

Original Article

Normal anatomic relationship between urethral sphincter complex and zones of prostate in young Chinese males on MRI

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Abstract: Objective In this research, the normal anatomic relationship between urethral sphincter complex and zones of prostate in young Chinese males has been studied. Methods: The sagittal, coronal, and axial T2-weighted non-fat suppressed fast spin-echo images of pelvic cavities of 86 Chinese young males were studied. Result: Urethral sphincter complex threaded through the prostate and divided it into 2 parts: transition zone (TZ), periurethral glands internal to the urethral sphincter and peripheral zone (PZ), central zone (CZ), anterior fibromuscular stroma (AFS) zone external to the urethral sphincter. The length of urethral striated sphincter is 12.26-20.94 mm (mean 16.59 mm) at membranous urethra. Conclusions: In this paper, we summarized the normal anatomic relationship between urethral sphincter complex and zones of prostate in young Chinese males with no urinary control problems.

Keywords: Urethral sphincter complex, zones of prostate, magnetic resonance imaging, Chinese young male

Introduction

In males, urethral sphincter complex is a cylindrical structure surrounding the urethra and extending vertically from bladder neck to perineal membrane (inferior fascia of urogenital diaphragm), consisting of urethral smooth sphincter [intermediate signal intensity on T2-weighted non-fat suppressed fast spin-echo (T2W-FSE-NFS) sequences] and urethral striated sphincter (low signal intensity on T2W-FSE-NFS sequences) [1]. Intact urethral sphincter complex plays a dual role in controlling urination and facilitating the discharge of semen into urethra. Posterior urethra can be divided into two functional parts bounded by verumontanum: (1) bladder neck-verumontanum section (including verumontanum) in charge of urinary continence and prevention of retrograde ejaculation, which consists of preprostatic sphincter (smooth sphincter) and urethral striated sphincter; (2) verumontanum-perineal membrane section (not including verumontanum), which is completely formed by urethral striated sphinc-

ter and in charge of urinary continence [2]. The glandular elements of the prostate have been divided into discrete zones, distinguished by the location of their ducts in the urethra, by their differing pathologic lesions, and, in some cases, by their embryologic origin: peripheral zone (PZ), transition zone (TZ), central zone (CZ) and anterior fibromuscular stroma (AFS) zone [3]. Besides, periurethral glands are also part of the prostate gland. Although these glands constitute less than 1% of the secretory elements of the prostate [4]. There is a close relationship between prostatic zones and urethral sphincter complex. The morphology of male urethral sphincter complex constantly changes along with the growth of prostate. Accurate description of the anatomic relationship between urethral sphincter complex and prostate gland in healthy young males would provide reference for the diagnosis of posterior urethral lesions in middle-aged and elderly men.

The anatomic studies of male urethral sphincter complex are based on 'the male pelvic anat-

Relationship between urethral sphincter complex and zones of prostate

omy reconstructed from the visible human data set' proposed by Brooks et al. [5]. Until now, there are still no description about on the normal anatomical relationship between urethral sphincter complex and zones of prostate on MRI. The origin and morphology of surgical capsule remain controversial internationally. What kind of relationship between surgical capsule and urethral sphincter complex? Surgical capsule is closely related to the transition zone (TZ) and periurethral glands which gives rise to benign prostatic hypertrophy. Chung BI et al. [4] held the opinion that the small periurethral glands extend between the fibers of the longitudinal smooth muscle to be enclosed by the preprostatic sphincter. At the angle dividing the preprostatic and prostatic urethra, the ducts of the transition zone arise and pass beneath the preprostatic sphincter to travel on its lateral and posterior sides. The transition zone surrounds the urethra proximal to the ejaculatory ducts. A discrete fibromuscular band of tissue separates the transition zone from the remaining glandular compartments. The transition zone commonly gives rise to benign prostatic hypertrophy, which expands to compress the fibromuscular band into a surgical capsule seen at enucleation of an adenoma. Hricak H et al. [6] held the opinion that Periurethral glandular region and preprostatic sphincter cannot be separated from transition zone. As all of the above studies were carried out in abroad populations, they may be not appropriate for the description of the relationship between urethral sphincter complex and zones of prostate in Chinese males.

With the rapid development of MRI technology, it shows superiority in the evaluation of structures and lesions of pelvic floor. Using multiplanar MR imaging, bladder neck, prostate, urethra, levator ani, and the surrounding structures can all be observed [7, 8]. We have studied normal anatomy of urethral sphincter complex in young Chinese males with MRI technology previously [9], but until now, there are still no description about on the normal anatomical relationship between urethral sphincter complex and zones of prostate on MRI, and there needs to be more studies done to evaluate male urethral sphincter complex and zones of prostate on MRI in various races. In this study, we summarized the imaging characteristics of urethral sphincter complex and zones of pros-

tate in young Chinese males, through MRI examination of these structures in 86 Chinese young men with no urinary control problem.

Methods

Subjects

A total of 86 young Chinese males aged from 18 to 44 years (mean 23.5 years) with no urinary control problems were enrolled. All patients received pelvic MRI in the outpatient clinic from September 2005 to March 2013 (20 cases of rectal tumor, 45 cases of suspected fistula, and 21 case of pelvic mass). Patients with diseases affecting bladder, prostate, or urethra were excluded. None of the subjects had history of abdominal, pelvic, or urethral surgeries or clinical manifestation of neurogenic lower urinary tract dysfunction. This study was approved by the Ethics Committee of Changzhou Central Hospital.

Research methods

Multiplanar pelvic MRI was performed on a 3.0 T MRI scanner (MAGNETOM Trio, Siemens Healthcare, Erlangen, Germany) for all subjects in the supine resting state. To obtain the T2W-FSE-NFS images, the following scanning parameters were used: TR = 4,500-5,500 ms, TE = 130-140 ms; flip angle = 90°; field of view, 225-400 mm; 4.0 mm slice thickness; gap = 0.4 mm; matrix, 512 × 512; scan time, 130-190 s; NEX = 6.0. After scanning, the image data were transmitted to the NUMARIS/4 workstation (Siemens, Syngo MR 2004A). Original images were used to show the zones of prostate and the contour, beginning, and ending of muscle bundles of young male urethral sphincter complex. In order to improve the measurement accuracy, multiplanar reconstruction was used as aids only when a certain muscle was displayed as non-axisymmetric in original images.

Image analysis

Since the zones of prostate (transition zone (TZ) and central zone (CZ) are of moderate signal intensity on T2W-FSE-NFS image, peripheral zone (PZ) is of high signal intensity, anterior fibromuscular stroma (AFS) zone is of low signal intensity) and muscle bundles of posterior urethral sphincter (low or moderate signal intensity

Relationship between urethral sphincter complex and zones of prostate

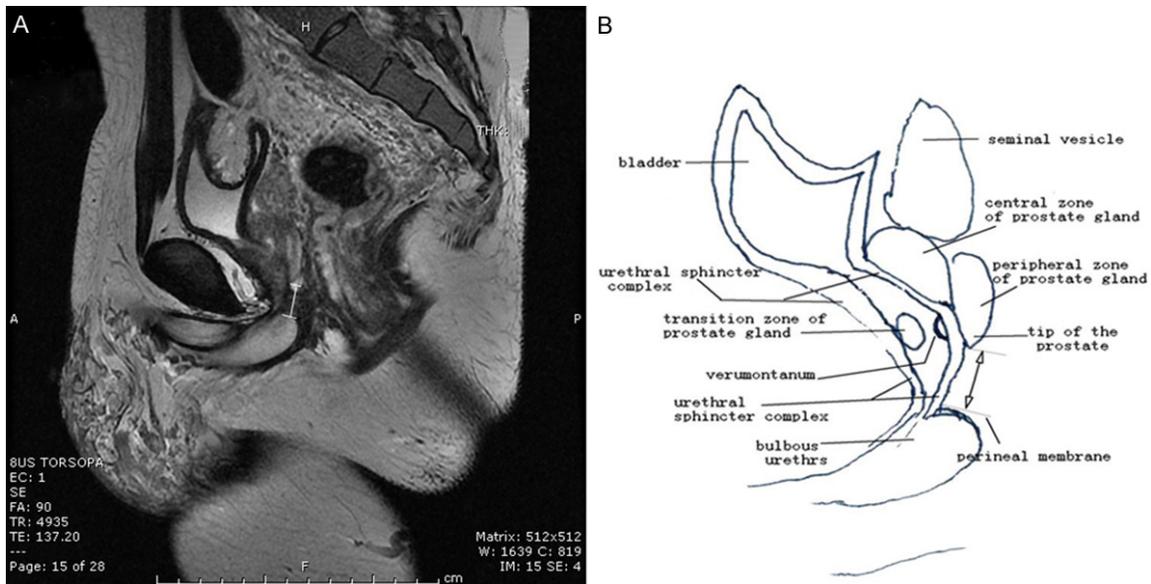


Figure 1. A. MRI image on the midsagittal plane: muscular length of membranous urethra (short line). B. Schematic picture of midsagittal plane.

on T2W-FSE-NFS image) have a sharp contrast with urethral mucosa and submucosa (high signal intensity on T2W-FSE-NFS image) as well as the surrounding fat-containing tissues (high signal intensity on T2W-FSE-NFS image) in young males, the zones of prostate and the contour, beginning, and ending of those muscle bundles can be well displayed. Hence, the length of urethral striated sphincter is measurable. The midsagittal image and measurement of muscle lengths are shown in (Figure 1); The distance between the apex of prostate and perineal membrane (inferior fascia of urogenital diaphragm) was measured, which is the length of membranous urethra [4]. After a urogenital radiologist with 15 years of experience in reading body MRI completed the measurement in NUMARIS/4 workstation, three urogenital radiologists with similar experience were consulted until a consensus was reached.

Results

Axial, coronal, and sagittal T2W-FSE-NFS images with good diagnostic quality have been obtained in the 86 subjects.

Sagittal MRI findings

Organs at the front and back of pelvic cavity can be clearly displayed on sagittal MRI images. Bladder, urethra and prostate are at the

front of the pelvic cavity. Because urine in the bladder is represented by high signal intensity on T2W1 with nonfat suppression, in sharp contrast with low-signal intensity bladder wall, the position of bladder neck can be easily determined.

On the midsagittal plane, the two-layer structure of urethra is clearly displayed. The inner layer of the anterior urethra wall is urethral mucosa and submucosa (central high signal intensity), while the outer layer is composed of urethral striated sphincter (low signal intensity). From the inside out, the posterior urethral wall consists of urethral mucosa and submucosa layer (central high signal intensity) and preprostatic sphincter (moderate signal intensity) and urethral striated sphincter (low signal intensity). Urethral sphincter complex is located between bladder neck and perineal membrane. At the front of it, urethral striated sphincter and prostatic anterior fibromuscular stroma are fused and contiguous, and the muscular layer is relatively thick. Preprostatic sphincter is the main component at the rear of urethral sphincter complex; the muscular layer is the thickest at bladder neck, but the thickness gradually decreases toward the direction of verumontanum; from verumontanum to perineal membrane, preprostatic sphincter is replaced by urethral striated sphincter which gradually gets thicker and extended backward at perineal

Relationship between urethral sphincter complex and zones of prostate

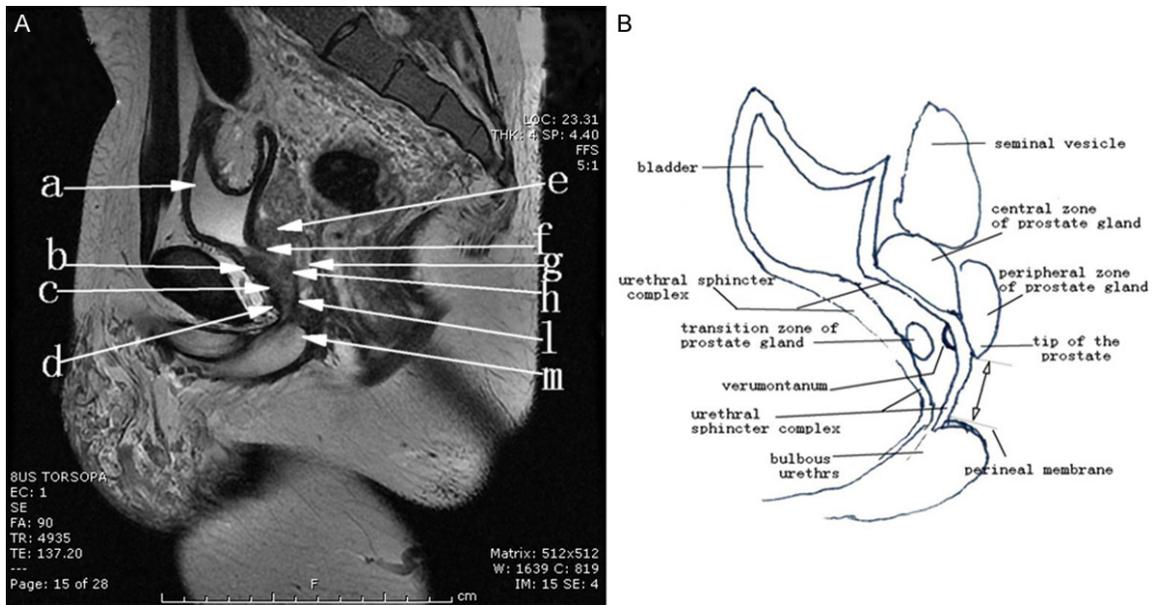


Figure 2. A. MRI image on the midsagittal plane: a bladder, b prostatic anterior fibromuscular stroma and urethral striated sphincter, c transition zone, d urethral striated sphincter, e central zone, f preprostatic sphincter, g peripheral zone, h verumontanum. m bulbous urethra. B. Schematic picture of midsagittal plane.

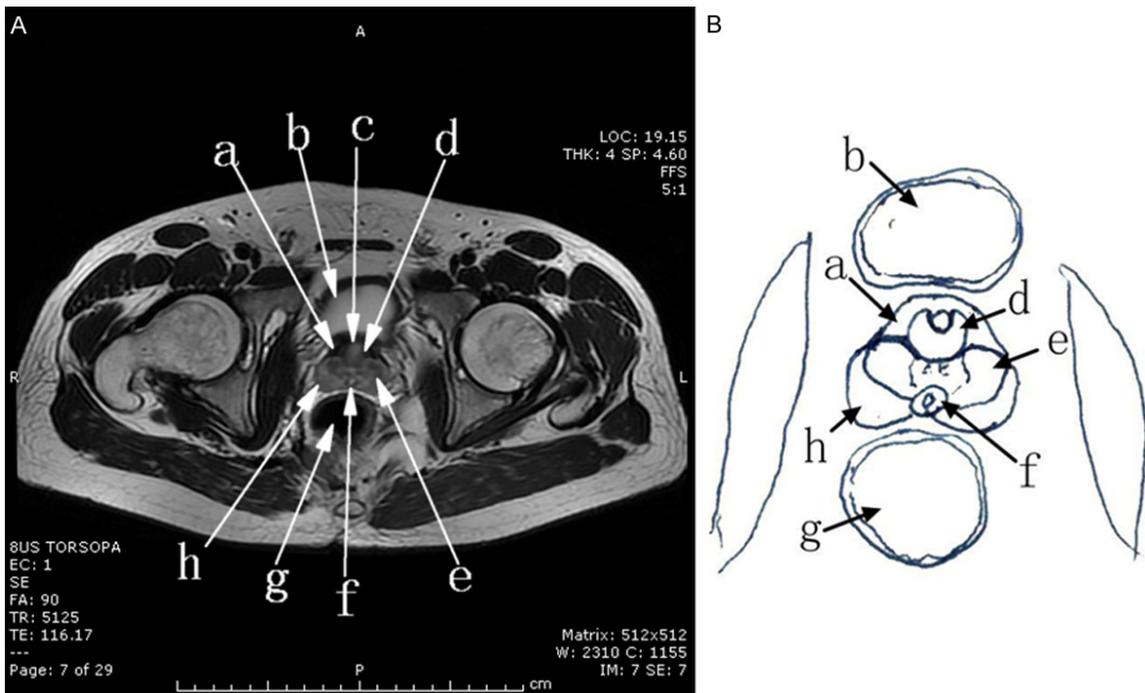


Figure 3. A. Axial plane image of bladder neck: a prostatic anterior fibromuscular stroma and urethral striated sphincter, b bladder, c urethral mucosa and submucosa, d preprostatic sphincter, e central zone, f ejaculatory ducts, g rectum. B. Schematic picture of axial plane of bladder neck.

membrane to be connected with central tendon of the perineum. The central zone (CZ) (moderate signal intensity) lies posterior to the

preprostatic sphincter, the peripheral zone (PZ) (high signal intensity) lies posterior to the central zone (CZ) and urethral striated sphincter.

Relationship between urethral sphincter complex and zones of prostate

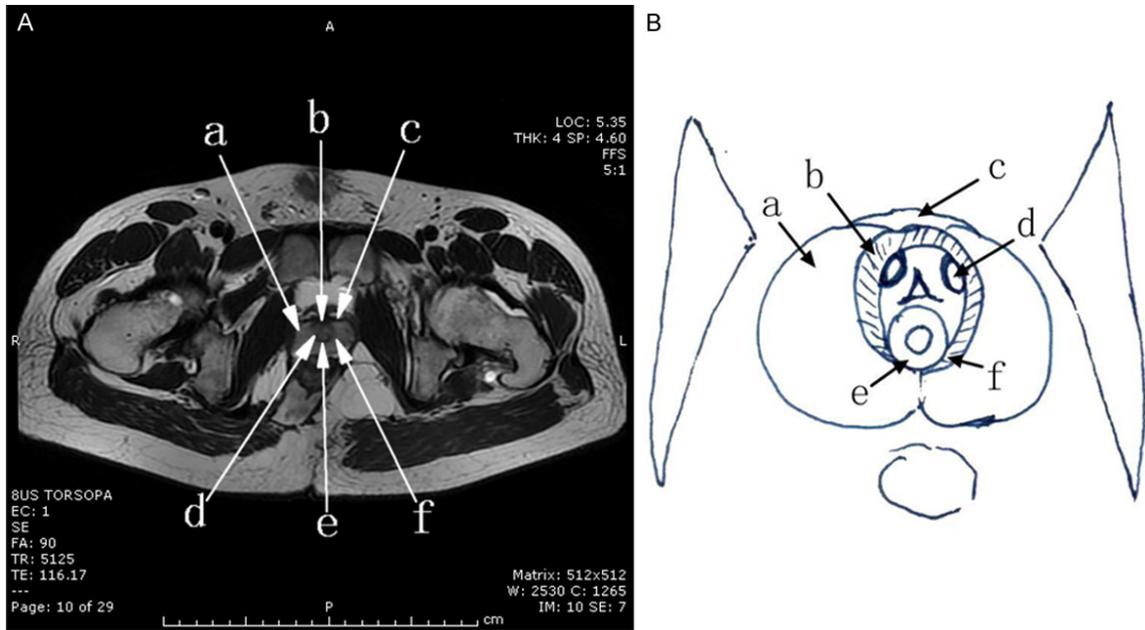


Figure 4. A. Axial plane image of verumontanum: a peripheral zone, b urethral striated sphincter, c prostatic anterior fibromuscular stroma, d transition zone, e verumontanum f preprostatic sphincter. B. Schematic picture of axial plane of verumontanum.

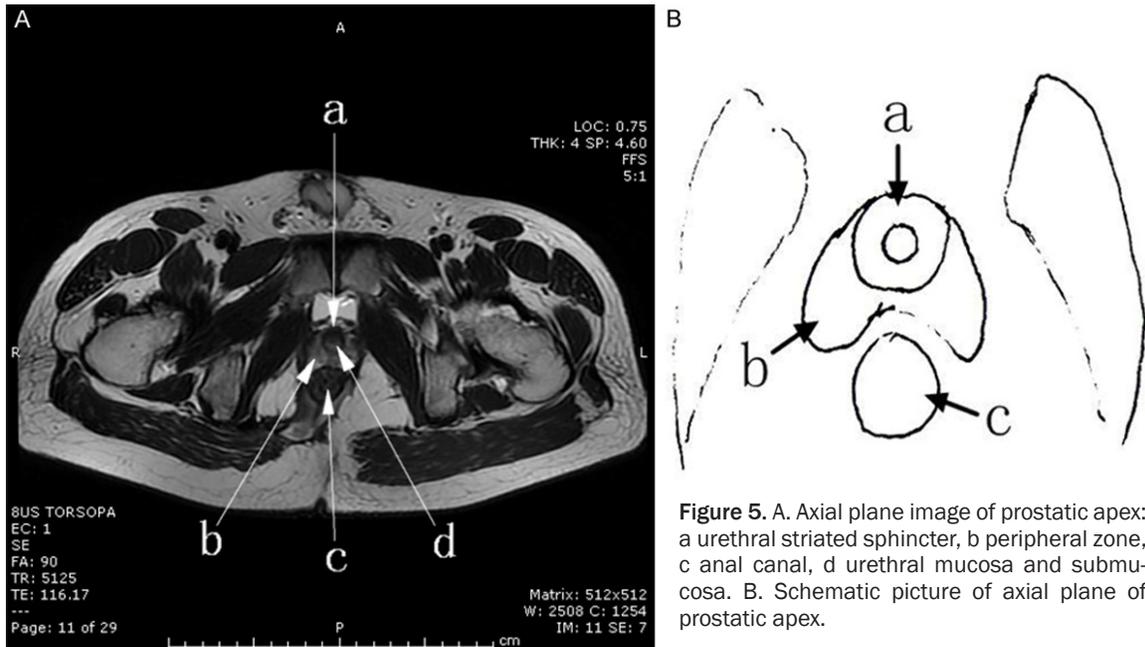


Figure 5. A. Axial plane image of prostatic apex: a urethral striated sphincter, b peripheral zone, c anal canal, d urethral mucosa and submucosa. B. Schematic picture of axial plane of prostatic apex.

The transition zone (TZ) (moderate signal intensity) lies between urethral striated sphincter and urethral mucosa and submucosa. Rectum is located at the upper rear of pelvic cavity, and anal canal is located at the lower rear of pelvic cavity (Figure 2). On the sagittal plane, the length of membranous urethra striated sphincter can be easily measured.

Axial MRI findings

Axial plane image of bladder neck: Bladder, urethra, prostate, rectum, and venous plexus around the bladder are clearly displayed. On T2W1 with nonfat suppression, the two-layer structure of urethra is clearly displayed. The inner layer of the anterior urethra wall is com-

Relationship between urethral sphincter complex and zones of prostate

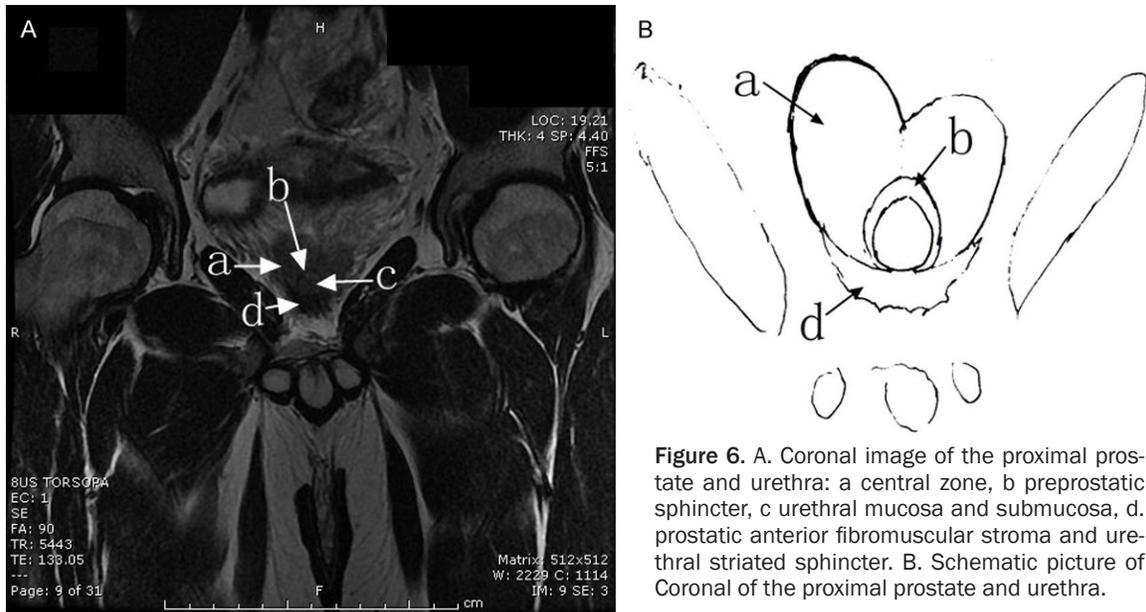


Figure 6. A. Coronal image of the proximal prostate and urethra: a central zone, b preprostatic sphincter, c urethral mucosa and submucosa, d. prostatic anterior fibromuscular stroma and urethral striated sphincter. B. Schematic picture of Coronal of the proximal prostate and urethra.

posed of urethral mucosa and submucosa (central high signal intensity), while the outer layer is composed of urethral striated sphincter. Prostatic anterior fibromuscular stroma cannot be distinguished from urethral striated sphincter (both components are of low signal intensity). From the inside out, the posterior and bilateral urethral walls consist of urethral mucosa and submucosa layer (central high signal intensity) and preprostatic sphincter (moderate signal intensity). The central zone (CZ) (moderate signal intensity) lies predominantly lateral and posterior to the preprostatic sphincter, the peripheral zone (PZ) (high signal intensity) lies predominantly lateral and posterior to the central zone (CZ). prostatic anterior fibromuscular stroma cover the anterior parts of urethral striated sphincter, the central zone (CZ) and the peripheral zone (PZ) in a 'hat' shape; (**Figure 3**).

Axial plane image of verumontanum: Prostatic anterior fibromuscular stroma covers the anterior parts of urethral striated sphincter and the peripheral zone (PZ) like a 'hat' (smaller than before), while urethral striated sphincter surrounds the urethra in a 'half-ring' shape. The central zone (CZ) disappears. Relatively thinner preprostatic sphincter is at the back and posterior-lateral side of urethra and it extends forward and connects with urethral striated sphincter. The transition zone (TZ) (moderate signal intensity) lies posterior to the urethral striated sphincter and anteromedial to the pre-

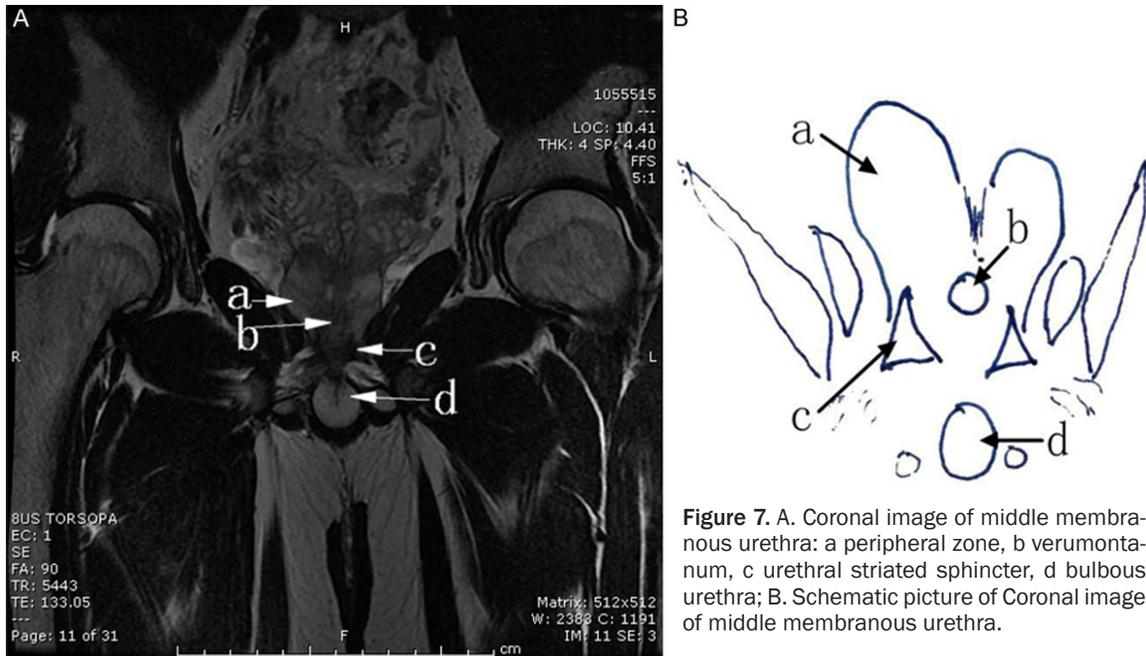
prostatic sphincter and anterolateral to the urethral mucosa and submucosa. (**Figure 4**).

Axial plane image of prostatic apex: Urethra, prostate, anal canal, levator ani, and retropubic venous plexus are clearly displayed. Urethral striated sphincter surrounds the urethra like a 'ring', the prostatic apex lies lateral and posterior to the urethral striated sphincter. Prostatic anterior fibromuscular stroma disappears (**Figure 5**).

Coronal MRI findings

Coronal image of the proximal prostate and urethra: On T2W1 with nonfat suppression, the two-layer structure of urethra is clearly displayed. From the inside out, in the anterior urethra wall, there are urethral mucosa and submucosa (central high signal intensity), followed by urethral striated sphincter (low signal intensity). From the inside out, in the posterior and bilateral urethra, there are urethral mucosa and submucosa layer (central high signal intensity), followed by the preprostatic sphincter (moderate signal intensity). The central zone (CZ) (moderate signal intensity) lies predominantly lateral and posterior to the preprostatic sphincter, prostatic anterior fibromuscular stroma cover the anterior parts of urethra and the central zone (CZ) in a 'hat' shape (**Figure 6**).

Coronal image of middle membranous urethra: Urethral striated sphincter is in a cone shape,



with wide base and narrow apex; it extends upward to the medial side of prostatic apex and ends at the distal part of verumontanum (**Figure 7**).

The length of urethral striated sphincter

The length of urethral striated sphincter is detected on midsagittal image (**Figure 1A**): 12.26-20.94 mm (mean 16.59 mm) at membranous urethra.

Discussion

Until now, there are still no description about on the normal anatomical relationship between urethral sphincter complex and zones of prostate on MRI. The results of this study show that Urethral sphincter complex threaded through the prostate and divided it into 2 parts: transition zone (TZ), periurethral glands internal to the urethral sphincter and peripheral zone (PZ), central zone (CZ), anterior fibromuscular stroma (AFS) zone external to the urethral sphincter. The anterior fibromuscular stroma extends from the bladder neck to the striated urethral sphincter [3], but it gets separated from urethral striated sphincter, and the latter is at the medial side of the former [9].

The origin and morphology of surgical capsule remain controversial internationally. The results

of this study support the perspectives of Chung BI et al. [4] and Hricak H et al. [6]. Sagittal MRI findings showed that the transition zone (TZ) (moderate signal intensity) lies between urethral striated sphincter and urethral mucosa and submucosa. Axial MRI findings showed that the transition zone (TZ) (moderate signal intensity) lies posterior to urethral striated sphincter and anteromedial to the preprostatic sphincter. And on these basis we consider that the transition zone (TZ) expands to compress urethral striated sphincter and preprostatic sphincter into a surgical capsule, while periurethral glands expands to compress preprostatic sphincter into a surgical capsule.

Currently, the database of different lengths of urethral striated sphincter among different races still needs to be consummated [10]. The muscular lengths of male membranous urethra are various in different studies. It is 12-50 mm (mean 20-25 mm) according to 'Campbell Walsh Urology' [4], 28-35 mm (mean 31.0 mm) in Naohito Mikuma's study [8] measured by MRI, 15-24 mm (mean 20.0 mm) in Myers RP's study [11], 6-24 mm (mean 14 mm) in Coakley's study [12], 14 mm in Paparel's study [13], and 10.40 ± 3.75 mm in Tae Joon Lim's study [10]. In this study, we have measured the muscular length of male membranous urethra in 86

Relationship between urethral sphincter complex and zones of prostate

young Chinese men, and the mean value is 16.59 mm (12.26-20.94 mm), consistent with the results reported abroad.

Conclusion

There is a close relationship between prostatic zones and urethral sphincter complex. Urethral sphincter complex is the anatomic landmark for well-developed posterior urethra in males. In this study, we summarized the normal anatomic relationship between urethral sphincter complex and zones of prostate in young Chinese males, through examination of these structures in 86 cases with normal urinary control by MRI, providing standards for diagnosis of lesions in posterior urethra of middle-aged and elderly Chinese males and practical basis for comparative study with various ethnic groups abroad.

Disclosure of conflict of interest

None.

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