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Comparison Of Accuracy Of Prostate Model Volume Measurement Between 2 Dimensional And 3 Dimensional Ultrasonography.

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Citation

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Abstract

Purpose: To compare accuracy of prostate model volume measurement between 2 dimensional (2D) and 3 dimensional ultrasonography (3D).
Materials and Methods: Sixty prostate models were made using devil's tongue jelly and shaped by cutting the surface. To compare the accuracy of prostate model volume measurement according to the size and shape of the prostate model, 60 models were divided into four groups according to shape (ellipsoid vs. ellipsoid–intravesical prostate protrusion, IPP) and size (20-50ml vs. 50-80ml). In vitro measurement of prostate models using 2D-HWL, 3D Axial mode, and 3D Sagittal mode was performed and compared. Statistical analysis including simple regression analysis, Bland-Altman plot, and paired samples t-test were performed.Results: The percentage of error in the measurement of ellipsoid prostate models (20 – 80ml) was 4.50% ± 2.33 (3D Sagittal mode), 4.85% ± 1.66 (3D Axial mode), 7.09% ± 2.60 (2D HWL) and there was no statistically different accuracy comparing to true prostate model volume among three measurement methods. Pierson's correlation coefficient revealed higher positive correlation between true volume and measured volume; 0.977 (3D Sagittal mode), 0.976 (3D Axial mode), 0.964 (2D HWL) in the ellipsoid prostate models measurement and 0.989 (3D Sagittal mode), 0.979 (3D Axial mode), 0.941 (2D HWL) in the ellipsoid-IPP model measurement. However, the percentage of error in the measurement of ellipsoid-IPP prostate models (20 – 80ml) was 4.87% ± 2.74 (3D Sagittal mode), 7.04% ± 3.36 (3D Axial mode), 23.56% ± 13.63 (2D HWL), and 2D HWL showed significantly different volume measurement comparing to true volume ($p < 0.001$). In addition, there was statistically significant difference between 3D Axial mode measurement and true volume ($p=0.047$) in the measurement of ellipsoid-IPP prostate models (50 – 80ml). Bland-Altman plot showed higher percentage of mean difference between 2D HWL and true volume in the measurement of ellipsoid-IPP prostate models (20 – 80ml).
Conclusion: In measuring prostate model volume, the 3D Sagittal mode is better than 3D Axial mode or 2D HWL measurement, especially irregular larger and IPP prostate models.

INTRODUCTION

An accurate measurement of the prostate volume provides the key clinical data. The prostate volume is one of the key examples. In making a diagnosis of the prostate hyperplasia, monitoring the treatment course or reducing the increased prostate volume, the treatment outcomes are not excellent in the prostate gland whose volume is lower than 50mL. Accordingly, an accurate measurement of prostate volume determines the type of surgical modality for corresponding cases. Besides, the PSA density which is obtained by dividing the prostate specific antigen (PSA) by prostate volume has been efficiently used to predict the prostate cancer. As described here, an accurate measurement of the prostate volume plays a key role in making a diagnosis of prostate diseases and treating them[1-3]. 2D TRUS HWL measurement method, where the height, width and length of prostate gland are measured on two dimensional transrectal ultrasound (2D TRUS) and its volume is calculated based on a Prolate Volume Ellipsoid formula ($V = \text{Height} \times \text{Width} \times \text{Length} \times \pi/6$) under the hypothesis that the prostate gland has an elliptical shape, has been extensively used at the present. As compared with the actual prostate volume, however, the measuring error of approximately 7 ~ 27% has been reported to occur[4, 5]. Particularly in cases in which the prostate gland has an irregular shape or is protruded superiorly (intravesical prostate protrusion, IPP), an elliptical shape of the prostate gland which is commonly used to calculate the prostate volume is not applicable and this may generate a great degree of measuring errors[3, 6, 7]. In recent years, Choi et al. reported that there are such disadvantages as the generation of measuring errors which are statistically significant depending on the technical expertise of investigators, in cases in which the prostate volume exceeds 30mL in particular, when the prostate volume is measured using 2D TRUS HWL methods[1]. Previous studies have attempted to measure the prostate volume using 3 dimensional transrectal ultrasound (3D TRUS). But it is disadvantageous in that a prolonged length of time is required for reconstructing a 3-dimensional ultrasonographic image. Accordingly, it has not been used in a clinical setting[6, 8, 9]. With the latest technical advancement of 3D TRUS equipment, it has become possible to use an automated 3D volume measurement (3D AVM) where the prostate volume is automatically calculated by reconstructing a 3-dimensional ultrasonographic image and keep tracking of the margin of prostate gland on a real-time basis.

Given the above background, we compared the accuracy of measurement of the prostate volume between 3D AVM and 2D HWL by preparing an experimental model of the prostate gland with a different elliptical shape and an IPP one and measuring its volume. Thus, attempts were made to examine more accurate, objective measurement of the prostate gland.

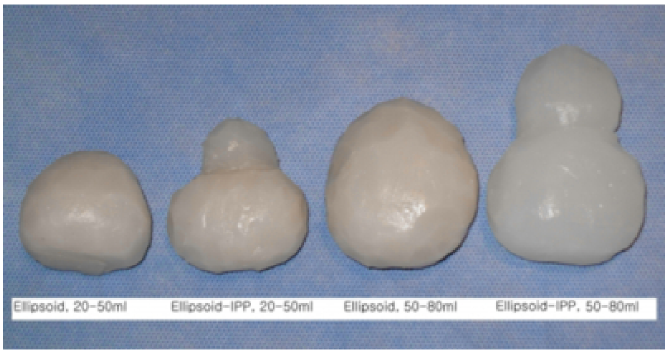
MATERIALS AND METHODS

(1) A PREPARATION OF THE PROSTATE GLAND USING DEVIL'S TONGUE JELLY

An experimental model of the prostate gland was prepared using Devil's tongue jelly whose ultrasonographic permeability is equivalent to that of the actual prostate gland. Using a commercially-available powder of Devil's tongue jelly (Milyang Agar, Milyang, Korea), Devil's tongue jelly was prepared and then sectioned at an appropriate size. Then, this was followed by the preparation of an experimental model of prostate gland with a different volume and shape. An experimental model of the prostate gland was prepared, according to the volume, into two groups: the group of 20-50mL and that of 50-80mL. It was also prepared, according to the shape, into two groups: the ellipsoid group and the IPP group where the shape is similar to the protrusion of prostate gland into the urinary bladder. In the IPP group, in the superior region of an experimental model of the prostate gland, various shapes were prepared with a trigone shape. An experimental model of the prostate gland was prepared in the following numbers and manners: 15 models from the ellipsoid group of 20-50mL in volume, 15 models from the IPP group of 20-50mL in volume, 15 models from the ellipsoid group of 50-80mL in volume and 15 models from the IPP group of 50-80mL in volume. Thus, a total of 60 experimental models of the prostate gland were prepared (Fig. 1).

Figure 1

Figure 1. Photograph of four types of experimental prostate model



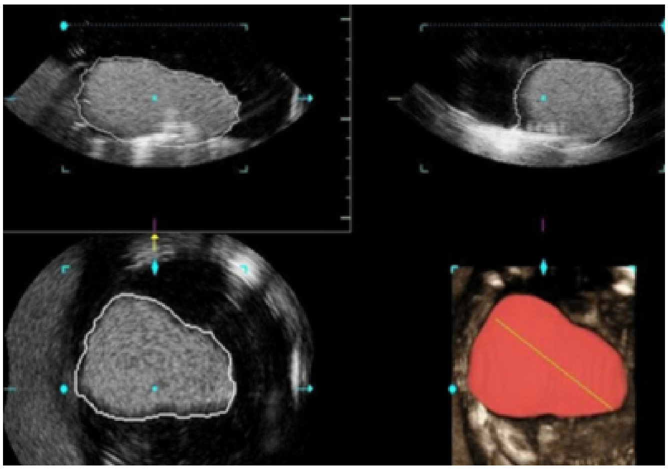
Note. --- IPP: intravesical prostate protrusion

(2) THE MEASUREMENT OF THE VOLUME OF AN EXPERIMENTAL MODEL OF THE PROSTATE GLAND USING 2D HWL AND 3D AVM

An MRI equipment which was used herein was Acouson S-2000 (Siemens Inc., Issaquash, WA). A probe was a 4 MHz 3D transrectal probe with an injection angle of 120 degree. In an experimental model of the prostate gland using Devil's tongue jelly, Devil's tongue jelly was dissected and then placed in a bath. Then, in a total of 60 experimental models of the prostate gland with a different shape and volume, the volume was measured using 2D HWL and 3D AVM in such a condition that the actual volume was unknown. In 3D AVM, if an experimental model of the prostate gland should be scanned using 3D ultrasonography, through a program which was installed in an ultrasonography machine, 3-D images of the scanned prostate models are synchronously reconstructed. Besides, we also used an automated 3D AVM where the margin of prostate gland is automatically recognized using software and the volume is measured accordingly (Fig. 2).

Figure 2

Figure 2. Automatic three-dimensional ultrasound measurement of prostate experimental model.



Note -- Detection of the margin of prostate model (white lines) and volume measurement were automatically performed following 3D ultrasound scanning and reconstruction of images.

The prostate volume which was measured using 2D HWL and 3D AVM was compared with the actual prostate volume. For a comparison of the rate of measuring errors and the correlation between the actual volume and the measurement and the accuracy between the measurement methods, a simple regression analysis, Bland-Altman plot and a paired samples t-test were performed. Statistical analysis was performed at a statistical significance of 95%.

RESULT

Sixty experimental models of the prostate gland, which were prepared using Devil's tongue jelly, were placed in a water bath. Then, an ultrasonography was performed. On ultrasonography, there was a mass with a moderate degree of echogenicity and a well-defined margin. These models were therefore appropriate for measuring the volume. In four groups of an experimental model of the prostate gland, which were classified based on the size and shape, the measurement was done using two different methods: 2D HWL and 3D AVM. The results were shown as below (Table 1).

Figure 3

Table 1. Difference of prostate model volumes measured by 2D HWL, 3D Axial mode, and 3D Sagittal mode.

		Ellipsoid prostate model			Ellipsoid - IPP prostate model		
		20-50 mL	50-80 mL	All	20-50 mL	50-80 mL	All
Mean volume ± SD (range)	Vol. (Real volume)	35.59 ± 7.02 (21.24- 49.32)	66.7 ± 9.41 (51.29-79.26)	52.04 ± 17.37 (21.24-79.16)	35.59 ± 7.02 (24.31-49.32)	66.73 ± 9.42 (51.29-79.26)	51.15 ± 17.82 (24.31-79.26)
	Vol. (2D HWL)	36.01 ± 8.15 (22.85-50.80)	67.57 ± 11.91 (47.02-84.96)	51.79 ± 18.93 (22.85-84.96)	42.67 ± 9.23 (29.17-60.47)	83.69 ± 14.88 (60.57-105.73)	63.18 ± 24.15 (29.17-105.73)
	Vol. (3D Axial)	35.72 ± 8.31 (22.34-51.02)	67.23 ±9.98 (49.24-82.84)	51.40 ± 18.39 (22.34-82.84)	35.73 ± 8.05 (24.04-53.57)	69.51 ± 10.31 (51.95-87.37)	52.61 ± 19.43 (24.04-87.37)
	Vol. (3D Sagittal)	36.22 ± 7.81 (23.58-53.81)	67.76 ± 9.62 (52.19-81.38)	51.99 ± 18.20 (23.58-81.38)	35.83 ± 7.54 (23.18-49.58)	67.46 ± 10.20 (52.14-84.15)	51.64 ± 18.34 (23.18-84.15)
Absolute % of error ± SD	Vol. (2D HWL)	6.20 ± 2.50	7.99 ± 2.47	7.09 ± 2.60	21.06 ± 11.97	26.07 ± 14.24	23.56 ± 13.63
	Vol. (3D Axial)	5.30 ± 1.75	4.39 ± 1.48	4.85 ± 1.66	6.52 ± 2.63	7.56 ± 3.99	7.04 ± 3.36
	Vol. (3D Sagittal)	4.84 ± 2.64	4.17 ± 2.01	4.50 ± 2.33	5.77 ± 3.23	3.98 ± 1.85	4.87 ± 2.74
R (Pearson's correlation coefficient),	Vol. (2D HWL)	0.960	0.885	0.964	0.829	0.716	0.941
	Vol. (3D Axial)	0.979	0.950	0.976	0.948	0.879	0.979
	Vol. (3D Sagittal)	0.967	0.954	0.977	0.941	0.958	0.989
P value (paired t-test)	Vol. (2D HWL)	0.571	0.509	0.796	0.001	<0.001	< 0.001
	Vol. (3D Axial)	0.537	0.858	0.452	0.841	0.047	0.062
	Vol. (3D Sagittal)	0.185	0.252	0.797	0.722	0.353	0.337

Note. -- Vol. (real model): real prostate model volume, Vol. (2D HWL): prostate model volume measure by 2D HWL method, Vol. (3D Axial): prostate model volume measure by 3D axial mode, Vol. (3D Sagittal): prostate model volume measure by 3D Sagittal mode.

In an ellipsoid experimental model of the prostate gland, the prostate volume was measured using three different methods in all the experimental groups of 20-50mL or 50-80mL in volume. According to this, as compared with the actual volume of overall ellipsoid experimental model of the prostate gland (52.04 ± 17.37 ml), the volume was measured to be 51.79 ± 18.93ml on 2D HWL and 51.99 ± 18.20ml on 3D AVM. These results indicate that there was no significant difference between the two measurement methods. A Pierson's correlation coefficient between the measurements and the actual volume of prostate gland was 0.964 in 2D HWL and 0.977 in 3D AVM. These results indicate that both methods had a high degree of correlation with the actual volume (Fig. 3).

Figure 4

Figure 3. Correlation between prostate volume measured by 2D HWL, 3D Axial, and 3D Sagittal mode in all ellipsoid model group (20~50mL group and 50~80mL group). Solid reference line represents line of symmetry (ie, x = y).

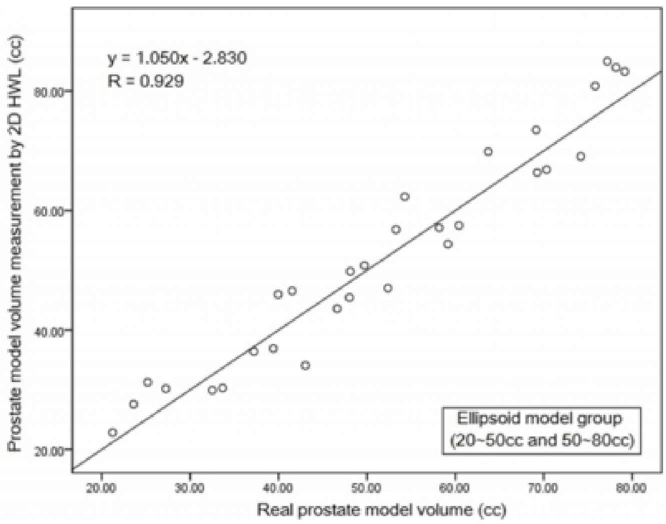


Figure 5

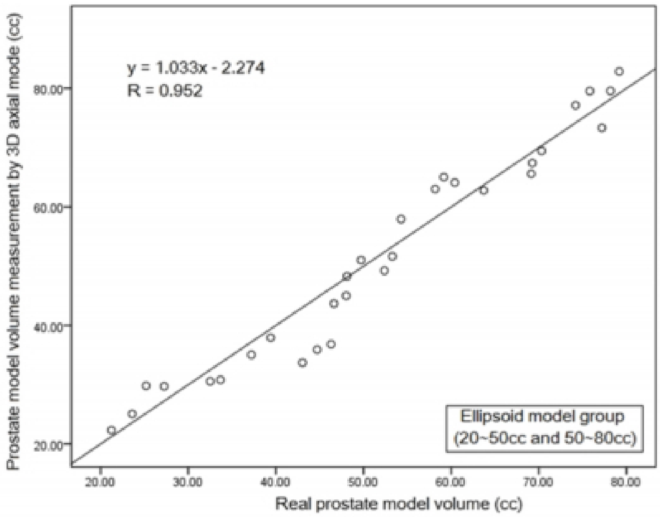
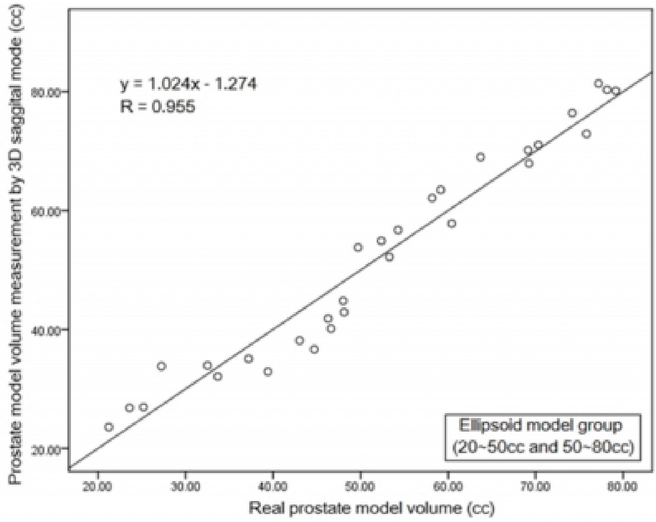


Figure 6



In an ellipsoid experimental model of the prostate gland, a percentage of error, which was calculated to examine the extent to which the prostate volume was measured to be higher or lower in a percentile value as compared with the actual one, was found to be 7.09% ± 2.60 on 2D HWL and 4.50% ± 2.33 on 3D AVM. These results indicate that the percentage of measuring errors was slightly higher on 2D HWL. But this was not statistically significant (P = .796). Following a comparison of the measurement of an ellipsoid experimental model of the prostate gland using Bland and Altman plot, a statistical method for comparing the difference between the two measurement methods, both measurement methods showed that most of the measurements were distributed within a 95% interval of error as compared with the actual volume. Besides, the mean value of measurement errors was shown to be approximately 0. This indicates that there were no significant differences in measurements between the two methods in an experimental model of the prostate gland (Fig. 4).

Figure 7

Figure 4. Bland and Altman plot for the percentage of the mean difference and 95% limits of agreement of the prostate model volume measurement (ellipsoid model group) between real prostate model volume and volume measured by 2D HWL method, 3D Axial and Sagittal mode.

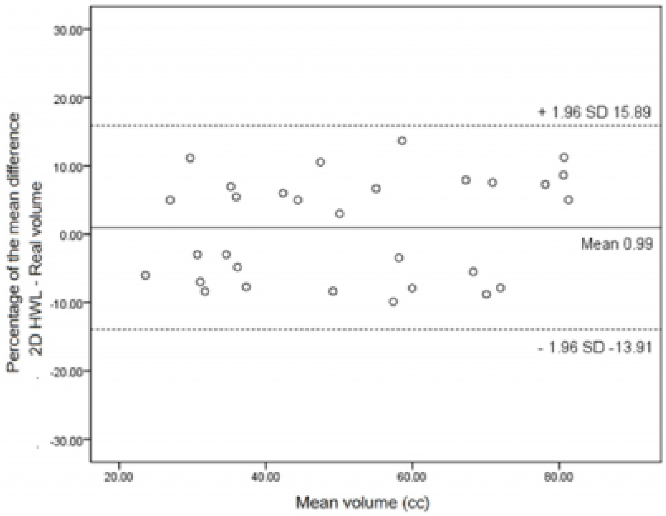


Figure 8

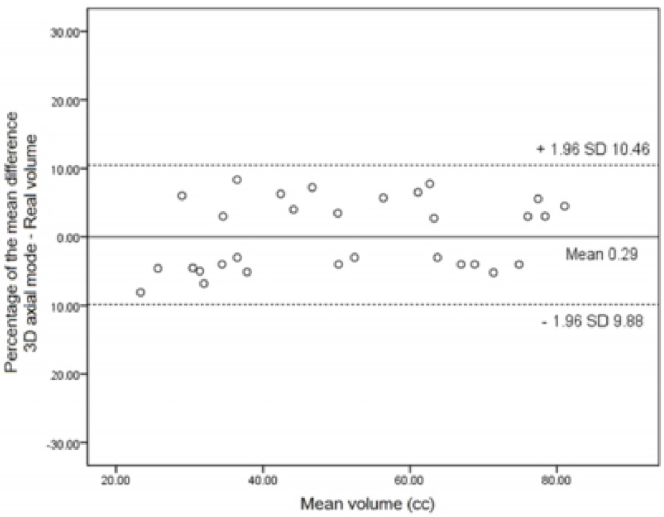
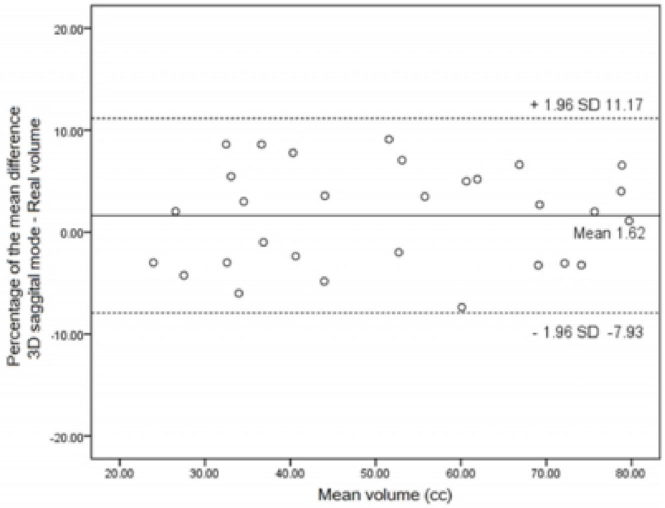


Figure 9



Following the measurement of prostate volume in the Ellipsoid-IPP group, an experimental model of the prostate gland, where the upper part of prostate gland was protruded, the degree of measuring error was relatively higher in the previous 2D HWL method as compared with the 3DAVM one. In association with this, there was a marked difference in the measurement in the group of an experimental model of the prostate gland of 50-80mL in volume as compared with that of a smaller volume. In other words, as compared with the actual volume (51.15ml ± 17.82) of the overall experimental model in the Ellipsoid-IPP group, the prostate volume was measured as 63.18ml ± 24.15 on 2D HWL and 51.64ml ± 18.34 on 3D AVM. These results indicate that the degree of accuracy was relatively higher in 3D AVM. On 2D HWL, there was a significant measuring error as compared with the actual volume ($P < .001$). On 3D AVM, however, there was no significant difference between the measurement and the actual value in the Ellipsoid-IPP group ($P = .337$). In the Ellipsoid-IPP group, a Pearson's correlation coefficient had a positive correlation. But it was lower than an ellipsoid experimental model of the prostate gland (Fig. 5).

Figure 10

Figure 5. Correlation between prostate volume measured by 2D HWL, 3D Axial, and 3D Sagittal mode in ellipsoid-IPP model group (20~50mL group and 50~80mL group). Solid reference line represents line of symmetry (ie, x = y).

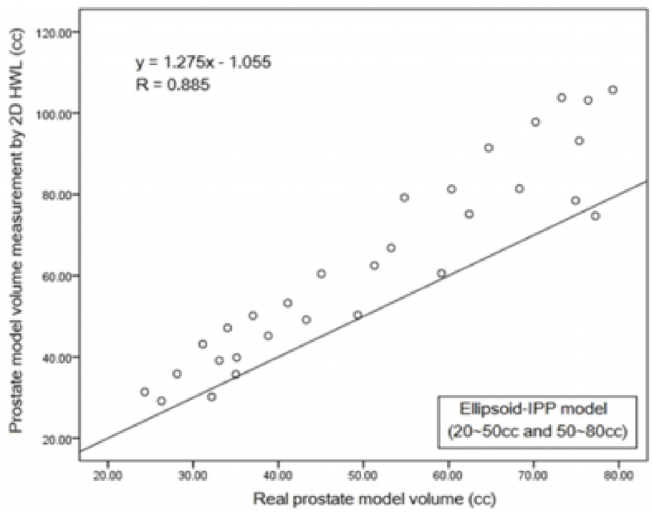


Figure 11

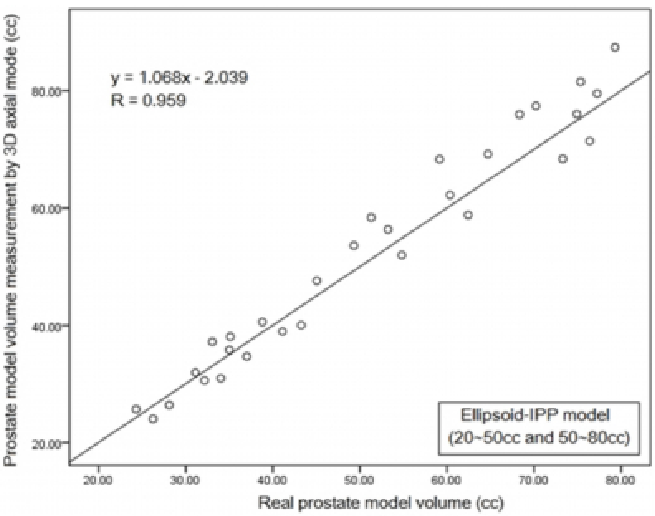
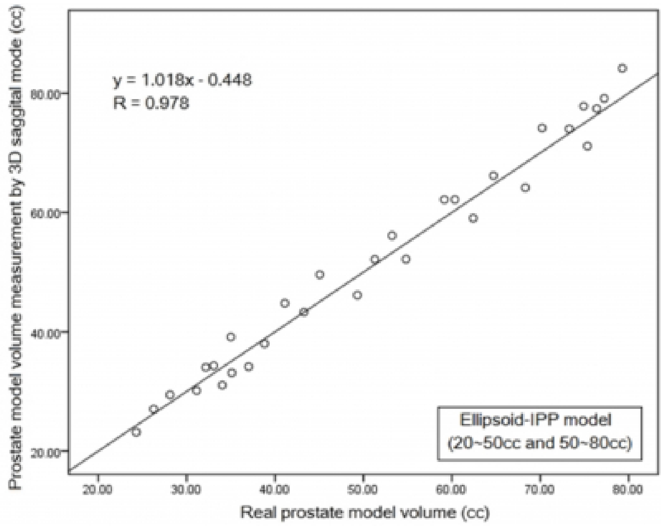


Figure 12



The errors of two measurement methods in the overall experimental model of the Ellipsoid-IPP group

Percentage of error was 23.56% ± 13.63 on 2D HWL and 4.87% ± 2.74 on 4.87% ± 2.74. On 3D AVM, as compared with the measurements obtained from an Ellipsoid experimental model, the degree of measuring error was not relatively higher. On 2D HWL, the measurement was higher by 24% on average as compared with the actual value. This implies that it was the most inaccurate measurement method. On a Bland and Altman plot, following the use of 3D AVM, as compared with the actual value, mean percentage rate and measurements were within a 95% interval of the measuring error. Following the use of 2D HWL, however, as compared with the actual value, the percentage rate was distributed to be at a 24% higher level. These results indicate that the measuring error was found to be relatively greater in an Ellipsoid-IPP experimental model (Fig. 6).

Figure 13

Figure 6. Bland and Altman plot for the percentage of the mean difference and 95% limits of agreement of the prostate model volume measurement (ellipsoid-IPP model group) between real prostate model volume and volume measured by 2D HWL method, 3D Axial and Sagittal mode.

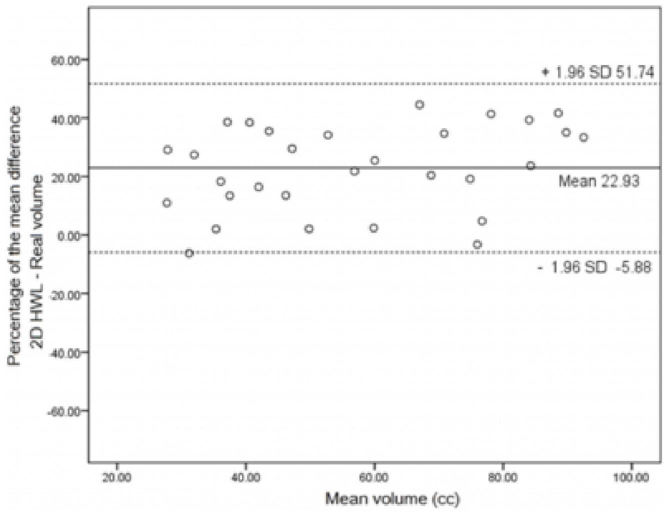


Figure 14

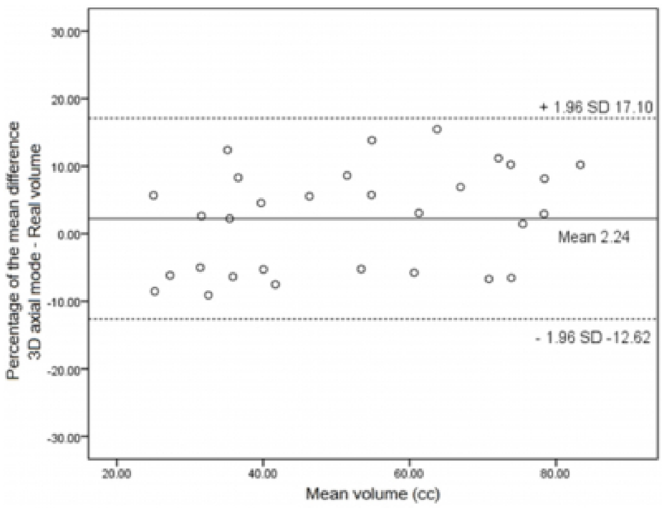
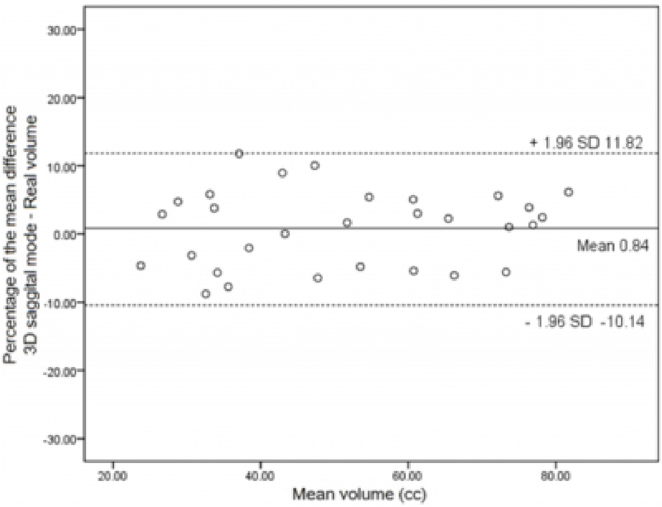


Figure 15



DISCUSSION

Of the methods for measuring the prostate volume under the ultrasonographic guidance that have been known up to present the most accurate one is an ultrasonographic planimetry. It is a method where the prostate gland is scanned at a certain degree of thickness using a trans-rectal ultrasonography; the area of prostate gland is obtained; and the volume is calculated from a sum of areas of the prostate gland. But this ultrasonographic planimetry requires extremely longer time and efforts with no respect to 2-D or 3-D images. Accordingly, it cannot be used in a clinical setting[6]. According to Petter et al., following a comparison of the prostate volume which was measured on 2D HWL with the actual value in an ellipsoid experimental model of the prostate gland, there were a correlation coefficient of 0.988 and a standard error of 4.0 mL. These results indicate that the prostate volume could be accurately measured[10]. At the present, the methods for measuring the prostate volume using 2D HWL are frequently used. 2D HWL measurement method is referred to as a method where the height (H), the width (W) and the length (L) of prostate gland are measured under the hypothesis that the prostate gland has an ellipsoid shape and the volume is calculated based on a formula ($V = H \times W \times L \times \pi/6$). In general, the measuring error has been reported to be 7-27%[4, 5]. In general, 2D HWL measurement method has a high degree of reproducibility and it can be used both promptly and conveniently in an actual clinical setting. Due to such reasons as a lack of the differentiality between the prostate gland and the adjacent structures including the urethra because of its height or length, the measuring error can also be greatly increased. Besides, the measuring error is also increased in the prostate gland whose size is relatively greater[4, 6, 7]. 2D HWL method measures the prostate volume to be lower than the actual value in most cases[11]. In recent years, MacMahon et al. modified a formula for calculating the prostate volume based on the hypothesis that the prostate gland has an ellipsoid shape to $H \times W \times L \times \pi/4.8$ to reduce the measuring error on 2D HWL method. As a result, these authors suggested that the prostate volume could be accurately measured in the prostate gland whose volume is smaller than 55ml[12].

As the efforts which have been made to improve the accuracy of measurement of prostate volume using 2D HWL method, the previous 2D HWL method has been used to measure the prostate volume using 3-dimensional ultrasonographic images[8, 9, 13]. In particular, in a study about a 3-D ultrasonographic measurement of the areas of prostate gland, Arnink et al. compared the measurement of prostate volume with the actual value and then reported a correlation coefficient of 0.93 and a mean measuring error of 5.0mL ± 4.1mL. Based on these results, these authors maintained that 3D ultrasonographic measurement of the prostate gland was more accurate than 2D HWL method[14]. In an actual clinical setting, however, it takes longer to acquire 3-D ultrasonographic images in an actual clinical setting. Because a planimetry cannot be used for a test and a measurement on a real-time basis, it has not been used in a clinical setting. In recent years, Giubilei et al. reported that mean absolute measuring error was ±0.3 - 3ml in a study about an automated measurement of the prostate volume on 3D AVM. According to these authors, as compared with a mean measuring error of ±0.4 - 5ml seen on 2D HWL, the prostate volume could be measured more accurately[15]. To date, however, no experimental studies have compared the prostate volume between 2D HWL method and a 3-D ultrasonographic image in the prostate gland whose shape was irregular or variable, as shown in those with a protrusion within the urinary bladder.

In a comparison of the methods for measuring the prostate volume under the ultrasonographic guidance, both methods (2D HWL and 3D AVM) showed no significant differences in the prostate volume in an ellipsoid experimental model. These methods were relatively accurate in measuring the prostate volume. A Pearson's correlation coefficient was found to be 0.977 in 3D AVM and 0.964 in 2D HWL, which showed a very high degree of correlation. A Pearson's correlation coefficient between the two methods showed a very high degree of correlation in both measurement methods. There was no significant difference between the two methods. In an Ellipsoid experimental model of the prostate gland (20-80mL), the percentage of measuring error was 4.50% ± 2.33 on 3D AVM (4.50% ± 2.33) and 7.09% ± 2.6 on 2D HWL (7.09% ± 2.6). Both measurements were relatively smaller. This implies that both 3D AVM method and 2D HWL method were accurate in measuring the prostate gland in an ellipsoid experimental model of the prostate gland. Following a comparison of the percentage of measuring error depending on the size of prostate model, on 2D HWL method, it was measured to be 6.20% ± 2.50 in an Ellipsoid experimental model of the prostate gland with a smaller size (20-50mL) and it was measured to be 7.99% ± 2.47 in an Ellipsoid experimental model of the prostate gland with a greater size (50-80mL). In an agreement with the previous reports, the degree of measuring error was relatively greater in the prostate gland whose size was relatively greater. On 3D AVM method, however, in an Ellipsoid experimental model of the prostate gland with a smaller size (20-50mL), it was measured to be 5.30% ± 1.75. Besides, in an Ellipsoid experimental model of the prostate gland with a greater size (50-80mL), it was measured to be 4.39% ± 1.48. These results indicate that the degree of measuring error was relatively lower in the prostate gland whose size was relatively greater. Despite a smaller degree of measuring error in the prostate gland whose size was relatively greater, there was no statistical significance.

In an ellipsoid experimental model of the prostate gland, there was a significant difference between the two measurement methods. In other words, in an Ellipsoid-IPP model (20-80mL), the mean percentage of measuring error was 23.56% ± 13.63 on 2D HWL method. This implies that the prostate volume was measured to be significantly higher than the actual value ($P < .001$). Besides, the mean percentage rate of measuring error on 2D HWL method was 21.06% ± 11.97 in an Ellipsoid-IPP model with a smaller size (20-50mL) and 26.07% ± 14.24 in that with a greater size (50-80mL). These results indicate that the degree of measuring error was increased as the size of prostate model was increased. This implies that it is a very inaccurate method for measuring the prostate volume in the IPP model. This might be because the measurements are exaggerated as compared with the actual value due to the protrusion occurring in the upper part of prostate model because of 2D HWL method. By contrast, on 3D AVM method, the mean percentage of measuring error was found to be 4.50% ± 2.33 in an Ellipsoid experimental model (20-80mL) and 4.87% ± 2.74 in an Ellipsoid-IPP model (20-80mL). These results indicate that the prostate volume could be measured accurately to such an extent that there is no statistical significance as compared with the actual value in measuring the volume of prostate gland with an irregular shape. On 2D HWL method, as the size of prostate gland was increased, the degree of measuring error was increased. By contrast, on 3D AVM method, the mean percentage of measuring error was 5.77% ± 3.23 in an Ellipsoid-IPP model (20-50mL) with a smaller size but it was 3.98% ± 1.85 in an Ellipsoid-IPP model with a greater size (50-80mL). These results indicate that 3D AVM method produced a more accurate measurement of the prostate volume in the prostate gland with a greater size. This implies that the prostate gland could be measured more accurately in the large-sized prostate gland with an irregular shape, which is disadvantageous in measuring the prostate volume.

Limitations of the current study are that it remains unclear whether 3D AVM method would also be effective in accurately measuring the prostate volume to the same extent as the measurement of prostate volume in an actual clinical setting although it showed a very accurate measurement of the prostate gland. There is a high possibility that 3D AVM method might produce inaccurate results of the measurement of prostate gland in an actual clinical setting unlike the measurement of prostate gland in an experimental model of the prostate gland. In association with this, the difference in the differential functions between the prostate gland and its margin with the adjacent tissue might be a responsible cause. To put this in another way, in the current study where an automated differentiation of the margin of prostate gland was attempted to reconstruct a 3-dimensional image by automatically differentiating the prostate gland from the adjacent tissue following the acquisition of 3-D ultrasonographic images in an experimental model of the prostate gland which was placed in a water bath, due to the marked margin between the prostate model and the adjacent water, there were almost no problems with an automated recognition of the prostate gland and the reconstruction of 3-D images. In measuring the volume of actual prostate gland, however, there was no marked discrimination from the adjacent tissues unlike an experimental model. Accordingly in cases in which the margins of prostate gland are obscure, the prostate gland might be overestimated or underestimated as compared with its actual volume. As compared with the results of the current study, the degree of measuring error would be increased. It is problematic that this 3D AVM measurement method cannot be used in an actual clinical setting. But this would be further improved with the increased use of 3-D ultrasonographic equipments, the widespread distribution of equipments as well as the technical advancement of applied programs such as those used for the automatic differentiation of the margins of prostate gland. Through these efforts, as shown in the current experimental study, the disadvantages of 2D HWL method, such as a high degree of measuring error depending on the shape and size of prostate gland and the difference in the technical expertise of investigators, would be markedly reduced.

In conclusion, through the current experimental study, both 2D HWL method and 3D AVM method were effective in accurately measuring the volume of prostate gland in an ellipsoid experimental model of the prostate gland. In measuring the volume of prostate gland with an irregular shape whose upper part has a protrusion, however, 2D HWL method has a high degree of measuring error and it is therefore unreliable. On 3D AVM methods, however, the volume of prostate gland could be accurately measured in both cases. Henceforth, further studies are also warranted to continuously examine the measuring technology based on 3D AVM method and to compensate it. This would also be helpful for accurately measuring the volume of prostate gland in an experimental model to an equivalent extent to an actual clinical setting.

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