

Review article:

A critique on Avicenna's (980 – 1037 A.D) studies on anatomy of the upper respiratory system and some otorhinolaryngologic concepts

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Abstract

Background: Avicenna (also known as Ibn Sina) was arguably one of the outstanding medical scientists and physicians of the time. He made significant contributions in the development of various medical fields in the golden age of Islamic medicine (9-12th century AD) and in Europe. Ibn Sina contributed immensely to human anatomy, physiology, pathology and management of most disorders of the human body. Of paramount importance was the systemic description of the anatomy of various organs and surgical interventions associated with the problems. Although neither formal dissection nor surgical training was recorded during his time, the anatomic and surgical information presented in the Canon of Medicine is congruent with modern advancement. The current study was undertaken to compare Avicenna's anatomy of the ear, nose, oral cavity, throat and larynx to modern anatomical texts. **Methods:** The current work analysed the anatomy information on the ear, nose, oral cavity, throat and the larynx as presented in volumes one and three of the Canon of Medicine. The information was compared to modern anatomic descriptions. **Results:** Avicenna described correctly the anatomy and functions of the external and internal ear, nose, oral cavity, parts of the throat and larynx. He described voice production in the larynx and subsequent contributions on the nose, uvula and tongue in shaping the syllables. The functional aspects, disorders and their management associated with the ear and the upper respiratory system were also described. **Conclusions:** The findings show that Ibn Sina's contributions had a major influence on the development and advancement of medical practise. His anatomic explanations are comparable to modern knowledge on the subject. They also show that the Canon of Medicine is still a valuable book in the study of the history of medicine.

Keywords: ear; nose, throat; pharynx, larynx; speech; uvula; uvulectomy; tracheotomy; Avicenna; anatomy; oral cavity

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Introduction

Avicenna contributed immensely to the growth and development of medical sciences in his time. His anatomy information derived essentially from Galen, Hippocrates and Roman sources¹. Ibn Sina collected the available information and compiled his famous book, the Canon of Medicine. The book is rich with the author's contributions on the anatomy, pathology and treatments of various disorders of the

body systems. The Canon of Medicine was the main reference text in European medical schools and as well as in the Islamic world until the 16th century². The book also influenced the basis for *Unani* (Greek) medicine, a form of traditional medicine still taught and practised in India and Pakistan³. Avicenna emphasised on holistic treatment and examination approaches to his patients⁴. He relied on the history, physical examination, signs and symptoms, diet

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and life style, environmental factors and individual temperament of the patients in the diagnosis, treatment and prevention of diseases⁴. Ibn Sina described systematically the anatomy of the human body in Volumes One and Three of the Canon of Medicine followed by the associated disorders and their management in other volumes. His anatomy knowledge is to a large extent comparable to modern anatomy although dissection of the human bodies was forbidden in his time⁵.

This study was intended to draw comparisons between Avicenna's descriptions in the Canon of Medicine on the anatomy and functions of otorhinolaryngologic components and the vocal tract to modern anatomic advances. The paper also explores some common disorders and management of the ear, nose, oral cavity, throat and larynx during Ibn Sina's time and infer on their relevance in current medical care and training. In addition the paper includes information on the maintenance of temperament of the different anatomical structures, described in terms of qualities of heat, coldness, moistness and dryness. Ibn Sina opines that every organ has an ideal temperament for optimum functioning⁶.

Materials and methods

This systematic review is a critique of the treatises obtained from the Canon of Medicine written by Ibn Sina and interpreted by⁶. The review focuses on the anatomy of the ear, nose, oral cavity, throat and larynx. This information was analysed for accuracy and relevance, and then compared with modern anatomical literature. In addition the work also analysed the functions, disorders and their management associated with this region of the body.

Results and discussion

Ear

The structural and functional components of the ear as an organ of hearing were presented systematically in the Canon of Medicine. Ibn Sina described and named the pinna of the ear as a funnel shaped structure on both sides of the head which helps to collect and channel airwaves into the external auditory canal⁵.⁶ According to Ibn Sina the external auditory canal channels the sound onto the tympanic membrane which will vibrate each time sound hits its surface⁶. In addition to the pinna, external auditory canal and tympanic membrane Avicenna identified the spiral-shaped cochlea to which he ascribed the function of collecting the sound and giving it an echo⁶. The cochlea forms part of the inner ear together with the semicircular canals and there are housed in the petrous

part of the temporal bone^{6,7}. Ibn Sina attributed the spiral shape of the cochlea to distance the sound waves have to travel such that cold air and the heat of the head had to mix gradually⁶. Concurrent with modern anatomic descriptions on the function of cochlea, Avicenna opined that the cochlea interprets the sound and a cranial nerve carries the sensation into the hindbrain⁶. According to Moore et al. the cochlea is involved in signal transduction, converting the mechanical stimuli from the endolymph into sensory stimuli which is conveyed by the cochlea nerve into the brain stem⁷. Ibn Sina's descriptions on the ear are not entirely congruent with modern anatomy. Ibn Sina's description of the ear did not include the middle ear and its ossicles. According to Avicenna the inner ear consisted of only the cochlea and semicircular canals omitting other components of the vestibulocochlear system such as the utricle and saccule. In addition Avicenna named the nerve to the cochlea as the sixth pair of cranial nerves, whereas the cochlea is innervated by the cochlea division of the vestibulocochlear nerve an eighth cranial nerve⁷. Apart from the anatomy of the ear and its function, Ibn Sina described explicitly a range of ear disorders, their symptoms and treatments⁸. Some of the ear disorders mentioned in the Canon of Medicine includes otalgia, ear tinnitus, ear infection and ulcer, ear bleeding, ear wax, ear fullness, ear trauma, insects in the ear canal and their removal and also the dangerous effects of sudden loud sounds on the eardrum^{6,8}. Avicenna also classified hearing loss as either acquired or congenital⁸. In accordance with the temperament theory, Ibn Sina advised physicians that the temperature of the ear drops applied to the ear canal should be moderate or warm^{5,6,8}.

Nose

Ibn Sina described the anatomy of the nose including its external and internal bones, cartilages and muscles accurately suggesting he may have seen or carried out dissection³. According to Ibn Sina the external nasal skeleton is formed by two triangular bones which are wide apart at their bases and joined at their apices⁶. In modern anatomy these two bones represent the two frontal processes of the maxilla which are joined together at the apices by the articulation with the nasal bones⁷. Avicenna also identified that the external nose was made up of both bone and cartilaginous skeletons, with cartilaginous part making the lower margins or tip of the nose⁶. In addition he noticed that the nasal cavity was divided into two chambers by the vertically placed nasal septum⁶. Avicenna described the nasal septum correctly stating that it has got a

hard bony part above and the soft cartilaginous part below⁶. According to Moore et al. the nasal septum consists of perpendicular plate of the ethmoid and the vomer which makes up its bony posterior part and the septal cartilage in front which articulates with the edges of the bony septum⁷. Regarding the muscles of the nose, Ibn Sina identified that the external nose had two small but strong muscles on both sides of the nostrils which strengthen the cartilaginous part of the nose and also assist with nasal opening⁶. These two muscles are the nasalis and levator labii superioris alaeque nasi which participate in dilating the nasal apertures for example during flaring and facial expression of anger or disgust⁷. Avicenna also identified a communication channel between the tearing end of the eye and the oral cavity through the nasal cavity, to prove the patency of the channel he stated that “when you apply collyrium to the eye, you can taste it on the tongue”⁶. According to Moore et al. the nasolacrimal duct drains tears from the lacrimal sac into the anterior end of the inferior nasal meatus and the nasal cavities communicate posteriorly with oropharynx⁷. Avicenna described the important functions of the nose which include smell, humidification of air, respiration, excretion of waste substances and speech⁶. On the sense of smell, he noted that it was one of the five external senses of the human body and noticed that perception was done by the two nipple-like structures located in front of the brain, and above the nasal apertures⁶. In modern anatomic descriptions, these structures are the olfactory bulbs located above the cribriform plate of the ethmoid bone on the under surface of the frontal lobes of the brain and they are involved in initial processing of the olfactory sense^{7,9}. In agreement with the theory of temperament, Ibn Sina opined that the nasal passages facilitate exchange of temperature between the brain and the external environment allowing the brain to maintain its natural heat⁶.

Ibn Sina also described accurately the function of the nose in speech production. He stated that “the nose helps in the proper intonation of voice and utterance of syllables. Thus, it prevents the collection of too much air in the voice organs and during phonation, it releases the air in a regulated manner as from the holes of a flute”⁶. Clinically, Ibn Sina described in detail the administration of various drugs through the nose which include dry and powdered snuffing drugs and liquid drugs which can be gargled^{6,8}. He also described disorders of the nose and their causes^{4,8}. He gave a description of disturbances of olfaction identifying two varieties that is first, obstructive due

to blockage of nasal passages and secondly, due to brain injury^{3,4,6}. Avicenna associated nasal polyps to haemorrhoids and advised on their surgical ligation³. Additional nasal disorders recorded in the Canon of Medicine include nose bleeding and its management, rhinorrhoea, flu, ulceration, infection, bone fracture, itching, allergies, snoring and sneezing^{3,4,6}.

Mouth, tongue and teeth

Ibn Sina suggested that the mouth was associated with various functions which included taking and directing food into the alimentary canal, air into the upper part of the respiratory system, and prevention of entry and removal of waste from the stomach⁶. The oral cavity was also identified as part of the speech apparatus through which a person speaks⁶. Avicenna noted that the oral cavity contained tongue, teeth and associated gums. Insignificant variations exist between Ibn Sina’s writings and modern anatomy texts on description of the mouth. According to Moore et al. the mouth/oral cavity is divided into the oral vestibule (a slit-like space between the teeth and gingivae and the lips and cheeks) and the oral cavity proper (a space between the maxillary and mandibular dental arches and the teeth they bear)⁷. Concurring with Avicenna, the tongue forms part of the oral cavity proper and the oropharynx⁷. On the structure of the tongue, Ibn Sina discerned that the tongue is a muscular organ covered by a well vascularised mucus membrane⁷. On the under/ventral surface of the tongue Avicenna identified the orifices of the ducts of the submandibular gland and described appropriately the source of saliva from the glandular tissue which he named “saliva producer” and the function of the saliva in maintaining moisture of the oral cavity^{6,7}. Ibn Sina also identified the deep lingual veins as green-coloured vessels on the under/ventral surface of the tongue⁶. Avicenna postulated that the tongue consisted of both intrinsic and extrinsic muscles which were responsible for various tongue movements. Ibn Sina attempted to classify the tongue musculature according to their origin on the styloid process, hyoid bone and mandible. From his descriptions, the following pairs of muscles can be construed: styloglossus, genioglossus, hyoglossus and imprecisely the intrinsic musculature¹⁰. Avicenna stated that the tongue is supplied by four different types of nerves more than any other organ of its size in body⁶. Concurring with Avicenna the tongue is innervated by different types of nerves namely: motor, special (taste), visceral (parasympathetic secretomotor) and general (pain and temperature) sensation^{7,9}. In addition four major nerves also supply

the tongue and these include the lingual nerve, facial nerve, glossopharyngeal nerve and vagus nerve ^{7,9}.

Functionally Avicenna noted that the tongue was involved in feeding/suckling, articulation of sounds and syllables, and in distinguishing various tastes ⁶. Avicenna highlighted on the structure, size, shape and movement of the tongue in the production of speech. He further described tongue deformities associated with speech abnormality, such as a very thick and flat or very small and compressed tongue ⁶. He also pointed out the tongue tie (ankyloglossia) deformity as a condition caused by an abnormally short lingual frenulum and he suggested on surgical ligation of the lingual frenulum to allow for mobility of the tongue but the surgeon had to avoid damage to the blood vessels under the tongue ⁸. In addition Avicenna described other tongue disorders such as loss of taste, ranula, fissured tongue, macroglossia and tongue fasciculation and also their treatment ^{6,8}.

Avicenna gave a detailed account of the teeth encompassing their structure, number, bony attachments, innervation, function and diseases. He pointed out that adult humans have a set of 32 teeth lodged in tooth sockets in both upper and lower jaws ⁶. Consistent with modern anatomy, Ibn Sina classified teeth into incisor, canines and molars, and associated them with functions of cutting, biting and grinding respectively ^{6,7,9}. He confirmed that sometimes individuals before adulthood have a set of 28 teeth lacking the four wisdom teeth which only erupt at around 30 years ^{6,7}. Ibn Sina described accurately the different structures of teeth stating that the incisors and canine have a single root and crown with a single tubercle/ cusp and the molars have two roots and more than one cusp ⁶. In addition Avicenna described the attachment of the roots of the teeth in the tooth sockets by strong fibrous ligaments. These ligaments are referred to as the periodontal ligaments and they help to firmly support teeth in their sockets and facilitate teeth grasp and grind hard substances. Following on Galen's opinion, Ibn Sina confirmed by observation that teeth are innervated by nerves, and the nerves are sensitive to pain, temperature ⁶. In both the upper and lower jaws teeth are innervated by sensory nerves through the superior alveolar nerve and inferior alveolar nerve respectively making teeth sensitive to pain and temperature ⁷. Ibn Sina described tooth ache as a disease emanating from the tooth itself and sometimes from the damage to nerves or gingivitis ^{6,11}.

Pharynx

Ibn Sina described the pharynx as a space/ passage

for both food and breath. He noted that the pharynx has additional parts such as the uvula, epiglottis and tonsils ⁶. According to Moore et al. the pharynx is divided into nasopharynx, oropharynx and laryngopharynx⁷. The nasopharynx is involved in respiration and speech modulation while the oropharynx and laryngopharynx participate mainly in swallowing^{7,12}. In accordance with modern anatomic texts, Ibn Sina described accurately the topography of the palatine tonsils in between the palatoglossal and salpingopharyngeal folds^{6,7}. Furthermore, Avicenna described lingual tonsils on the posterior third of the tongue ⁶. He described tonsillitis and a surgical technique for tonsillectomy. Ibn Sina suggested the prone position of the patient during and after surgery to avoid aspiration. He also advised on the foreign bodies in pharynx such as bone fragments and ingested leech and their management.

Ibn Sina's descriptions of the structure of the uvula and its functional implications were to a large extent congruent with modern anatomy and debate. The uvula is suspended on the posterior free edge of the soft palate ⁷. According to Avicenna, the uvula is made up of muscle covered by a membrane and its functions include protecting the respiratory system by preventing entrance of smoke and dust particles, warming the inspired air by gradually opening the oropharynx, and also shaping of the voice during speech ⁶. He cautioned that cutting the uvula will compromise the voice quality. Dating back from the ancient times up to the present day, many hypotheses have been suggested as regarding the functions and the conditions associated with the uvula. In ancient times, Galen (122-199AD) believed that the uvula was important in speech production and also contributed to the beauty of the voice¹³. In modern times, the uvula has been associated with speech in maintaining the quality of voice by controlling resonance of the air column above the larynx ^{14,15}. The uvula was also attributed to many functions such as swallowing ¹⁶; protection of the Eustachian tubes ¹⁷ and immunological protection of the respiratory system ¹⁸. Mukai et al. opined that the uvula helps in eating and swallowing of hot foods, as after uvulectomy patients often burn their throats even after sensing that the food was not hot by their mouth¹⁹. Finklestein et al. suggested that the uvula has the capacity to produce large quantities of saliva and its main function is lubrication of the pharynx²⁰. The uvula has been associated with many disease conditions and hence uvulectomy is still practised in both western and traditional medical practises. In the

4th century BC Aristotle and Hippocrates referred to the uvula as a source of inflammation and oedema capable of causing suffocation¹³. Descriptions of uvulectomy have been found in Greek texts of Byzantine physicians (324-1453 AD)²¹. Various conditions have been attributed to uvula till today, and these include coughing, inflammation, insomnia, risk of suffocation, obstructive sleep apnoea^{22, 23}. Traditional uvulectomy is still widely practiced in the Middle East and Africa for various reasons²⁴⁻²⁶. Some of the reasons for uvulectomy include: curative of symptoms of vomiting, diarrhoea, anorexia, rejection of the mothers' breast, growth retardation and fever^{21, 25, 27, 28} and prophylactic to prevent throat infections, cough and loss of voice²⁹⁻³¹.

Larynx

Ibn sina described the larynx as a structure designed for voice production and obstruction of breath⁶. He deduced these functions based on the movements permitted by the musculoskeletal components of the larynx. Avicenna stated that the larynx is made up of three cartilages⁶. On the contrary the larynx is made of nine cartilages, which are connected by joints, membranes, ligaments and muscles^{7, 9}. From descriptions of the three cartilages in Canon of Medicine, Avicenna described correctly the structure, location and articulations of the thyroid, cricoid and epiglottic cartilages. On the thyroid, he noticed that it was located in front of the neck acting as a shield and can be palpated in thin individuals⁶. In modern anatomy, the thyroid cartilage is described as a prominent and palpable convex structure below the hyoid bone^{7, 9}. Avicenna described the second cartilage as the one lying behind the thyroid cartilage, without giving its name. He further stated that the second cartilage articulated inferiorly with the first on both right and left joints⁶. The joint between the inferior cornu of the thyroid and the cricoid cartilage is classified as a synovial hinge joint which permits a wide range of movement beneficial during voice production³². Ibn sina's explanations on the third cartilage suit the modern descriptions of the epiglottis. He stated that the cartilage was separated

from the thyroid cartilage and its shape was like an inverted bowl⁶. His descriptions were correct to an extent, because the wider portion of the epiglottis is free and only its narrow part is attached to the postero-superior aspect of the thyroid cartilage⁷. Ibn Sin's description of the laryngeal cartilages was to some extent erroneous, because in some sections in his book he talks of the arytenoids cartilages instead of the cricoid cartilage. On the muscles of the larynx, Avicenna described concisely their origin, insertion and functions without naming them. It can be construed that the muscles he described are the thyrohyoid, sternothyroid, cricothyroid, oblique arytenoid and posterior arytenoid^{7, 10}. Ibn Sina noted the importance of laryngeal muscles in opening and closing the larynx during swallowing and also the anterior and posterior widening of the larynx during voice production⁶. He noticed that voice production could be affected by damage to the nerve which innervates muscles of the larynx during surgery⁴. Furthermore, Avicenna put forward other factors which might cause voice defects, such as simple illness with or without sputum, presence of sputum in the larynx, inflammation and trauma to the neck⁴. Avicenna described tracheotomy and a method for cleaning upper airways secretions for the treatment of respiratory distress³³.

Conclusions

The information presented in the discussion shows the importance of Avicenna's pioneering work on otorhinolaryngologic concepts during medieval age and how they have influenced and revolutionised modern medical care and training. The discussion also focused on speech production and its disorders. Avicenna's explanations on the anatomy topics discussed are to a large extent comparable to modern knowledge.

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