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Three-dimensional transrectal ultrasound of the male urethral rhabdosphincter

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Abstract The rhabdosphincter of the male urethra is an omega-shaped loop of striated muscle fibers that surrounds the membranous urethra at its lateral and anterior aspects. We investigated whether this muscle can be visualized by means of three-dimensional ultrasound to define morphological and dynamic ultrasound criteria. We examined the rhabdosphincter of the male urethra in 77 patients by means of this new imaging technique; 37 patients presented with urinary stress incontinence after transurethral resection of the prostate or radical prostatectomy while 40 were fully continent after radical prostatectomy and served as a control group. Contractility of the muscle was quantified by a specially defined parameter (rhabdosphincter–urethra distance). The anatomical arrangement and the contractions of the rhabdosphincter-loop could be clearly visualized in three-dimensional transrectal and transurethral ultrasound; during contraction the rhabdosphincter retracts the urethra, pulling it towards the rectum. We detected defects and postoperative scarrings in the majority of the patients with postoperative urinary stress incontinence. Furthermore, the patients presented with thinnings in parts of the muscle and atrophies of the rhabdosphincter. The rhabdosphincter–urethra distance was significantly lower in the incontinent group than in the continent group (59 vs. 1.42 mm). Our study shows that the rhabdosphincter of the male urethra can be visualized by means of three-dimensional transrectal ultrasound. The sonographic pathomorphological findings of postoperative urinary stress incontinence are well correlated well with the clinical symptoms

Keywords Rhabdosphincter · Three-dimensional ultrasound · Urinary incontinence · Rhabdosphincter

In the past few years great efforts have been made to investigate the morphological and functional basis of urinary stress incontinence after transurethral resection of the prostate or radical prostatectomy [1]. Until now it has not been very difficult to directly assess the rhabdosphincter, the main muscular structure in the region of the membranous urethra, either by means of imaging techniques or by functional tests [2, 3, 4, 5]. For this reason an ultrasonographic study was undertaken to investigate whether this muscle can be visualized by means of three-dimensional transrectal ultrasound. The aim of this study was to provide basic sonomorphological data for the investigation of normal urinary function and male urinary incontinence.

Materials and methods

The rhabdosphincter of the male urethra was investigated in 77 patients by means of this new imaging technique and urodynamics. Of these, 37 presented with urinary stress incontinence after transurethral resection of the prostate ($n=2$) or radical prostatectomy ($n=35$), and 40 were fully continent and served as control group. The ultrasound equipment used for three-dimensional transrectal ultrasound consisted of a Combison 530 and a Voluson three-dimensional multiplanar endorectal transducer (7.5 + 10 MHz; Kretz-Technik). Three-dimensional transrectal ultrasound provides sonographic pictures in three planes simultaneously. Apart from the additional information obtained by the third, i.e., the coronal plane, this new technique permits precise three-dimensional analyses of relevant anatomical and pathological structures [6, 7, 8].

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Initially, a volume scan of the relevant anatomical region is performed. This examination takes approximately 3–4 s, during which both the patient and the physician must avoid any movement to guarantee a flawless scan. Once this scan has been obtained, the patient's role in the examination is finished. All the sonographic data obtained are collected in a volume image store. On the monitor of this system three sections in horizontal, sagittal, and coronal planes which are at 90° angles to one another can be displayed. The coronal image is calculated by the computer from the information of the scan. The positions of the individual planes are indicated in the two other planes by reference lines. The three planes can be targeted on any site recorded in the volume scan by means of three position keys [6, 7, 8].

To reliably measure and quantify the contractions and the function of the muscle new ultrasonographic parameters had to be defined. Three-dimensional transrectal ultrasound of the rhabdosphincter was performed at rest and during voluntary contraction of the muscle; the distance between the inner aspect of the rhabdosphincter and the dorsal aspect of the membranous urethra (rhabdosphincter–urethra distance, RUD) was measured in both cases. The mean differences between the readings of the normal and the contracted rhabdosphincter then served as a parameter for the contractility of the rhabdosphincter measured by means of three-dimensional transrectal ultrasound (mean decrease in rhabdosphincter–urethra distance = Δ RUD; Fig. 1).

The Ingelman-Sundberg-classification was used to determine the degree of urinary incontinence. The Wilcoxon-test was used to assess statistical significance of differences in contractility of the rhabdosphincter by means of three-dimensional transrectal ultrasound in incontinent and continent patients. A *P* value less than 0.05 was taken as statistically significant.

Results

Three-dimensional transrectal ultrasound proved an accurate imaging technique for visualizing the mem-

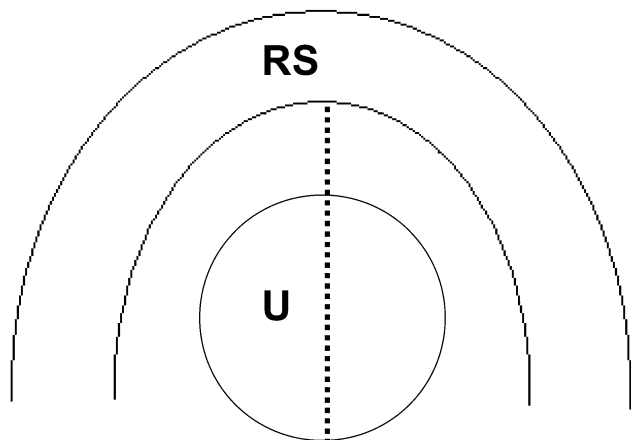


Fig. 1 Schematic drawing of measurement of the rhabdosphincter–urethra distance (red). RS Rhabdosphincter; U urethra

branous urethra and the rhabdosphincter. It was possible to visualize the rhabdosphincter in all patients, and the contractions of the muscle were clearly observed. The omega-shaped muscular loop presents as a hypo-echoic structure surrounding the membranous urethra at its ventral and lateral aspects. The inner aspects of the rhabdosphincter adjacent to the membranous urethra are sharply demarcated from the connective tissue of the membranous urethra. In seven patients it was not possible to determine the thickness of the muscle because its peripheral aspects could not be clearly differentiated from the dorsal venous complex and the pubic symphysis. Consequently, assessment of the thickness of the muscle or its cross-sectional area, as proposed by other authors, did not provide sufficient and reliable data on continence function of the muscle [9].

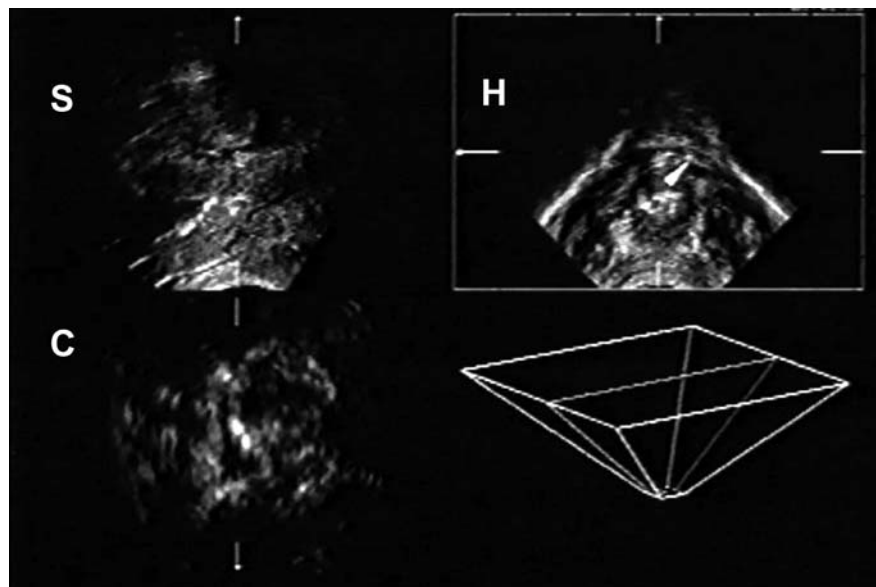
As the rhabdosphincter contracts, it pulls the urethra towards the perineal body, thereby compressing the urethral lumen. In continent patients the muscle loop approaches the membranous urethra to a mean Δ RUD of 1.42 ± 0.19 mm; no contractions of the membranous urethra itself were observed. In the group of incontinent patients Δ RUD was only 0.59 ± 0.26 mm ($P < 0.001$). In incontinent patients the membranous urethra was not adequately forced against the perineal body; in two patients the lumen of the membranous urethra was not compressed at all. The decrease in contractility assessed by means of three-dimensional transrectal ultrasound was well correlated with the degree of urinary stress incontinence; the mean decrease in Δ RTD was 0.82 ± 0.12 mm in stress incontinence of grade I ($n = 12$), 0.55 ± 0.17 mm in grade II ($n = 20$), and 0.18 ± 0.15 mm in grade III ($n = 5$). The present data suggest that patients with a decrease in Δ RUD of less than 1.0 mm are likely to suffer from postoperative urinary incontinence.

Distinct morphological defects of the rhabdosphincter were visualized in the 37 patients presenting with postoperative urinary stress incontinence, while there were no such pathological findings in the continent patients. In the majority of patients the continuity of the muscle fibers was interrupted ventrally by scar tissue or local atrophies which made adequate contractions impossible (Fig. 2). When the intact fibers contracted, this merely caused stretching of the involved segment; as a result the muscle did not approach the urethra and was unable to compress it. In addition, several incontinent patients presented with complete atrophy of the muscle; in these patients approximation and compression of the urethra were found to be insufficient as well. In one patient hardly any contractions of the muscle were noted.

Discussion

The rhabdosphincter of the adult male is a muscular coat ventral and lateral to the membranous urethra and prostate, the core of which is an omega-shaped loop around the urethra. Both tendinous ends of the

Fig. 2 Transrectal three-dimensional ultrasound of the rhabdosphincter of an incontinent patient. *S* Sagittal plane; *H* horizontal plane; *C* coronal plane. The rhabdosphincter of this incontinent patient has a ventral atrophy (*arrow*)



omega-shaped sphincter insert at the perineal body. The sphincter-loop is continuous with muscle bundles which run along the anterior and lateral aspects of the prostate and extend cranially until they reach the bladder neck [1, 10]. The results of the present study support earlier findings that the rhabdosphincter is the key muscular structure of the urethral closure mechanism after prostate surgery [11, 12, 13, 14].

Three-dimensional transrectal ultrasound proved to be an uncomplicated procedure that allows exact assessment of all parts of the rhabdosphincter loop, which can be considered the core of male urinary continence after radical prostatectomy and transurethral resection of the prostate. In all patients three-dimensional transrectal ultrasound could be performed without any problems or complications. During contraction the rhabdosphincter presses the urethra against the perineal body, thus closing the membranous urethra. The rhabdosphincter loop is capable of producing powerful contractions which are responsible for male urinary continence in healthy subjects. Marked differences can be observed between continent patients and those suffering from urinary incontinence. The Δ RUD parameter was much higher in continent patients than in incontinent patients. The present data strongly suggest that a Δ RUD of less than 1.0 mm is inevitably associated with postoperative urinary stress incontinence.

Assessment of the urethral rhabdosphincter in urinary incontinence is certainly one of the more promising applications of this relatively new imaging technique [15]. Further ultrasonographic studies on the rhabdosphincter are being performed with the aim of obtaining reliable parameters for evaluating postoperative urinary incontinence. Imaging of the rhabdosphincter contributes to improved diagnosis and thus management of patients suffering from stress urinary incontinence after prostate surgery.

Conclusions

Three-dimensional transrectal ultrasound permits direct assessment of the contractility of the rhabdosphincter by means of a newly defined quantitative parameter (Δ RUD). Unlike intraurethral pressure profiles, which reveal only zones of higher intraluminal pressure between the bladder and the penile urethra, this parameter is highly specific for the rhabdosphincter. This new technique allows the rhabdosphincter and its contractions to be visualized well. In patients suffering from stress urinary incontinence after prostate surgery contractility of the rhabdosphincter is markedly decreased. Furthermore, in these patients morphological defects can be seen.

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