A brief review of the abdominal viscera and the digestive system from the Canon of Medicine

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Introduction

Ibn Sina, known as Avicenna in Europe (980-1037 A.D) was the most influential Iranian physician and philosopher (Emtiazy et al. 2013; Madineh, 2008). He was born in Bukhara, an ancient Persian city in 980 AD and died in the year 1037 AD in Hamadan, Iran (Madineh, 2008). Avicenna authored the Canon of Medicine text book which was the famous medical encyclopaedia of the time. The book was adopted as the main medical reference textbook in the Middle East and Western universities. In his treaties, Avicenna adopted the practical approach to the descriptions of the human body and disease associated (Nejabat et al. 2012). This experimental approach remains the domain in the medical and scientific practise. In addition he emphasised the importance of learning the anatomy of the human body and

encouraged physicians to consider the normal anatomy of organs in their diagnosis. Corresponding with the ancient Greek medicine (Unani- Tibb) philosophy, Avicenna advocated for the prevention of disease rather than cure in the maintenance of health (Buranova, 2015, Bhikha et al. 2008). In the human being the concept of temperament extends from cells to tissues to organs and finally to each individual having a unique temperament. This is broadly characterised as four humours which are produced by the liver: sanguinous, phlegmatic, bilious (also known as choleric) and melancholic, each with its overall qualities (Bhikha et al. 2008). The Tibb philosophy states that as long as the overall quality of the humours is in line with the overall quality of the temperament of an individual, homeostasis (or harmony) will be maintained. Whilst the overall quality of an individual's temperament is fixed, the overall quality of humours are subject to change arising from the lifestyle factors such as food and drink, environmental air and breathing, movement and rest, sleep and wakefulness, emotions, and elimination (Bhikha, 2017).

Part sixteen (16) of the third book in the Canon of medicine describes the anatomy of the intestines and introduces some mechanical diseases of the intestines such as volvulus and intestinal obstruction. Avicenna noticed that the aetiology of the two conditions was mainly from the tearing of the ligaments (see mesenteries in Moore et al. 2014) which supports the intestines from the posterior abdominal wall (Bakhtiar, 1999; Moradi et al. 2016). Besides, Avicenna hypothesised that the overall length and thickness of the intestines was related to the efficiency of digestion, absorption and evacuation of faeces (Bakhtiar, 1999). In addition the structure and functional correlations of accessory digestive organs and some abdominal organs was established. The current study analysed and compared the descriptions of the anatomy of the digestive tract, accessory organs and some abdominal organs as viewed by Avicenna in the Canon of Medicine to modern anatomy literature, particularly to the medical textbooks commonly used in medical schools.

The oesophagus

The oesophagus is a fibromuscular tube extending from the pharynx to the stomach and conveys ingested food (Moore et al. 2014). Avicenna noticed that the oesophagus consists of both muscular layers and mucosal folds. He described the mucosa of oesophagus as folded vertically to allow for easy passage of food during swallowing (Bakhtiar, 1999). The submucosa and the mucosa in the empty oesophagus form

longitudinal folds that give the lumen an irregular outline (Kierszenbaum and Tres, 2011). During swallowing the longitudinal folds of mucosa temporarily disappears and reappear thereafter (Kierszenbaum and Tres, 2011). According to Avicenna the longitudinal folds of mucosa creates a suction pressure gradient that pulls the food downwards into the stomach during swallowing (Bakhtiar, 1999). The muscular layers of the oesophagus consist of two layers the outer longitudinal and inner circular layers (Moore et al. 2014). Avicenna mentioned only the circular layer which he described as orientated horizontally to the longitudinal folds of mucosa (Bakhtiar, 1999). He also stated that the upper portion of the muscular layer consists of skeletal muscle which helps to move the trachea upwards during swallowing. In modern descriptions, the outer longitudinal muscle layer of the oesophagus consists of striated muscle in its superior third; the inferior third is composed of smooth muscle, and the middle third is made up of both types of muscle tissue (Moore et al., 2014). Avicenna described the topographic anatomy of the oesophagus in relation to other cervical structures concisely. He mentioned that the oesophagus is located in front of the cervical vertebrae and behind the trachea where it gains protection of both structures (Bakhtiar, 1999; Mazengenya and Bhikha, 2016). Avicenna mentioned that the oesophagus descends into the thorax on the right side form T1 to T4 and the level of the fourth thoracic vertebra (T4), the oesophagus shifts slightly to the left to make way for the arch of the thoracic aorta (Bakhtiar, 1999, Moore et al., 2014). Below the arch of the aorta the oesophagus shifts back to the left and pierces the diaphragm at the level of the T10 vertebra (Moore et al. 2014). At the oesophageal hiatus Avicenna mentioned that the oesophagus is surrounded by a ligament which raises it during the movements of the diaphragm and prevent compression and damage of the thoracic aorta and the accompanying nerves respectively (Bakhtiar, 1999). According to Moore et al. (2014), the oesophagus is attached to the margins of the oesophageal hiatus by the phrenico-oesophageal ligament which permits independent movement of the diaphragm and the oesophagus during respiration and swallowing. Below the diaphragm, the oesophagus shifts towards the left side of the 11 and 12th vertebra and dilates to form the stomach orifice (Bakhtiar, 1999, Moore et al., 2014). Avicenna described the relationship between the oesophagus and the vagus nerves throughout its course from the neck to the stomach. He mentioned that nerves from the brain descends of either side of the oesophagus, pierce the diaphragm together with the oesophagus and twist

around it just before the stomach and innervate the orifice (Bakhtiar, 1999). The vagus nerves descends as right and left trunks to the oesophagus, at the oesophageal hiatus, they become anterior and posterior gastric branches which supply the oesophagus and cardiac region of the stomach together with contributions from the thoracic sympathetic trunks (Moore et al. 2014). According to Avicenna, the innervation to the cardiac region senses hunger and need for nutrition and informs the brain of an individual or animal. The feeling of hunger is driven by a complex interaction of chemical signals in the hypothalamus which are triggered by the sight, smell and or memory of food. An empty stomach also triggers the release of the Ghrelin hormone which is also a neuropeptide hormone which regulates appetite and gastric feeling (Nakazato et al. 2001).

The stomach

Avicenna described the stomach as a continuation of the oesophagus. He affirmed this describing the similarity in the orientation of the mucosa between the oesophagus and stomach (Bakhtiar, 1999). The stomach is a dilated part of the alimentary tract between the oesophagus and the intestines, which is specialised for accumulation of food and prepares it for both chemical and mechanical digestion (Moore et al. 2014). Avicenna described the pyloric part of the stomach as continuation into the duodenum and also as a sphincter that regulates gastric emptying thereby facilitating digestion. Avicenna mentioned that the stomach has a greater curvature which is associated with a larger artery and also attachment of the peritoneum (Bakhtiar, 1999). He described the blood supply to the greater curvature of the stomach through the right gastroomental artery and its numerous braches. In addition, he stated that the peritoneum connects the stomach with other organs (Bakhtiar, 1999). Avicenna mentioned that the liver and the spleen lie to the right and under (posterior) to the stomach respectively. The relationship of the stomach to the other abdominal organise was regarded as a vital source of heat which helps in the digestion of food (Bakhtiar, 1999).

The Peritoneum

According to Avicenna, the peritoneum consists of an outer layer (parietal) which reinforces the abdominal in addition to abdominal muscles and the inner (visceral) layer which covers abdominal contents (Bakhtiar, 1999). This description of the peritoneum persists in modern anatomy whereby the parietal peritoneum lines the abdominopelvic wall and the visceral peritoneum invests the visceral structures (Moore et al. 2014). The two layers of peritoneum are actually made up one continuous layer lining the abdominal pelvic cavity during embryological development; the separation into parietal and visceral layers comes into effect after the invagination of developing of organs into the abdomen through the posterior layer of the peritoneum (Williams and Warwick, 1980; Moore et al. 2014; Moore et al. 2016). Avicenna described this arrangement and mentioned that the inner and outer layers of the peritoneum attaches at the diaphragm and both layers fuse at the back (Bakhtiar, 1999). Furthermore, Avicenna described the deep inguinal rings in relation to the peritoneum and their functions of conveying blood vessels through the anterior abdominal wall. Avicenna cautioned that if the deep inguinal ring is larger than normal intestines can herniate through it. Congenital (indirect) inguinal herniation involves the passage of intestinal loops through the deep ring into the inguinal canal following increased intra-abdominal pressure (Moore et al., 2016). This condition is common in males and is associated with intestinal torsion, compression of testicular arteries and necrosis of testicular tissue. In agreement with modern anatomic descriptions, Avicenna noted that the aorta and the inferior vena cava including the back were located behind (retroperitoneal) the parietal peritoneum. He also noticed that all digestive organs were covered by the peritoneum. Although in modern anatomy some sections of the abdominal organs such as the duodenum have large sections which are retroperitoneal. Besides, Avicenna stated that peritoneum attaches the stomach to other organs and specifically described the greater omentum, emphasising on its broad distribution and its fat content (Bakhtiar, 1999). Avicenna ascribed the function of heat production to the omentum and suggested that the heat facilitates digestion in the stomach. Structurally peritoneum forms ligaments and mesenteries which support abdominal contents against each other and from the posterior abdominal wall. It also helps to distribute blood vessels and nerves to visceral organs.

The liver, gall bladder and spleen

The liver was observed to lie on the right side of the body and its topographic and functional anatomy was well elucidated in Canon of Medicine. Avicenna described the intimate relationship of the convex surface liver to the doom of the diaphragm and suggested that the doom shape of the diaphragm allows for free movement of the diaphragm and acting as fan over the liver (Bakhitar, 1999). Avicenna also described the covering of the convex surface of the liver with lower ribs. Besides, Avicenna described the attachments of the liver to the stomach and the diaphragm through the omentum, and ligaments respectively. The liver is attached to the diaphragm through the reflections of the viscera peritoneum on the diaphragm and liver which forms anterior and posterior coronary ligaments (Moore et al. 2014). In addition, the falciform ligament attaches it to the anterior abdominal wall. Connections of the liver to the heart are formed by inferior vena cava (Bakhtier, 1999). The concave surface of liver corresponds to the visceral surface in modern descriptions and according to Avicenna the inferior vena cava exist this surface to supply blood to the rest body and the portal vein brings nutrient rich blood from the intestines and enters the concave surface of the liver. In the Canon of medicine the shape and overall description of the gross structure of the liver compares to that of the dog, with five lobs. This description stems back to Galen (200 A.D) and was carried over during Avicenna's time. However, Avicenna further analysed the structure and innervation of the liver. He mentioned that the liver has no nerves and these were distributed on the tough membrane covering the liver. The tough membrane alluded to by Avicenna is the Glisson's capsule named after Francis Glisson following his book on the liver in 1659. The liver was regarded as a blood forming organ and hence its reddish brown structure. In addition Avicenna mentioned the functions of the liver associated with the production of four humours including clean blood, water, yellow bile (bilious humour) and black bile (atrabilious humour). And these humours will be distributed as clean blood to the rest of the body through vessels, water sent through the branches of the inferior vena cava to the kidneys, yellowish bile to the gallbladder through the common hepatic duct and the black bile to the spleen through vessels (Bakhtiar, 1999). Avicenna opined that the analysis of urine can determine the health of the liver and that the liver contributes to the production of urine (Bakhtiar, 1999). The liver is the central organ of metabolism and its waste by-products are filtered and excreted by the kidneys as urine.

Avicenna mentioned the gallbladder and described it as a sac which receives bile from the liver (Bakhtiar, 1999). Topographically, Avicenna stated that gallbladder lies on the concave surface of the liver closer to the stomach. In agreement with modern anatomy, Avicenna described the biliary tree although he did not mention the anatomical names. He mentioned that bile from the liver is channelled to the gallbladder through deep vessels (see hepatic vessels in Moore et al. 2014) and excreted to the duodenum. In addition, he described the anatomic variations on the presence of either major and minor or both duodenal papilla in different people. Avicenna suggested that the bile is used in cleaning extra foam from the intestines and purification of blood. Bile helps with the emulsification of fats during digestions and increases their absorption; it is an important part of the absorption of the fat-soluble substances, such as the vitamins A, D, E, and K (Hall, 2015). Besides its digestive function, bile serves also as the route of excretion for bilirubin, a by-product of red blood cells recycled by the liver (Hall, 2015). The anatomy of the human spleen was not well enumerated in the Canon of Medicine. Instead the tongue like shape described by Avicenna corresponds to the bovine spleen suggesting that he studied the anatomy of this organ in animal models. Despite the lack of the knowledge of the lymphatic system, Avicenna understood the function of the spleen in fighting diseases (Emtiazy et al. 2013). He mentioned that the spleen receives black bile (atrabilious humour) from the liver and also digest residues from burned blood (sanguineous humour) cleaning the blood. Apart from immunological function, the spleen is involved in filtration of blood removing dead red blood cells from the body (Kierszenbaum and Tres, 2011).

Intestines

Avicenna presented elaborate information on the anatomy of the intestines, dividing it into six parts in correct sequence whose names are still returned in modern anatomy including duodenum, jejunum, ileum, caecum, colon and the rectum. He opined that the length, twisting course and varied thickness of the intestines are adaptations for effective digestion, absorption and holding of waste. Avicenna associated the smaller lumen of the upper part of the intestines (small intestines, see Moore et al. 2014) with effective digestion and absorption of nutrients. Avicenna mentioned that bile ducts open into the duodenum (Bakhtiar, 1999) this corroborates the modern descriptions where the major and minor duodenal papillae empty into the second part of the duodenum (Moore et al. 2014). Avicenna analysed the similarities and

differences on the structure and vascularity of the duodenum, jejunum and ileum and concluded that the jejunum and ileum contain circular folds of mucosa (*plicae circulares*) whereas the duodenal mucosa lacks them. He suggested precisely the function of *plicae circulares* in slowing the flow of chime along the intestines and increases the efficiency of digestion and absorption. In addition Avicenna mentioned that the jejunum has abundant blood vessels including branches of the portal vein. According to Moore et al. (2014) the jejunum has great vascularity; large, tall and closely packed circular folds of mucosa than the ileum. The caecum and colon were described as the most dilated parts of the intestines and were ascribed the functions of collecting and maturation of stools and absorption of excess materials (Bakhtiar, 1999). He mentioned that the caecum was a blind pouch lying on the right of the body and has higher chances of herniation (Bakhtiar, 1999). Besides he observed the continuous distribution of portal vein tributaries in the colon further affirming that absorption takes place in the colon. In modern anatomy, the large intestines are involved in the absorption of water from indigestible residues and prepare and store faeces temporarily (Moore et al. 2014). Avicenna described the rectum as a straight and dilated tube leading into the anal canal. In addition he described the topography of the rectum as positioned anterior to the sacral bones, closely associated with external musculature which aid in defecation.

Conclusions

Avicenna expounded on the structural, topographic and functional anatomy of the digestive and associated organs fairly and comparable to modern anatomic descriptions. He emphasised on the topographic relationship of organs in maintaining their temperament and efficiency. He also recommended the importance of the anatomy and health of the intestines to physicians for effective treatment of various illnesses.

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