3D Virtual Endocavity Ultrasound in Detection of Urinary Bladder Tumors with Pathomorphological Correlations

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INTRODUCTION
Urinary bladder tumors (UBT) are a frequent condition in urology. Urinary Bladder Carcinoma (UBC) accounts for 2% of all malignancies; and 70% of malignancies of the urinary tract [1]. Improvements in surgical techniques, urinary reconstruction, and multimodal therapy require accurate diagnosis of UBT [2,3]. The latest technological advances in computer systems and new US high-frequency transducers have allowed a revolutionary use of 3D technology in real-time scanning of the so called “virtual US,” in a manner similar to a urologist manipulating a cystoscope. The possibility of virtual US cystoscopy has been extensively studied over the past few years, as mentioned in one of our first reports [4] and some recent reports [5,6].

PURPOSE
The purpose of the study was to determine the possibilities of 3D Virtual Endocavity ultrasound (3D VEUS) to depict tumors of the urinary bladder, to calculate the sensitivity and specificity in detection of bladder tumors, and to compare the findings with 2D conventional US and cystoscopy and final histopathology. Another purpose was to learn how to perform 3D US of the urinary bladder and to determine a US investigation algorithm in the cases of urinary bladder tumors.

MATERIALS AND METHODS
Fifty six patients, in whom findings from routine urological clinical examinations made them potential victims of UBTs, were referred from the urology department; there were 10 (18%) females and 46 (82%) males (ages ranged from 45-76 y.; mean 73±7 y.). Written informed consent was obtained from each patient, and the study was approved by our local Ethics Committee.

All patients underwent 3D VEUS, followed by conventional cystoscopy within 14 days. Sonographic examinations were performed with an ACCUVIX XQ system (MEDISON Co.,Ltd.) and 4 to 7 MHz volume transabdominal and 5 to 8 MHz volume Endocavity transducers were used to create images.

EXAMINATION PROTOCOL
Approximately an hour before the US examination, 500 ml of water was given to each patient orally. The examination was performed with the bladder filled up to 350 ml, or up to each patient’s tolerance. Routine 2D scanning with documentation of the longitudinal and transverse planes of the bladder was recorded.

TECHNICAL ASPECTS
Three-dimensional ultrasound volumes were generated by the automatic rotation of the transducer. 3D data acquisition was based on high quality 2D US images of the UB with the sample window encompassing the prostate in men and the cervix in women. Rotational angles ranged from 45 to 90 degrees, with a rotational field width of 5 to 10 cm. The quality of the data collected was set at High or Extreme for better delineation of the tumors and internal bladder surfaces. Small artifacts were trimmed from the 3D data by increasing or decreasing the threshold, allowing better appreciation of the image. We also improved the quality of US images by application of a special algorithm for speckle reduction and edge enhancement on an ACCUVIX XQ - DynamicMR. For each patient, the 3D sonographic examination and image reconstruction procedures were completed within 10 to 15 minutes.

The 3D US protocol included:
1 - Acquisition of 3D transabdominal scan through the whole urinary bladder for detection of possible UBTs, finding locations and interactions with ureteric jets, bladder necks and trigones and calculating their numbers;
2 - Voiding 3D VEUS cystourethrography in patients with more than 1 UBT, and with tumors in the trigone region. 3D Virtual reconstructions of the urethra were constructed during micturition for exclusion of possible additional tumors; and

3 - 3D virtual endocavity ultrasound through the minimally distended urinary bladder was performed for detection of small UB lesions. The tumor size, volume and overall basement area of the tumor lesion were calculated for the surgery planning. Also, all the tumors were studied with Power Doppler for evaluation of vascularity.

Postprocessing was performed after collecting the 3D data. Surface rendering was used to obtain cystoscopic-like US volumetric images of the urinary bladder, and a Multi-Slice View special program was used for reslicing the 3D data. All 2D, static 3D volumes and live 3D cineloops (4D real-time clips) based on surface renderings were recorded on the hardware for further evaluation.

Tumor locations, numbers, sizes and tumor basement areas were estimated during cystoscopy for TUR planning. US results were compared with cystoscopy findings which served as a "gold standard." Two-dimensional (2D) sonographic results were compared with the findings of 3D sonography and with conventional cystoscopy. The McNemar test was used to compare these results.

RESULTS

Conventional cystoscopy revealed UBTs in 33 (59%) of the remaining 56 patients. The total number of the UBTs detected by conventional cystoscopy was calculated as 49 in 33 patients. Twenty four (69%) patients had solitary and nine (31%) had multiple tumors. Morphologically, the most frequent type of tumor was polypoids in 42 (85% of lesions) cases, followed by infiltrating in seven (15%) cases. Malignant tumors were revealed in 20 (61%) of 33 patients. The most common types of tumor on final histopathology were transitional cell carcinomas in 14 patients, transitional cell papilloma in 12 patients, one metastatic carcinoma, two adenocarcinomas, 13 cases of proliferative cystitis and 10 cases of BPH with urethritis. And there were another 4 patients with normal UBs and calculi.

The trigone region of the bladder and the distal ureters can also be seen in greater detail on both transrectal and transvaginal scanning (fig.1, A,B). The Multi-Slice View available in the system gave a more precise assessment of the basement of the tumor. With this technology intact, submucosa was clearly shown in different resliced images (fig.2, A-F). Infiltrating tumors were detected in seven cases. Five of them were accurately found on 3D VEUS better than on 2D grey scale images (fig.3, A-D). Using 3D surface rendering, 3D reconstructions of the organ, including virtual cystoscopic views, multiple, tiny, polypoid lesions that presented as focal mural thickening on the corresponding 2D images were revealed in our study in five cases (fig.4, A,B). In all patients with multiple tumors and a history of UBC treated by TUR, we performed sonourethrography. Sonourethrography in our study was informative for detection of posterior urethra tumors in the case of those with a previous history of UBT resection (fig.5, A,B). The possibility to perform multi-slice reformating in three orthogonal planes helped to define invasions in the muscularis propria of the tumors at the T2a stage. No evidence of the hyperechoic line of the mucosa was highly predictive for muscle invasion in our study (fig.6, A-D).

Our findings showed that conventional gray scale 2D sonography had a sensitivity of 92%, and a specificity of 76.7% for tumor detection. 3D virtual sonography had a sensitivity of 94% and a specificity of 70.6%, for tumor detection. The combination of grey scale sonography, MPR, and 3D virtual sonography increased the diagnostic performance for tumor detection to a sensitivity of 94%, and a specificity of 86%.

Using the McNemar test, we could not find a statistically significant difference between these observations (for 2D and 3D sonography, \( P = .471 \); for 3D sonography and the combination of 2D sonography, MPR, and 3D sonography, \( P = .598 \)). Adding the 2D sonography and MPR to 3D virtual sonography did not significantly alter sensitivity but increased specificity values.
FIGURE 2. Small bladder tumor Ta stage in a 70-year-old man. A. Gray scale sonography shows polypoid lesion 0.1x0.2cm in size protruding into the bladder lumen. B. Multi-Slice View gives a more precise assessment of the tumor’s basement, showing an intact hyperechoic line of the submucosa. C. 3D Virtual cystoscopic image of the tumor. Surface-rendered 3D sonography clearly shows subtle lesion. D. Multi-planar reconstruction 3D sonography shows a polypoid mass. E. Conventional cystoscopic image of this tumor. F. Pathomorphology specimen showed transitional cell papilloma.

FIGURE 3. Infiltrating bladder tumor in a 56-year-old woman. A. Gray scale sonography missed the lesion, but showed irregularity of the bladder wall. B. Volume rendered 3D sonography in a cystoscopic view clearly shows the sessile lesion with marked irregularity on the tumor’s surface. C. Conventional cystoscopic image of this tumor. D. Microscopic specimen revealed transitional cell carcinoma with muscle invasion.
CONCLUSIONS

3D Endocavity US is a promising method which provides additional diagnostic information in detection of UBTs. 3D VEUS is a useful screening tool which can direct the surgeon to an appropriate area for a biopsy.

3D ultrasound virtual cystoscopy simulates the endoluminal view seen in conventional cystoscopy.

3D US represents a promising new approach for bladder tumor screening with potential advantages in sensitivity and specificity over the conventional two-dimensional US technique.

REFERENCES