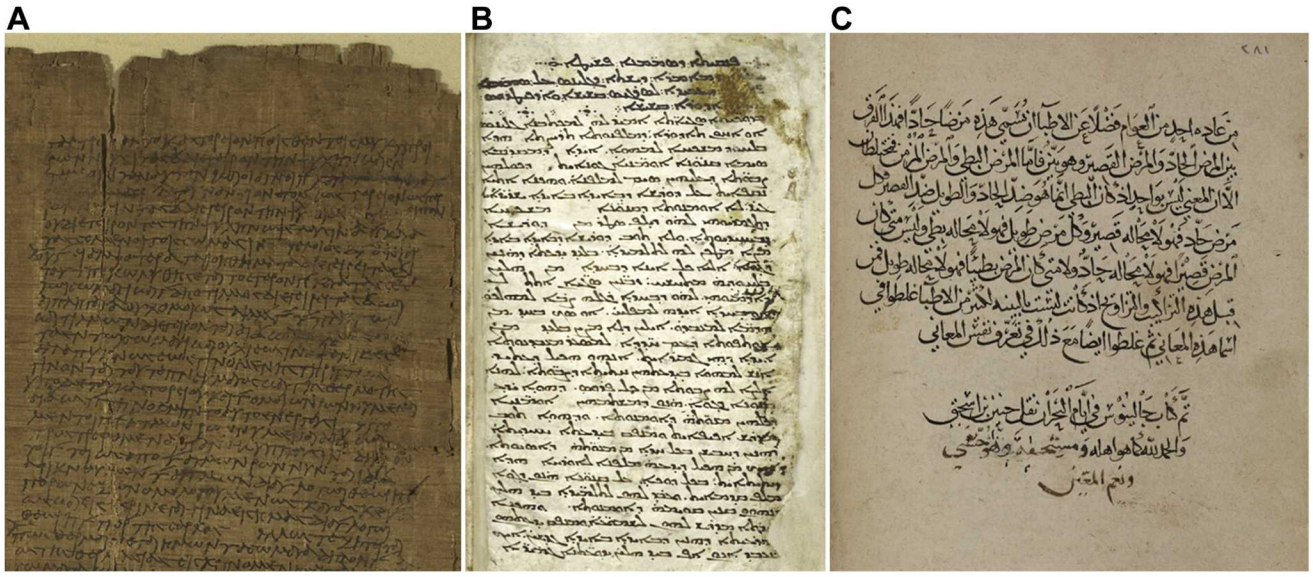

Figure 1. The translation movement of medical manuscripts in the East during the Middle Ages from Greek to Syriac and Arabic. (**A**) The London Medical Papyrus written in Greek in the first century A.D. and discovered in Egypt. (Public domain from The British Library [papyrus 137]. Available at: https://www.bl.uk/collection-items/the-anonymus-londiniensis-papyrus.) (**B**) Syriac manuscript of Galen's *de Simplicibus* (*On the Powers and Mixtures of Simple Drugs*) as translated by the Syriac scholar Sergius of Reshaina (6th century A.D.). (Public domain from The British Library [MS 14661]. Available at: https://www.bl.uk/collection-items/syriac-translation-of-galen.) (**C**) *Three medical treatises* by Galen, copied by al-Kilani in Damascus in 1184 A.D. from an earlier translation by Hunayn Ibn Isshaq. (Public domain from The British Library [Or 6670]. Available at: https://www.bl.uk/collection-items/three-galenic-treatises-in-arabic.)

Figure 2. Map of the Mediterranean basin. Aramaic and Syriac languages were spoken in antiquity and the Middle Ages, respectively, in the regions of the Levant and Mesopotamia. For political reasons, the Syriac schools of Edessa, Nisibin, and Gundishappur flourished at the border between the Eastern Roman Empire and the Persian Empire.

(Figure 2). It is believed that these cities held the first known universities and medical schools, further spreading the teachings of Hippocrates and Galen.[1]

When these cities fell under Arab Muslim rule in the 7th century, Syriac scholars gained recognition, becoming personal physicians to the Caliphs of Baghdad. With growing interest in Ancient Greek science, the Caliphs invested in collecting and translating valuable Greek textbooks into Arabic. Christian Syriac scholars in particular played a pivotal role in initiating the translation movement in the Muslim empire[1] due to their long tradition of Greek-Syriac translation and their fluency in Arabic, a Semitic cousin of Syriac/Aramaic (see Figure 1). The physician Hunayn Ibn Isshaq (Latin: *Johannitius*; born 809 A.D.), who in the 9th century was in charge of Bayt al Hikmah, the library of Baghdad (Figure 3), is one famous example. Thanks to the widespread influence of Syriac physicians, evidence of ancient Greek medicine was found as far as Central Asia.[1]

SYRIAC-ARAMAIC MEDICINE AND THE TRANSLATION MOVEMENT

Sergius of Reshaina (died 536 A.D.), believed to have studied in Alexandria, is reputed to be the early leading scholar in translating the works of Galen from Greek into Syriac (see Figure 1). His work is considered to be the first translation of Galen's corpus into a Semitic language.[1] Some of Galen's work has only been preserved through Sergius's manuscripts and continues to be studied to this day. Other Syriac historical figures include Atanos of Amid, Philagrius, Simon the Monk, Gregory the Bishop, Theodosius the Patriarch, George the son of Bokht-Isho', Yahya Ibn Masawaih, Iso Bar Ali, and John the son of Serapion.[3,4]

Abul Faraj Gregory—or Bar Hebraeus (born 1226 A.D.)—practiced medicine in Aleppo and also translated many works by Galen, Dioskorides, Hippocrates, and others into Syriac.[4] However, the most famous of all was Hunayn Ibn Isshaq (809–873 A.D.), who translated 95 of Galen's books into Syriac and 39 into Arabic.[5-7] Hunayn is credited with writing the first comprehensive textbook on ophthalmology (*Book of the Ten Treatises on the Eye*),[8] which included the first documented diagram of ocular and orbital anatomy (Figure 4). He is also credited with developing a new Arabic medical vocabulary and curriculum, which was later adopted by Arab scholars.[5]

Syriac translators employed a rigorous philological method of translation. Historians agree that Arabic and Syriac translations of ancient medical textbooks were considered to be of higher quality than later Latin translations of Arabic texts.[1] While Hunayn's books were mostly incorporated into the works of Arab scholars, his book *Masa'il fil Tibb* was translated to Latin as *Isagoge Johannitii ad parvum artem Galeni* (see Figure 3) and used as an introduction to the Articella, or "Ars Medicine," the medical curriculum employed in the European medical schools of Paris, Bologna, and Padua. It was printed in Leipzig in 1497 and in Strasbourg in 1534. His book *Ten Treatises on the Eye* was also taught in Latin but mistakenly known as *Galeni Liber de Oculis Translatus a Demetrio*.[5,6]

SYRIAC SCHOLARS AND EVOLUTION OF NEUROSURGERY

Hunayn Ibn Isshaq translated most of Galen's known corpus into Syriac, which included his ideas on the anatomy of the nervous system, the classification of hydrocephalus and intracranial hematomas, the treatment of head injuries and spine trauma, epilepsy, and headaches. He also translated many of Hippocrates' works including those related to ancient neurosurgical practice, which he combined with Galenic commentaries, such as the *Aphorisms*, *On Wounds in the Head*, *On Fractures*, and trepanations.[9]

Hunayn translated the *Seven Books of Paulus Aegineta*, written by a Byzantine physician from the 7th century, and famed for his encyclopedic medical endeavors. Along with the Greek physician and medical writer Oribasius, he copied and developed Hippocrates' techniques of spinal reduction on a flat board and described laminectomies to treat spinal fractures.[10]

Figure 3. Latin manuscripts. (**A**) Illustration from the *Isagoge Johannitii in Tegni Galeni*, or Hunayn Ibn Isshaq's introduction to the *Articella*, the medical curriculum in medieval Europe. This manuscript dates to the 13th century in Oxford England (courtesy of the National Library of Medicine, Bethesda, Maryland). Available at: https://www.nlm.nih.gov/hmd/medieval/articella.html.) (**B**) Another translated manuscript of the same book from Paris, France in the 14th century (Public domain from The British Library [Harley MS 3140]. Available at: https://www.bl.uk/onlinegallery/onlineex/illmanus/harlmanucoll/t/largeimage76150.html.)

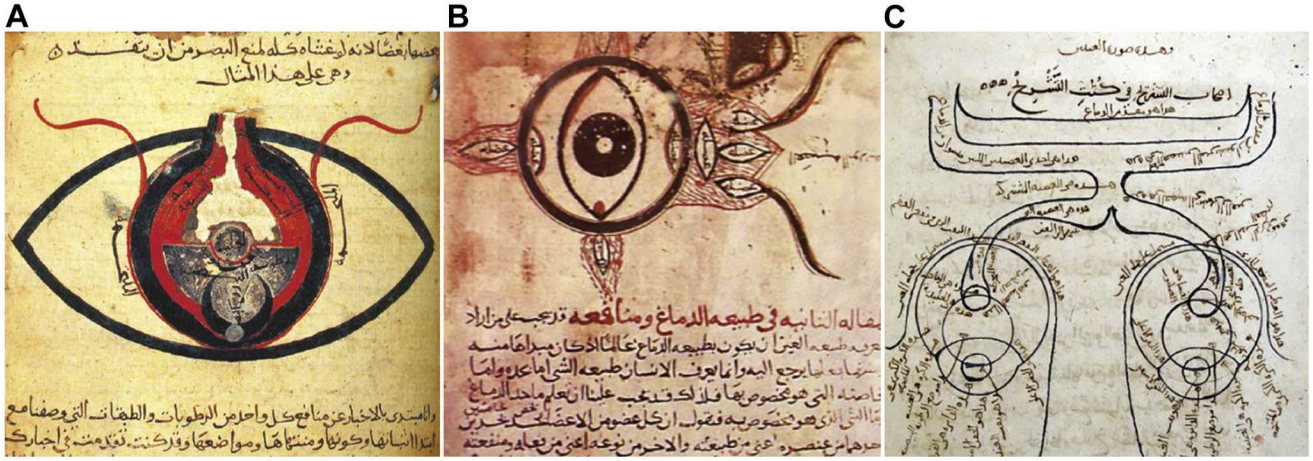

Figure 4. (**A** and **B**) The eye according to Hunayn Ibn Ishaq. Note the illustration of the orbit, oculomotor muscles, and their innervation. (In public domain due to copyright expiration. 12th century manuscript. The eye according to Hunain ibn Ishaq—ophthalmology in medieval Islam. Available at: https://commons.wikimedia.org/wiki/File:Cheshm_manuscript.jpg.) (**B**) These represent the earliest known diagrams of orbital anatomy, likely copied from earlier Syriac and Greek manuscripts (in public domain due to copyright expiration. Arabic manuscript from the 12th century held at the Cairo National Library). (**C**) Alhazen's (Ibn al-Haytham), father of modern optics—illustration of the optic chiasm, inspired by Hunayn Ibn Isshaq (in public domain due to copyright expiration. 11th century manuscript of Kitab al-Manazer, MS Fatih 3212, vol. 1, Suleymaniye Mosque Library, Istanbul. Available at: https://en.wikipedia.org/wiki/Book_of_Optics#/media/File:Alhazen1652.png.)

One disciple of Hunayn, Rhazes, wrote *Al Hawi (Continens)* in 923 A.D. about improving the classification, diagnosis, and treatment of hydrocephalus.[11] Syriac and Arabic translations of Galen and Celsus's classification of spine fractures later contributed to a more accurate classification and description of functional anatomical localization of spinal injuries written by Abulcasis Al-Zahrawi (an Andalusian surgeon and the father of modern surgery, 936–1013 A.D.).[12] Ibn Sina referenced Hunayn Ibn Isshaq in his book *The Canon* (1037 A.D.), which later became the central textbook for European medical schools in the Middle Ages.[13]

Ibn al-Haitham (Latin: *Alhazen*) in his famous book *On Optics* in 1030 A.D. further elaborated on Hunayn's ophthalmologic work and included a physical analysis of optics. On the basis of empirical analysis, he demonstrated for the first time that vision occurs in the brain rather than in the eye and is caused by light particles reflected from the object to the retina.[14]

NEUROSURGICAL ELEMENTS IN HUNAYN'S *TREATISES ON THE EYE*

A philological analysis performed by the German ophthalmologist Julius Hirschberg in 1929 demonstrated that Hunayn's book *Ten Treatises on the Eye*[8] is the earliest comprehensive book in ophthalmology.[15] Although focused on the eye, our review demonstrated elements relevant to the field of neurosurgery. Hunayn stated, for example, "he who wishes to know the nature of the eye must necessarily be informed as to the nature of the brain, as the eye has its origin in the brain." Like Galen and Hippocrates—and in disagreement with Aristotle—Hunayn believed that the brain is the "source of perception, voluntary movement and of the will," operating "through nerves into all sensory and motor organs."[8]

From an anatomic perspective, the book followed the basic teachings of Galen as described in *De Usu Partium*. However, Hunayn did not hesitate to disagree with Galen on multiple occasions, such as believing that the crystalline lens to be spherical rather than flat and located in the center of the eye.[8]

Neuroanatomy

Like Galen, Hunayn described 4 ventricles in the brain: "two cavities in the anterior part, one in the posterior part, and one in the intervening space between them." The brain is vascularized by 2 pairs of arteries arising from the heart and forming a "net" on its undersurface (referring to the circle of Willis). The brain has 2 meningeal membranes, one soft (pia mater), and one hard (dura mater). In the skull, every nerve is surrounded by both layers, including the optic nerve, while the orbit has a similar covering called Epipephykos (periorbita). Hunayn described 7 pairs of cranial nerves: optic, oculomotor, taste and feeling (facial/trigeminal nerve), oral cavity (glossopharyngeal), hearing (cochlear), intestines (vagus), and muscles of the tongue (hypoglossal).

According to Hunayn, the optic nerve is "larger than the other cranial nerves and more resilient." He references the optic chiasm when he wrote that the optic nerves "arise near the ventricles, meet near the nose, then separate again, joining the contralateral eye."[8] This description was later copied by Alhazen (see **Figure 4**) and used to elaborate his theory of optics and vision.[14]

Hunayn proposed different theories to explain the functional role of optic decussation. In his opinion, 2 explanations hold: 1) the ability to see the whole field with one eye at a time; and 2) avoiding double vision when both eyes are open. Hunayn's contribution to the anatomy and function of the optic chiasm is obviously much earlier than that of the Persian physician Zayn al-Din Gorgani, who was influenced by Hunayn and also credited with being the first to discuss functional decussation in the chiasm (1042–1137 A.D.).[16]

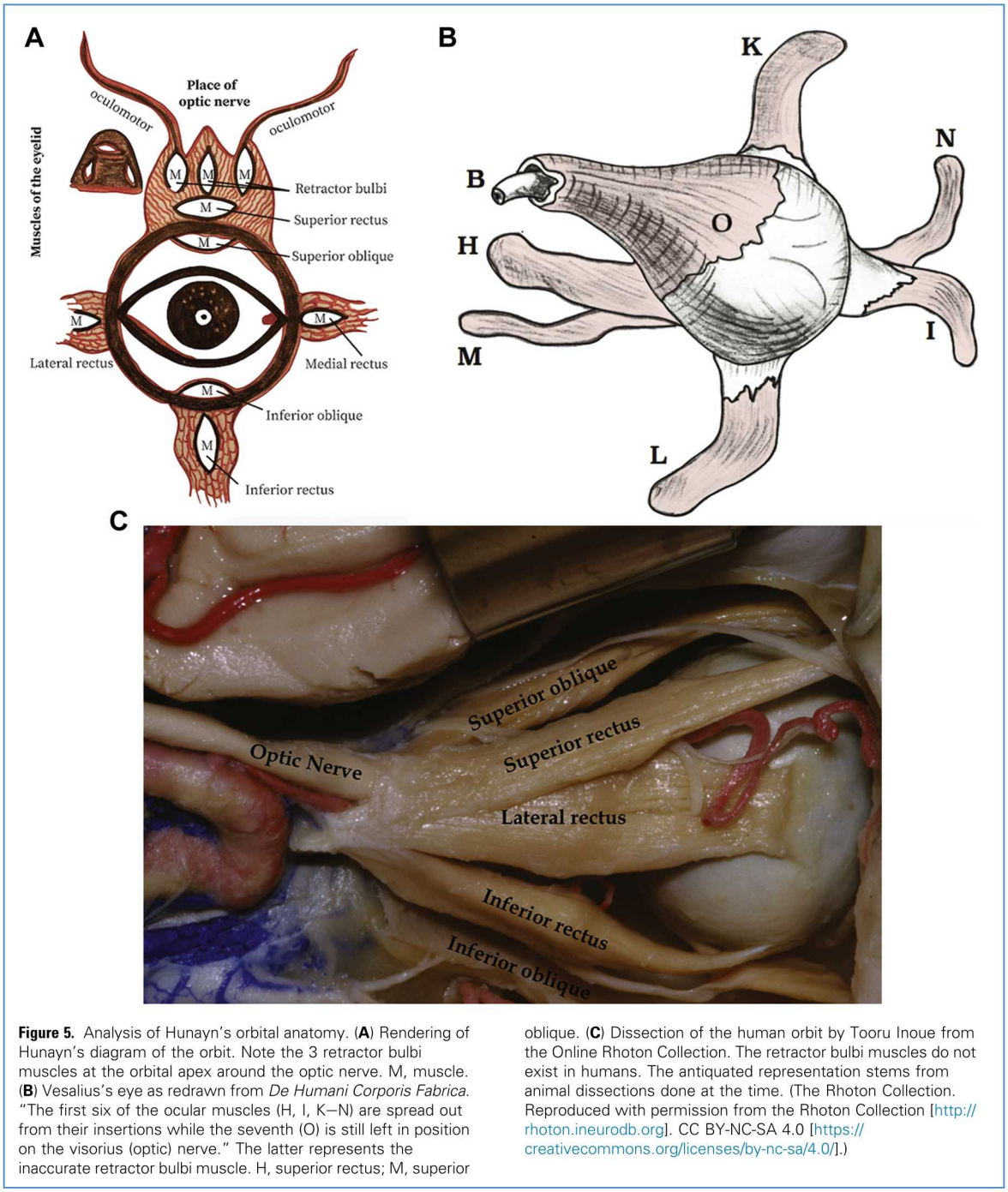

Figure 5. Analysis of Hunayn's orbital anatomy. (**A**) Rendering of Hunayn's diagram of the orbit. Note the 3 retractor bulbi muscles at the orbital apex around the optic nerve. M, muscle. (**B**) Vesalius's eye as redrawn from *De Humani Corporis Fabrica*. "The first six of the ocular muscles (H, I, K–N) are spread out from their insertions while the seventh (O) is still left in position on the visorius (optic) nerve." The latter represents the inaccurate retractor bulbi muscle. H, superior rectus; M, superior oblique. (**C**) Dissection of the human orbit by Tooru Inoue from the Online Rhoton Collection. The retractor bulbi muscles do not exist in humans. The antiquated representation stems from animal dissections done at the time. (The Rhoton Collection. Reproduced with permission from the Rhoton Collection [http://rhoton.ineurodb.org]. CC BY-NC-SA 4.0 [https://creativecommons.org/licenses/by-nc-sa/4.0/].)

Orbital Anatomy

Hunayn's book contains the first historical diagrams of orbital and ocular anatomy (see Figures 4 and 5). Hunayn described the 6 extraocular muscles of the eye; however, like Galen, he added the hypothetical "one to three" retractor bulbi muscles (Figure 5), which exist in animals but not in humans. (Galen based many of his anatomic descriptions on animal specimens since human dissections were banned at his time.) We have found references for human dissections in the later *Syriac Book of Medicines* (see later),[4] which explained, "According to what we have learned from the openings (dissections), the muscles which move the eye are six in number" and innervated by "the nerve emerging from the second exit of the skull" (superior orbital fissure). Although the author also admitted the theoretical existence of the retractor bulbi muscles, he retained a degree of skepticism by

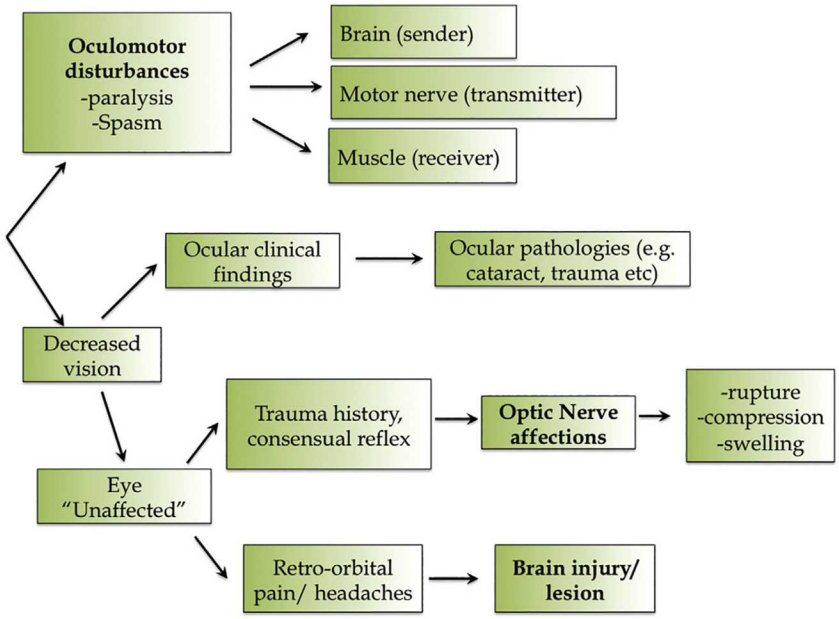

Figure 6. Illustrative rendering of Hunayn's logical sequence in diagnosing optic and oculomotor nerve affections used before the development of radiologic and ophthalmoscopic tools. Note the resemblance to modern day algorithms in the medical literature.

writing "whether it is right for us to say they are two, or three, or one matters nothing in this place." He stated that from a functional standpoint, the first 6 muscles matter the most, and that the only possible effect of the theoretical muscles is to cause proptosis: "these affect the whole eye, only outwardly … and the vision is unimpaired."[4] This error was even repeated by Vesalius (see Figure 5), who refuted many of Galen's mistakes when he compared his findings with actual human dissections. The absence of the retractor bulbi muscles was not demonstrated until later by the Italian Fallopia in the 16th century.

Optic Nerve Pathology

In Hunayn's sixth treatise *On the Latent Affections of the Eye*, he classified the pathology related to orbital nerve injuries into oculomotor disturbances and optic nerve affections. Oculomotor disturbances result in paralysis or spasm with the etiology originating either in the brain (sender of the power), motor nerve (transmitter), or muscle (receiver of the power). He wrote, "When one of the oculumotor muscles is paralyzed, the eye is turned to the opposite side."[8]

Hunayn's diagnostic thought process was based on a logical sequence similar to the decision-making trees or algorithms used in modern medical literature, which compensated for the lack of imaging and ocular examination technology (Figure 6). Optic nerve affections are either related to an optic nerve injury ("swelling, obstruction, compression or interruption of continuity") or to a brain lesion. Optic nerve injury is diagnosed when the vision is affected, but "there is no apparent changes of the eye," such as clouding of the cornea and the pupil. A history of head trauma can indicate optic nerve injury. Hunayn referenced the relative afferent pupillary defect well before the Scottish ophthalmologist Robert Marcus Gunn (1850–1909) when he wrote that "obstruction of the nerve" can be also diagnosed "if you shut one eye and observe whether the pupil of the other is dilated or not."[8] He also mentioned that blindness combined with "heaviness behind the orbit and in the head" points to a brain lesion.[8]

Hunayn also suspected vascular congestion as an etiology for "optic nerve swelling." He noticed that in such instances, the "veins of the forehead and temples might be thickened and swollen" and recommended "incisions of the temples and cataplasms." While the suggested treatment is currently not endorsed, his rationale is not far-fetched from the modern belief that venous obstruction can lead to increased intracranial pressure and papilledema (pseudotumor cerebri from venous sinus stenosis).[17,18]

SYRIAC BOOK OF MEDICINES AND LOCALIZATION OF NEUROLOGIC INJURIES

We have reviewed the *Syriac Book of Medicines* as translated by E. A. Wallis Budge, based on a manuscript written by an unknown Nestorian Syriac physician, which is dated to the 12th century.[4] The book includes a summary of anatomy, pathology, and therapeutics and is translated and revised from the works of famous Greek physicians, such as Hippocrates, Galen, and Dioskorides. It also includes localization of neurosurgical deficits (Table 1). While the book referenced the Alexandria School of Medicine and famous Greek scholars, it also contains medical prescriptions that mirror findings from the Ebers Papyrus in ancient Egypt and ancient Mesopotamian medicine.[19,20]

Epilepsy and Headaches

The unknown Syriac author described epilepsy or falling sickness as "a rigidity of all members of the body"; the author was also certain that its origin was in the brain. Syriac physicians were meticulous clinical observers and described the aura that precludes an epileptic attack including epigastric auras. For example, the text noted "There was a certain youth who was about thirteen years old … the beginning of the pain came to him from his leg, and from this point it proceeded directly upwards, through his thigh and through the epigastric region … towards the neck up to his head." Capitalizing on the works of Diaclos, the text further emphasized the importance of the sympathetic system, connecting the brain and the gastrointestinal system.

The author thought that headaches were either due to "membranes that surround the brain … or to … that membrane which is beneath the skin." The author also described migraine attacks, which involve "half the head" and were accompanied by nausea and vomiting. During these attacks, they describe how the patient "wishes to lie down in a quiet place and in the dark." The attacks are of episodic nature, which is described as

Table 1. Anatomic Localization of Neurologic Deficits Based on *The Syriac Book of Medicine**

Anatomic Location	Sign/Symptoms
Brain	Hemibody weakness and face
Brainstem	Hemibody weakness, face, cranial nerves
Cervical spinal cord	Face is spared, can be unilateral or bilateral
Above C4	Breathing is affected
Below C4	Breathing is preserved
Thoracic/lumbar	Upper extremities are spared
Cervical nerve root	Individual dermatome/myotome
Brachial plexus	Multiple dermatomes/myotomes

*This includes the first clinical depiction of diagnosing a brachial plexus injury in history.

"a middle period wherein they do not suffer pain."[4]

Head Trauma

When dealing with head injuries, the author stated that it was necessary to know "how the man has been struck and from what height," as these are prognostic factors to determine the seriousness of the injury. The text further described that "sometimes both the head and the brain within it are very violently shaken and then stupor and delirium supervene, and this is a very difficult illness for in the majority it brings on death." In cases of open skull fractures, the author recommends washing the wound with "warm wine and oil of roses" (alcohol has aseptic characteristics). "If the bone cannot be reunited" (comminuted fractures), the recommendation was to remove the fractured pieces, sew the skin with a "silk thread," and apply a dressing soaked with "wine and oil," which must be changed daily. Breathing function is a major prognostic factor of brain injury, especially in apoplexy (stroke). The author explained, for example, "for then those who are stricken down with apoplexy die because of the destruction of their power of breathing"[4] (inability to maintain their airway).

Spinal Injuries

Neurologic deficits were described to be more likely to happen in cases of acute deformities of the spine versus chronic changes of curvature. The author described "when the marrow does not become curved little by little in one of its parts, but suddenly, as for instance through some smashing blow, then all the lower members become injured of necessity; but if it becomes curved little by little, in a circular fashion (e.g., scoliosis), then no injury whatsoever takes place."[4] The spine can also be injured by "some fall, or through some blow, or through some unnatural swollen sore which contracts or loosens the ligaments that hold fast the vertebrae." The latter are referred to as "unopened abscesses." A long discussion on spinal infections follows, and the author stated that its alarming symptoms include abnormal breathing ("abundant, or sudden"), fever ("feel the breast"; "transient flushes"), tachycardia ("feel the arteries"), headaches ("fiery heat in the head"), and symptoms of hypovolemia ("intense thirst and dryness of the tongue"). The author stated that the signs of infection, combined with "weakness," point to an affection of the nerves, and thus the spine.[4] This description is one of the earliest references to spinal abscesses and spinal meningitis.

Localization of Neurologic Deficits

Syriac physicians built on Galen's writings to further develop a rationale to localize neurologic injury (see **Table 1**). Throughout the book, there are signs of a continued drive for accurate neurologic diagnosis based on both anatomic dissections and personal experience.

- "If therefore a man knows from the making of dissections the sources of the nerves which come to each one of the members, this man, I say, can cure successfully the want of feeling and the want of motion of each one of the members."

The anatomic description proceeds from cranial to caudal:

- "If the top of the spinal column is injured (brainstem and medulla), those members which are in the head" are affected ("eyes, skin of the cheeks, lips, root of the tongue").
- If the spinal column is affected, "all the members that are below, with the exception of the face, are without motion and without feeling."
- "If the face is also affected, it shows that the disease is also in the brain."
- If a vertebra is injured, "all those members which are below that vertebra become incapable of feeling and motionless."

While a unilateral injury causes ipsilateral deficits (Brown-Sequard syndrome), a complete spinal cord injury will affect both sides. The author described the case of a man who was paraplegic while his face was preserved. The patient "involuntarily voided urine and excrement"; however, "his power to breathe still existed." The author accurately localized the injury to the cervical spine below the fourth vertebra (below C_4).

The author included another report of man "who fell from a horse and hurt the upper part of his back and feeling was paralyzed in two of his fingers and the half of a third." This patient recovered in a few days, pointing to cervical radiculopathy. Elsewhere in the book, it is stated that the nerve roots may be injured in their foramina rather than the spinal cord itself: "when twisting arises in the neck, because the nerves go forth from the region that is between the two vertebrae, they are compressed," and "paralysis follows in those members into which the nerve on which there is pressure enters."

The author then listed the anatomic distribution of the cervical roots: "Feeling in the hands persists entirely, together with motion, in those in whom the fifth vertebra of the spinal column [C_5] is affected." C6 causes a minor injury to the

hands because "the front portions of the arm are preserved uninjured," while C7 causes further—but still partial—deficit. The author continued: "If the disease is in the eighth vertebra [T1], the sense of feeling is only slightly injured; and if the ninth vertebra [T2] is diseased, the sense of feeling in the hands is not injured in any way." The scheme appears to be partially correct, but inaccurate, with confusion among the C8, T1, and T2 nerve root distributions.

Other patients were described with lower spinal injuries "whose lower members, except the hands, were paralyzed through some fall." Other patients presented with cauda equina syndrome: "Behold a certain man who was once catching fish in a river, and he became so chilled in those parts of the body which are round about his anus and his bladder that he evacuated and made water involuntarily."[4]

First Historical Account of Brachial Plexus Palsy

The Syriac Book of Medicines reports the story of another patient whose "arm, both the front and the back, as far as the elbow, and also no small portion of the forearm, and the part which reached the top of his fingers, remained without feeling. His fingers were also slightly injured, and they could not move."[4] The author logically deduces that the symptoms do not correspond with a brain, spinal cord, an individual nerve root or peripheral nerve lesion, but rather correlates the clinical findings with a brachial plexus injury based on anatomic dissections: "Therefore, in the case of this man the nerves of the first and second muscles, and those between the ribs (anterior and middle scalene muscles) were injured, for from these comes the first part, which is of no small depth, and it is mixed with the part which is in front of it, and then it is also spread through many parts, which you see in dissections; for from these they come to the top of the fingers, within the inside of the arm." He claims that the man, "was cured when a suitable ligature was placed on the place where the nerves issue over the first and second muscle, which are between the ribs."[4]

DISCUSSION

Only by considering the crucial role of Syriac scholars in transmitting medical knowledge (including neurosurgical knowledge) between antiquity and the Middle Ages can an uninterrupted history be reconstructed from the ancient Greeks to Arab polymaths and later to the Latin Renaissance.[1] Without the efforts of Syriac translators between the 6th and 12th centuries, much of this ancient medical knowledge would have been lost. The Syriac scholars laid the foundations for an objective translation method that served the universality of science and its multicultural exchange, well before our modern day "international meetings and seminars."

Syriac scholars also made major contributions to the establishment of medical curricula in the Middle Ages and Renaissance with significant emphasis on clarity, logic, and education. Medical knowledge was translated, summarized, simplified, commented on, and criticized, allowing for future developments. Considering the translations of earlier Greek books, later incorporations into Arabic manuscripts, and loss of many original Syriac texts, it is difficult to discern the exact original works of Syriac scholars.

With Hunayn's particular interest in ophthalmology, his contribution to optic nerve anatomy and pathology is worth studying. Zain al-Din Gorgani is credited with the first descriptions of the optic chiasm and its role in vision.[16] However, Hunayn's account in the text, along with a functional analysis, appears to be a much earlier documentation of the structure and its function. His reference to the afferent pupillary reflex and its role in differentiating brain from optic nerve affections may be one of the earliest. Also, confirming Hunayn's statement, the optic nerve was demonstrated to be the most resilient nerve in a recent biomechanical study.[21] Furthermore, modern neurosurgeons agree with Hunayn that venous congestion can lead to increased intracranial pressure and papilledema.[17] Venous sinus stenosis has been suggested as a cause of pseudotumor cerebri and is increasingly treated with endovascular stents.[18] Hunayn's work is probably the first detailed documentation of such a neurosurgical entity.

The Syriac Book of Medicines demonstrates the authors' meticulous clinical observation, as evidenced with their detailed descriptions of epilepsy and "auras." The book may also include one of the earliest discussions of spinal infections and spinal meningitis in the medical literature. Their approach to traumatic brain injury was systematic and pragmatic with an aim to assess prognosis based on clinical findings and intervene to repair skull fractures when necessary, while preventing further harm and wound infections.

One can only imagine the difficulty in localizing neurologic injuries before the development of cranial and spinal imaging. Syriac physicians were meticulous clinicians, who continuously corroborated their findings with anatomic dissections and clinical experience. Given their notoriety, they must have examined a high volume of patients with neurologic deficits. It is thus not a surprise to note their diagnosis and treatment of one of the earliest cases of brachial plexus pathology. Earlier reports have been attributed to Homer[22]; however, these were purely descriptive and did not include anatomic attributions. Galen described the brachial plexus based on animal dissections (ox, pig, macaque).[23] It is traditionally accepted that the first clinical description of brachial plexus palsy had to wait for the English physician William Smellie in 1764 A.D.[24]

With continued analysis of Syriac manuscripts, further medical knowledge from antiquity and the Middle Ages will be uncovered. Such texts can be compared against Greek, Arabic, and Latin passages to further analyze the scientific exchange process and the contribution of each culture. The Syriac Christian scholars, working for Muslim Arab Caliphs to translate Greek "Pagan" books, illustrated the spirit of universal science: one that favors cooperation over competition, dialogue over conflict.

CONCLUSION

The Syriac scholars greatly contributed to the knowledge that led to the development of neurosurgery, both by translating

ancient Greek texts, and with their own original observations. They promulgated medicine as a science based on anatomic dissections, clinical experience, and scientific knowledge summarized and interpreted from their predecessors. Their original work on an objective scientific translation method, orbital anatomy, optic nerve pathology, spinal infections, localization of neurologic injuries, and brachial plexus pathology illustrated their pivotal importance in the evolution of neurologic surgery.

ACKNOWLEDGMENTS

The authors would like to thank Ashlinn de Schonen for her professional work on the figures and digital art.

REFERENCES

1. Angeletti LR. Transmission of classical medical texts through languages of the Middle-East. *Med Secoli*. 1990;2:293-329.
2. Alghamdi MA, Ziermann JM, Diogo R. An untold story: the important contributions of Muslim scholars for the understanding of human anatomy. *Anat Rec (Hoboken)*. 2017;300:986-1008.
3. Kessel G. A Syriac medical Kunnāšā of Īšō' bar 'Alī (9th c.): first soundings. *Intellect Hist Islam World*. 2017;5:228-251.
4. Budge EAW. *Syrian anatomy, pathology and therapeutics, or "The Book of Medicines". The Syriac text, edited from a rare manuscript, with an English translation*. London, England: Oxford University Press; 1913.
5. Vagelpohl U. The user-friendly Galen: Ḥunayn ibn Isḥāq and the adaptation of Greek medicine for a new audience. In: Bouras-Vallianatos P, Xenophontos S, eds. *Greek medical literature and its readers: from Hippocrates to Islam and Byzantium*. Oxon (UK): Routledge; 2018.
6. Habbi J. Le role de Hunayn, medecin et traducteur [The role of Hunayn, physician and translator]. *Med Secoli*. 1994;6:293-308.
7. Dalfardi B, Daneshfard B, Nezhad GS. Johannitius (809-873 AD), a medieval physician, translator and author. *J Med Biogr*. 2016;24:328-330.
8. Meyerhof M. *The book of the ten treatises on the eye ascribed to Hunain Ibn Is-Haq. Translated from Arabic Manuscripts*. Cairo, Egypt: Government Press; 1928.
9. Missios S. Hippocrates, Galen, and the uses of trepanation in the ancient classical world. *Neurosurg Focus*. 2007;23:E11.
10. Missios S, Bekelis K, Roberts DW. Neurosurgery in the Byzantine Empire: the contributions of Paul of Aegina (625-690 AD). *J Neurosurg*. 2014;120:244-249.
11. Grunert P, Charalampaki P, Ayyad A. Concept and treatment of hydrocephalus in the Greco-Roman and early Arabic medicine. *Minim Invasive Neurosurg*. 2007;50:253-264.
12. Silver J. History of cervical spine surgery: from nihilism to advanced reconstructive surgery. *Spinal Cord*. 2014;52:339.
13. Sarrafzadeh AS, Sarafian N, von Gladiss A, Unterberg AW, Lanksch WR. Ibn Sina (Avicenna). Historical note. *Neurosurg Focus*. 2001;11:E5.
14. Unal N, Elcioglu O. Anatomy of the eye from the view of Ibn Al-Haitham (965-1039). The founder of modern optics. *Saudi Med J*. 2009;30:323-328.
15. Hirschberg J. *Geschichte der Augenheilkunde. In: Graefe-Saemisch, Handbuch der gesammten Augenheilkunde*. 13. Leipzig, Germany: Springer; 1908:1-282.
16. Davis MC, Griessenauer CJ, Bosmia AN, Shane TR, Shoja MM. The naming of the cranial nerves: a historical review. *Clin Anat*. 2014;27:14-19.
17. Horton JC, Seiff SR, Pitts LH, Weinstein PR, Rosenblum ML, Hoyt WF. Decompression of the optic nerve sheath for vision-threatening papilledema caused by dural sinus occlusion. *Neurosurgery*. 1992;31:203-211.
18. Arac A, Lee M, Steinberg GK, Marcellus M, Marks MP. Efficacy of endovascular stenting in dural venous sinus stenosis for the treatment of idiopathic intracranial hypertension. *Neurosurg Focus*. 2009;27:E14.
19. Bhayro S. The reception of Galen's Art of Medicine in the Syriac Book of Medicines. In: Barbara Zipser, ed. *Medical Books in the Byzantine World*. Bologna, Italy: Dipartimento di Filologia Classica e Medioevale; 2013:123-144.
20. Bhayro S, Rudolf SM. *Budge's Syriac book of medicines after one hundred years: problems and prospects. In: Mesopotamian Medicine and Magic*. London, England: Brill; 2018:116-130.
21. Tubbs RS, Wellons JC 3rd, Blount JP, Salter EG, Oakes WJ. Forces necessary for the disruption of the cisternal segments of cranial nerves II through XII. *Clin Anat*. 2007;20:252-255.
22. Aydn A, Tümerdem B, Yazar M, Erer M. Three-thousand-year-old written reference to a description of what might be the earliest brachial plexus injuries in the Iliad of Homer. *Plast Reconstr Surg*. 2004;114:1352-1353.
23. Swanson LW. Neuroanatomical terminology: a lexicon of classical origins and historical foundations. London, England: Oxford University Press; 2015.
24. Robotti E, Longhi P, Verna G, Bocchiotti G. Brachial plexus surgery. An historical perspective. *Hand Clin*. 1995;11:517-533.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 28 April 2021; accepted 7 June 2021

Citation: World Neurosurg. (2021) 152:71-79.
https://doi.org/10.1016/j.wneu.2021.06.024

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***

1878-8750/$ - see front matter