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

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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 = \(\frac{\pi}{6} \times \text{width (cm) thickness (cm) length (cm)}\)) 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.\(^{1,2}\) 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.\(^{2,3}\) 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.\(^{6,7}\) 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

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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).

Figure. Correlation between prostate volumes measured by transrectal ultrasonography (PV TRUS) and computed tomography (PV CT). PVCT ellipsoid was calculated by the means of ellipsoid formula (PV = \pi/6 \times \text{width (cm)} \times \text{thickness (cm)} \times \text{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.1 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.13 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.

<table>
<thead>
<tr>
<th>PVTRUS Quartile</th>
<th>Range (cm³)</th>
<th>PVCT Ellipsoid/PVTRUS</th>
<th>PVCT 3D Reconstruction/PVTRUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>1</td>
<td>9.36-21.12</td>
<td>1.15</td>
<td>1.09</td>
</tr>
<tr>
<td>2</td>
<td>21.13-25.71</td>
<td>1.08</td>
<td>1.08</td>
</tr>
<tr>
<td>3</td>
<td>26.13-46.19</td>
<td>1.02</td>
<td>1.02</td>
</tr>
<tr>
<td>4</td>
<td>46.66-223.81</td>
<td>0.99</td>
<td>1.01</td>
</tr>
</tbody>
</table>

Abbreviations: PVCT, prostate volume measured by computed tomography; PVTRUS, prostate volume measured by transrectal ultrasonography.
LUTS in men are a common health problem that increases with age. BPH causes LUTS that may affect quality of life and patient satisfaction. 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.

PV has been measured through ellipsoid formula that was designed in accordance with geometric shape of the prostate. For determining more accurate PV, step section planimetry may be also employed in patients with prostate cancer. Previous literatures reported an excellent reproducibility of PV measurements by planimetry. However, it is difficult for urologists 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. 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. However, CT scan consistently overestimated the prostate volume compared with TRUS by 17-50%. 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. 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. 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 studies. Thus, PVCT ellipsoid may be more accurate than PVCT 3D reconstruction because previous studies demonstrated a trend toward greater underestimation by TRUS in PV. CT scan, with its inferior soft tissue contrast, compared to TRUS is not regarded as primary diagnostic modality for the prostate. 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. 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. 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 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


