REVIEW ARTICLE

The Anatomy of Urinary Continence

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Abstract

The urethral sphincter complex comprises of an internal urethral sphincter (IUS) and an external urethral sphincter (EUS) reinforced by pelvic floor muscles. The IUS is comprised of smooth muscle, and is under the control of autonomic nerves. The EUS is composed of skeletal muscles, thus it is under the control of somatic nerves. When sympathetic outflow overrides the parasympathetic outflow, the IUS contracts and the bladder relaxes and fills with urine. Simultaneously the pudendal nerves stimulate the contraction of the voluntary EUS. Local reflex arcs at the spinal level controls micturition. Higher centres regulate this reflex. The pontine micturition centre (PMC) facilitates micturition while frontal inhibitory centre (FIC) inhibits it.

Article

Introduction

Urethral sphincters, its innervation and central neural coordination are essential to maintain urinary continence. Historically, the sphincter mechanism was described as two components: the internal urethral sphincter (IUS) and the external urethral sphincter (EUS). Subsequently, the concept of a rhabdosphincter evolved, where a continuous longitudinal muscle coat encircles the membranous urethra. The urethral sphincters are innervated by both somatic and autonomic nerves. The pontine micturition centre and the inhibitory centres in the frontal cortex coordinate the neuronal signalling, thus enabling the control of micturition. In this article, we describe the anatomical basis of urinary continence: the historical perspective and the new understanding.

Anatomy of the urethra and the sphincter complex

Anatomy of the urethra

The urethra extends from the internal orifice of the urinary bladder to the external urethral opening. Male urethra is approximately 18 to 20 cm long. It has an initial short course, approximately 1 cm in length, before it reaches the prostate gland (preprostatic urethra). Then it tunnels through the prostate for 3-4 cm (prostatic urethra). Having emerged slightly anterior to the apex of the prostate, it traverses a region historically known as the urogenital diaphragm. This part of the urethra is known as the membranous urethra. The prostate rests on the urogenital diaphragm. The membranous part of the urethra is 2-2.5 cm in length. It is the least distensible part of the urethra. Then the urethra progresses with an anterior curvature (bulbar urethra) within the superficial perineal space. It terminates at the urethral meatus or the external orifice after traversing the corpus spongiosum of the penis (penile urethra). The female urethra is approximately 4 cm long. It passes through the deep perineal space and terminates at the vestibule.

The internal urethral sphincter (IUS)

The IUS is situated at the junction between the urinary bladder and the proximal urethra. In males, it is considered to be located at the preprostatic urethra. The IUS consists of smooth muscles. These muscle fibres are in continuity with the detrusor muscle of the urinary bladder. But the detrusor muscle fibres do not contribute to the IUS. The smooth muscle fibre bundles of the IUS are arranged in a horseshoe shape manner. There are inner longitudinal and outer circular muscle layers reinforced by elastic connective tissues.

The external urethral sphincter (EUS)

The historical understanding was that the urethra was encircled by skeletal muscles as it traverses the deep perineal space. This region was described to be comprised of the EUS muscles sandwiched by two layers of fascia. The inferior fascial layer of this region was also known as the perineal membrane. The EUS was also known as the urogenital sphincter. This was described as being located immediately below the bladder in females (Figure 1) and at the level of the membranous urethra in males.

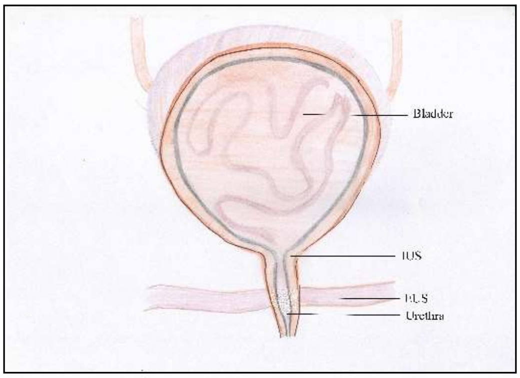

Figure 1: The female urethral sphincter complex according to the historical understanding. (IUS - Internal Urethral Sphincter, EUS - External Urethral Sphincter)

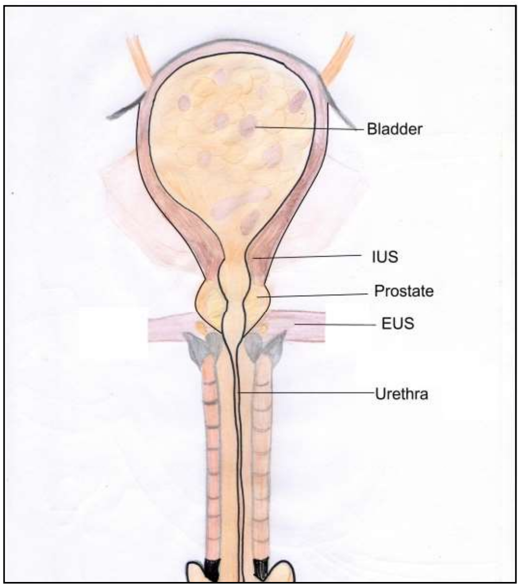

Figure 2: The male urethral sphincter complex according to the historical understanding. (IUS - Internal Urethral Sphincter, EUS - External Urethral Sphincter)

The Rhabdosphincter

In 1980s, Oelrich compared and contrasted microscopic and macroscopic anatomy of the urethral sphincters in males and females. His detailed histological examinations provided the foundation for the current understanding of the anatomy of the EUS. Moul described that the EUS extended from the distal part of the prostatic urethra to the urogenital diaphragm. In 1997, Keith et al histologically evaluated cadaveric dissections and the tissue samples of radical prostatectomies. According to him the urogenital diaphragm does not exist. The EUS is a cylindrical muscle surrounding the membranous urethra. This idea was reinforced by several other studies. These muscle fibres start as two separate bundles on either side of the urethra. These expand towards the anterior surface of the urethra and are continued with the corresponding fibres of the opposite side of the body. Collectively it forms a broad arcing muscle layer anterior to the urethra. Imaging studies conducted by Wang et al. in 2014 confirmed that the urethral sphincter complex was a cylindrical structure surrounding the urethra and extending vertically from the bladder neck to the perineal membrane, which is more dense inferior to the colliculus seminalis. This cylindrical muscle coat is currently referred to as the rhabdosphincter (Figure 3: male rhabdosphincter). In the female the rhabdosphincter is described as mainly surrounding the upper and middle thirds of the urethra (Figure 4: female rhabdosphincter).

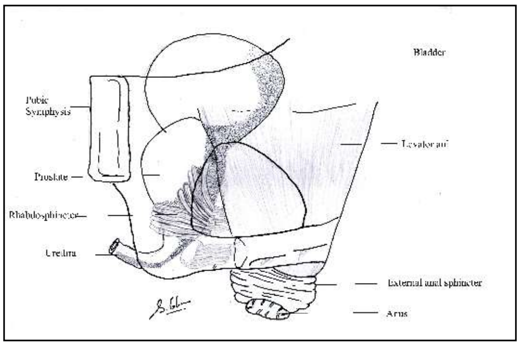

Figure 3: The male urogenital system showing the male rhabdosphincter

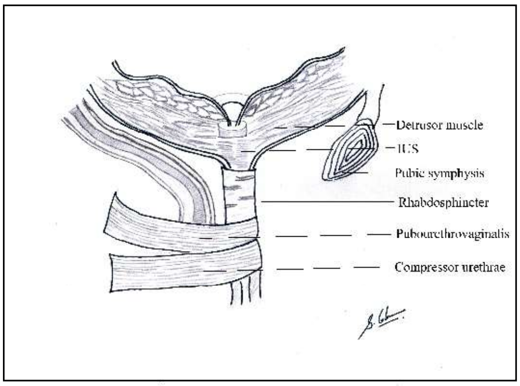

Figure 4: The female urogenital system showing the female rhabdosphincter. (IUS - Internal Urethral Sphincter)

The pelvic floor muscles

The continence mechanism at the level of the membranous urethra in males is reinforced by the pubourethral component of the levator ani muscle in the male. The striated fibres of the pubourethralis arise from the inner surface of the ischiopubic ramus and surround the membranous urethra like a sling. In females, a similar muscle is found to encircle both the urethra and the vagina (pubourethrovaginalis). Additionally, in the female, fibres arise from the ischial rami and pass anterior to the urethra (compressor urethrae). These pelvic floor muscles act independently from the IUS and EUS, thus should not be confused with the urethral sphincter complex.

Urethral coaptation

Deep to the two smooth muscle layers of the IUS, there is a well-developed venous plexus. It is situated in the submucosa of the urethra. The watertight closure of the urethral lumen is thought to be achieved by the presence of this venous plexus, thus contributing to urinary continence. The circular arrangement of the submucosal elastin fibres at the neck of the bladder also contributes to urinary continence.

Innervation of the urethral sphincters

The IUS has smooth muscle fibres. Hence, it is innervated by the autonomic nervous system. The sympathetic nerves supplying the IUS and the bladder are derived from T10 to L2 spinal segments (the thoracolumbar sympathetic outflow). The preganglionic fibres relay in the inferior mesenteric ganglion and the ganglia of the inferior hypogastric plexus. The postganglionic fibrespass via the inferior hypogastric plexus and its branches and small plexuses surrounding the pelvic organs which it supplies. The parasympathetic fibres to the IUS are transmitted via the pelvic splanchnic nerves (also known as the nervi erigentes) arising from theS2 to S4 spinal segments (the sacral parasympathetic outflow). These also contribute to the inferior hypogastric plexus. The inferior hypogastric plexus is situated in the extraperitoneal connective tissue on either side of the rectum in the male and rectum and vagina in the female. The smaller complexes surrounding the pelvic organs arise from this. The vesical and prostatic complexes lie posterolateral to the seminal vesicles, prostate and the base of the urinary bladder. The upper limit of the plexus is beneath the peritoneum of the rectovesical pouch. At its inferior limit, the cavernous nerves emerge. It passes forwards on either side of the prostate, with a spray-like distribution within the false capsule of the prostate and external to its true capsule. These fibres are important for erectile function apart from maintaining urinary continence. In females, the inferior hypogastric plexus lies lateral to the uterine cervix, vaginal fornices and the posterior part of the urinary bladder. The nerves emerging from this plexus run anteriorly in the base of the broad ligament Thus these nerves are liable for damage during surgical procedures such as radical prostatectomy, anterior resection and total abdominal hysterectomy.

The EUS is derived from skeletal muscles. Therefore it has a somatic innervation. The somatic nerves to the EUS originate from a specialized area named Onuf's nucleus in the sacralspinal cord. This nucleus extends from S2 to S4 spinal segments. The somatic outflow is carried via the perineal branch of the pudendal nerve to the EUS. Muscles of the pelvic floor are also supplied by a similar group of somatic nerve fibres arising from S2 to S4 spinal segments.

The neural control of micturition

Micturition has two phases: filling phase and the voiding phase. This process depends on the neuromuscular coordination of the reservoir (the bladder) and the outflow tract (the urethra and the sphincter mechanism). Micturition is an autonomic reflex. But it is regulated by voluntary neural mechanisms which involve centres in the brain and the spinal cord.

The function of autonomic and the somatic nervous systems

There is a tonic discharge of both the sympathetic and parasympathetic nervous systems. The balance between the two systems determines the phase of micturition. During filling, increased sympathetic activity contracts the IUS and relaxes the detrusor muscle of the urinary bladder. Noradrenaline is released by postganglionic sympathetic nerve endings. Noradrenaline acts on the α-adrenergic excitatory receptors on the IUS to contract it. Noradrenaline also acts on the β-adrenergic inhibitory receptors in the detrusor, to relax the bladder. Conversely with voiding, increased parasympathetic activity contracts the detrusor and relaxes the IUS. Postganglionic parasympathetic nerve fibres release both cholinergic (acetylcholine) and non-adrenergic, non-cholinergic neurotransmitters. Contraction of the urinary bladder is mainly mediated by acetylcholine acting on M3 muscarinic receptors in the detrusor muscle. The IUS is relaxed via nitric oxide released by the parasympathetic nerves. The skeletal muscles of the EUS relax once the somatic outflow is inhibited during micturition.

Local reflex arc at the level of the spinal cord

A plexus of sensory neurons is situated deep to the urothelium of the bladder. This plexus is particularly dense at the neck of the bladder. The sensation of bladder fullness is carried to the spinal cord via the inferior hypogastric plexus.The afferent Aδ and C fibres relay in the spinal segments S2-S4 and T11-L2. The efferent parasympathetic nerves cause relaxation of the IUS. Inhibition of the EUS occurs when somatic efferents are inhibited.

The higher centres

There are few neuronal cell populations in the brain and brainstem which are specific for the control of micturition: these include the pontine micturition centre(PMC), the frontal inhibitory centre and the midbrain periaqueductal grey matter (PAG). There are interconnections between these higher centres. The ascending and descending spinal neurons also synapse with these higher centres.The PMC is situated in the rostral pontine tegmentum. When the bladder is distended, the afferents to the PMC run through the spinotegmental tract of the spinal cord. The efferents from the PMC descend in the lateral funiculus of the spinal cord to inhibit thoracolumbar sympathetic nucleus and the sacral Onuf's nucleus, while promoting the activity of the sacral parasympathetic nucleus. Thus, the PMC promotes micturition. The frontal inhibitory centresare situated in the inferior frontal gyrusand the anterior cingulated gyrus. These centres inhibit the local reflex arc of micturition by descending pathways. Thus, it increases the sympathetic outflow, reduces parasympathetic outflow. A human positron emission tomography (PET) study showed that the midbrain PAG is active during micturition. The midbrain PAG receives afferents from the sacral spinal segments, which possibly convey sensations concerning the degree of the bladder filling. In turn, the PAG sends signals to the PMC to facilitate micturition. Afferents from the PAG reach higher cortical centres and are important for the conscious perception of the fullness of the bladder.

Conclusions

Urinary continence is a complex mechanism. It involves the internal and the external urethral sphincter complex reinforced by the muscles of the pelvic floor. Local reflex arcs at the spinal level and the higher centres are essential for the coordination of micturition.

Acknowledgements

We would like to thank Dr. Samanmali Colonne for the illustrations.

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