

The Usefulness of Virtual Cystoscopy with Spiral CT in Evaluating Bladder Tumor¹

Tae Woong Chung, M.D., Yong Yeon Jeong, M.D., Heoung Keun Kang, M.D.,
Sang Gook Song, M.D., Yun Hyeon Kim, M.D., Jeong Jin Seo, M.D.,
Kwang Woo Jeong, PhD, Jae Kyu Kim, M.D., Jin Gyoong Park, M.D.

Purpose : To compare the role and clinical usefulness of virtual and conventional cystoscopy in patients with known bladder tumors.

Materials and Methods : Seventeen patients with a known bladder tumor underwent virtual and conventional cystoscopy. As a result of conventional cystoscopy and surgery, 32 tumors were detected. Prior to examination, each patient lay supine on the CT table, and the urinary bladder was catheterized, drained of all urine, and inflated with air. Spiral CT of the pelvis was then performed. CT data were transferred to a separate workstation and three-dimensional and virtual cystoscopic images were reconstructed. The latter were interpreted by two radiologists, who recorded the number, size, morphology, and exact location of the masses observed. The results of virtual CT cystoscopy were correlated with conventional cystoscopic findings.

Results : Twenty-two (69%) of 32 bladder tumors detected during conventional cystoscopy were visualized by virtual cystoscopy. Four (36%) of 11 tumors measured 0.5 cm or less, 15 (83%) of 18 measured 0.5 -3 cm and all (100%) of tumors measured 3 cm or more. With regard to tumor morphology, six (86%) of seven sessile tumors and 16 (64%) of 25 which were pedunculated were detected. The procedure was well tolerated by all patients, and no complications were reported.

Conclusion : Due to its intrinsic weakness, virtual cystoscopy cannot replace its conventional counterpart, though by developing data scan and acquisition techniques and software, and on the basis of clinical experience, the latter can be used in the future for the diagnosis and follow up of bladder tumors.

Index words : Bladder neoplasms, CT

Computed tomography (CT), helical

Computed tomography (CT), three-dimensional

Computed tomography (CT), technology

Conventional radiography such as intravenous urography (IVU) has been used in patients with hematuria

or other symptoms of bladder cancer prior to cystoscopy (1-3). Once a diagnosis of bladder cancer has been established, cross-sectional imaging such as ultrasonography, computed tomography (CT) or magnetic resonance imaging (MRI) may be performed for tumor staging and follow-up (4, 5). Cystoscopy, however, is an essential examination for bladder cancer diagnosis, treatment, and follow-up study because of the inherent advantages of

¹Department of Diagnostic Radiology Chonnam University Medical School

Received August 25, 1998 ; Accepted December 17, 1998

Address reprint requests to : Tae Woong Chung, M.D. Department of Diagnostic Radiology Chonnam University Medical School
#8 Hakdong, Dongku, Kwangju, 501-757, Korea.

Tel. 82-62-220-5751 Fax. 82-62-226-4380

direct visualization.

The development of spiral CT makes it possible to perform fast scan and thin slice scanning, and to create various CT images such as virtual colonoscopy or bronchoscopy with the aid of virtual-reality data-postprocessing techniques and computer technology (6-8). Virtual reality imaging became available as a result of postprocessing of volumetric CT data. A vigorous study of virtual reality allowed interactive navigation into the hollow viscus, thus providing images similar to those previously obtained only through endoscopy. However, since Vining et al. (9) reported the use of CT cystoscopy in a healthy volunteer and in two patients with known bladder tumors, there have been few reports of virtual cystoscopy (10, 11).

The purpose of this study was to compare the role and the clinical usefulness of virtual and conventional cystoscopy in patients with known bladder tumors.

Materials and Methods

Seventeen consecutive patients (13 men and 4 women aged 41-82 [mean, 66]) with bladder cancer already diagnosed by conventional cystoscopy and surgery were studied prospectively between November 1997 and February 1998. All patients underwent virtual cystoscopy 1-6 days earlier than conventional cystoscopy.

The clinical symptoms of 14 patients were hematuria, with two patients exhibiting fever and chills, and there was one asymptomatic patient. As a result of conventional cystoscopy and surgery, 32 tumors were detected within the urinary bladder, and were pathologically proven to be transitional cell carcinomas.

For spiral CT, a Hi-speed Advantage was used, and for virtual cystoscopy, an Advantage Window Workstation and Navigator software (all from GE Medical System, Milwaukee, Wisconsin, U.S.A.).

Prior to examination, each patient lay supine on the CT table and the bladder was catheterized with a 12-F Foley catheter and drained of all urine. It was distended with 300 - 550 cc of room air, in accordance with a patient's tolerance. Prior to scanning, an anteroposterior scout view of the pelvis was obtained, and a single-breath-hold spiral CT scan of the air-distended bladder was obtained using the following parameters: section thickness of 5 mm, table speed of 5 mm/sec, 1-mm reconstruction, 230 mA, 120 kVp, and a 512 X 512 matrix.

These image data were transferred to an independent workstation through a fiberoptic cable, and virtual cystoscopic images were obtained using Navigator software and the following parameters: a threshold value of between -500 and -700 HU, black in white mode, aperture size of 40 cm to 60 cm, and smooth mode. Virtual cystoscopy was performed according to the findings of conventional cystoscopic examination. The procedure started from the bladder base, continuing to the posterior wall, both lateral walls, the anterior wall and finally to the bladder dome. Images obtained during virtual cystoscopy were interpreted by two radiologists who were unaware of the findings of conventional cystoscopy,

Table 1. Detectability of Bladder Tumors According to the Size at Virtual Cystoscopy

Size (mm)	No. of case	Detectability (%)
< 5	11	4(36)
5 - 30	18	15(83)
> 30	3	3(100)
Total	32	22(68.7)

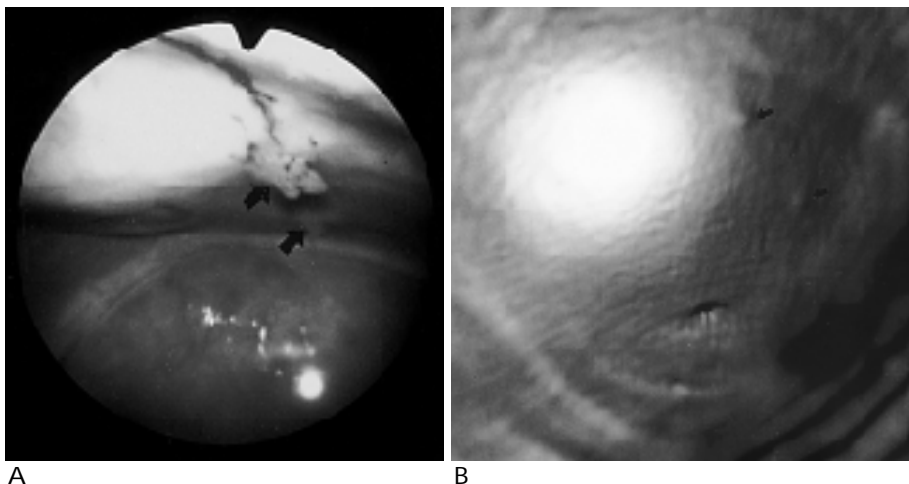


Fig. 1. 69-year-old female with hematuria

Conventional cystoscopy (A) and Virtual cystoscopy (B) show 1.0-cm (maximum dimension) and 0.5-cm (maximum dimension) pedunculated tumors (arrows) in the anterior wall of the urinary bladder, but papillary surface of the tumors can not be demonstrated at virtual cystoscopy.

with differing interpretations resolved by consensus. The number, size, morphology, and exact location of masses observed during virtual cystoscopy were recorded. Masses were either sessile or pedunculated, the former being defined as a lesion in which the width of the tumor base was greater than height. The location of bladder lesions observed during virtual cystoscopy was described using conventional cystoscopic terminology.

Results

Twenty-two (69%) of 32 bladder tumors detected by conventional cystoscopy were visualized during virtual

cystoscopy. Four (36%) of 11 tumors measured 0.5cm or less (Fig 1), 15 (83%) of 18 tumors measured 0.5-3cm (Figs. 2, 3) and all (100%) of three measured 3cm or more (Fig. 4) (Table 1). Three of 18 tumors measuring 0.5-3cm in maximum dimension were not detected by virtual cystoscopy. Two, located on the posterior wall (one pedunculated type, maximum dimension 1.5cm; and one sessile type, maximum dimension 0.8cm), were not detected because there were masked by residual urine (Fig 5). The other (sessile type, maximum dimension 3cm), located on the lateral wall, was not found because it was very superficial. Differences in the size of tumors between values measured both by virtual and

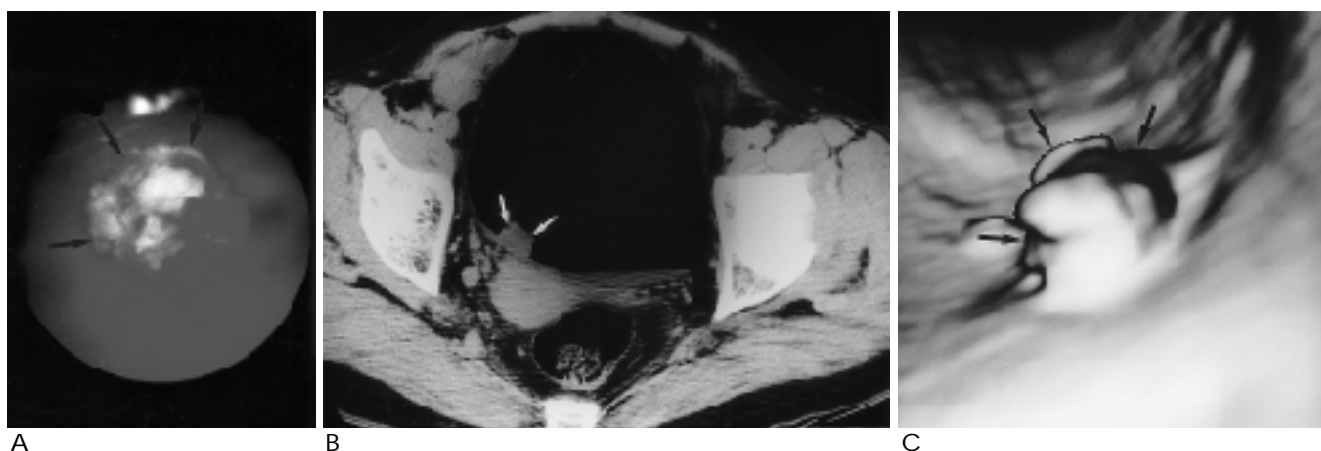


Fig. 2. 67-year-old female with hematuria
A. 2-cm (maximum dimension) pedunculated tumor (arrows) is seen at conventional cystoscopy.
B. Axial CT of air-filled bladder shows a tumor (arrows) in the right posterior wall of the urinary bladder.
C. Virtual cystoscopy shows a pedunculated tumor (arrows).

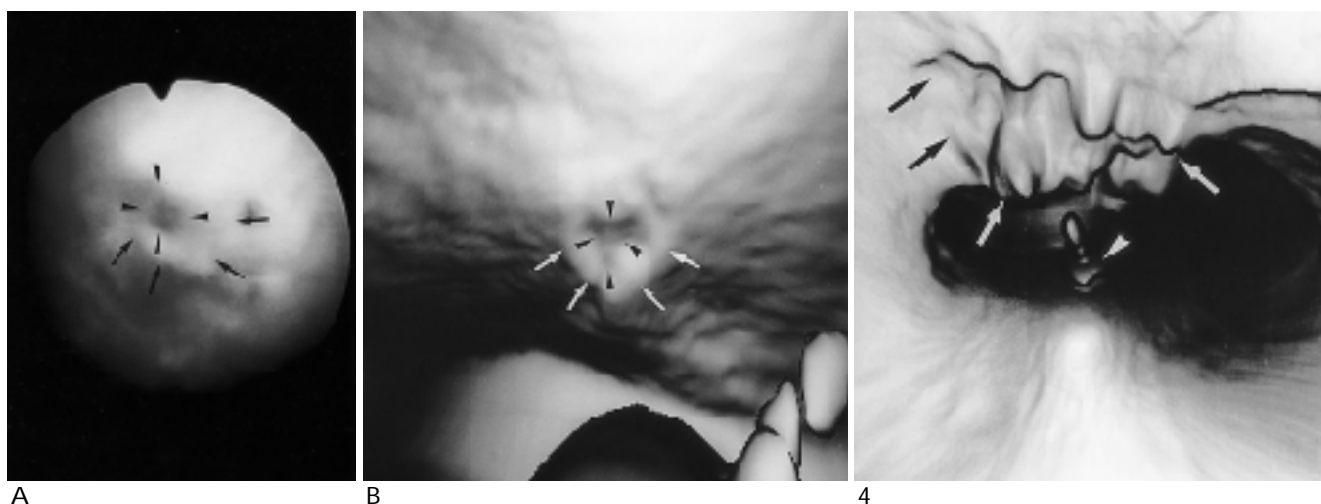


Fig. 3. 55-year-old male with hematuria
An about 2-cm (maximum dimension), shallow ulcerated (arrowheads), broad based mass (arrows) is shown in the anterior wall of the urinary bladder at conventional cystoscopy (A) and virtual cystoscopy (B).
Fig. 4. 64-year-old man with fever and chills
Virtual cystoscopy shows an about 5-cm (maximum dimension) sessile tumor (arrows) in the anterior wall of the urinary bladder. A Foley catheter is seen (arrowhead).

conventional cystoscopy averaged within 0.15cm for all tumors which were 0.5cm or less, within 1.78cm for all 0.5cm-3cm, and within 2.67cm for all larger than 3cm.

With regard to tumor morphology, six (86%) of seven sessile tumors (Figs. 3, 4) and 16 (64%) of 25 which were pedunculated (Figs. 1, 2) were detected by virtual cystoscopy (Table 2). One reason for the low detectability of pedunculated type tumors was that tumors smaller than 1cm were classified as this type. Morphological evaluation (pedunculated or sessile) did not differ according to whether virtual or conventional cystoscopy was used. Regarding the exact location of the tumors, seven (64%) of 11 at the posterior wall, nine (75%) of 12 at the anterior wall, and four (67%) of six at the lateral wall were detected by virtual cystoscopy. However, if the presence of a tumor was revealed by conventional cystoscopy, nor was it revealed by its virtual counterpart.

The average duration of a virtual cystoscopic examination, including patient preparation and complete vir-

tual cystoscopic navigation was 36 (range, 28-46) minutes. Average preparation time prior to CT scanning was 10-15 minutes. Average scanning time and reconstruction time was 10-15 seconds and 7-14 minutes, respectively, with an average virtual cystoscopic navigation time of 10-20 minutes. The procedure was well tolerated by all patients, and there were no complications.

Discussion

Bladder cancer can be examined by means of a series of radiographs, but due to the difficulties of morphological classification and insensitivity to small lesions, radiography may be inefficient for diagnosis and follow up. Such limitations account for the greater popularity of cystoscopy for the examination of bladder tumors. This procedure also suffers certain limitations, however. Sedation is frequently necessary, and iatrogenic injury to the urethra and bladder may occur. Urinary sepsis develops in 5% - 10% of patients (12). Cystoscopy is also time consuming, is limited to the surface of the urinary bladder, and cannot evaluate adjacent perivesical structures.

In response to rapid advances in the specifications of CT scanners and computer software, a variety of CT techniques have recently been proposed as alternatives to conventional cystoscopy. In the west, radiologists have been interested in 3D images of the colon, used for the treatment of common colonic diseases, and since

Table 2. Detectability of Bladder Tumors According to the Morphology at Virtual Cystoscopy

Size (mm)	Pedunculated type		Sessile type	
	No. of case	Detectability (%)	No. of case	Detectability (%)
< 5	11	4 (36)	0	0 (0)
5 - 30	13	12 (92)	5	3 (60)
> 30	1	1 (100)	2	2 (100)
Total	25	16 (64)	7	6 (86)

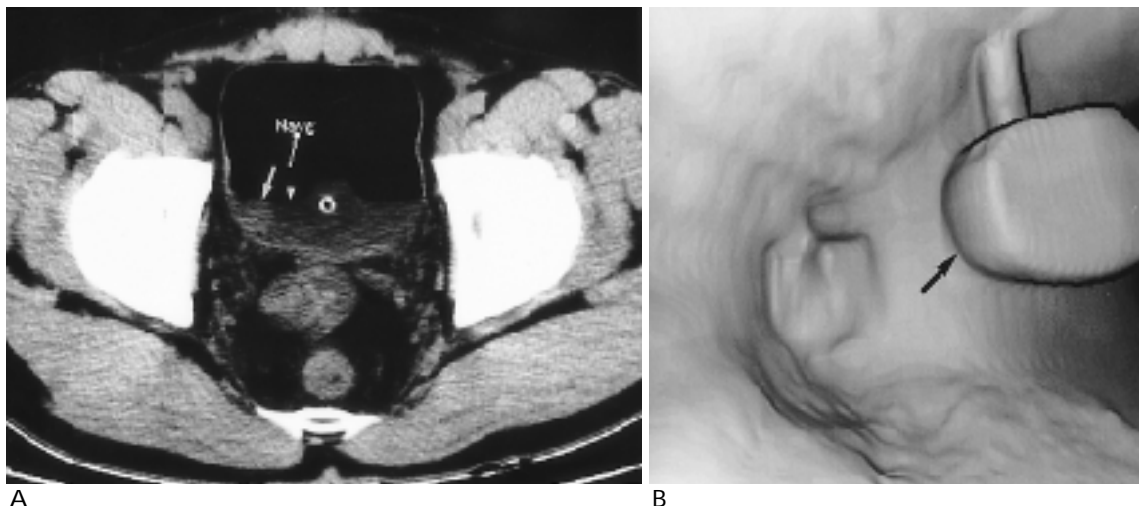


Fig. 5. 50-year-old male with hematuria

A. Axial CT of the urinary bladder shows a 1.5-cm (maximum dimension) tumor (arrow) in the posterior wall and large amount of residual urine (arrowhead).

B. Virtual cystoscopy can not demonstrate a tumor because it is masked by residual urine.

A Foley catheter is seen (arrow). "Navg" is an abbreviation of the Navigator, which is used to control the position of the inner view within the anatomy.

virtual colonoscopy was first invented by Stanford University, CT bronchoscopy, gastroscopy, and cystoscopy have been used (6-11,13).

In 1996, Vining et al. (9) described three-dimensional renderings of an air-distended urinary bladder since during CT cystoscopy in one healthy volunteer and two patients with known bladder tumors. These investigators successfully used a volume-rendering algorithm to gain an intraluminal perspective of the bladder mucosa. More recently, Narumi et al. (10) performed CT cystoscopy by using surface-shaded displays of spiral CT data sets of an air-distended bladder. There are two kinds of virtual reality data processing: volume rendering and surface rendering (surface-shaded display). According to Fenlon et al. (7), during CT endoscopy of the colon and bronchus, although a volume rendering algorithm is time consuming and needs an expensive computer, it is more accurate than a surface-shaded display because volume-rendered images are "data rich", i.e. they use 100% of available CT data for 3D reconstruction. A sense of depth, distance, and motion can be achieved by using a perspective algorithm. Perspective volume rendered images are realistic and rather than the flat opaque appearance of images created using a surface-shaded display. Fenlon et al. (11) reported that during virtual cystoscopy using a perspective volume rendering algorithm they were able to detect all of 31 lesions detected by conventional cystoscopy, 19 of which measured 1 cm or less in maximum dimension. The navigator software we used to obtain 3D virtual cystoscopic images utilized a perspective volume-rendering algorithm. Our virtual cystoscopy showed 69% detectability, which is lower than the result of Falcon et al. In particular, the detectability of tumors less than 0.5cm in maximum dimension was only 36%. This relatively low rate was due to CT scanning with 5mm slice thickness as well as the fact that masses were obscured by residual urine. CT scanning with a thinner slice setting and the patient in a different position might increase detectability.

Virtual cystoscopy images often have "stair-step" artifacts in which the bladder has the appearance of several concentric rings that can be minimized by thin slice of CT scanning (9). The bladder wall may appear transparent due to partial volume effect of surrounding bowels, but this can be solved by controlling the threshold level (9,14). Before examination, urine should be eliminated from the urinary bladder since any residue may mask bladder lesions. We experienced a case in which a very

small amount of residual urine at the posterior wall prevented the detection of tumors by virtual cystoscopy. Such problems might be prevented by changes in the scanning position and performing 2-3 sections of CT scans in order to detect residual urine before virtual cystoscopy

As mentioned previously, virtual cystoscopy suffers certain limitations. First, it is hard to detect subtle changes in mucosa and small lesions, and second, although it depends on the examiner, virtual cystoscopy is time consuming (14). Because of the simple anatomic structure and small size of the urinary bladder, however, the procedure is thought to require less time and be easier than virtual endoscopy of other organs. Finally, virtual cystoscopy-guided biopsy is impossible.

However, virtual cystoscopy also has many advantages, the most outstanding of which is that it can obviate the invasiveness of conventional cystoscopy. Virtual cystoscopy is useful for follow-up study after surgical or chemotherapeutic treatment, it allows a wider FOV and can measure the diameter of tumors with greater accuracy. In contrast, due to the limited flexibility of the cystoscope, cystoscopy offers a limited visual field, and this precludes observation of certain areas of the urinary bladder recognized as potential blind spots. For that reason, conventional cystoscopy is rather inefficient for observing the bladder neck, prominent bladder trabeculations, and mucosa within the bladder diverticulum (11). In addition, since the technique lacks an objective scale standard, accurate measurement of tumor size is difficult with conventional cystoscopy. Virtual cystoscopy, on the other hand, permits the observation of tumor from various angles by compressing many sections of CT data to one interactive image. It is, in addition, a reproducible technique; an initial examination can thus be repeated.

In conclusion, although it is difficult to replace conventional cystoscopy with its virtual counterpart, the latter can be used as an additional means of diagnosis and follow-up in patients with bladder tumors.

References

1. Webb JAW. Imaging in hematuria. *Clin Radiol* 1997;52:167-171
2. Lee CH, Kook SH, Chung EC, Rhee CS. Diagnostic value of bladder tumors by excretory urography. *J Korean Radiol Soc* 1986;22:885-890
3. Dershaw DD, Scher HI. Serial transabdominal sonography of bladder cancer. *AJR* 1988;150:1055-1059

4. Amendola MA, Glazer GM, Grossman HB, Aisen AM, Francis IR. Staging of bladder carcinoma: MR-CT-Surgical correlation. *AJR* 1986;146:1179-1183
5. Lee CK, Song HJ, Lim JH, Ko YT, Kim SY. Accuracy of computed tomography (CT) staging in bladder carcinoma. *J Korean Radiol Soc* 1988;24:132-137
6. Hara AK, Johnson CD, Reed JE, et al. Detection of colorectal polyps with CT colography: initial assessment of sensitivity and specificity. *Radiology* 1997;205:59-65
7. Fenlon HM, Ferrucci JT. Virtual colonoscopy: What will the issues be? *AJR* 1997;169:453-458
8. Summers RM. Navigational aid for real-time virtual bronchoscopy. *AJR* 1997;168:1165-1170
9. Vining DJ, Zogoria RJ, Liu K, Stelts D. CT cystoscopy: an innovation in bladder imaging. *AJR* 1996;166:409-410
10. Narumi Y, Kumatani T, Sawai Y, et al. The bladder and bladder tumors: imaging with three-dimensional display of helical CT data. *AJR* 1996;167:1134-1135
11. Fenlon HM, Bell TV, Ahari HK, Hussain S. Virtual cystoscopy: early clinical experience. *Radiology* 1997;205:272-27
12. Denholm SW, Conn IG, Newsa JE, Chisholm GD. Morbidity following cystoscopy: comparison of flexible and rigid technique. *Br J Urol* 1990;66:152-154
13. Lee DH, Ko YT, Gastric lesion: evaluation with three-dimensional images using helical CT. *AJR* 1997;169:787-789
14. Dessl A, Giacomuzzi SM, Springer P, et al. Virtual endoscopy by use of helical computed tomography datasets. *Eur Radiol* 1997;7(p):s71

1999;40: 745- 750

