Original article

The assessment of normal female urethral vascularity with Color Doppler endovaginal ultrasonography: preliminary report

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Abstract: In this study we compared vascular intensity in female urethra in its midsagittal plane at 3 predefined parts (intramural, midurethral and distal) and in its axial plane at the level of midurethra (rhabdosphincter vs. the inner part of urethra) in premenopausal, nulliparous, continent patients. Eighteen nulliparous patients, mean age 32.67 years (range 18-53 years) with no pelvic floor disorders and no history of incontinence were enrolled in the study. In the first part of their menstrual cycle, the subjects underwent endovaginal ultrasound with the use of a biplane, high frequency (5-12 MHz) transducer. Vascular pattern of the urethra was obtained in color-doppler mode using both, the linear and transverse arrays of the transducer and the data were registered as video files in a stable position of the probe. For each patient two video acquisitions were taken, one in midsagittal plane, second in axial plane at the level of midurethra. For the quantitative assessment of the blood flow, a PixelFlux software was applied. The comparison of intensity among three levels of vascularity observed in sagittal section as well as the comparison of vascular intensity between outer (rhabdosphincter) and inner (circular smooth muscle, longitudinal smooth muscle and submucosa) rings of the urethra were performed. The results of the analysis show that the midurethra has got the largest intensity of vascularity, which is statistically significantly better that the latter part of urethra (intramural and distal parts). Statistical analysis showed the differences of vascular intensity between intramural part of urethra and midurethra (0.47, $p < 0.05$) and between midurethra and distal urethra (0.43, $p < 0.05$). No statistically significant differences were found between the vascular intensity of in outer and inner part of the midurethra; but on contrary the values were very similar (0.76, $p < 0.05$). High frequency transvaginal ultrasound with the use of Color Doppler mode is a very reliable method enabling visualization of urethral vessels distribution. The data obtained from the scans may be further analyzed with the use of dedicated software in order to define the intensity of urethral vascularity and different anatomical areas, which are responsible for various functionalities.

Key words: Urethral vascularization; Color-doppler; Endovaginal ultrasound.

INTRODUCTION

The female urethra has very complex anatomy and function which are still not fully understood.[1] Vascularity is one of the major factors contributing to maintaining the normal function of urethra. The usefulness of color-doppler as well as of spectral analysis of blood flow within the urethral vessels have been already described in the literature.[2-4] From these reports it is known that a number of various elements, such as age, parity, body mass index, estrogen/gestagen profile, menopause, hormone replacement therapy can influence the appearance of Doppler flow spectrum in urethral vessels. However, the research describing the number and the distribution of urethral blood vessels is scarce. It is known from anatomy that the female urethra is supplied by 3 different vessel networks manifested by 3 major vascular levels – proximal (intramural), middle (midurethra) and distal. The aim of the study was a comparison of intensity of the vascularity of urethra at 3 levels in its sagittal plane (intramural, midurethra and distal part), and in its axial plane at the level of midurethra (rhabdosphincter vs. the inner part of urethra) in premenopausal, nulliparous, continent patients.

MATERIAL AND METHODS

Eighteen nulliparous patients, mean age 32.67 years (range 18-53 years), consecutively referred for gynecologic ultrasound due to symptoms other than SUI, voiding dysfunction, POP, cystocoele or entero/rectocele were recruited from 2nd Department of Gynecology of the Skubiszewski Medical University of Lublin. All the women gave written informed consent and underwent endovaginal ultrasound using a biplane transducer (type 8848, B-K Medical, Herlev, Denmark) 21 mm in diameter, frequency range from 5 to 12 MHz. The patients were scanned in the first part of their menstrual cycle. Ultrasound scanning was performed at rest in the supine position. Longitudinal images of the bladder neck and urethra were displayed using the 12 MHz linear array of the transducer positioned towards the symphysis pubis (SP). The transducer was placed in the vagina in the neutral position. The position of the transducer was assumed as symmetrical when the lumen of the urethra was visualized along the entire length of the urethra, from the bladder neck to external meatus of urethra.

The vascular pattern of the urethra was obtained in color-doppler mode using both the linear and transverse arrays of the transducer and the data were registered as video files in a stable position of the probe (Fig. 1 *a, b*). For each patient, two video acquisitions were taken: one in the sagittal plane at the level of urethral lumen, and the second in the axial plane at the level of midurethra. For the quantitative assessment of the blood flow, the Pixel Flux software (Chameleon Software, Freiburg, Germany) was applied. With the use of PixelFlux software, the vascular pattern was analyzed within manually defined regions of interest (ROI). At first, the video files in the sagittal plane were used for the analysis. Regions of interest were set at sequence at 3 levels (intramural, midurethra and distal urethra) (Fig. 2 *a, b, c*) for each patient. Subsequently, video files recorded in the axial plane at the level of midurethra were studied. Two regions of interest were defined for each patient – one comprising the rhabdosphincter (the outer ring of urethra), and the second comprising the circular smooth muscle, the longitudinal smooth muscle and the submucosa (the inner ring of the urethra) (Fig. 3 *a, b*). The intensity of vascularity defined as the ratio between the area of the vessels detected in Color Doppler and the area of ROI was calculated for each patient for all 3 regions of interests in sagittal plane and 2 regions in axial plane. Two measurements of the intensity were performed for all patients:

1. A comparison of intensity among three levels of vascularity based on the data obtained from files recorded in sagittal section.
2. A comparison of intensity between two rings of vascularity (the outer ring and the inner ring of the urethra) based on the data obtained from files recorded in axial section.

The descriptive statistics (SPSS 14.0 PL for Windows) for continuous data was performed. The results were given as mean values with standard deviation (SD). The Kolmogorov-Smirnov test (KS-test) was used to define the distribution of data. Subsequently, the relationships

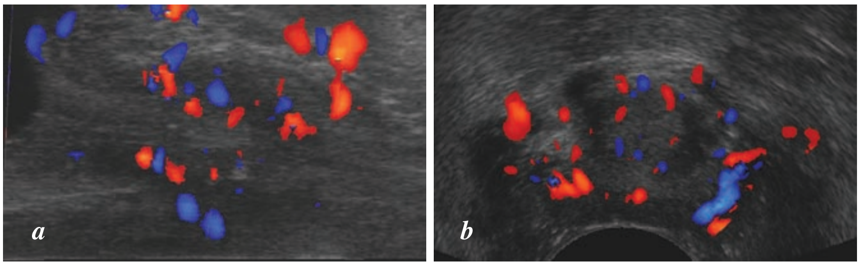

Fig. 1*a,b*. – Vascular pattern of the urethra obtained in color-doppler mode using the linear transverse array of the transducer.

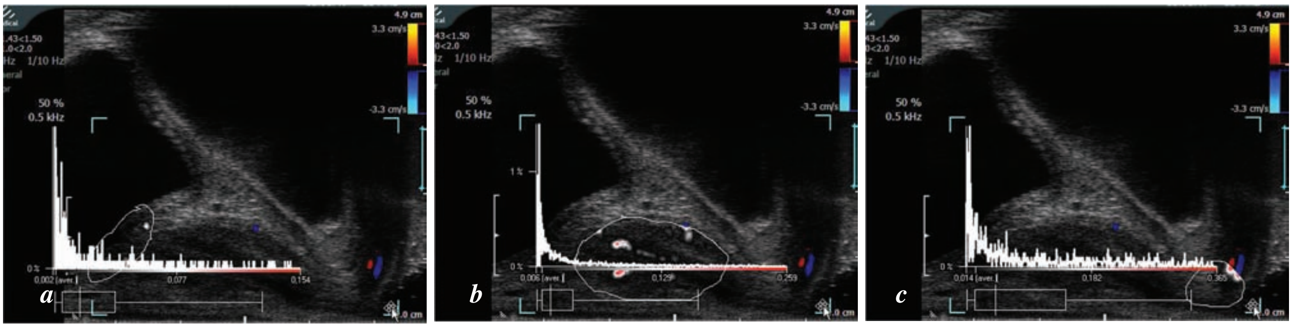

Fig. 2. – *a)* Analysis of intensity of urethral vascularity with the use of PixelFlux software. Region of interest set at the level of intramural part of urethra. Sagittal plane; *b*) Analysis of intensity of urethral vascularity with the use of PixelFlux software. Region of interest set at the level of midurethra. Sagittal plane; *c*) Analysis of intensity of urethral vascularity with the use of PixelFlux software. Region of interest set at the level of distal part of urethra. Sagittal plane.

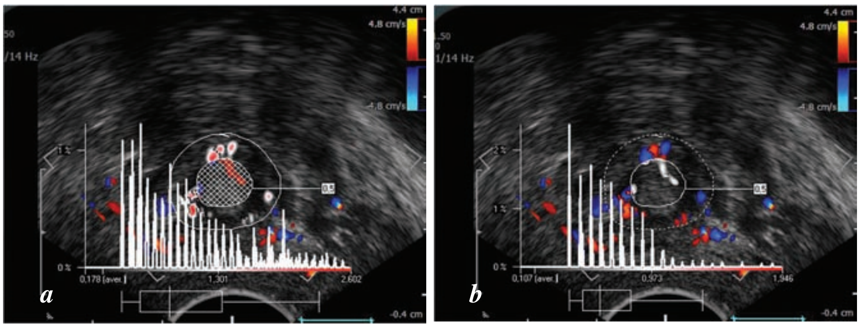

Fig. 3. – *a)* Analysis of intensity of urethral vascularity with the use of PixelFlux software. Region of interest set at the outer ring of urethra (rhabdosphincter). Axial plane; *b*) Analysis of intensity of urethral vascularity with the use of PixelFlux software. Region of interest set at the inner ring of urethra (circular smooth muscle, longitudinal smooth muscle and submucosa). Axial plane.

among different variables were assessed with T test for dependent samples. $P < 0.05$ was considered as statistically significant.

RESULTS

Statistical differences of intensity of vascularity were observed between intramural part of urethra and midurethra and also between midurethra and distal urethra. The results of the analysis show that the midurethra, which is the part of urethra comprising rhabdosphincter muscle, has got the largest intensity of vascularity, which is statistically significantly better that the latter part of urethra (intramural and distal parts). While performing the analysis of the urethra in its axial section at the level of midurethra, the authors did not find any statistically significant differences in the intensity of vascularity in vessel distribution between the outer ring of the urethra (rhabdosphincter) and the inner ring of the urethra (circular smooth muscle, longitudinal smooth muscle and submucosa). On the contrary, the intensity of vascularity in both anatomical areas was very similar (0.76, $p < 0.05$).

DISCUSSION

Up till now no reliable diagnostic tool existed that would enable a quantitative analysis of urethral vascularization. Different authors assessed urethral vascularity with the use of color and spectral doppler techniques. [2-6] However, the appearance of the Doppler flow spectrum can be impaired by number of factors, among which the sexual hormones profile is the most important one.[7] Besides, spectral Doppler studies are generally time consuming and relatively difficult to perform from the technical point of view, particularly for the vessels of a very small diameter, such as found in the urethra. Moreover, this kind of examination is usually performed from the transperineal approach, where the urethra is prone to be pressed by the transducer, which results in artificial increasing of resistance index (RI) giving false results. Additionally, moving artifacts, breathing artifacts, the difficulty in obtaining proper insonation angle, as well as placing the gate properly in a little vessel greatly limit the usefulness of spectral Doppler studies in the assessment of urethral vascularity.

Because of these limitations, it is important to find an easy method which would allow assessment of the number of vessels and their distribution. According to Ashton-Miller, the lumen of the urethra is surrounded by a prominent vascular plexus that is believed to contribute to the continence by forming a watertight seal via coaptation of the mucosal surfaces.[6] Basing on this theory, the authors believe that the distribution of vessels, their number and localization, as well as

TABLE 1. – *The intensity of vascularity (the ratio between the area of the vessels detected in color-doppler and the area of ROI) at 3 vascular levels - intramural, midurethra and distal urethra based on the data obtained from files recorded in sagittal section.*

Intensity	*Number of patients*	*Minimum*	*Maximum*	*Mean*	*Standard deviation (SD)*
Intramural urethra	18	0.000	0.040	0.00689	0.009863
Midurethra	18	0.001	0.077	0.01433	0.017617
Distal urethra	18	0.000	0.017	0.00528	0.004921

TABLE 2. – *Intensity of vascularity (the ratio between the area of the vessels detected in color-doppler and the area of ROI) at 2 urethral rings (the outer ring and the inner ring of the urethra) based on the data obtained from files recorded in axial section at the level of midurethra.*

Intensity	*Number of patients*	*Minimum*	*Maximum*	*Mean*	*Standard deviation (SD)*
Outer ring	18	0.004	0.131	0.02906	0.029345
Inner ring	18	0.001	0.125	0.03244	0.042521

TABLE 3. – *Statistical analysis for the significance of the differences in intensity of vascularity among three levels (intramural, midurethra and distal urethra) in sagittal section and two rings (the outer ring and the inner ring of urethra) in axial section.*

Pair	*Statistical significance ($p<0.05$)*
Intramural urethra - Midurethra	0.47
Intramural urethra - Distal urethra	0.57
Midurethra - Distal urethra	0.43
Outer ring – Inner ring	0.76

the regions supplied by them, seem to play a very important role. Thus, in order to acknowledge the normal vascularity of the urethra, the study including premenopausal, nulliparous, continent patients was performed. The authors believe that, together with the urethral dysfunctions and morphological disturbances, particularly urinary incontinence and pelvic organ prolapse, a change in urethral vascularity may occur, possibly prior to the appearance of clinical signs.[8-10] In such a situation the assessment of urethra vascularization could become a predictive value which would give the opportunity to implement the prophylaxis or early treatment for the patients, before the symptoms become severe. The technique used in the study appeared very useful in the assessment of the vascular pattern of the urethra, being at the same time easy and fast to perform, with the results obtained as an absolute value. The literature review does not contain much information about urethral vascularity. Siracusano et al.[11] performed transperineal ultrasound after intravenous application of ultrasound contrast media in order to enhance Doppler signals from the urethral vessels. The method, although it might give information about the vessels in the urethral complex, is invasive and relatively expensive. The transperineal access with a large array of the transducer, too deep a focus, and a large distance to the urethra, also greatly limit the reliability of the method. In another study, the same author[(2)] assessed urethral vascularization in healthy young women using Color Doppler and spectral Doppler scans, defining resistance index (RI) in urethral vessels at three parts of urethra (proximal, middle and distal). This study was also performed from the transperineal access. In the current study, the authors applied a transvaginal high frequency ultrasound which, due to almost direct contact of the urethra to the transducer and owing to the focus transverse point placed on the right depth, creates the opportunity of precise evaluation of the assessment of urethral vascularity. High frequency 5-12 MHz biplane transducer, with perpendicular and transverse ultrasound beam formation appeared to be a very reliable diagnostic tool in the assessment of urethra vascularity. The results showed that the midurethra is the most vascularized part of the urethra, with the latter parts (intramural and distal) having less blood supply, comparable to each other. While Siracusano's study [6] depicted similar spectrum of blood flow within midurethra and distal urethra, with increased RI in proximal (intramural) part. In conclusion, high frequency transvaginal ultrasound with the use of Color Doppler mode is a very reliable method enabling visualization of urethral vessels distribution. The data obtained from the scans may be further analyzed with the use of dedicated software in order to define the intensity of urethral vascularity and different anatomical areas, which are responsible for various functionalities.

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