History of Medicine

The Structure and Function of the Central Nervous System and Sense Organs in the Canon of Medicine by Avicenna

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Abstract

Ibn Sina (1037 AD), also known as Avicenna in the West, is recognized as one of the forefathers of modern medicine. He was widely accepted as an influential and leading scientific figure of the medieval ages. His book the "Canon of Medicine" collected all aspects of medical knowledge available from ancient Greek and Muslim sources and also added his own. The medical information he collected ranged from basic medical sciences to applied and specialized medical fields.

In the current vignette, we present an analysis of the basic anatomy of the brain, spinal cord and some sense organs as presented in the Canon of medicine and compare their relevance in modern medical practice and human anatomy knowledge.

Keywords: Avicenna, brain, ear, eye, nervous system, spinal cord

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Avicenna, Arabic Ibn Sīnā, in full Abū ʿAlī al-Ḥusayn ibn ʿAbd Allāh ibn Sīnā, was born in 980 near Bukhara, Iran (now in Uzbekistan) and died in 1037 in Hamadan, Iran. Avicenna also known as Ibn Sina, recognized as one of the founders of modern medicine (Figure 1),[1] was well versed in intracranial anatomy and expanded on the Galenic knowledge of the fundamental structure of the brain and its functions. It was he who recognized physiological psychology for the treatment of emotions. He also pioneered the psychosomatic medicine by associating changes in the pulse rate with inner feelings. According to Syed,[2] the psychosomatic practices encompassed the idea of associating words and names to experiences. Based on this principle, Avicenna was the first to diagnose love sickness (*Ishq*) when he treated patients by feeling their pulse and reciting aloud the names of familiar places and names of people.[2] He noticed the changes in pulse and decided that the patient was in love with a girl whose home Avicenna had located. Ibn Sina also noticed the association between physical and psychological illnesses in his description of the melancholia (depression) as type of a mood disorder associated with fears. With these and a lot other conditions, Ibn Sina associated psychological conditions with changes in the temperament of the brain.

The *temperamental theory* is derived from Greek philosophers who hypothesized that everything in the universe is created from four primary elements with corresponding qualities: fire (hot and dry), air (hot and moist), water (cold and moist), and earth (cold and dry). Depending on the ratio of the four primary elements that make up an entity, the opposing qualities in the entity will reach a state of equilibrium resulting in an overall *quality*. This overall quality is known as *temperament.* Every part of creation is it mineral, plant or animal has an overall temperament. In the human being, the concept of temperament extends from cells to tissues to organs and finally to each individual having a unique temperament. The concept of temperament in understanding anatomy is critical within the context of the relationship between temperament, structure and function, where changes to either the temperament or structure will negatively affect the function/s of anatomical structures. Ibn Sina describes the temperament of the brain as cold and wet (moist), where the quality of cold allows for the brain to work as hard as it does and the quality of moistness is to prevent dryness in the large number of functions that takes place within the brain.[3,4]

Being a respected physician, Ibn Sina recommended other physicians to take cognisance of the temperament of an organ in relation to its structure and function.[4] In the current treaties, we examine Ibn Sina's contribution to the anatomy and function of the brain and its associated sense organs as described in the Cannon of Medicine.

In the current treatise, we present a critique on the anatomy of the central nervous system, sense organs and their functions as viewed by Ibn Sina in his book, the Canon of Medicine. On the anatomy of the brain, Ibn Sina noted that the brain consisted of the frontal, middle and rear parts.[5,6] This description complements the division of the brain during early embryonic stages into prosencephalon, mesencephalon and rombencephalon. Ibn Sina also described the separation of the cerebrum into hemispheres. He further stated that the "separation of the frontal lobes is more prominent than any other parts".[5] The cerebral hemispheres are separated by a longitudinal fissure into left and right halves. The fissure is wider in front between the two frontal lobes and posteriorly between the occipital lobes. Ibn Sina ascribed the frontal part of the brain to important and strong sensations.[3,5] The frontal lobe in the prosencephalon part of the brain has centers for speech in the inferior frontal gyrus and the prefrontal lobe has cognitive functions of higher order which include intellectual, judgemental, initiative or predictive faculties and the planning of

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Figure 1. A portrait of three medieval teachers of medicine: Galen, Avicenna and Hippocrates

Figure 2. The *rete mirabile* according to Vesalius; **A)** and Galen; **B)** Adopted from Lo and Ellis.[12]

behaviour.[10] The mesencephalon and rhombencephalon contains specialized centers, for example the reticular formation and respiratory centers.[7]

On the brain matter, Ibn Sina expanded on the views of Galen and divided it into the outer cortex and inner medulla.[5,9] This corroborates modern descriptions in neuroanatomy textbooks were the cortex is the outer gray-colored layer composed of neuronal cell bodies whereas the medulla is the inner white matter composed of nerve fibre bundles.[10] Avicenna considered that the spinal cord is a continuation of the brain posteriorly, and he described it as a "broad stream which flows smoothly out of the bubbling source of the brain".[5,11] In addition Ibn Sina stated that the "spinal cord is hard in nature and it is a representative of the brain which originates from its back extending from the brain stem and exits the skull through a large hole".[3,5] In agreement with Ibn Sina' assertions, the spinal cord extends caudally from the medulla oblongata (part of brain stem) and exits the cranial cavity through the foramen magnum.[10] After the foramen magnum, the spinal cord is protected in the vertebral canal of the vertebral column. Avicenna also noted this location of the spinal cord and suggested that the vertebral column offers protection to it.[3,5] To further support the partitioning of the brain into the anterior sensory part and the posterior motor part, Ibn Sina noted that the front portion of the brain gives vital sensory nerves, the optic and olfactory nerves and the posterior part together with spinal cord give off motor nerves.[3,5,12] Ibn Sina proposed that the spinal cord brings closer the nerves to the recipient organs to avoid damage to them and to improve the function since impulses have to travel short distances from the central nervous system to effecter organs as in the case of reflexes.[3,5] Avicenna described the separation of motor and sensory nerves by a membrane as they exit or enter the spinal cord. [5] This description is accurate as the motor nerves exit the spinal cord anteriorly and the sensory nerves and their ganglia enter from the posterior aspect in humans.[10] On the structure of the nerves, Ibn Sina noted that they were surrounded by a fatty substance which provides nutrition.[4,5] The fatty substance alluded to by Avicenna is the myelin sheath which not only cushions the nerve fibers but also helps functionally by increasing the speed of impulse conduction through salutatory conduction.[10]

On the covering matter of the brain, Ibn Sina noted that the brain is covered by thin and thick membranes, the thin membrane being closer to the brain and the thick membrane furthest from the brain and in closer association with the skull.[3,5,12] The brain has two major coverings/ meninges; the dura matter (thick) and

the letpomeninges (thin) i.e. the arachnoid and pia matter.[10] The dura matter forms the tough and thick outer covering of the brain and is attached to the skull though septa at certain points for example the crista galli in front and the clinoid process inferiorly and through short ligaments to skull bones and their sutures.[10] The thin letpomeninges consist of two layers, the pia matter which is closely applied to the brain matter and the arachnoid matter with the subarachnoid space between them. Concurrent with Aviccena, the dura matter sends septa which divide the brain; for example, falx cerebri, tentorium cerebelli, and falx cerebelli. These septa help to limit the movement of the brain in the cranial cavity and hence protect the delicate brain matter and cranial nerves. The most intriguing observation made by Ibn Sina on this section is that of the close association between the thin matter (leptomeninges) and blood vessels as they penetrate the brain substance.[3,5] Functionally, the pia matter forms a covering of the blood vessels reinforcing the blood brain barrier, which helps to prevent entrance of noxious substances into the brain. Ibn Sina was the pioneer physician to describe meningitis as a disease.[4,11] After he developed a headache due to long hours of studying, he explained the origin of the headache as pain from the membranes covering the brain. Avicenna recommended cooling the head with large amount of ice as treatment to the pain. In line with temperament theory, the brain has a cold and moist temperament[3,4] and to achieve normalcy after disease or reduce pain any intervention has to work towards restoring its ideal temperament.

On brain cavities, Ibn Sina used the term ventricles to describe them and the term is still widely used in modern anatomy. He categorized the brain ventricles as two frontal ventricles, one posterior connected by the middle one.[3,5] This description of brain ventricles is entirely correct; the human brain, similar to that of all mammals, has two large lateral ventricles in the cerebral hemispheres which communicate with the third (middle) ventricle through the interventricular foramen of Monro. The third ventricle subsequently communicates with the fourth ventricle through the cerebral aqueduct. The fourth ventricle has outlet channels to the subarachnoid space in its roof, namely two lateral apertures, foramen of Luschka and the median single aperture, the foramen of Magendie. Functionally, Ibn Sina ascribed the function of the two front ventricles as that of emitting waste through sneezing, association with sense of smell, distribution of sensations and reaction of imaginations.[5] He associated the middle ventricle with the function of connecting imagination and memory.[5] Contrary to these opinions, the brain ventricles accumulates the cerebrospinal fluid which is secreted by the choroid plexus and this fluid helps to collect and remove metabolic waste substances, offers buoyancy (protection) to the brain among other functions.[10]

Related to the third (middle) ventricle in its roof, Ibn Sina identified a worm like structure, which he described as being similar to a human buttock.[5] These descriptions by Avicenna befit those of the caudate nucleus with its head, body and tail stretching from the frontal lobe to the temporal lobe of the cerebral hemisphere. Ibn Sina also described the inferior communication of the third ventricle with the infundibulum leading to the pituitary gland.

Regarding the sense of smell, Avicenna stated that, "there are two bulging things that look like pacifiers that originate in the front of the brain. They are the source of smell".[5] Accordingly, the sense of smell originates from the olfactory receptor cells in the roof of the nasal cavity and reaches the olfactory bulbs at the base of the frontal lobe through the olfactory nerve. The sensation hence distributes to the olfactory cortices through the olfactory tract.[10] Ibn Sina also described in detail the trajectory of the optic fibers from the eyes. He stated that visual information from each of the optic nerve crosses at the level of the chiasm to be conveyed to the contralateral lateral ventricle.[5,6] The arrangement allowed for superimposition of the visual stimuli provided by each eye into a single image. To this, he opined that the middle and posterior ventricles serve as unification chambers.[5] The optic chiasm is recognized in modern anatomy as a point where partial decussation of the fibers from the two visual eye fields takes place. On the sense of hearing, Ibn Sina correctly described the ear drum as a tiny membrane which responds to sound vibrations.[3,5]

Lastly, Avicenna described the blood supply to the brain, of which he noticed that two large vessels from the heart carry blood to the brain. He stated that "the placenta-like object under the brain is woven from these branches. There is a mass that is of the quality of glands in the middle of these branches of vessels".[5] This notion was in accordance with observations made by Galen who described the arterial pattern as the "*rete mirabile*".[13] According to Viale,[14] Ibn Sina described the location and function of the *rete mirabile* according to the Galenic dogma: the *rete* is situated "underneath the brain, close to the basal bone and between the dura matter and the bone and the animal spirit needs this '*rete mirabile*' in order to spring everywhere, namely within the cerebral arteries" (Figure 2). Later on, Thomas Willis (1621 – 1675) refined the description of cerebral arteries at the base of the brain and the structure is now known as the Circle of Willis.[10] The circle of Willis is a system of anastomotic arteries that help to distribute the pressure of blood between the carotid and vertebral artery systems and ensure adequate and continuous blood supply to the brain in case one systems fails. In accordance with the temperamental and humoral theory by Ibn Sina, the blood from the heart is hot and moist and the brain is cold and moist, the circle of Willis together with middle ventricles will help with maturation of the blood from the heart to suit the temperament of the brain.[3,4]

In conclusion, despite a prohibition on the dissections of human cadavers during his time in the Islamic world, Avicenna's treaties of 1000 years ago on the anatomy of the central nervous system and senses were fairly accurate, relevant and informative in modern days. They have to a large extent influenced the development and advancement of neurosurgery and neurosciences.

Conflict of interest: *None.*

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