Clinical Application of Computed Tomography on Prostate Volume Estimation in Patients with Lower Urinary Tract Symptoms

Tae Wook Kang,[1] Jae Mann Song,[1] Kwang Jin Kim,[1] Hyun Keun Byun,[1] Young Joo Kim,[1] Hyun Chul Chung,[1] Yun Byung Chae,[2] Hong Wook Kim,[3] Jae Hung Jung[1*]

Purpose: To compare estimated prostate volume (PV) based on computed tomography (CT) scan and transrectal ultrasonography (TRUS) in patients with lower urinary tract symptoms (LUTS).

Materials and Methods: Between January 2010 and October 2012, 107 consecutive patients with LUTS were analyzed, retrospectively. PV measures were performed by the means of ellipsoid formula (PV = π/6 [width (cm) thickness (cm) length (cm)]) from TRUS (PVTRUS) and CT (PVCT ellipsoid). In addition, PV was calculated as the sum of the area of each slice and the CT slice interval using commercial software program (PVCT 3D reconstruction).

Results: Mean PVCT ellipsoid was 40.63 ± 31.06 cm^3 (range, 8.34-217.46). Mean PVTRUS and PVCT 3D reconstruction were 39.20 ± 33.04 (range, 4.00-223.81) and 45.30 ± 32.98 (range, 8.90-248.30), respectively. PVCT ellipsoid was highly correlated with PVTRUS and PVCT 3D reconstruction (r = 0.935, P < .001; r = .970, P < .001, respectively). Moreover, there was very strong agreement for PV measurements with all three methods (intraclass correlation coefficient = 0.934, P < .001).

Conclusion: PVCT ellipsoid is adequate method for quick volume assessment with reasonable accuracy. Therefore, we can easily predict PV by CT scan using ellipsoid formula without performing additional TRUS in patients with LUTS.

Keywords: lower urinary tract symptoms; male; image enhancement; methods; prostate; anatomy; organ size; tomography; X-ray computed; ultrasonography.

INTRODUCTION

Several prostatic conditions including benign prostatic hyperplasia (BPH), acute/chronic prostate inflammation, and prostate cancer represent a huge health problem in aging society.[1] To access these conditions, prostate volume (PV) measurement has come to be an important step in the diagnosis and management of both benign and malignant prostatic diseases.[2]

During the last decade, many urologists had used imaging techniques for the differential diagnosis of lower urinary tract symptoms (LUTS). Transrectal ultrasonography (TRUS) has been used as a common imaging modality to measure PV.[2,3] However, TRUS has the disadvantage of depending on the operators who require a set of special technical skills. Recently, computed tomography (CT) scan as an alternative technique is performed for PV estimation in particular situation, such as external beam radiotherapy and interstitial brachytherapy implantation to deliver radiation.[4-6] Nevertheless, 3D rebuilt images of prostate are needed for volume estimation using CT scan, and such procedure is time consuming. Furthermore, there are only few reports about the comparability of these two diagnostic procedures in patients with LUTS. Therefore, we compared estimated PV based on CT scan and TRUS. In addition, we evaluated whether the ellipsoid formula is able to substitute 3D reconstruction in the setting of CT scan.

MATERIALS AND METHODS

Between January 2010 and October 2012, 107 consecutive patients with LUTS were analyzed retrospectively. Each patient underwent TRUS and CT scan over 14 days or less period. The individual images were interpreted independently by different urologist (J.H.J and H.K.B). PVs estimated by different modality were collected on independent data sheet, respectively. Final data were combined during statistical analysis. The study was approved by the Institutional Review Board (IRB approved protocol number: YWMR-12-05-032).

Prostate Volume Estimation with TRUS and CT

TRUS images were obtained with ultrasound system

[1] Department of Urology and Radiology, Yonsei University, Wonju College of Medicine, Wonju, Republic of Korea.
[2] Department of Urology, Cheongju St. Mary's Hospital, Cheongju, Republic of Korea.
[3] Department of Urology, Konyang University, College of Medicine, Daejeon, Republic of Korea.
*Correspondence: Department of Urology, Yonsei University, Wonju College of Medicine, 20 Ilsan-ro, Wonju 220-701, Republic of Korea.
Tel: +82 33741 0654. Fax: +82 33741 1930. E-mail: geneuro95@yonsei.ac.kr.
Received April 2014 & Accepted October 2014

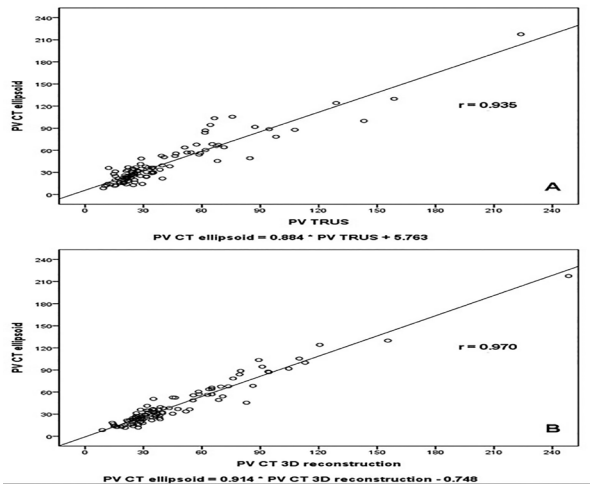

Figure. Correlation between prostate volumes measured by transrectal ultrasonography (PV TRUS) and computed tomography (PV CT). PVCT ellipsoid was significantly correlated with PVTRUS (A) and PVCT 3D reconstruction (B).

(Aloka, Tokyo, Japan) using transrectal probe with the patient in lithotomy position. PV measured by TRUS (PVTRUS) was calculated by the means of ellipsoid formula (PV = π/6 [width (cm) thickness (cm) length (cm)]). The width (right-left) and thickness (anterior-posterior) were estimated on the transverse plane, and length (cranial-caudal) was estimated on the sagittal plane. H.K.B measured PV using TRUS in real time.

Prostate images using CT scanner (Phillips Medical System, Amsterdam, The Netherlands) were obtained with the patient in supine position. CT axial images were scanned with 0.25 cm interval from visualized base of the gland to apex. The CT images were scanned into commercial software program (Phillips Medical System, Amsterdam, The Netherlands). Prostate contours were drawn on each slice by one urologist who was unaware of PVTRUS. The volume (PVCT 3D reconstruction) was calculated as the sum of the area of each slice and the CT slice interval. In addition, PV measured by CT scan using the ellipsoid formula (PVCT ellipsoid) was also calculated. J.H.J estimated PVCT ellipsoid and PVCT 3D reconstruction with 1 month interval only using patient's ID to avoid bias.

Statistical Analysis

Pearson's and intraclass correlation coefficients (ICC) of the exact type for the two-way mixed model were used for correlation of these two diagnostic procedures. All analyses were performed with Statistical Package for the Social Science (SPSS Inc, Chicago, Illinois, USA) version 13.0 and two-tailed *P* value of less than .05 was considered statistically significant.

RESULTS

The mean age and prostate specific antigen (PSA) of the patients were 64 years old (range, 34-93) and 7.00 ng/mL (range, 0.10-100), respectively. Indication for CT scan included urological disorders (n = 45, 42.1%), such as hematuria, persistent pyuria, urolithiasis, and malignancy, medical health checkup (n = 45, 42.1%), gastrointestinal presentations (n = 10, 9.3%), solid organ malignancy (n = 5, 4.7%) and others (n = 2, 1.9%). Eight patients (7.5%), among 19 patients (17.8%) with a PSA level of 4 ng/mL or more, were diagnosed with prostate cancer. Transurethral resection of prostate was performed in 12 patients (11.2%) with LUTS.

PVTRUS, PVCT 3D reconstruction and PVCT ellipsoid were 39.46 ± 32.87 cm3 (range, 9.36-223.81), 45.30 ± 32.98 (range, 8.90-248.30) and 40.63 ± 31.06 (range, 8.34-217.46), respectively. PVCT ellipsoid was on average 8.4% (range, –52.0 – 197.0) larger than PVTRUS. PVCT 3D reconstruction was on average 23.5 % (range, –38.0 –136.0) larger than PVTRUS. The PVTRUS divided into quartiles are shown in **Table**. Table showed that the overestimation of PV by CT scan was greatest for smaller PV. PVCT ellipsoid was highly correlated with PVTRUS and PVCT 3D reconstruction (r = .935, P < .001; r = .970, P < .001, respectively) (**Figure**). Moreover, there was very strong agreement for PV measurements with all three methods (ICC = .934, P < .001).

DISCUSSION

Imaging plays a key role in the diagnosis and management of urological disease. Medical applications of ultrasonography (US) were first introduced in the 1960 and the use of US has increased dramatically in the past two decades.[7] With wide use of abdominal US, TRUS is a common clinical procedure for prostatic disease. TRUS has the capability to assess inflammatory disease, BPH and cancer based on echogenicity and blood flow signal.[3,8] Like US, CT scan have been used widely for trauma and unexplained abdominal symptoms. Urological indications for CT scan include evaluation of hematuria, renal masses, urolithiasis, staging urological cancer, renal donor evaluation and characterization of incidental adrenal lesions.[7] Although it is well known that CT is more sensitive than US in the evaluation of upper urinary tract, CT scan have been performed in brachytherapy and three dimensional conformal radiotherapy for the treatment of localized prostate cancer.[2,4,5]

Table. Ratio of PVCT ellipsoid and PVCT 3D reconstruction to PVTRUS by quartile PVTRUS.

PVTRUS Quartile	Range (cm^3)	PVCT Ellipsoid/PVTRUS		PVCT 3D Reconstruction/PVTRUS	
		Mean	Median	Mean	Median
1	9.36-21.12	1.15	1.09	1.38	1.41
2	21.13-25.71	1.08	1.08	1.27	1.23
3	26.13-46.19	1.02	1.02	1.13	1.11
4	46.66-223.81	0.99	1.01	1.07	1.17

Abbreviations: PVCT, prostate volume measured by computed tomography; PVTRUS, prostate volume measured by transrectal ultrasonography.

LUTS in men are common health problem that increases with age. BPH causes LUTS that may affect quality of life and patient satisfaction.[1,3] According to American Urological Association guidelines, digital rectal examination should be performed to assess approximate size, consistency, shape and nodularity suggestive of prostate cancer. However, additional imaging of the prostate by US is needed to make a correct diagnosis when specific treatments including medicine and transurethral resection of prostate are planned.[9]

PV has been measured through ellipsoid formula that was designed in accordance with geometric shape of the prostate.[2-6,8] For determining more accurate PV, step section planimetry may be also employed in patients with prostate cancer.[10,11] Previous literatures reported an excellent reproducibility of PV measurements by planimetry.[11] However, it is difficult for urologist to estimate PV using time consuming step section planimetry and requires special equipment, specifically for screening purpose. In the present study, it takes about 15-30 min in the measurement of PVCT 3D reconstruction for each patient. Furthermore, it is not clear whether additional TRUS should be necessary or not, if the patient already underwent CT scan due to other causes. In addition, we determined whether the ellipsoid formula is able to replace with 3D reconstruction in the setting of CT scan.

Several investigators reported that volume determinations based on the formula were comparable to planimetry and real specimen volume.[2,11,12] Although there are some discrepancies, CT scan defined volumes using 3D reconstruction method are closely correlated with those obtained by TRUS using step section planimetry.[4,5,11] However, CT scan consistently overestimated the prostate volume compared with TRUS by 17-50%.[4-6,10-12,14] In our study, a strong correlation was also found between CT scan and TRUS measurement of PV. PVCT ellipsoid and PVCT 3D reconstruction were 8.4% and 23.5% larger than PVTRUS. This finding supports that CT overestimated PV. However, we reported just 8.4% and 23.5% differences between CT scan and TRUS in contrast to 50% of prior researches.[6,14] One explanation could be that CT scan imaging lacks the soft-tissue resolution required to distinguish prostate anatomy from adjacent structures, such as seminal vesicle, the bladder wall, the rectal wall, the puborectalis muscle, the anterior venous plexus and the muscles of pelvic floor. Badiozamani and colleagues excluded these soft tissues from the volume and finally concluded that CT scan did not overestimate PV compared with TRUS. Therefore, we followed Badiozamani's rules in tracing of prostatic margin. Secondly, Yang and colleagues delineated that increased slice thickness of the CT scan images usually reduces estimated PV because larger slice thickness cannot reproduce the correct contour of the prostate in the base and apex.[6] We performed CT scan with smaller slice interval of 0.25 cm in contrast with published reports with 0.5 cm interval. Interestingly, our study suggests that simpler formula provided measurements were comparable to planimetry in prostate volume estimation by CT scan (**Figure, B**). Additionally, mean ratio of PVCT ellipsoid to PVTRUS was smaller than that of PVCT 3D reconstruction. These results that prolate ellipsoid formula underestimated the prostate volume are consistent with those of other study.[12] Thus, PVCT ellipsoid may be more accurate than PVCT 3D reconstruction because previous studies demonstrated a trend toward greater underestimation by TRUS in PV.[4-6,10-12,14]

CT scan, with its inferior soft tissue contrast, compared to TRUS is not regarded as primary diagnostic modality for the prostate.[15] Furthermore, we should concern radiation hazard and adverse reaction of contrast media when using CT scan. Typical radiation exposures in directly irradiated organs are in the range of 20-30 milliSievert (mSv) for current diagnostic CT scan examination.[16] Recently, despite of diagnostic CT scan, the potential for adverse consequences may arise with increasing CT scan utilization. The overall incidence of adverse reaction is about 5%. Although most reactions are minor, cardiopulmonary and anaphylactoid reactions can be fatal.[16] However, with wide range of indications, for example medical health checkup, cancer staging, or gastrointestinal presentations, CT scan may be considered as an alternative in selected patients with pathology of the prostate.

CONCLUSION

As a result, PV determination by CT scan using formula is effective method for quick volume measurement with reasonable accuracy. However, PVCT 3D reconstruction that requires manual contouring of the consecutive is more time consuming. Therefore, simple formula based on prostate diameters is preferable alternative in the clinics without performing additional TRUS in patients with LUTS.

CONFLICT OF INTEREST

None declared.

REFERENCES

1. Yoo TK, Cho HJ. Benign prostatic hyperplasia: from bench to clinic. Korean J Urol. 2012;53:139-48.
2. Park SB, Kim JK, Choi SH, Noh HN, Ji EK, Cho KS. Prostate volume measurement by TRUS using heights obtained by transaxial and midsagittal scanning: comparison with specimen volume following radical prostatectomy. Korean J Radiol. 2000;1:110-3.
3. Abdi H, Kazzazi A, Bazargani ST, Djavan B, Tele grafi S. Imaging in benign prostatic hyperplasia: what is new? Curr Opin Urol. 2013;23:11-6.
4. Badiozamani KR, Wallner K, Cavanagh W, Blasko J. Comparability of CT-based and TRUS-based prostate volumes. Int J Radiat Oncol Biol Phys. 1999;43:375-8.
5. Hoffelt SC, Marshall LM, Garzotto M, Hung A, Holland J, Beer TM. A comparison of CT scan to transrectal ultrasound-measured prostate volume in untreated prostate cancer. Int J Radiat Oncol Biol Phys. 2003;57:29-32.
6. Yang CH, Wang SJ, Lin AT, Lin CA. Factors affecting prostate volume estimation in computed tomography images. Med Dosim. 2011;36:85-90.

7. Bueschen AJ, Lockhart ME. Evolution of urological imaging. Int J Urol. 2011;18:102-12.
8. Wasserman NF. Benign prostatic hyperplasia: a review and ultrasound classification. Radiol Clin North Am. 2006;44:689-710.
9. McVary KT, Roehrborn CG, Avins AL, et al. Up date on AUA guideline on the management of benign prostatic hyperplasia. J Urol. 2011;185:1793-803.
10. Kälkner KM, Kubicek G, Nilsson J, Lundell M, Levitt S, Nilsson S. Prostate volume determination: differential volume measurements comparing CT and TRUS. Radiother Oncol. 2006;81:179-83.
11. Gloi A, McCourt S, Zuge C, Goettler A, Schlise S, Cooley G. A Bland-Altman analysis of the bias between computed tomography and ultra sound prostate volume measurements. Med Dosim. 2008;33:234-8.
12. Eri LM, Thomassen H, Brennhovd B, Håheim LL. Accuracy and repeatability of prostate volume measurements by transrectal ultrasound. Prostate Cancer Prostatic Dis. 2002;5:273-8.
13. Terris MK, Stamey TA. Determination of prostate volume by transrectal ultrasound. J Urol. 1991;145:984-7.
14. Narayana V, Roberson PL, Pu AT, Sandler H, Winfield RH, McLaughlin PW. Impact of differences in ultrasound and computed tomography volumes on treatment planning of permanent prostate implants. Int J Radiat Oncol Biol Phys. 1997;37:1181-5.
15. Talab SS, Preston MA, Elmi A, Tabatabaei S. Prostate cancer imaging: what the urologist wants to know. Radiol Clin North Am. 2012;50:1015-41.
16. Semelka RC, Armao DM, Elias J Jr, Huda W. Imaging strategies to reduce the risk of radiation in CT studies, including selective substitution with MRI. J Magn Reson Imaging. 2007;25:900-9.