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Clinical and Functional Anatomy of the Urethral Sphincter

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Continence and micturition involve urethral closure. Especially, insufficient strength of the pelvic floor muscles including the urethral sphincter muscles causes urinary incontinence (UI). Thus, it is most important to understand the main mechanism causing UI and the relationship of UI with the urethral sphincter. Functionally and anatomically, the urethral sphincter is made up of the internal and the external sphincter. We highlight the basic and clinical anatomy of the internal and the external sphincter and their clinical meaning. Understanding these relationships may provide a novel view in identifying the main mechanism causing UI and surgical techniques for UI.

Keywords: Urethral sphincters; Pudendal nerve; Autonomic nervous system; Urinary incontinence; Urination

INTRODUCTION

The urethral sphincter is crucial for the maintenance of urinary continence [1,2]. The urethral sphincter refers to one of the following muscles [3]: 1) the internal urethral sphincter (IUS), which consists of smooth muscle and is continuous with the detrusor muscle and under involuntary control, and 2) the external urethral sphincter (EUS), which is made up of striated muscle and is under voluntary control. Anatomically, there are notable differences between men and women in the urethral sphincter. For example, the EUS is more intricate in women than in men. In women, the muscles constituting the external sphincter lead to constriction of both the urethra and the vagina [4]. Oelrich, in an accurate description, reviewed the macro- and micro-anatomical findings of the urethral sphincter in men and women, respectively [4,5].

Malfunctioning of the urethral sphincter causes disorders of the lower urinary tract [6]. Urinary incontinence (UI) is the involuntary loss of urine. UI affects both men and women of all ages but is approximately twice as prevalent in women as in men [7]. Malfunctioning of the urethral sphincter is one of the factors causing UI. In women, vaginal childbirth causes anatomical damage to the ligaments, facial support, and pelvic floor musculature, including the levator ani [8]. The pudendal nerve innervating the EUS is susceptible to injury during vaginal birth because it travels between the sacrospinous and sacrotuberous ligaments [9]. In this article, we discuss the basic and clinical anatomy of the urethral sphincter and the relationship between the urethral sphincter and UI.

ANATOMY OF THE URETHRA

The urethra is a small tube with a mucous membrane that connects the urinary bladder to the genitals for the removal of fluids to the exterior of body [10]. In males, the urethra passes through the penis and carries semen as well as urine. The male urethra travels through the center of the prostate gland after leaving the bladder. After leaving the prostate, the urethra enters the base of the penis and passes through the center of the penis. It then ends as a urinary meatus at the tip of the penis. The average length of the male urethra is 22.3 cm [11]. In females, the urethra is shorter and lies directly behind the symphysis pubis. The female urethra emerges above the vaginal opening as it passes through the muscular floor, the levator ani

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muscle, of the pelvis. The urethra passes from the bladder to the external urinary meatus for a distance of about 4 cm [12]. Although in females the urethra is used only for urinating, the relationship of the urethra with the vagina is functionally important to the muscular pelvic floor after vaginal delivery of a baby [13]. In males, the urethra is used for both urinating and ejaculating. At this point, in the urethral structures, the EUS, a striated muscle, controls voluntary urination [14].

ANATOMY OF THE URETHRAL SPHINCTER

Within the deep perineal pouch, a group of muscle fibers surround the urethra and form the urethral sphincter [5]. Two muscles as urethral sphincters are used to control the exit of urine in the urinary bladder through the urethra. The two muscles are the internal and EUS.

IUS

The IUS is located at the inferior end of the bladder and the proximal end of the urethra. The IUS also lies at the junction of the urethra with the urinary bladder and is a continuation of the detrusor muscle. In males, the proximal fibers are a bundle lying between the base of the bladder and the superior border of the prostate [15]. The muscle fibers form a horseshoe-like arrangement that is continuous with the smooth muscle fibers of the bladder [16]. Because the IUS is composed of smooth muscle, it is not under voluntary control. However, the IUS is controlled through the autonomic nervous system [17]. The IUS muscle controls the flow of urine by contracting around the internal urethral orifice. The sympathetic nervous system maintains tonic contractions of the internal urethral muscle [18]. However, the parasympathetic nervous system relaxes the internal sphincter muscle during micturition [18]. The IUS is made of a layer of smooth muscle, which is surrounded by layers of striated muscle [19,20]. Thus, the combination of the smooth muscle of the IUS and these striated muscles surrounding the IUS acts to control the removal of fluids from the body.

EUS

The perineal membrane (PM) is a complex, three-dimensional structure and is an anatomical term for a thick, fibrous, and triangular membrane attached to the bony framework of the pubic arch [21,22]. The PM is the inferior border of the deep perineal pouch, which contains a layer of skeletal muscle [22]. This deep pouch refers to the region between the PM and the pelvic diaphragm. In both men and women, where the urethra passes through the deep pouch, it is surrounded by skeletal muscles called the EUS [23]. The EUS is a secondary sphincter to control the flow of urine through the urethra. The EUS is located at the distal inferior end of the bladder in females [22] and at the level of the membranous urethra in males [24]. Unlike the IUS, the EUS is composed of skeletal muscle; therefore, it is voluntarily controlled through the somatic nervous system [25]. The EUS plays a role in squeezing the urethra and closing where the urethra exits the body. A few causes, such as injury or illness, can result in the EUS becoming weak [26]. The weakening also occurs in women who have carried children [26]. Thus, the weakening of the EUS often results in UI [27].

External Sphincter Muscle of Male Urethra

The muscle fibers inferior to the caudal prostate are circular and form the external sphincter of the membranous urethra [24]. The external fibers arise from the junction of the inferior rami of the pubis and ischium [24]. The external sphincter lies in the urogenital hiatus of the pelvic diaphragm [26]. The EUS fills the area between the pudendal canals below the pelvic diaphragm [23]. The external sphincter muscle is surrounded by fibrous integument [24]. This fibrous integument is a continuation of the prostatic sheath, which is derived from extraperitoneal connective tissue. The proximal fascia of the pelvic diaphragm intermingles with the fascial sheath of the external sphincter and forms a common fascia that travels around the medial border of the pelvic diaphragm. This common fascia then joins the fascia of the pudendal canal [24].

External Sphincter Muscle of Female Urethra

The female EUS is more elaborate than the male EUS because it is made of striated muscle and is more properly referred to as a urogenital sphincter [4]. The female EUS includes 1) the true annular sphincter around the urethra (urethral sphincter), 2) a part that passes anterior to the urethra and that attaches to the ischial rami (compressor urethral muscle), and 3) a part that encircles both the urethra and the vagina (urethrovaginal sphincter).

In females, the urethral sphincter (M. sphincter urethrae, pars urethrae) surrounds the urethra in the middle third of its length [26]. It starts from the base of the bladder and is a continuation of the peripheral component of the compressor ure-

thral muscle [26]. In this sphincter, the ventral side of the urethra is thickest and the dorsal side of the urethra is thin. There is a dorsal septum into which the fibers attach [19]. This fibrous septum affects the manner in which muscle fibers constrict the urethra [19]. Compressor urethral muscles (M. compressor urethrae, pars urethrovaginalis) are directly continuous with the inferior border of the urethral sphincter [26]. These muscle fibers begin as a small tendon attaching to the ischiopubic ramus in the lateral side [26]. This muscle expands to the anterior surface of the urethra and is a continuation of the corresponding fibers of the opposite side of the body [19]. It then forms a broad arcing muscle. The role of the compressor urethral muscles is to squeeze the urethra from its ventral part [19]. This muscle can affect pulling caudally and inferiorly the urethral meatus and assist the urethral elongation as a way of providing continence. The urethrovaginal sphincter (M. sphincter urethrovaginalis) is a thin, flat, and broad muscle [26]. This muscle intermingles ventrally with the compressor urethral muscle [26]. These muscle fibers begin on the ventral side of the urethra to extend dorsally along the lateral wall of the urethra [19]. These fibers also extend to the vagina to the beginning of the vestibular bulb [19]. These fibers are continuous with the posterior vagina and correspond to the muscle of the opposite side. The contraction of these fibers that encircle the vagina and the urethra leads to constriction of both the vagina and the urethra [19].

INNERVATION OF THE URETHRAL SPHINCTER

The innervation of the urethral sphincter is from both the somatic and the autonomic nervous systems. Urination is prevented by the voluntary motor innervation of the EUS muscle. The striated sphincter is innervated by the pudendal nerve from the S2 to S4 nerve roots [28,29]. The neurons that innervate the urethral sphincter originate in the cord, in an area termed Onuf's nucleus [30]. The autonomic nervous system also controls the IUS muscle because it is made of smooth muscle fibers. The sympathetic innervation of the bladder begins at the lower thoracic and upper lumbar spinal cord segments (T10 to L2) [31,32]. The preganglionic axons run to sympathetic neurons in the inferior mesenteric ganglion and the ganglia of the pelvic plexus, and the postganglionic fibers from these ganglia pass in the hypogastric and pelvic nerves to the bladder [31]. The sympathetic activity results in the closing of the IUS [18]. However, parasympathetic activity causes the bladder to contract and allows the internal sphincter to open [18]. When the bladder is full, the fully filled bladder increases parasympathetic tone and decreases sympathetic activity, allowing the internal sphincter muscle to relax and the bladder to contract [17]. Thus, the combination of functional innervations via the somatic pudendal nerve and autonomic innervation manages urination.

FUNCTION OF THE URETHRAL SPHINCTER

The urethral sphincter can be used to control micturition. Voiding urine begins with voluntary relaxation of the external sphincter muscle of the bladder. Parasympathetic impulses induce contractions of the bladder and relaxation of the internal sphincter [18]. Voluntary control of urination is possible only if neural innervation of the bladder and urethra is intact [31]. Occasionally, injury and malfunctioning to any of the supplying nerves causes involuntary emptying of the bladder [27]. This involuntary urination is called incontinence. On the other hand, in males, during ejaculation, the closure of the urethral sphincter prevents mixing between urine and semen and backward flow of semen into the bladder [33].

UI

UI is the involuntary loss of urine. UI is most commonly caused by urethral sphincter incompetence [27]. Incontinence can be caused by a weak vagina [34], pipestem urethra, denervation in neurogenic patients, or estrogen deficiency [27]. UI has a great influence on quality of life and affects mostly the elderly. There are three main types of UI: urge incontinence, stress incontinence, and mixed incontinence. The notable feature of urge incontinence is frequent micturition accompanied by the urge to void. Stress incontinence is characterized by the loss of urine during coughing, sneezing, or physical activity. Mixed incontinence is a mixed form between urge incontinence and stress incontinence. It was reported that 77% of incontinent patients are women [35]. Approximately 88% of all incontinent patients have stress incontinence [36]. Stress incontinence is a problem of the closing mechanism of the urinary tract outlet, and the urethral sphincter is most important to this closing mechanism.

CONCLUDING REMARKS

In general, incontinence is common in women aged over 50 years, with a peak in incidence around menopause [37]. UI can

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negatively affect quality of life. Therefore, it is very important to understand the main mechanism causing UI. The urethral sphincter and UI are closely related and many theories in that regard exist. However, more intensive research is necessary to understand this relationship and the functional and anatomical mechanism of age-induced UI associated with a problem of the urethral sphincter. Normal urethral sphincter function depends on the complex interaction of the somatic and autonomic pathways. This bilateral innervation is essential for urethral sphincter functioning. Several neurological conditions can cause UI. In particular, vaginal distension during childbirth causes direct muscular and supportive tissue damage and neurologic injury. Therefore, further research into the clinical and functional anatomy of the urethral sphincter and the promotion of continence recovery could be a crucial focus to benefit women's health.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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