Prostate Volume Ultrasonography: The Relationship of Body Weight, Height, Body Mass Index and Ethnicity in Transabdominal Measurement

Ng Kent Hoo, Muhammad Akmal Ayob, Maheza Irna Mohamad Salim, Christina Pahl, Heamn Noori Abduljabbar, Eko Supriyanto

***Abstract*—**Prostate volume measurement is frequently used to diagnose the abnormalities of the prostate. Abnormal enlargement of the prostate may due to inflammation or virus infection. In a more severe case, the abnormal enlargement may indicate prostate cancer. So far, prostate abnormalities detection is best carried out by using ultrasonography due to its rapid measurement and good sensitivity. In clinical setting, there are several ways of conducting prostate ultrasonography including transperineal, transrectal and transabdominal. Transperineal and transrectal scanning offer a higher sensitivity imaging than the transabdominal route. However, reproducibility of the image is very low since both methods are operator dependant. Therefore, this study proposes the use of transabdominal scanning in the measurement of prostatic volume of 10 healthy multiethnic Malaysian populations. The objective of this study is to find the relationship between body weight, height, body mass index and ethnicity to prostatic volume of Malaysian population. Previous researches on prostate volume measurements only focused on subjects' ages. However, that is not the only factor that affects the volume of prostate, as parameters like body weight, height, body mass index and ethnicity may contribute a lot in the differences of prostate volume. During the study, all subjects are requested to fully fill their urinary bladder to obtain clear prostatic gland images. The recorded digital image was further processed in Matlab for segmentation of the prostate area. Finally, prostate volume measurement was conducted by using the ellipsoid formula which calculates volume by considering the largest anteroposterior height (H), transverse width (W), cephalocaudal length (L) and diameters. The findings show that prostate volume increases linearly with body weight and height of a person and almost linearly with BMI. In addition to that, ethnicity comparison shows that Chinese ethnic has the highest prostate volume followed by Indian and finally malay ethnic.

***Keywords*—** Prostate volume, height, weight, body mass index, ethnicity

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I. Introduction

Reliable and precise ultrasonography measurement of prostate volume (PV) is very important for the management of prostate diseases. It is crucial not only for diagnosis purposes but also in planning non-invasive treatments of prostate cancer and follow ups [14].

A. Prostate Volume Ultrasonography Measurements

In clinical setting, measurement of prostate volume via ultrasonography is conducted in several ways namely transperineal (TPUS) [12], transrectal (TRUS) and transabdominal (TAUS) [14-15].

Historically, transperineal route was the first one used to reach and image prostate [16] as it was used to guide biopsy procedure since 1950. In transperineal ultrasound imaging, ultrasound transducer is placed in the perineal area while the patient lies down in supine lithotomy position. Due to the position of the transducer, images of bladder and prostate are allowed to be reached since anatomically, both structures fall within the transducer's field of view [17]. However, the sensitivity of TPUS in imaging clear prostate is very limited as report from previous studies showed that TPUS done by experienced sonographer can only be able to detect a very low percentage of known cancer. This is due to its restriction in visualizing abnormalities of the prostate, particularly at hyperechoic area [18-19].

Transrectal ultrasound examination is a common outpatient procedure involving digital ultrasound for the assesment of prostate via rectum [13]. The examination is performed by placing a small and lubricated intracavity probe of 7.5MHz into the rectum either for imaging or guiding biopsy [10]. Nowadays, transrectal guided biopsy is a gold standard for diagnosis of prostate cancer as the combination of prostate

biopsy and prostate ultrasonography yield the best diagnostic outcome of prostate cancer. The transrectal method provides a clear image of organs in the pelvis. Normally, transrectal ultrasound is used for the evaluation of the prostate gland with elevated prostate specific antigen (PSA) or prostatic nodules on digital rectal examination [10]. Although this method is reported to give high accuracy, its usage requires high patient tolerance as it involves insertion of the intracavity probe into the rectum. Another issues concerning the usage of transrectal ultrasound is the intraobserver variations. Depending on the sonographers's knowledge and experience, values measured by each sonographer are different resulting in low reproducibility of clinical result and causes clinical decision making to be complicated. Hence, transabdominal method has become a standard clinical tool for a rapid, simple and non-invasive screening of the prostate.

Transabdominal ultrasound uses 3-5MHz transducer through a partially or fully filled urinary bladder with caudal angulation to send the ultrasound beam under the pubic arch and permit global volume measurements of the prostate [15]. In this method, the transmitted and reflected ultrasound waves visualize the organs through the abdominal wall. The advantage of transabdominal ultrasound is the procedure can be performed quickly, and non-invasively [11].

B. Importance of Prostate Volume measurements

Measurements of prostate volume have become very important clinically since its association with different diseases and variables of malignancy [35]. The American Cancer society found that prostate cancer is one of the most common cancers in men [3] and is getting serious attention from the world as it has become a significant cause of death every year.

A few researches reported that prostate volume highly contributes in diagnosis of prostate cancer. These studies show that large prostate volume has an increased risk of malignancy [2].

However, another studies with the same scope concluded that prostate gland harbouring carcinoma were significantly smaller than in men without malignancy [37-39]. This include the most recent study on relationship between prostate volume and some histological criteria of malignancy which concluded that small prostate volume having weight smaller than or equal to 20g harbors tumors of great malignancy while those of large volume with weight greater than 90g is more often harbors unifocal and low grade tumors [36].

As the critical size related to malignancy is stated concisely in this study ($\leq$20g and $\geq$90g), it is yet to determine the range of normal volume of prostate since its volume is influenced by so many factors including adiposity [27-30], ages [31], body size [33] and frequency of sexual activity [32]. Other than that, previous report also shows that prostate volume may also be influenced by ethnicity and migration [34]. Therefore, this presents study will investigate the correlation between body weight, height and BMI as well as ethnicity to healthy multi-ethnic Malaysian population as an early baseline study before abnormal volume measurements.

C. Prostate Anatomy

Prostate is a compound tubuloalveolar exocrine gland of the male reproductive system. The function of prostate is to secrete slightly acidic fluid, which has the characteristic of milky or white in appearance. The secretion usually constitutes 20% to 30% of the volume of the semen along with spermatozoa and seminal vesicle fluid. In medical practice, most of the prostate abnormalities are diagnosed by measuring their volume [2]. Normally, the prostate volume range between 250mm^3 at birth to 10000mm^3 sized at puberty. After puberty, the prostate volume will continuously grow as the age increase for most of the male's life. A healthy human male prostate has the volume of 10000mm3. The prostate is located above the base of the penic and below the urinary bladder and backs into the front wall of rectum. The prostate secretes some of the fluid for semen, stops urination during ejaculation, and enhances sexual pleasureable sensations [7]. Figure 1 shows the anatomy of prostatic gland.

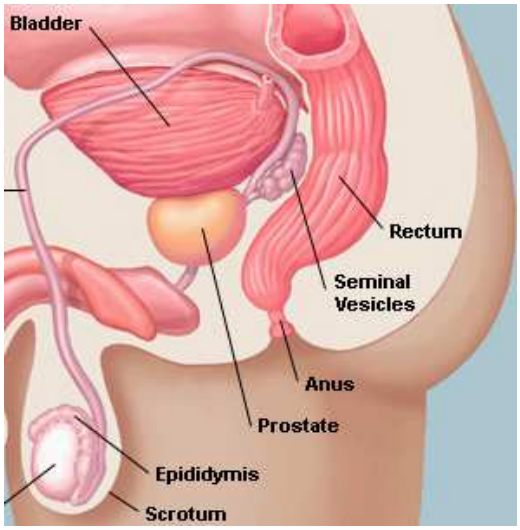

Fig. 1. Anatomy of the prostatic gland

II. METHODOLOGY

A. Subjects

In this study, 10 male subjects from the age of 20 years old to 25 years old were selected to undergo the transabdominal ultrasonography scanning. All the subjects are belonging to Malaysian multiethnic background consisting of 4 Malay subjects, 3 Chinese subjects and 3 Indian subjects. The subjects were randomly selected with different heights and weights to find the correlation of weight and height to normal prostate volume. Since, this study focuses on normal prostate volume, subjects with the history of abnormal prostate condition were automatically excluded from the study.

B. *Prostate Ultrasonographic Scanning Protocols*

Overall ultrasonographic scanning was conducted by using Toshiba Aplio MX, Toshiba Medical System, Tochigi, Japan. The device was set to a 2D mode and a convex probe with frequency of 8 MHz was used for imaging from longitudinal plane as shown in Fig. 3. Measurements were conducted under general setting of the ultrasound machine. The subjects were first instructed to fully fill their urinary bladder by consuming water 30 minutes before the measurement. This was to ensure that the anatomy of prostate could be well-imaged and observed. The measurement was conducted by placing the transducer on the superficial of the abdominal area with subjects laid in supine position during scanning.

Fig. 2. Toshiba Aplio MX model ultrasound used in the study.

Fig. 3. Transabdominal scanning of prostate from longitudinal plane [22]

C. *Image Processing*

Segmentation of the edge of prostate gland will provide better accuracy for volume measurement. In this study, overall image processing works were conducted in Matlab, Mathwork Inc., Natick, Massachusetts, USA. The original images contain unwanted data and noises. Hence, image processing was started by cropping, to isolate the region of interest from its background that contains unwanted information. Then, the cropped image was filtered by using median filter to remove noises and enhanced the image contrast in the region of interest. Later, the image format was converted from its original matrix scale to gray scale and finally to black and white scale to ease the edge detection process of the prostate image.

D. *Prostate Size Measurements*

This study employs ellipsoid formula to calculate prostate volume by multiplying the largest anteroposterior height (H), transverse width (W), cephalocaudal length (L) and diameters by $0.524(H \times W \times L \times \frac{\pi}{6})$ [11].

III. RESULT AND DISCUSSION

A. *Prostate Image*

Fig.4 shows the raw ultrasound image obtained during the measurements. The raw image contains skin and adipose layer of the abdominal walls, urinary bladder and prostate that falls within the field of view of the ultrasound transducer.

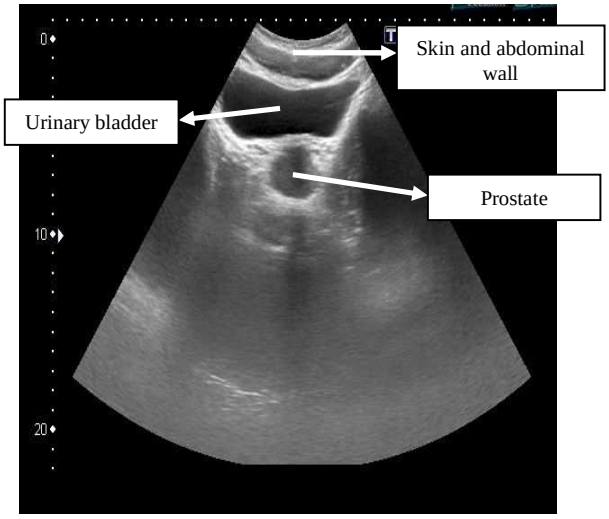

Fig. 4. Sample of raw ultrasound image of prostate obtained via transabdominal scanning

B. *Subjects Analysis*

10 healthy male subjects representing Malaysian's multiethnic of Malay, Chinese and Indian were participated in this study. The age ranges from 20 to 25 years old. Details

including mean and standard deviation of the subject's weight, height and BMI are shown by Table 1.

Table 1: Variations in subjects weight, height and BMI.

Subject	Weight (kg)	Height (m)	Body Mass Index (BMI)
1	70	1.68	24.80
2	77	1.76	24.86
3	57	1.63	21.45
4	82	1.80	25.31
5	62	1.64	23.05
6	68	1.64	25.28
7	79	1.78	24.93
8	75	1.74	24.77
9	74	1.74	24.44
10	55	1.62	20.96
Mean ±Stdev	69.9±9.29	1.703±0.068	23.985±1.6

C. Image Processing Result

The objective of image processing in this study is to isolate the prostate image from its adjacent organ to ease volume calculation since the presents of adjacent organ may cause inaccurate volume measurements. The images collected from the subjects were firstly cropped by using the MATLAB function "imcrop" to extract the desired part. Fig. 5 shows the original image and the cropped image.

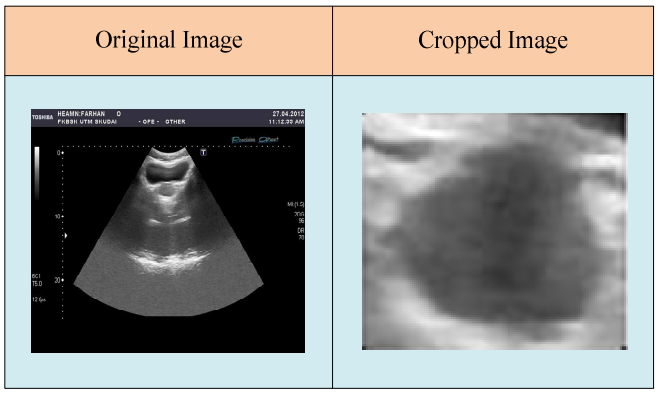

Fig. 5. Extraction of the prostate from the original image.

However, the cropped prostate image resulting from the first step still contains noises that may cause errors in volume calculation. Therefore, median filter was chosen for de-noising. Other than that, filtering was also used to enhance the image contrast. Figure 6 shows the filtered image. After filtering, the image of prostate was enhanced to ease the next image processing steps.

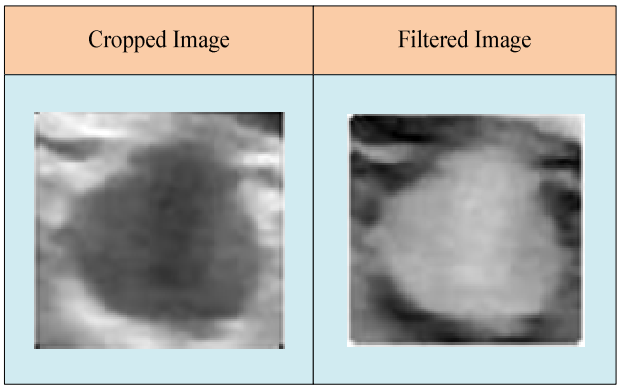

Fig. 6. Comparison of the filtered image and the original image.

Edge detection process involved conversion of the original image format from matrix scale to gray scale and finally to black and white format. Fig. 7 and 8 show the conversion of the matrix scale to the gray scale and to black and white scale respectively.

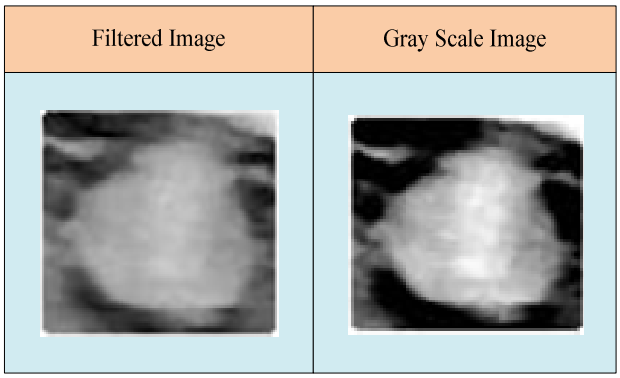

Fig. 7. Conversion of the filtered image to the gray scale image.

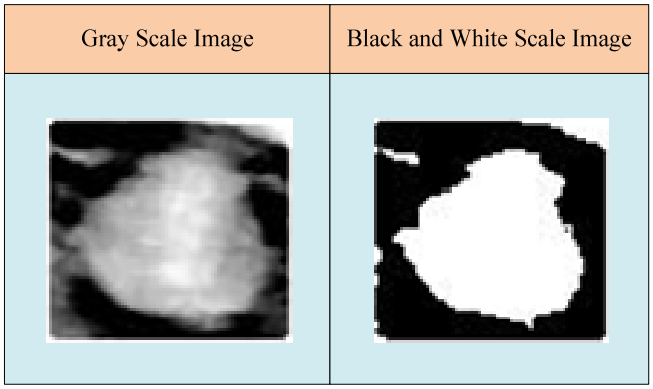

Fig. 8. Conversion of gray scale image to black and white scale image.

The resulting black and white image in Fig. 8 shows that the image consists of noises. Fig. 8 shows the image after noise elimination.

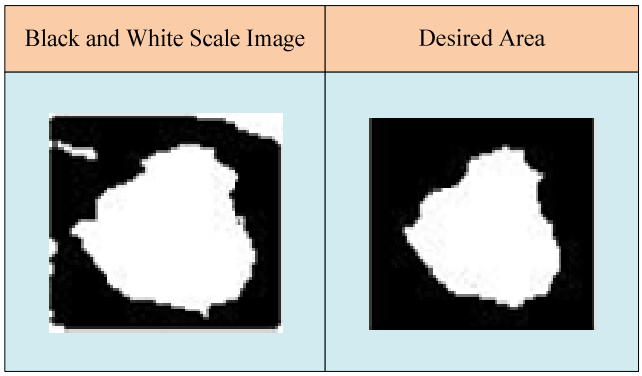

Fig.9. Elimination of the unwanted areas from the converted image.

The final step of the edge detection was superimposistion of the black and white image with the original image from which the boundary of the image was defined. Fig.9 and 10 show the results of superimposition of two images.

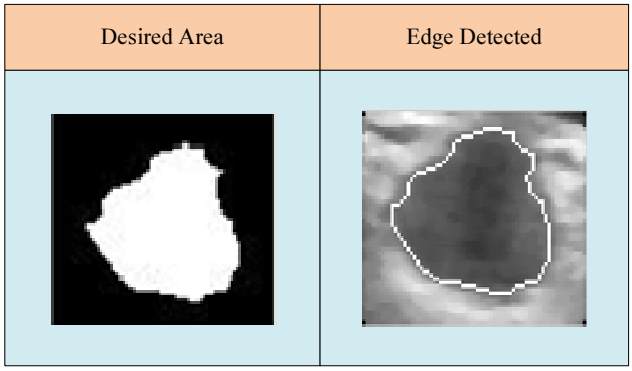

Fig.10. Superimpose result of the original image and the desired area.

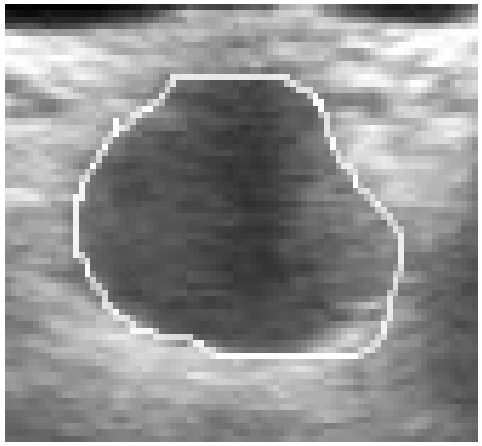

Fig. 11. Images after processing shows the boundary of the prostate.

After the boundary of the prostate has been defined, volume calculation was conducted by using the ellipsoid formula. This formula calculates prostate volume by multiplying the largest anteroposterior height (H), transverse width (W), cephalocaudal length (L) and diameters expressed as volume,V=0.524(H X W X L X π/6) [11]. Fig. 11 shows a few calculation marks for H, W and L in the prostate image.

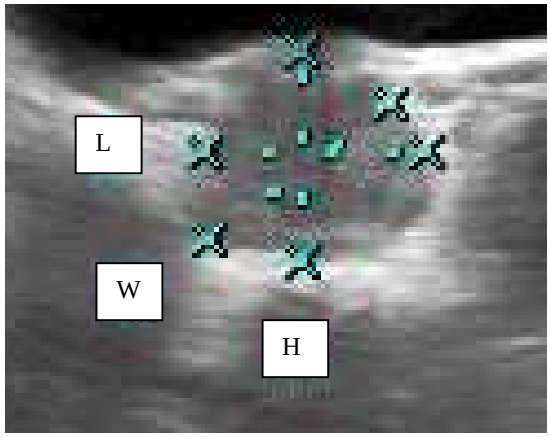

Fig. 12. Prostate volume measurement's parameters.

D. Prostate Volume Measurement Result

The final prostate volume measurement result for each subject is presented by Table 1. From the table, it is shown that the calculated volume for all ethnic of Malaysian population ranges from 8014.2 mm^3 to 11686.7 mm^3 with mean prostate volume of 9873.83 mm^3. This normal volume is acceptable since it is very close to the average prostate volume of adult after puberty as reported in section 1C. Other than that, table 2 also shows mean value of prostate's anteroposterior height, transverse width and cephalocaudal length which are 30.64 ± 1.15mm, 28.3 ± 1.34mm and 21.7 ± 1.77mm respectively. Later, the collected data were plotted into graphical representation to observe the relationship of the prostate volume with the body weight and height as shown by Fig. 13 and Fig. 14.

Table 2. Results of Prostate volume measurement of 10 subjects.

S	APH (H) {mm}	TW (W) {mm}	CCL (L) {m}	PV {mm^3}
1	30.2	28.8	21.0	9563.5
2	31.1	27.8	24.0	10864.6
3	29.9	25.6	21.1	8456.6
4	31.0	30.0	24.0	11686.7
5	29.9	28.7	19.9	8941.4
6	32.0	27.8	21.0	9781.7
7	31.8	29.4	23.4	11454.8
8	32.2	29.9	20.0	10082.2
9	29.4	27.7	23.2	9892.6
10	28.9	27.3	19.4	8014.2
Mean± stdev	30.64 ± 1.15	28.3 ± 1.34	21.7 ± 1.77	9873.83 ± 1213.46

(S-subject, APH- Anteroposterior height, TW- Transverse width, CCL-Cephalocaudal length, PS-Prostate size)

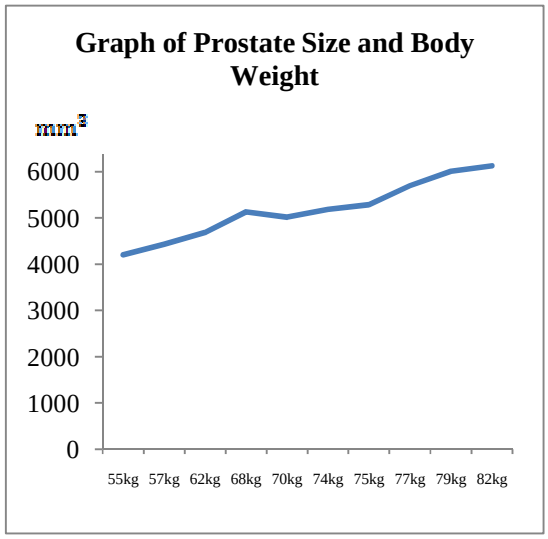

Fig. 13. Graph of prostate volume and body weight.

The graph in Fig. 13 shows a linear relationship between prostate volume and body weight of a male. This means that, as the body weight increases, prostate volume will also increase. Hence, a man with heavier body weight compared to a lighter one will have a larger prostate volume. Body weight of a person reflects the level of human growth and development under the influence of a person's genotype and environment. Genotype and environments reflects mostly on the person's ethnicity which will be discussed further in next section.

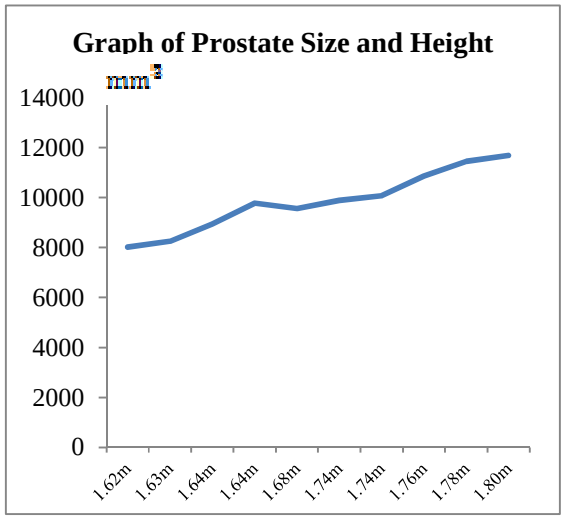

Fig. 14. Graph of prostate volume and height.

Other than that, Fig. 13 shows another relationship between prostate volume and the subjects' height. The figure shows that with the increase of height, the prostate size will also increases in a linear pattern. However, it is also observed from the graph that two subjects with the same height of 1.64 m, having different prostate volume. The reason of this difference is due to the different in body weight of these 2 subjects.

To find a more detail relationship between body weight and height to a person's prostate volume, body mass index for every subject was calculated as shown in Table 3 and a graph of BMI against prostate size were plotted as in Fig. 14.

Table 3. Correlation BMI and prostate size.

Subject	Body Mass Index (BMI)	Prostate Volume (mm^3)
1	24.80	9563.5
2	24.86	10864.6
3	21.45	8456.6
4	25.31	11686.7
5	23.05	8941.4
6	25.28	9781.7
7	24.93	11454.8
8	24.77	10082.2
9	24.44	9892.6
10	20.96	8014.2

The graph in Fig. 15 shows that prostate volume increases for greater BMI value. Therefore, a hypothetical formula was calculated from the graph representing a correlation between BMI and prostate volume.

$$Prostate\ Volume = 832.77\ BMI - 9440.58$$

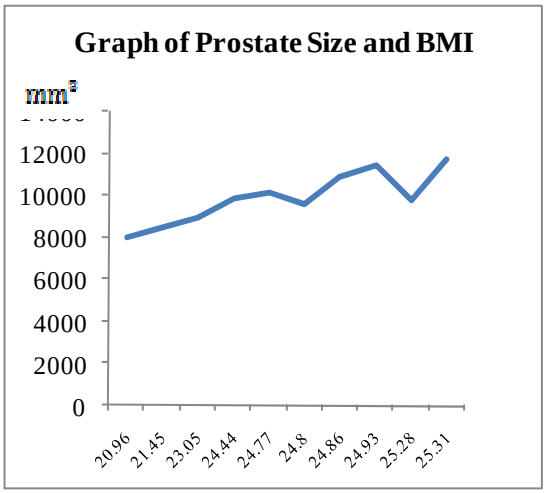

Fig. 15. Graph of prostate volume and BMI.

E. *Prostate Volume and Ethnicity*

Further investigation to find the relationship between prostate volume and ethnicity was conducted by categorizing each subject to their ethnicity background to observe the differences of prostate volume between Malaysian ethnic. In this study, the Malay ethnic was represented by 4 subjects whereas the other 2 ethnic namely Chinese and Indian were represented by 3 subjects each.

Fig.16, 17 and 18 show the relationship between prostate volume to body weight, height and BMI for Malay, Chinese and Indian ethnic respectively. In general, the 3 graphs show

that prostate volume increase with body weight, height and BMI as explained earlier in the previous section.

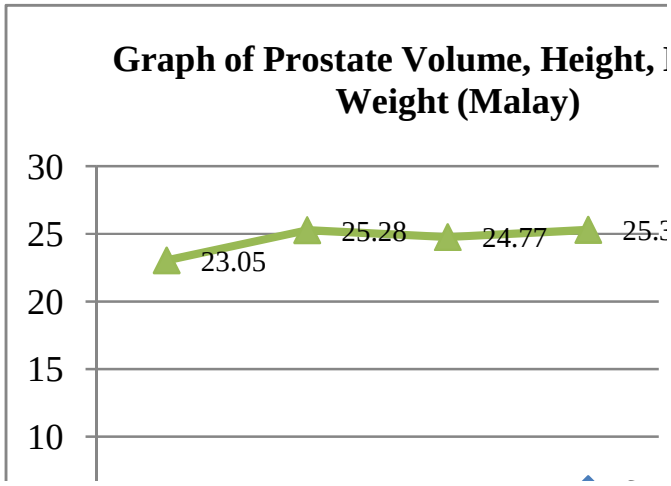

Fig. 16. Prostate volume of Malay ethnic.

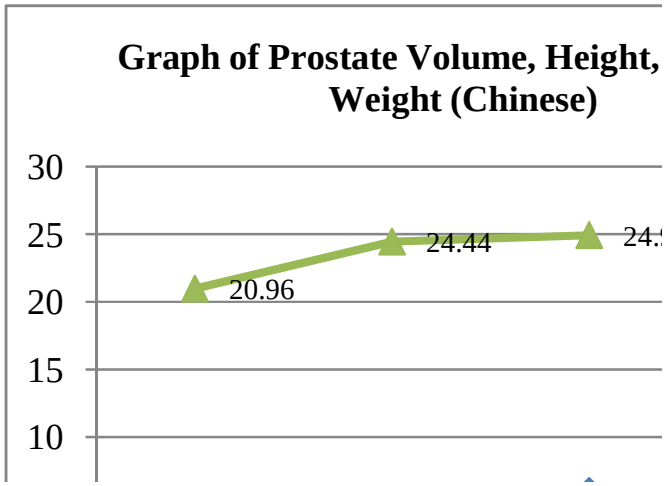

Fig. 17. Prostate volume of Chinese ethnic.

However, those graphs do not give detail information on relationship between prostate volume and ethnicity. Hence, a more detail relationship was found by calculating the ratio between body weight, height and BMI in every ethnic group as shown in Table 4.

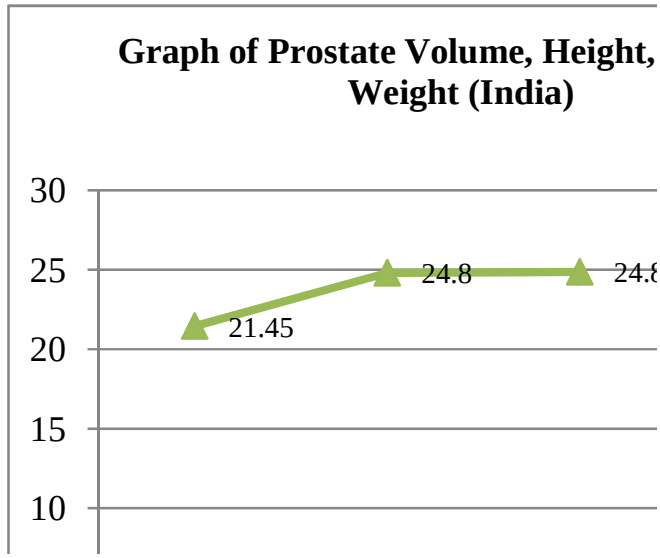

Fig. 18. Prostate volume of Indian ethnic

Table 4: Ration of weight, height and BMI to Prostate Volume

Malay ethnic (PV: 5.304cm^3)			
Mean Value	W=71.75	H=1.75	BMI=24.6
Mean Value/PV	W/PV=13.528	H/PV=0.329	BMI=4.638
Chinese Ethnic (PV: 5.13cm^3)			
Mean Value	W=69.33	H=1.71	BMI=24.44
Mean Value/PV	W/PV=13.515	H/PV=0.333	BMI=4.764
Indian ethnic (PV: 5.045cm^3)			
Mean Value	W=68.00	H=1.69	BMI=23.703
Mean Value/PV	W/PV=13.479	H/PV=0.335	BMI=4.698

From Table 4, ratio between body weights to prostate volume is highest for Chinese ethnic, followed by Malay ethnic and finally Indian ethnic. This means that, compared to Malay and Indian, a Chinese man has a higher prostate volume for every kilos of their bodyweight. In terms of body height, ratio between height to prostate volume is highest for Indian ethnic, followed by Chinese and finally malay ethnic. This means that, compared to Malay and Chinese, an Indian man has higher prostate volume for every centimeters of their height. Finally, ratio between BMI to prostate volume shows that the value is highest for Chinese ethnic, followed by Indian ethnic and malay ethnic. Again, this means that a Chinese man has a higher prostate volume per unit of body mass index.

From the comparison, it can be concluded that, Chinese ethnic has the highest prostate volume followed by Indian ethnic and finally malay ethnic.

IV. CONCLUSION

Our study shows that transabdominal measurement is the most convenience, rapid and simple way of prostate measurements. Hence, this method can be used as a standard screening method for imaging prostate. Therefore, transrectal scanning can be used only when necessary or when ambiguity is present during transabdominal scanning.

This study also found that prostate volume increases linearly with body weight and height of a person, and almost lineary with BMI.

Relationship between prostate volume to ethnicity shows that Chinese ethnic has a higher prostate volume followed by Indian ethnic and finally malay ethnic.

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