



The genitourinary system: Interpretation of Avicenna's (980-1037 AD) treatise in the Canon of Medicine

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Introduction

Ibn Sina (Avicenna in the west), was a Persian Muslim scientist and one of the greatest physicians and philosophers. He was born in 980 AD in old Persia and died in 1037 AD in Hamadan, Iran (Madineh, 2008). Avicenna became famous through his medical textbook the Canon of Medicine. The textbook was adopted as the main referral book in western and Arabic universities for centuries (Shoja and Tubbs, 2007). The medical principles presented in the Canon of Medicine were based on traditional Greek (*Unani*), Roman and Chinese medicine (Beg, 2015). Avicenna emphasised on integrative, holistic treatment and examination approaches to his patients (Hashemi and Raza, 2009; Bhikha and Gylmn, 2017). Traditional integrative medical approaches rely on the history, physical examination, signs and symptoms,

diet and life style, environmental factors and individual temperament of the patients in the diagnosis, treatment and prevention of diseases (Hashemi and Raza, 2009; Bhikha and Gylmn, 2017).

Avicenna's information on the genitourinary system, although it was presented about 1000 years ago still compares with modern information in anatomy, physiology, internal medicine surgery and pathology textbooks. Under urology section, Avicenna described the anatomy and pathology of the urinary tract and reproductive system in both males and females. He advised on urine analysis, whereby he suggested the timing of urine collection and urine characteristics such as colour, turbidity, consistency, odour, sediments, volume and foaminess (Bhakhtiar, 1999). He distinguished urine characteristics in health and disease (Hanafy et al. 1976). Avicenna also expounded on obstructive disease of the urinary tract and suggested on herbal and surgical treatment of these disorders. He distinguished the pain from kidney and urinary bladder stones and suggested the former was more painful than the latter. He advised on the herbal treatment of stones as a first line of treatment and cautioned against cystolithotomy unless the surgeon was well versed in the anatomy of the bladder, seminal ducts and blood vessels to avoid sterilising the patient (Hanafy et al. 1976; Bhakhtiar, 1999). The current study analysed the descriptions of the anatomy of the genitourinary system as viewed by Avicenna in the Canon of Medicine and compared them to modern anatomy and physiology literature, particularly to the medical textbooks commonly used in medical schools. In addition Avicenna's insights as to why the genitourinary anatomy has been created the way it is has also been included.

The kidney

The anatomical description of kidneys in relation to the liver as presented in the Canon of Medicine stems from Galenic principles. Similar to Galen (200), Avicenna erroneously ascribed higher position of the right kidney and closer to the liver than the left. This was based on the misconception that the liver and the right kidney are connected together by small ducts (Bhakhtiar, 1999). The left kidney was alleged to occupy a lower position because pressed down by the spleen (Bhakhtiar, 1999). However, the right kidney is located below the liver at a lower level than the left kidney and the left kidney is intimately related to

the stomach, spleen, tail of the pancreas, jejunum and descending colon (Moore et al. 2014). Avicenna mentioned that the kidneys are designed for excretion of excess water (aqueous humour) and waste substances from the blood (sanguineous humour). He stated that “The humor was abundant, there was a need to create either a single large organ or two small organs. A single large organ would have caused crowding... the benefits of two small organs is that if either is diseased the other would compensate for its function” (Bhakhtiar, 1999; Mujais, 1987). This compensatory mechanism in kidney disease was further developed to allow for kidney transplantation, first implemented by Surgeon Yurii Voronoy (1895–1961) in 1933 (Matevossian et al., 2009). Avicenna described the blood supply to the kidneys through the renal arteries and veins in Volume 1 of the Canon of Medicine. He described the origin and course of the renal vessels and the relationship between the left renal and left testicular vessels. He assumed that both renal arteries and veins bring blood and nutrition to the kidney and this blood was supposed to be delivered to the kidney in amounts compatible with the kidney’s capacity otherwise it will be excreted together with urine (Bhakhtiar, 1999). Avicenna described the renal pelvis as a space within the kidney, how it fills with urine and subsequent transport of urine to the urinary bladder through the ureter. He also described the innervation of the kidney through sensory nerves in the covering capsule.

Urinary Bladder

Avicenna described the structure and function of the urinary bladder in the Volume 3, book 19, treatise 1 of the Canon of medicine. The section also covers the pathological basis of various diseases associated with the bladder and excretory ducts. In this section we focused more on the anatomy and functional aspects of the urinary tract as described in the Canon of medicine than the disease conditions. Avicenna described the function of the bladder based on a two phase dogma which still stands in modern physiology information. He stated that “God has created an organ similar to the cyst in human body to remove the useless and removable liquids (or urine). This allows the urine to gradually pour into the bladder and at a necessary time, it can completely be expelled from the body. Otherwise, the human would have to urinate every minute and every hour, so as in patients with urinary dribbling. This leather-like bottle is named the bladder (urocyst) in which the removable liquid (or urine) accumulates”. (Ibn Sina 1593). According to

Yoshimora and Chancellor, (2007) the urinary bladder functions in two separate phases: the storage phase where the bladder fills with urine and the voiding or emptying phase whereby urine is excreted to the external environment. Avicenna assumed the bladder wall consisted of elastic tendons after observing the expansion in volume and diameter during bladder filling. He stated that “The bladder has been made by interlaced tendons and there are 2 real hidden reasons for this composition. First, the bladder becomes more fortifiable and inseparable; second, it becomes elastic” (Bhakhtiar, 1999; Ibn Sina 1593). During his times histological examinations was unpopular and hence he could not distinguish between the muscle and connective tissues. The bladder wall consists of smooth muscle tissue which is distensible on filling and contracts during emptying (Kierszenbaum et al., 2015). On the walls of the urinary bladder, Avicenna stated that “The bladder has 2 layers: the internal and external layers. The internal layer is undercoat of the bladder and its power and firmness is twice as much as the external layer, because the internal layer has to be in touch with the astringent urine” (Ibn Sina 1593, Bhakhtiar, 1999). During Avicenna’s time microscopic examination of tissues was not common and hence he described the bladder as having two layers instead of three which include the urothelium, muscular layer and the adventitia, the latter were described as one by Avicenna (Madineh, 2008; Ashtiyani et al. 2011). The cells of the urothelium are joined by tight junctions on their apical surfaces making them impermeable to water (Kirshenbaum et al. 2015, Madineh, 2008). Avicenna pointed to the course of ducts transporting urine from the renal pelvis to the urinary bladder. Interestingly he described the anti-reflux mechanism of the termination of the ureters into the urinary bladder. He stated that “God, because of his grace and wisdom, has decided that the removable liquid (urine) pours into the bladder and then be expelled out. For this purpose, 2 water transporting tubes (ureters) descend from the kidneys to the bladder. When the ureters reach the bladder, the bladder opens its two layers and includes the ureters in it. First, these tubes pass the hiatus of the first layer, and then, they pass between the two layers at the necessary distance. Then, they perforate the lining undercoat layer and reach the depth and the cavity of the bladder. Removable and useless liquid (urine) pours into the bladder until the bladder become full. The internal layer adheres to the external layer and these layers are in contact together as if they are united originally and there is no pore and passage between them. Because of the unity and adherence, the retained urine in the bladder has no retrograde

pathway to the ureters or anterograde pathway to the urethra” (Ibn Sina 1593; Bhakhtiar, 1999). The ureters enter the urinary at an angle and pierce the fibromuscular layers (adventitia and muscular layers). The ureters traverse about 2 cm in the submucosa of the urothelium before piercing and opening in the urothelium. When the bladder fills with urine the urothelium becomes closely applied to the muscular wall thereby closing the orifices of the ureters and preventing reflux of urine into the ureters (Hall, 2015). Avicenna astonishingly described the mechanism of bladder filling confirming that he was well versed in physical science way before the advent of cystometrogram. He proclaimed that “When the bladder is filled with urine, it extends and remains fixed, and the human can expel urine voluntarily when the bladder is full” (Bhakhtiar, 1999, Ibn Sina, 1593). The mechanism of bladder filling obeys the Laplace’s law which was coined by Pierre Simon Marquis de Laplace (1779-127) (Madineh, 2008). The law stipulates that when the urinary bladder is filling with urine, its diameter increases but the intravesicular pressure remains almost constant. This allows the urinary bladder to collect as much urine until micturition reflex is initiated which allows for emptying of the bladder (Hall, 2015). The intravascular pressure change during filling of the urinary bladder and the tone of the muscle of the bladder wall can be measured experimentally on a cystometrogram (Hall, 2015). Micturition reflex can be suppressed by the central nervous system and normal voiding of urine is a voluntary exercise particularly in mature individuals.

On the neck of the bladder, Avicenna identified the prostate gland, muscle and connective tissue fibres surrounding the proximal urethra. He affirmed that the glandular and fibromuscular structures were sensitive implying that they were highly innervated. The prostate gland, urethra and internal urethral sphincter at the level of the bladder neck are innervated by autonomic nerves from both the pelvic splanchnic nerves and the sympathetic trunk through the inferior hypogastric plexus (Moore et al. 2014). Extending from the prostate gland and the prostatic urethra, Avicenna described the external urethral sphincter on the membranous part of the urethra. He affirmed that the sphincter which is voluntary is aided by the abdominal muscles during normal voiding of urine. Avicenna wrote, “There is gullet-like organ which is encircled at its origin in the proximal part by a muscle, the function of which is to compress and obstruct the urethra, so that urine is not expelled out without the human being’s willing. This gate-keeping muscle is helped by abdominal muscles. This work is done very regularly unless this

gate keeper and water distributor muscle or its helper muscles are traumatized” (Bhakhtiar, 1999; Ibn Sina, 1593). The external urethral sphincter consists of the striated muscle which surrounds the membranous urethra forming trough like structure in males and disc shaped structure in females. The sphincter fuses with muscles of the pelvic floor in female individuals and is innervated by branches of the pudendal nerve (Moore et al., 2014). In addition to internal and external urethra sphincters, Avicenna described the curvatures of the urethra and suggested that they help in preventing involuntary voiding of urine. He wrote, “God in his power, has made a gullet-like organ to eliminate the removable liquids (urine) through the penile urethra. Thus, this organ that is similar to a water pipe is continuous from the bladder to the penile urethra and it has multiple curvatures so that the liquid material would not be expelled out suddenly and totally. These curvatures in the male’s urethra are more than those in the female. There are 3 curvatures in males and only 1 in females, because the female’s bladder is very near to the uterus” (Bhakhtiar, 1999; Ibn Sina, 1593). The male urethra is about 25 cm in length and is longer than the female urethra which is about 4 cm long. The male urethra has five different parts which include the preprostatic, prostatic, membranous, spongy and glandular urethra and along its length they are various curvatures between its segments and these help to trap urine and avoid involuntary voiding (Madineh, 2008, Moore et al. 2014). The Female urethra has a single curve between the neck of the bladder and the beginning of the urethra and there is no definite internal urethral sphincter to guard the urine like in males hence the curve helps preventing involuntary voiding of urine during coughing, sneezing and lifting heavy objects (Madineh, 2008, Moore et al. 2014).

The morphology of male and female genitalia and reproductive concepts

In the Canon of Medicine, the anatomy of the male genitalia and reproductive system was described very briefly compared to the females’. Avicenna’s descriptions of the anatomy of male and female reproductive systems and genitals was based on Galen’s (200 A.D) one sex model which depicted that the female and male reproductive organs were homologous anatomical structures differing only in size and complexity. Female organs were regarded as less complex than man’s and were described as an inverted form of the man’s reproductive organs. The physician of the antiquity, Galen wrote “All the parts, then, that men

have, women have too, the difference between them lying in only one thing, which must be kept in mind throughout the discussion, namely, that in women the parts are within, whereas in the men they are outside, in the region called the perineum... The scrotum would necessarily take the place of the uteri, with the testes lying outside, next to it on either side; the penis of the male would become the neck of the cavity that had been formed; and the skin at the end of the penis, would become the female pudendum” (Galen, 1968). Avicenna ascribed the cold and moist temperament of the females as the main reason they are smaller than man (Ibn Sina 1593; Bhakhtiar, 1999). Avicenna mentioned that the male reproductive organs (penis, testes and the scrotum) were located outside the body. Avicenna mentioned that testes were responsible for the production of semen. He described the transportation of semen from the testes through long and twisted ducts to the prostatic urethra at the neck of the urinary bladder. His description befits that of the twisted epididymis and the length vas deferens which subsequently empty into the prostatic urethra together with the ducts of the seminal vesicles.

Uterus and ovaries

Avicenna extensively described the anatomy and functions of uterus. Avicenna subscribed to the Galenic dogma of the inverted genitalia. He described the uterus as inverted penis, whereby the scrotum represents the body of the uterus, the shaft of the penis making the neck (cervix) and the foreskin (prepuce) forming the vagina. On the description of the uterine wall, Avicenna mentioned that the wall is capable of stretching and contraction. He attempted to explain the basis for the extensibility of the uterus during pregnancy without success. The reader is constantly reminded that during his time no microscopes were available to clearly delineate the various tissues of the body. The uterus consists of smooth muscle tissue is contractile and hyperplastic (Kierszenbaum et al. 2015). In addition, he noticed that the uterus was small in girls than in married women and during pregnancy the uterus and the breast continuously grow until the fetus reaches maturity (Bhakhtiar, 1999). Due to the lack of microscopy advancement, Avicenna described a two layered uterus consisting of the thick inner lining and the outer covering layers instead of the three layered uterus including the perimetrium (fibrous), myometrium (smooth muscle) and endometrium (mucosa). Astoundingly, he described the menstrual cycle. He pointed out that the uterine wall thickens during the menstrual cycle and menstrual blood comes from the inner lining of the uterus. The thickening

of the endometrium happens during the proliferative and secretory phases of the menstrual cycle and the period coincides with a surge in luteinising hormone (Hall, 2015) Furthermore he mentioned that the inner uterine wall shrinks on cessation of the menstrual blood flow (Bhakhtiar, 1999). Avicenna studied both gravid and non-gravid uteri in his treatise. He observed the uterus during pregnancy and reported that the wall of the uterus decreases in thickness as the pregnancy progresses and fetal membranes particularly the placenta attaches to the inner lining of the uterus through blood vessels. Avicenna described correctly the location and anatomical relations of the uterus in the pelvic cavity. He observed that the uterus is positioned postero-superior to the urinary bladder with body resting on the superior surface of the bladder and the rectum is posterior to the uterus. He also described the ligamentous attachments of the uterus to the sacrum in a manner similar to the distribution of uterosacral ligaments; that is the uterosacral ligaments attach the uterine cervix to the sacrum posteriorly aiding in passive support of the uterus in the pelvic cavity. Avicenna described the innervation and blood vessels to the uterus and suggested they can be seen during examination although he did not explain how. The uterine arteries and veins are closely related to the uterus and the autonomic nerves follow the course of the blood vessels to innervate the uterus Avicenna mentioned the opening of the uterine tubes into the cavity of the uterus on both sides and described the cervix and affirmed that its folds increase during pregnancy (Bhakhtiar, 1999). He also described the vagina and its functions as a conduit for semen, menstrual blood flow and birth canal. In addition he mentioned the presence of hymen in the vagina during virginity. He also described the urethra meatus above the vaginal orifice in the vulvar.

Avicenna suggested that female ovaries are equivalent to the male testis and they produce female eggs (ova) for reproduction. He mentioned that each ovary was enclosed in a membrane with sensory nerves and were located on each side of the uterus at the end of uterine horns. He affirmed that the female eggs were transported by ducts (uterine horns) towards the uterus.

Reproductive concepts

Avicenna explained reproduction, particularly fertilisation based on principles from his predecessors, Aristotle, Hippocrates and Galen. He expounded Aristotle's concepts of males contributing more than women towards the development of the fetus. At the same he acknowledged the contribution of females more like Hippocrates and Galen. Avicenna wrote "according to the teaching of philosophy, the process of generation may be compared with the processes which take place in the manufacture of cheese. Thus the male semen is equivalent to the clotting agent of milk, and the female semen is equivalent to that of milk. The starting point of the clotting is in the rennet; so the starting point of the clot is in the male semen" (Ibn Sina, 1593). Avicenna also described male erection and its stimulants. He described increase in blood pressure and engorgement in the penis during erection. In addition he cited the sexual intercourse, thoughts particularly during sleep in stimulating and maintaining penile erection.

In conclusion, as the Scottish medical student John Moir wrote in 1620, "A consideration of the genital members is very difficult, and everything should not be revealed particularly with youths, because sin makes the subject of generation diabolical and full of shame, and a discussion might excite impure acts." Studies on the genitalia and reproductive system were hampered by religious beliefs and very few scholars if they attempted did not carry out thorough examination of the differences between the male and female genitalia. However, Avicenna impeccably described the anatomy of this region and offered guidelines to the surgical procedures of common conditions such as obstruction of the urinary tracts. Information of the urinary tract, urinoscopy and urinary tract disorders and management still form the hall mark of urology practice. Additionally his information on female internal genitalia corroborates modern anatomy and gynaecology.

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