Virtual Cystoscopy Using 3D Ultrasound

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**Background:** The urinary bladder has many inherent characteristics that make it an ideal structure for evaluating with three-dimensional (3D) volume ultrasound (US). The purpose of this study was to evaluate the application of 3D sonography in assessing bladder pathologies.

**Materials and methods:** One hundred patients were evaluated in this study. The cases were taken from the pool referred for the evaluation of the renal system (kidney, ureter, and bladder), abbreviated as US KUB at our hospital. The examination was performed with the bladder filled up to 250–350 ml, or whenever adequate distension was noted with wide separation of the bladder walls. Routine (two-dimensional) 2D scanning was followed with the acquisition of 3D volume using abdominal and endocavitary probes.

**Results:** Application of surface rendering algorithm on obtained 3D data sets yielded near cystoscopy-like images of the urinary bladder. The anatomy of the trigonal region of the bladder and the ureteric orifices was obtained in detail. Various bladder pathologies, notably bladder mass, diverticuli and ectopic ureteric openings, were noted.

**Conclusion:** 3D virtual cystoscopy is a promising technique for evaluating bladder pathologies. Its multiplanar capabilities and surface rendering capabilities are helpful for further characterizing the lesions seen on 2D US. It can serve as a good road map prior to cystoscopy.

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Introduction

The urinary bladder has many inherent characteristics, which makes it an ideal structure for evaluating with three-dimensional (3D) volume ultrasound (US). This aperistaltic fluid-filled structure makes volume acquisition and 3D reconstructions easy. The purpose of this study is to evaluate the application of 3D sonography to the assessment of bladder pathologies.
Materials and methods

The study employed a technique wherein approximately an hour prior to the US examination, 500 mL of water was given to each patient orally.

The examination was performed with the bladder filled up to 250–350 mL, or wherever adequate distension was noted with wide separation of the bladder walls. Routine 2D scanning was followed with the acquisition of 3D volume using abdominal and endocavitary/transvaginal probes: RAB2-5L, 3D abdominal (2–5 MHz), and RIC5-9H endocavitary (5–9 MHz) on an US system (Voluson 730 PRO, GE Medical Systems, Milwaukee, WI, USA).

The maximum field of view (FOV) was chosen to encompass the entire bladder volume and to provide depth perception. High-resolution near-field images were acquired using a smaller FOV.

After collecting the 3D data, a surface rendering algorithm was used for postprocessing to obtain cystoscopy-like US images of the urinary bladder.

One hundred patients were evaluated in this study. The cases were taken from the pool referred for the evaluation of the renal system (kidney, ureter, bladder) abbreviated as US KUB at our hospital. In this article, few selected observations are presented.

Results

The trigone region of the bladder and the distal ureters can be seen in detail on the 3D-rendered images shown in Fig. 1 in all of our evaluated patients.

An elderly gentleman who had complaints of increased frequency of micturition was examined in this study. Routine 2D US revealed an enlarged prostate gland. Using 3D US, the indentation of the median lobe into the base of the bladder was clearly observed (Fig. 2).

In another patient who had undergone transurethral resection of the prostate (TURP), post-TURP changes were noted, similar to those in cystoscopic findings (Fig. 3).

In this study, an ectopic ureteric opening with reflexive "golf-hole" type appearance was localized (Fig. 4A). The patient was a 2-year-old girl having recurrent urinary tract infections and hydronephrosis and hydroureter. The micturating cystourethrogram showed Grade 3 reflux (Fig. 4B).

In one patient who presented with hematuria, bladder mass was observed. On using 3D US, one could better understand its morphology and spatial orientation. This agreed well with the cystoscopic findings, as shown in Fig. 5.

3D US also delineated diffuse bladder wall urothelial irregularity in patients who experienced burning and urgency of micturition. The diagnosis of cystitis was made, which correlated with urine microscopy, as shown in Fig. 6.

In one elderly patient with obstructive uropathy, diverticula were observed in the 3D cystoscopic view, as shown in Fig. 7.

Using the inversion mode and surface rendering technique, the bladder cast for morphological evaluation of the shape was obtained. One interesting observation was the classical "Christmas tree" appearance of the bladder in a child with a neurogenic bladder, as shown in Fig. 8A. This was an 8-year-old female with sacral agenesis (Fig. 8B).

In a 40-year-old female patient, using endovaginal volume probe, one could observe the adder-head-type morphology of a ureterocele (Fig. 9). This patient’s earlier US had shown mild hydronephrosis on the affected side.

Discussion

Recent advances in computer technology and display techniques have made it possible to obtain virtual endoluminal views of hollow organs similar to those obtained with conventional endoscopy [1].

Bladder is the most suitable anatomical model for 3D US. Being a fluid-filled aperistaltic hollow viscus, there is a considerable contrast gradient between the bladder lumen and its wall. Thus, by making use of a surface rendering
algorithm on volumetric data, near cystoscopic images of the bladder can be obtained.

Virtual cystoscopy has been described previously with computed tomography (CT) and magnetic resonance imaging (MRI), where a Foley catheter was utilized for instilling gas or saline. This is, however, invasive in nature in comparison to the 3D US methodology.

In a study by Song JH et al [2], who investigated the role of CT and virtual cystoscopy in detecting bladder tumors, the complications related to catheter removal are described. The patient, an 80-year-old man, developed the inability to void because of hemorrhage and intravesical clot formation. In this study, no complications were encountered. Obtaining 3D volumes required additional 10-15 minutes and did not prolong the time of the study unusually.

Ramos [3] evaluated the utility of 3D US for bladder tumors in cases of hematuria and concluded that 3D US was more sensitive than 2D US in diagnosing bladder tumors.

Fig. 3  Two-dimensional and virtual cystoscopic appearance of post-transurethral resection of the prostate changes.

Fig. 4  (A) Virtual cystoscopic view revealing ectopic “golf-hole” type of ureteral opening. (B) Micturating cystourethrogram revealing Grade 3 reflux.
The 3D US showed a sensitivity of 83.3% and a specificity of 100% with positive and negative predictive values of 100% and 93.8%, respectively [3].

In our case of bladder mass, the location, size, and morphologic features of the lesion agreed with the findings on conventional cystoscopy.

Virtual cystoscopy has the potential to localize and characterize lesions in a manner similar to conventional cystoscopy. As it provides an en face view of lesions, surgeons can proceed with conventional cystoscopy with a mental image of the lesion, when a cystoscopic biopsy or follow-up is contemplated [4].

Hirahara et al [5] evaluated the role of four-dimensional (4D) sonography in assessing the bladder shape in patients with lower urinary tracts symptoms and voiding dysfunction. A rotational method using virtual organ computer-aided analysis (VOCAL) was utilized for obtaining the cast of the urinary bladder [5]. Utilizing the inversion mode and surface rendering algorithm, the 3D casts of the bladder was generated to the satisfaction of the urology team (Fig. 8).

Lyon et al [6] graded the ureteric orifices according to their configuration. Accordingly, Grade 0 was a normal cone-shaped orifice; Grade 1, the stadium orifice; Grade 2, the horseshoe orifice; and Grade 3, golf-hole orifice. The appearance of the ureteric orifice changed with increasing severity of reflux [6]. Note the normal cone-shaped ureteric orifice in Fig. 1 and the grossly refluxive type in Fig. 4.

Ureterocele is the balloon dilatation of the intramural portion of the ureter that bulges into the bladder. This bulge can be clearly seen in the rendered view of the bladder base [7].

3D US-based virtual cystoscopy is feasible in the pediatric urinary bladder without sedation. It provides detailed surface information that is not accessible by 2D US, improving the detection of pathologic conditions such as atypically shaped ureteral ostium. 3D US-based cystoscopy may become a valuable adjunct to 2D US of the pediatric urinary tract and may potentially help in reducing the need for endoscopic cystoscopy [8].

Virtual cystoscopy has some limitations, the most important being its inability to show flat or intramural lesions (carcinoma in situ), which appear as subtle mucosal color changes on conventional cystoscopy [9]. The limitations include the inability to obtain tissue for histologic examination or to perform endoscopic resection of pedunculated lesions. The technique is less sensitive than conventional cystoscopy in the detection of sessile lesions or very small polyps [10].

3D virtual cystoscopy requires fewer steps for patient preparation; it is inexpensive and patient compliance is not an issue, which are the basic attributes of screening tests [11].

3D virtual cystoscopy is a promising technique for evaluating bladder pathologies. Its multiplanar capabilities and surface rendering capabilities are helpful for further characterizing the lesions seen on 2D US. In certain cases, it can be used as a diagnostic modality, especially in circumstances where conventional cystoscopy may not be possible.
It can serve as a good road map prior to cystoscopy. Presently, the author feels that it can serve a complimentary adjunctive role prior to cystoscopy, and larger prospective studies are encouraged to establish its further role in clinical practice.

Fig. 8  (A) 3D bladder cast demonstrating the elongated configuration of “Christmas tree” appearance in a neurogenic bladder.  (B) Lateral radiograph revealing sacral agenesis. 3D = three-dimensional.

Fig. 9 Multiplanar and 3D cystoscopic appearance of a ureterocele. 3D = three-dimensional.

References


