SONOGRAPHIC EVALUATION OF PROSTATE AND POST-VOID RESIDUAL URINE VOLUMES IN PATIENTS WITH PROSTATIC ENLARGEMENT IN PORT HARCOURT

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NOVEMBER 2005.
ATTESTATION

This is to attest that the Dissertation titled,

“Sonographic Evaluation of Prostate and Post–Void Residual Urine Volumes in Patients with Prostatic Enlargement in Port Harcourt.”

Submitted to the National Post Graduate Medical College of Nigeria in part fulfillment for the Award of the Diploma of (FMCR) is a record of original research carried out by Dr. Orelu Godwin Onyisi in the University of Port Harcourt Teaching Hospital Port Harcourt.

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DEDICATION

This dissertation is dedicated to God, for his uncountable blessings upon my life.
ACKNOWLEDGEMENT

All praise is given to Almighty God who by his GRACE made it possible for me to go through the rigors of residency training and to my parents and my brothers for their sacrifice towards my education.

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My special thanks also go to my wife, Mrs. A. Orelu for standing by me during this difficult period

DR ORELU GODWIN

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INTRODUCTION

Most men, irrespective of their race or colour can be expected to have enlargement of the prostate gland at sometime during their lifetime.\textsuperscript{1-3} The enlargement of the prostate gland either as a result of benign prostatic hypertrophy (BPH) or carcinoma is the commonest source of urinary complaints in men.\textsuperscript{4-6} It is probably the most common abnormality seen in a typical urology clinic.\textsuperscript{5-6}

The development of lower urinary tract symptoms (LUTS) as manifestation of prostatic enlargement is insidious. Literature documents that the prevalence of moderate to severe LUTS increases with age and negatively impacts mental and physical aspects of health.\textsuperscript{2-7} The economic and health service implications are significant especially with the increasingly aged population in both developed and developing countries.\textsuperscript{5-8}

An important step in evaluating patients with obstructive symptoms is to assess the prostatic size and evaluate the post void residual urine in the bladder.\textsuperscript{2-4,6,8} Evaluating prostatic enlargement by means of Digital Rectal Examination (DRE), urethrocystoscopy and intravenous urography may lead to errors of judgment that diminish their reliability.\textsuperscript{2,4,9} Other considerations like the potential problems of exposure to ionizing radiation, invasiveness, cost and adverse reaction associated with these modalities should discourage their routine use.\textsuperscript{1-3} Ultrasonography, which is a non-ionizing, less-invasive, cost effective alternative, will demonstrate clearly the relationship of the urinary bladder volume to the prostate gland size.\textsuperscript{10-12} Significant “post-void residual urine volume” (PVR) is a frequent manifestation of prostatic enlargement and this can be evaluated accurately by ultrasound.\textsuperscript{13,11}

Previous work done by Ibinaiye\textsuperscript{2} on prostatic volume measurement have showed that prostatic volume obtained by transabdominal
ultrasonography correlates well with that obtained by transrectal approach but the latter method is invasive and not readily available.\textsuperscript{2,10} Similarly Amole et al\textsuperscript{13} has reported that results of transabdominal ultrasound measurement of post-void residual urine volume compare favourably with measurements obtained by catheterization. The catheter method is also invasive and inconvenient to some patients.\textsuperscript{13-19}

In our environment an accurate, affordable, simple and less invasive imaging modality that complements clinical evaluation of the prostate and either facilitates a prompt diagnosis or redirects diagnostic measures to the real source of the patient’s problem is desirable. Transabdominal ultrasonography is a non invasive, available, affordable and easily reproducible method of evaluating both post-void residual urine volume (PVR) and the prostate volume.

This study is therefore designed to determine the values of prostatic volume and PVR in individuals with prostatic enlargement by transabdominal ultrasonography and possibly determine if there is any relationship between the PVR and the size of the prostate.
LITERATURE REVIEW

The normal urinary bladder when fully distended appears in transverse section as a rounded rectangle and in longitudinal section as a triangular anechoic structure centrally located in the anterior part of the pelvic cavity.\textsuperscript{11,12,20} In males the urinary bladder is surrounded by the rectus muscles anteriorly, the obturator muscles laterally and the prostate gland at the base.\textsuperscript{20,21} A normal human bladder has a capacity of 400-500ml.\textsuperscript{11,12,20}

The prostate gland is a flattened, conical structure located in the floor of the urinary bladder, anterior to the rectum and extends from the bladder neck to the urogenital diaphragm along with the transecting posterior urethra.\textsuperscript{5,6,12,20} The prostate has a base superiorly, an apex inferiorly and an anterior and two lateral walls.\textsuperscript{5,6,11} In a sagittal section, there is more prostatic tissue posterior and lateral to the urethra than anterior.\textsuperscript{5,6,20} (Fig.1) The anterior surface is blunt and rounded. The posterior surface is flattened and rests against the lower aspect of the rectum.\textsuperscript{5}

The prostate gland comprises secretory epithelium made up of epithelial, basal and neuroendocrine cells; connective tissue and smooth muscle. The arterial blood supply to the prostate gland arises from the middle rectal and inferior vesical arteries. These vessels enter the gland at the posterolateral angle on each side. The venous drainage is into the prostatic plexus which lies at the junction of the base of the prostate and the bladder neck and drains finally into the internal iliac veins.\textsuperscript{5,6,20}

Sonographically, the prostate gland consists of a heterogeneous slightly echogenic central zone and a more homogenous slightly hypoechoic peripheral zone.\textsuperscript{11-12, 20-21} The prostate comprises of three glandular zones: transition, central and peripheral, and one non-glandular region (the anterior fibro-muscular stroma) [Fig.2]. In the young adult prostate, the transition
zone constitutes about five percent of the prostatic glandular tissue and is located on both sides of the prostatic urethra. It is in this region that BPH develops. The central zone which is situated at the base of the prostate and relatively resistant to disease processes constitutes about twenty five percent of the glandular tissue. The peripheral zone constitutes seventy percent of the glandular tissue and lies in the posterior and lateral aspect of the gland. Carcinoma and prostatitis are diseases of the peripheral zone.\textsuperscript{3,5,6,20} This implies that BPH and carcinoma can co-exist in the same prostate.\textsuperscript{3,6}

Normal prostate gland measures 3.0-4.0cm in the cephalo-caudal (Longitudinal) diameter; 2.5-3.0cm anterior-posterior diameter and 4.0-5.0cm in the transverse diameter.\textsuperscript{3,9,11,20-21} These dimensions may increase with age.\textsuperscript{3,5,6} The prostate volume ranges from 12-20cm\textsuperscript{3} and approximate weight from 18–26gm \textsuperscript{5,11,12,20} Tahir and Ahidjo\textsuperscript{9} in a local study of normal adult men in Nigeria reported prostate volume and weight ranges from 7.1 – 29cm\textsuperscript{3} and 7.4– 31.4gm respectively. A statistically significant variation of the prostate volume and weight was also observed with age by this study\textsuperscript{9}

The prostate gland thus shows a slow and continuous increase in size through out adult life in most men.\textsuperscript{3,5,21} The three most common causes of prostatic enlargement are BPH 80\%, carcinoma of the prostate 18\% and prostatitis 2\%.\textsuperscript{1,2,4-8} Prostatic enlargement is as common in Africans as in Europeans and Asians occurring from 5\textsuperscript{th} to 7\textsuperscript{th} decade of life with a peak incidence in the 7\textsuperscript{th} decade.\textsuperscript{1,2,4} Amaku et al\textsuperscript{4} and Amole et al\textsuperscript{13} in their study of a comparative Nigerian population reported a peak incidence of BPH in the 60-70 years age group. The prevalence of prostatic enlargement in men under 60 years is 51 percent and in men under 80 years and above is 80 percent\textsuperscript{5,6,8} In Nigeria, about 1,000 per 10,000 adult male hospital admission is attributable to prostatic enlargement.\textsuperscript{2}
FIGURE 1:
Diagram of Sagittal Anatomy of the prostate gland
FIGURE 2:
Diagram demonstrating the breadth (line AB) and the outline of the prostate in transverse (a) and Sagittal planes (b). P = peripheral zone. C = central zone. A = anterior fibromuscular stroma
According to McNeal as early as the fourth decade, nodules begin to develop in the transition zone and periurethral tissue of the prostate gland. The nodules in the transition zone are glandular from their origin and later in life these nodules enlarge to form the mass of the prostatic enlargement. As the disease progresses, the number of small nodules increases and are found in the transition zone. Formation of these nodules involves the budding of new small glandular nodules from pre-existing ducts with the creation of new glandular architecture. Terris et al observed that transrectal ultrasound measurement of transition zone dimensions correlate better with the severity of BPH, than total prostatic dimensions or calculated prostatic volumes. They documented that, of these, the transverse transition zone dimension demonstrated the best correlation by recording a positive correlation with PVR.

Tahir and Ahidjo reported that after the third decade the size of the prostate remains fairly constant until the age of 45-50 years, when the prostate either may undergo benign hypertrophy and the size then increases gradually until death, or the gland may undergo progressive atrophy. As the prostate enlarges, it becomes asymmetrical and bulges upwards into the base of the urinary bladder and alongside the midline proximal posterior urethra. The capsule of the prostate transmits the pressure of tissue expansion due to prostatic enlargement to the urethra thereby increasing the urethral resistance which produces the lower urinary tract symptoms (LUTS).

Obstruction to urine flow is due to; the static component of the bulk of the glandular and fibro muscular tissue, and the dynamic component due to the contraction and tension of the smooth muscles. Prolonged increased contractility leads to stretching of the smooth muscles and subsequent decreased ability of the muscles to contract. This results in: poor urinary
stream, intermittency and incomplete bladder emptying consequently resulting in increased residual urine.$^{5-7}$ Clinical evidence demonstrates that the progressive nature of these symptoms can lead to serious complications such as urinary retention, recurrent urinary tract infection, bladder diverticula, trabeculations and calculi formations.$^{4-7}$

WHO sponsored studies, estimating the prevalence of deaths from benign prostatic hyperplasia (BPH) in fifty countries, reveals a wide variation from 1.8 per 100,000 in the United States with well developed management strategies for BPH to 29.7 per 100,000 in the former East Germany.$^6$ Amaku et al.$^4$ were of the opinion that, the incidence of retention of urine and mortality in patients with prostatic obstruction in Nigeria is likely to be the same as will be documented in developed nations.

A first line approach in evaluation of patients with obstructive symptoms is to determine whether the prostate is enlarged or not. The assessment of the prostate by digital rectal examination (DRE) is an old and well tested technique that is still in current usage. DRE also evaluates the walls of the anal canal and the lower rectum. The volume of the prostate estimated by a digital rectal examination does not usually correlate with symptom severity, degree of obstruction or treatment outcomes.$^{2,5,7}$.

The estimation of the size of the prostate and post void residual urine volume by means of significant post micturation findings in routine cystourethrogram and intravenous urography can lead to errors of judgment.$^{1-3,8}$ Intravenous urography provides indirect evidence of prostatic enlargement but no information on its nature.$^{8,23}$ Unfortunately these modalities have the inherent potential problems of exposure to ionizing radiation, invasiveness, cost and adverse reaction.$^{1-3}$
Unlike the above methods of examination, ultrasound scanning can determine the prostatic volume and reveal the internal structure of the prostate gland including the capsule as well as evaluate the residual urine volume in the bladder.$^{3,7,10,20}$ The prostate can be imaged ultrasonographically through the transabdominal, transrectal, transurethral and transperineal routes.$^{1-3,8-10,24}$ The transrectal and transurethral routes are significantly cumbersome and a lot more invasive,$^{10}$ but the latter gives better visualization of the transition zone. Measurement of the transition zone correlates better with the symptoms and urodynamic variables of obstruction.$^{22}$ The transperineal approach is rarely used and has no advantage over the transabdominal imaging.$^{2,3}$ The transabdominal route has the advantages of: being available and less invasive and allowing a measurement of PVR. However it cannot visualize zonal anatomy and volume with comparable quality to that obtainable with transrectal ultrasound scan.$^2$ Sonometrics, a combination of transrectal sonography and biometrics is another accurate method of determining prostate volume and weight$^{2,9,25}$.

Other imaging modalities like Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) have been shown to be more accurate than ultrasonography in evaluating the prostate volume, but their routine use cannot be justified.$^{10,20}$

Since significant “post-void residual urine volume” is a frequent manifestation of benign prostatic hyperplasia, assessment of these volumes now form an important routine investigation.$^{6-9,13}$ However it is well recognized that a normal sized prostate can cause a similar degree of symptoms.$^{2,6,22,25}$
Transabdominal ultrasonography (TAUS) as a non invasive, affordable and easily reproducible method of evaluating “post-void residual urine volume” (PVR) has been recommended as an alternative to catheter estimation by many authors. Several workers are of the opinion that transabdominal ultrasound imaging if used correctly, provides more accurate results and can compete with the cost, convenience and ease of use of the other modalities for measurement of both PVR and prostate gland size.

Bladder catheterization is the method regarded as gold standard for evaluation of post void residual urine volume, and transrectal ultrasonography is the gold standard for prostate gland volume estimation. Both modalities are however invasive methods. Intermittent bladder catheterization carries the potential risk of urinary tract infection, urethral trauma and discomfort to the patients, while the transrectal approach is quite inconvenient to some patients. Some authors have reported that the bladder catheterization method is inaccurate to some extent because the bladder may not be completely drained in about twenty five percent of individuals. Results of most studies suggest that though transabdominal ultrasound measurement of post-void residual urine volume have some limitations with regards to accuracy, they still compare favourably with measurements obtained by catheterization.

Assessment of PVR and prostate volume can justifiably be used as the basis for diagnosis of bladder outlet obstruction in men with lower urinary tract symptoms suggestive of BPH. The clinical prostate score (CLIPS), introduced by the International Continence Society (ICS), is composed of scores for prostate volume, post void residual urine volume, voided volume and maximum urinary flow rate. Van Venrooij et al. reported that this score had a superior correlation with urodynamic bladder outlet obstruction.
than the isolated parameters that comprise it. Screening with these parameters is thus of great importance in the early detection and proper diagnosis of specific disease entity.\textsuperscript{1,6,29} Measurements of these parameters allow therapeutic decisions to be made regarding bladder function and bladder outlet obstruction\textsuperscript{12,15-18,29,30} Serial monitoring of the prostate volume and the PVR may serve as indicators for diagnostic and prognostic clinical progress as both could be used as reliable tools in monitoring therapeutic effects on BPH patients in terms of relief of obstruction.\textsuperscript{12-15,30-36}

In Nigeria, several authors have documented studies on ultrasonography of the prostate gland.\textsuperscript{1-6,8,9,13} The earliest, by Iko et al\textsuperscript{8} evaluated capsular, periprostatic and extra-organ features, utilizing them to discriminate between malignant and benign prostatic disease. They documented that spherical enlargement of the prostate gland with predominantly homogenous echogenicity was common to most of their reviewed cases.\textsuperscript{8} Kuti et al\textsuperscript{1} studied the prostate by correlating the histological and sonographic findings of prostates of patients in Ife-Ijesha areas of the South-West geo-political zone of Nigeria. They found spherical or ovoid pattern of glandular enlargement in patients with carcinoma of the prostate, benign prostatic hypertrophy and prostatitis among the 43-91 years age group. Majority of the prostates they evaluated were of mixed echogenicity. Unfortunately both studies did not document the value of the estimated weights or volumes of the enlarged prostate glands studied. Tahir and Ahidjo\textsuperscript{9} in a local study of normal adult men in Nigeria reported prostate volume and weight ranges from 7.1 – 29cm\textsuperscript{3} and 7.4 – 31.4gm respectively. A statistically significant variation of the prostate volume and weight was also observed with age by this study\textsuperscript{9}

Badoe et al.\textsuperscript{6} documented that the average volume and weight of the prostate with confirmed histological BPH were 31.36±15cm\textsuperscript{3} and 33±16gm
respectively. Their study showed that the development of BPH is initiated before thirty years of age and that the average-age-related increase in prostatic size is 6gm per decade. Ibinaïye ² also carried out a study in a comparative population, evaluating prostatic volumes using transrectal and transabdominal ultrasonography in 119 patients with BPH in Ibadan and reported a mean volume of 50.2cm³±37.3. They also recorded a volume range from 24.8cm³ to 382.7cm³. The peak incidence for benign prostatic hypertrophy in their study was in the seventh decade of life.

Similar studies in Caucasians showed comparative values. ⁷,¹⁰,³⁷ Henneberry et al¹⁰ studied 29 patients with enlarged prostate undergoing prostatectomy. Their estimated prostatic weight by ultrasound was in the range of 45-65gm and the post resection weight was usually less than 45gm. Hill et al⁷ documented prostate weight of 20-75gm in a 5-year multicenter prospective study carried out on 121 men with symptomatic BPH. Yuen et al³⁶ in a transabdominal ultrasonographic evaluation of 22 patients with BPH documented mean prostatic volumes of 47.9cm³. These volumes obtained by transabdominal sonography correlated well with transrectal prostate volume. ³⁶

The most recent study carried out by Amole et al¹³ proffered formula that can be utilized in assessing PVR obtained by transabdominal sonography, in patients with benign prostatic hyperplasia. In their comparative evaluation of fifty-two patients with symptoms and clinical signs of prostate gland enlargement, who had ultrasound measurement and catheter estimation of PVR, they reported a mean PVR of 220.51±190.46ml as against 220.76±194.4ml after catheter estimation. Their catheterized residual urine volume ranged between 26ml and 801ml and ultrasound estimates between 33.2ml and 772ml.¹³ They found a good correlation between the catheter estimated urine volume and the ultrasound measured volume.¹³ On the
contrary, Ibinaie\textsuperscript{2} reported a much lower PVR of $50.48\text{cm}^3 \pm 71.3\text{cm}^3$ and documented a poor correlation between PVR and prostate volume.

Badoe et al\textsuperscript{6} observed that though there is considerable intra-individual variability of PVR, that values larger than 200ml may still be regarded as indicative of a need for surgery. Such individuals with larger volumes of PVR are more likely to develop urinary retention. These submissions by Bodoe et al\textsuperscript{6} imply that significant PVR can result in symptoms of urinary frequency, overflow incontinence and recurrent urinary tract infection. Dunsmuir et al\textsuperscript{37} in a study of forty men with symptomatic BPH recorded an approximately constant PVR variation in the range of 120ml in one third of the men and a wide intra-individual variation in the range of 150-670ml in two-third of the men. They inferred from these results that PVR may be a useful indicator of bladder dysfunction or outlet obstruction.

Dicuio et al\textsuperscript{31} carried out similar studies in a Caucasians population (mean age $67.5 \pm 8.0$ years) and reported transabdominal sonographic PVR values of $92 \pm 8\text{ml}$. The voided urine volume was $220 \pm 127\text{ml}$ and the pre void bladder volume was $309 \pm 158\text{ml}$. Their study also documented a strong correlation between the pre-voiding urine volume and the voided volume ($r=0.836; \ P<.0001$).\textsuperscript{31}

Girman et al\textsuperscript{38} in a study measured the PVR by transabdominal ultrasonography after voiding and prostate volume by transrectal approach in 477 randomly selected caucasians and found a weak but positive correlation of PVR with the prostate volume ($r_s= 0.24, \ p<0.0001$). They added that the odds of obtaining a PVR value that is greater than 50ml is about three times greater for men with enlarged prostate volume larger than $30\text{cm}^3$ than in those with smaller prostates. The post void residual urine volume (PVR) did not appear to be associated with age or peak urinary flow rate.\textsuperscript{38} They documented
in addition that, men with prostate volumes of 30cm$^3$ and above have three times increased incidence of acute urinary retention.$^{38}$ They also documented a significant relationship between post void residual urine volume and prostate volume.$^{38}$

In a double–blind placebo–controlled study, in the treatment of outflow tract obstruction due to BPH, with pollen extract, Buck et al$^{30}$ reported that PVR decreased significantly in patients receiving pollen extract compared with the placebo group. They also found that the chance of clinical success with this modality of treatment for BPH appeared to be determined by the degree of obstruction as indicated by the post void residual urine volume.$^{30}$ The result by Buck et al$^{30}$ appeared to imply that PVR can be used to monitor conservative treatment outcomes in patients with BPH. However, for PVR values less than 50ml, the results were excellent while PVR between 50 and 100ml, the results were recorded as “usually quite good”.$^{30}$ They further noted that when the PVR is more than 150ml, pollen or palmetto extract and other botanical medicines were not likely to produce any significant improvement and that the extract produced a significant decrease in the size of the ventral and dorsal lobes of the prostate gland.$^{30}$

The measurement of the maximum urinary flow rate, has become the most frequently used urodynamic examination$^{24,32,30}$ and maximum urinary flow rate depends on voided urine volume. Buck et al$^{30}$ and van Venrooij et al.$^{29}$ recommended that maximum urinary flow rate should be urinary flow rate recording when the voided urine volume is at least 150ml at one or more uroflowmetry studies. McNeill$^{32}$ reported that high PVR was associated with low “maximum urinary flow rate” in BPH patients with lower urinary tract symptoms (LUTS). The percentage of men with a PVR greater than 100mL was higher in those with low “maximum urinary flow rate” of below 8ml per
second than in those with higher maximum urinary flow rates. According to some other authors, after adjusting for age, men with prostatic volumes of 50cm$^3$ are three and half times more likely to have maximum flow rates of <10mls per second than men with smaller glands.$^{7,38}$

Though measuring prostatic volume and PVR to some degree of accuracy is viewed to be rarely required for clinical purposes by some authors, because these volumes are not necessarily related to symptoms or urodynamic findings in men with prostatic enlargement.$^1$ Some authors have found a good correlation between prostate volume and impairment of flow, whereas others have found a poor correlation between symptoms and urodynamic findings.$^{2,6,31,32-36}$

Prostatic sonography has been amply reported from developed nations and Literature is replete with Caucasians values. The main advantages of transabdominal ultrasonography are its ease of use and non-invasiveness and also its ability to estimate accurately the prostate size and PVR. Serial measurements of prostate size and PVR have been documented as important in monitoring both operative and non operative management outcomes.

Only one preliminary report of transabdominal ultrasonography of the prostate gland from the South-South geo political zone of Nigerian has been done.$^8$

The foregoing has informed the decision to undertake this study on transabdominal ultrasonographic evaluation of postvoid residual urine volume (PVR) and prostate gland volume in patients with prostatic enlargement.
AIMS AND OBJECTIVES

(a) To establish the prostate gland volume and post void residual urine volume (PVR) in individuals with prostatic gland enlargement, by transabdominal ultrasonography, in a Nigerian population.

(b) To establish any variations in prostate volume with the age of the patient.

(c) To correlate the obtained values of the post void residual urine volume to the measured values of the prostate gland volume.
MATERIALS AND METHODS

A total of two hundred and eight adult male patients referred to the Department of Radiology between August 2004 to August 2005 on grounds of clinical diagnosis of prostate gland enlargement, had transabdominal ultrasonography. These patients were drawn from the Radiology Department of University of Port Harcourt Teaching Hospital, and Nigerian Port Authority Medical Centre all in Port Harcourt.

All the patients were Nigerians, resident in the south-south geo-political zone with age range of 48-92 years.

Patients with clinical evidence of carcinoma of the prostate or with pathologies other than prostate diseases, as well as patients with in-dwelling bladder catheters due to acute urinary retention or neurological diseases were excluded from the study. Also excluded were patients with sonographic evidence of dilatation of the upper urinary tract and vesical diverticula.

Each patient had two examinations. The first was with a full bladder and the second immediately after voiding. The transabdominal examinations were performed using a real time ultrasound machine model 93/94 EEC ESAOTE CE-0051 connected to a 3.5- megahertz sector transducer.

Patients were requested to achieve a full bladder by taking a water load. Scanning was performed when the patient had a strong desire to void. Each patient lying in the supine position, the scan was carried out in two planes; the longitudinal and the transverse planes. In the longitudinal scan, the maximum longitudinal diameter \( D_1 \) in cm of the prostate gland was measured. With a ninety degree turn of the probe which was then angled up and down while maintaining same contact point in a transverse scan, the maximum transverse diameter \( D_2 \) in cm and the maximum anterior-posterior diameter \( D_3 \) in cm of the prostate gland were recorded. With the above parameters: maximum
longitudinal diameter of the prostate ($D_1$), maximum transverse diameter of the prostate ($D_2$) and maximum anterior-posterior diameter of the prostate ($D_3$), the ultrasound machine automatically computes the prostate volume and weight. In same manner, the maximum longitudinal diameter ($D_1$) in cm of the pre void urine in the bladder was measured in the longitudinal scan. With a ninety degree turn of the probe which was then angled up and down while maintaining same contact position in the transverse plane, the maximum transverse diameter ($D_2$) in cm and maximum anterior-posterior diameter ($D_3$) in cm of the pre void urine in the bladder were also recorded (Fig4). With the parameters $D_1$, $D_2$, and $D_3$ of the pre void urine in the bladder, the machine automatically computes the pre void urine volume. Thereafter the patient would be requested to pass urine immediately, then the maximum diameter ($D_1$) in cm of the post void residual urine in the bladder was measured in the longitudinal scan. With the probe still in same contact point, and with ninety degree turn of the probe to transverse plane, the maximum transverse diameter ($D_2$) in cm and the maximum anterior-posterior diameter ($D_3$) in cm of the post void residual urine in the bladder were also recorded. The PVR was also computed by the ultrasound machine with longitudinal ($D_1$), transverse ($D_2$) and anterior-posterior ($D_3$) diameters of the post void residual urine (Fig 2-7). The displayed values were all recorded.

Errors in the study were minimized by the following measures:

1. The ultrasound scans were carried out solely by the author.

2. A full bladder was ensured when patient had a strong desire to void before the measurement of the pre voiding urine volume and prostate volume.
3. The intra-observer reliability as well as inter-time accuracy was ensured as the post void residual urine volume (PVR) was measured immediately after voiding.

The data was collected and collated manually and entered into the computer spreadsheet. Microsoft Excel (Microsoft Corporation USA) and Statistical Package for Social Sciences (SPSS) for window (SPSS Inc USA) Version 11.0 and double checked to ensure accuracy of entry.

Data analysis was carried out using statistical package SPSS version. Correlation among the parameters was conducted with the spearman’s rho correlation coefficient. At 95% interval, two tailed p-values less than or equal to 0.05 were considered to be statistically significant. The analyzed data are presented in tables, bar chart and graphs.
Fig. 3: Pelvic Sonograph showing Measuring Calipers in Longitudinal and Transverse Image of the Prostate Gland

Fig. 4: Pelvic Sonograph showing Measuring Calipers in Longitudinal and Transverse Image of the Urinary Bladder
Fig. 5: Sketches of transabdominal longitudinal ultrasonographic appearance of the prostate showing sites of measurement

Longitudinal Scan

$D_1$ = (Longitudinal Diameter)
Fig. 6: SKETCHES OF TRANSABDOMINAL TRANSVERSE ULTRASONOGRAPHIC APPEARANCE OF THE PROSTATE SHOWING SITES OF MEASUREMENTS

Transverse Scan.

\( D_2 = \text{Maximum Transverse Diameter} \)

\( D_3 = \text{Maximum Anterior-Posterior Diameter} \)
Fig. 7:  LONGITUDINAL AND TRANSVERSE ULTRASONOGRAPHIC IMAGE OF PROSTATE SHOWING SITES OF MEASUREMENTS

Pelvic Sonograph showing Measuring Calipers in Longitudinal and Transverse Image of the Prostate Gland
ANALYSIS AND RESULTS

The age of the patients in the study group ranged from 48-92 years with a mean age of 69.8 years. The distribution of the patients according to their ages is shown in table 1 and figure 8. The age range of 70-79 years had the highest frequency distribution. The frequency at first showed a steady increase with age before it began to decrease. The peak incidence for prostatic enlargement was in the seventh decade of life.

Table II shows the mean values and standard deviations of the prostate volume and weight in each age group. The total mean prostate volume is 68.3 cm$^3$ with a standard deviation of 30.2 cm$^3$ while the total mean prostate weight is 71.9 gm with a standard deviation of 31.7 gm. The mean prostate volume and weight for all age group ranged from 47 cm$^3$ to 76.5 cm$^3$ and 50.9 gm to 80.3 gm respectively. The highest value of group mean prostate volume (76.6 cm$^3$) and weight (80.3 gm) were recorded at the age group of 80-89 years. Both values increase from 40-49 years age group to a peak at the 80-89 years age group, there after the volume and weight reduced. An evaluation of the relationship of mean prostate volume and weight with age group was statistically significant with a P value of 0.005 and 0.006 respectively.

The mean values and standard deviations of the pre-void urine volume and weight in each age group are shown in Table 111. The mean pre-void urine volume for all the age groups ranged from 249.9 cm$^3$ to 452.0 cm$^3$ with a total mean of 369.8 cm$^3$ and standard deviation of 107.6 cm$^3$ while the mean pre-void urine weight for all the age groups ranged from 263 gm to 470 gm with a total mean of 388.9 gm and a standard deviation of 112.7 gm.
### TABLE 1: AGE DISTRIBUTION OF PATIENTS STUDIED

<table>
<thead>
<tr>
<th>AGE GROUP (YEARS)</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
<th>VALID PERCENT</th>
<th>CUMULATIVE PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-49 (n= 8)</td>
<td>8</td>
<td>2.9</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>50-59 (n= 52)</td>
<td>32</td>
<td>11.4</td>
<td>11.4</td>
<td>14.3</td>
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FIGURE 8: BAR CHART SHOWING THE AGE DISTRIBUTION OF PATIENTS

AGE IN YEARS

AGEGRP

AGEGRP

90-100
80-89
70-79
60-69
50-59
40-49

Frequency

120
100
80
60
40
20
0
**TABLE II: THE MEAN PROSTATE VOLUME AND WEIGHT AMONG THE VARIOUS AGE GROUPS STUDIED**

<table>
<thead>
<tr>
<th>AGE GROUP (YEARS)</th>
<th>MEAN VOLUME (cm$^3$)</th>
<th>STANDARD DEVIATION</th>
<th>MEAN WEIGHT (gm)</th>
<th>STANDARD DEVIATION</th>
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<tr>
<td>40-49 (n=8)</td>
<td>47</td>
<td>5.3</td>
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<td>68.4</td>
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<td>70-79 (n=112)</td>
<td>71.2</td>
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<td>80-89 (n=28)</td>
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<td>90-99 (n=7)</td>
<td>73.6</td>
<td>19.9</td>
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MEAN (SD) 68.3cm$^3$ 30.2 71.9gm 31.7
TABLE III: THE MEAN PRE VOID URINE VOLUME AND WEIGHT AMONG THE VARIOUS AGE GROUPS STUDIED

<table>
<thead>
<tr>
<th>AGE GROUP (YEARS)</th>
<th>MEAN VOLUME (cm³)</th>
<th>STANDARD DEVIATION</th>
<th>MEAN WEIGHT (gm)</th>
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<td>40-49 (n=8)</td>
<td>452.0</td>
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<td>50-59 (n=52)</td>
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<td>70-79 (n=112)</td>
<td>363.2</td>
<td>120.4</td>
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<td>80-89 (n=28)</td>
<td>372.1</td>
<td>94.4</td>
<td>392.0</td>
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<td>90-99 (n=7)</td>
<td>249.9</td>
<td>110.5</td>
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<tr>
<td>MEAN (SD)</td>
<td>369.8cm³</td>
<td>107.6</td>
<td>388.9gm</td>
<td>112.7</td>
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### TABLE IV: THE MEAN POST VOID URINE VOLUME AND WEIGHT AMONG VARIOUS AGE GROUPS STUDIED.

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<tr>
<th>AGE GROUP (YEARS)</th>
<th>MEAN VOLUME (cm$^3$)</th>
<th>STANDARD DEVIATION</th>
<th>MEAN WEIGHT (gm)</th>
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<td>40-49 (n=8)</td>
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<td>60-69 (n=93)</td>
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<td>69.0</td>
<td>163.4</td>
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<td>90-99 (n=7)</td>
<td>122.9</td>
<td>36.8</td>
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<td>38.6</td>
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<tr>
<td>MEAN (SD)</td>
<td>131.8cm$^3$</td>
<td>55.1</td>
<td>138.6gm</td>
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The highest group mean pre-void urine volume (452 cm$^3$) and weight (470 gm) were recorded at the age group of 40-49yrs. An evaluation of the relationship of mean pre void urine volume and weight with age was statistically insignificant with a P value of 0.881 and 0.788 respectively.

The Table IV shows the mean values and standard deviations of the PVR urine volume and weight in each age group. The total mean PVR urine volume is 131.8 cm$^3$ and standard deviation is 55.1 cm$^3$ while the weight is 138.6 gm and standard deviation is 58 gm. The PVR urine volume and weight for all the age group ranged from 103.5 cm$^3$ to 155.3 cm$^3$ and from 108.3 gm to 163.4 gm respectively. The highest group mean PVR urine volume (155.4 cm$^3$) and weight (163.4 gm) were recorded at the age group of 80-89 years. The PVR increases from 40-49years age group to a peak at 80-89 years age group, thereafter the volume reduces to a lower value at 90-99 years age group.

An evaluation of the relationship of mean PVR and weight with age was statistically insignificant with a P value of 0.072 and 0.069 respectively.

The variables maximum longitudinal diameters ($D_1$), maximum transverse diameters ($D_2$) and maximum anterior-posterior diameters ($D_3$) of the prostate and post void residual urine volumes were considered in estimating the actual prostate and PVR urine volumes. The relationship between the volumes and these variables were examined. The scatter plots of volume against each of the variables revealed curvilinear relationship. (Fig. 9&10) Since the relationship is described by a curve, the Spearman correlation coefficient was used as the appropriate test to determine the degree of correlation between the prostate and post void residual urine volumes and these variables respectively. Maximum longitudinal diameter ($D_1$) of both the prostate and post void residual urine volumes were found to have the best correlation.
The mean value for the voided urine volume is 237cm³ with standard deviation of 103cm³. There is negative and poor correlation between the voided volume and prostate volume (rs=-0.309) and also negative and poor between the voided volume and PVR, (rs= -0.194).

The prostate volume and weight measured by the transabdominal method ranged from 25.00cm³ to 248cm³ with a mean 68.3cm³± 30.2 cm³ and from 26.00gm to 261gm with a mean of 71.9gm ± 33.2 gm. respectively (Table V). A strong statistical correlation between the two with a correlation coefficient [r_s= 1.00] was found. (Table VI and Fig.11)

The post void residual urine volume obtained ranged from 18.2cm³ to 341cm³ with a mean value of 131.8cm³± 55.2cm³ while the post void residual urine weight ranged from 19gm to 359gm with a mean value of 138.6gm ± 58gm (Table V).

Fig. 12 is a scatter diagram of the relationship between the post void residual urine volume (PVR) and prostate volume. The study showed a weak correlation between the PVR and prostate volume [r_s=0.284](Table VI)

Fig.13 is a scatter diagram of the relationship of the patient’s age and prostate volume. The study showed statistically significance between the patients’ age and the prostate volume [r_s=0.159, p<0.008](Table VI)

Fig. 14 is a scatter diagram of the relationship of the patient’s age and post void residual urine volume. The study showed no statistically significance between the patients’ age and PVR. [r_s=0.110, p>0.05] (Table VI)
TABLE V: THE MEANS, RANGE AND STANDARD DEVIATION OF ALL PARAMETERS.

DESCRIPTIVE STATISTICS

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TABLE VI: THE STATISTICAL SIGNIFICANCE OF THE DIFFERENT VALUES OBTAINED FOR ALL THE PARAMETERS MEASURED USING THE SPEARMAN’S RANK CORRELATION COEFFICIENT.

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** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).
FIG. 9: SCATTER PLOTS OF PROSTATE VOLUME AGAINST THE MAX. LONG. DIAMETER (D₁)
FIG. 10: SCATTER PLOTS OF POST VOID RESIDUAL URINE VOLUME AGAINST THE MAX. LONG. DIAMETER ($D_1$).
FIG. 11 SCATTER DIAGRAM SHOWING THE RELATIONSHIP BETWEEN PROSTATIC VOLUME AND POST-VOID RESIDUAL URINE VOLUME MEASURED BY TRANSABDOMINAL METHOD
FIG. 12: SCATTER DIAGRAM SHOWING A COMPARISON OF PROSTATIC VOLUME AND POST-VOID RESIDUAL URINE VOLUME MEASURED BY TRANSABDOMINAL METHOD
FIG. 13: SCATTER DIAGRAM SHOWING THE RELATIONSHIP BETWEEN THE PATIENT AGE AND PROSTATIC VOLUME.
FIG. 14: SCATTER DIAGRAM SHOWING THE RELATIONSHIP BETWEEN PATIENT’S AGE AND POST–VOID RESIDUAL URINE VOLUME.
DISCUSSION

The age of patients in this study ranged from 48-92 years and the mean age was 69.8 years. The frequency of occurrence of prostatic enlargement increased significantly between 60-69 years and peaked at the 70-79 years age group or 7th decade. This finding agrees with that of Ibinaieye\(^2\) Amaku et al.\(^4\) and Amole et al.;\(^13\) who all worked in a Nigerian population. They all reported that the peak incidence of benign prostatic hypertrophy was in the seventh decade of life. Similar findings in Caucasians were also documented by Venrooij et al.,\(^29\) Buck et al.\(^30\) and Dicuio et al.\(^31\)

The present study showed a general pattern of increase in frequency with age as reported by Ibinaieye\(^2\) and Amaku et al.\(^4\) The three studies (present study inclusive) having taken place in a similar population collaborates a definite increasing prevalence of prostatic enlargement with age in our local population. In 1997, Harold Ellis\(^39\) had expressed the opinion that, “after the age of 45 years, some degree of prostatic hypertrophy is invariable and is as much a sign of ageing as graying of the hair”

Present study also showed the prostate gland increasing in volume and weight from the 40-49 years age group up to the eighth decade. This is in agreement with the findings of Tahir and Ahidjo\(^3,9\) These authors also attributed the prostate size increase after the age of 45-50 years to benign hypertrophy. They observed that the prostate increases slightly in size until puberty and this increase continue gradually until death or the gland may undergo atrophy. Though the prostate volume and weight values obtained by Tahir and Ahidjo\(^3,9\) were in normal adult men, their values still showed a progressive increase with age.

In this present study, there was an average-age related increase in the prostate size of 5gm per decade observed in the 60-69 years age group up to
the 90-99 years age group. This observation marginally corroborates the findings of 6gm per decade documented by Badoe et al. However, it must be noted that reports from a recent study demonstrated a different trend. Other authors have also reported that the prostate possesses a unique ability to grow with age causing direct and indirect consequences to the quantity and quality of a man’s life.

The range of the mean prostate volume and weight of the patients studied are 47cm³ to 76.5cm³ and 50.9gm to 80.3gm respectively. These values are similar to the values obtained by Henneberry and Yuen et al in Caucasians with a slightly narrower range. Both studies reported prostate volume and weight range of 41.4cm³ to 50.6cm³ and 45gm to 65gm respectively. No considerable variation was found between these values and value obtained in this present study. A mean prostate volume of 50.2cm³±37.3 was documented by Ibinaiye which did not differ significantly with the values of this present study which gave a figure of 68.3cm³±30.2

A mean value of 131.8cm³ for post void residual urine volume (PVR) was obtained from this study. The mean PVR for the age groups ranged from 103.5cm³ to 155.4cm³ and is lower than the values documented in similar studies by Amole et al. and Dunsmuir et al. However, PVR values of present study was noted to be similar to values obtained by many authors. Some of these authors have proffered that though considerable intra-individual variability exist in PVR values, the variation is less marked in mean PVR value less than 100ml. The reason for this variation was not stated by the authors. Amole et al had reported a mean PVR of 220.51±190.46ml and concluded that significant post void residual urine volume is a manifestation of benign prostatic hyperplasia.
An evaluation of the relationship between mean post void residual urine volume and prostate volumes of the present study showed a relative increase in the PVR with increasing prostatic volume, an observation that is supported by other studies. Factors which have been implicated as the cause of this; include the insufficient amount of urine voided by BPH patients and incomplete bladder emptying.\textsuperscript{6,29-31}

The present study also showed a positive but weak correlation between the PVR and the prostate volume. This finding agrees with that of Ibinaiye\textsuperscript{2} who reported a poor correlation between the post void residual urine volume (PVR) and prostate volume. Buck et al\textsuperscript{30} and Girman et al.\textsuperscript{38} also corroborated this finding. The latter reported a weak but significant correlation between the post void residual urine volume and prostate volume.\textsuperscript{38} They also observed that the odds that the PVR would be greater than 50ml. were three times greater for men with prostate volume greater than 30cm\textsuperscript{3} than for men with smaller prostates. More importantly they noted that men with prostate volume of 30cm\textsuperscript{3} have three times more chances of developing urinary retention.\textsuperscript{38}

Buck et al\textsuperscript{30} showed a statistically significant decrease in residual urine volume in patients treated with Cernilton and also a decrease in the antero-posterior (A-P) diameter of the prostate. They concluded that Cernilton produces a significant decrease in the size of the ventral and dorsal lobes of the prostate gland. The chance of clinical success with the above treatment of BPH appears to be determined by the degree of obstruction as indicated by PVR. Their studies showed that patients with PVR levels less than 100mL experienced significant improvement, but at PVR levels greater than 100mL the botanical medications produced no significant improvement.\textsuperscript{30} The observation of PVR values denoting the degree of obstruction corroborates the
finding of this study which revealed a positive correlation existing between PVR and prostate volume.

The mean values for the pre void urine volume obtained in this study showed significant variation with age. Though variation of pre void volumes with age was also noted by several authors, the exact values (Pre void urine vol.309±158mL) obtained by some of them were lower than those obtained in our study (Pre void urine vol.369.8cm³±107.6). The present study showed that a significant decrease in pre void urine volume occurred with relative increase in the prostate gland. (See Table 111) This observation disagrees with documentation from reviewed literature as some have documented that a normal or small prostate size can cause similar degree of symptoms and abnormalities of measurement of bladder pressure and urine flow, as observed in large prostates. The reason as provided by these authors is the effect of the prostate size and bladder wall status on the bladder capacity. Ibinaiye reported a poor correlation between the urinary bladder wall status, the degree of back pressure changes in the kidney with prostate volume. Our study showed a negative but strong correlation between the pre voiding measured volume and the voided volume.

The mean voided volume in this present study is 237.02cm³ (Table V) This finding agrees with the value (220±127mL) obtained by Dicuio et al. The voided volume is a measure of the effective capacity. The effective capacity is defined as the ‘bladder volume at strong desire to void’ minus the ‘residual urine volume’. Thus effective capacity represents the voided volume at strong desire to void. Hill et al has correlated peak urinary flow rate of 12ml per second or less with a minimum voided volume of at least 150mL. Peak flow rate, prostate volume, post void residual urine volume and voided
volume were used by Hill et al.\textsuperscript{17} and others\textsuperscript{29,32} as inclusion criteria for diagnosis of bladder outlet obstruction (BOON).

CONCLUSION

In this study, the peak incidence of benign prostatic hypertrophy has been documented to be at the 7\textsuperscript{th} decade. We also showed a general pattern of definite increasing prevalence of prostatic enlargement with age in our local population. An average-age related increase in the prostate size of 5gm per decade was documented by the study in the 60-69years to 90-99years age group compared to 6gm per decade documented by Badoe et al.\textsuperscript{6} The highest value of group mean prostate volume and weight occurred at the age group of 80-89years. Mean prostate volumes and weights of 47cm\textsuperscript{3}-76.5cm\textsuperscript{3} and 50.9gm-80.3gm did not differ significantly from values obtained in Caucasians and other studies carried in Nigeria. Mean post void residual urine volume (PVR) of 131.8cm\textsuperscript{3} was obtained by present study. The range of PVR values agreed with figures obtained in many studies\textsuperscript{6,29,31} and were lower than figures obtained in others\textsuperscript{13,37}, without showing any population differences.

We have been able to show a positive but weak correlation between the PVR and prostate volume as other authors documented. This relationship appears to have implications for predicting those patients that will develop urinary retention\textsuperscript{38}, lower urinary tract infection as a result of low maximum urinary flow rate\textsuperscript{32} and in identifying patients that would need surgery.\textsuperscript{6} With all these anticipated clinical management benefits of PVR values, the authors recommend that PVR be obtained routinely in any patient being evaluated for prostate enlargement. Significant PVR denotes or can be used as a marker to evaluate or predict degree of obstruction caused by enlarged prostate.
The study also showed that a significant decrease in pre void urine volume occurred with relative increase in the prostate gland and also a negative but strong correlation between pre voiding and voided urine volumes which means that as the prostate gland increases in size, the pre void urine volume decreases and the voided urine volume reduces as the peak flow rate reduces and PVR increases.

With an increase in demand for pharmacological rather than surgical management of patients with Lower Urinary Tract Symptoms [LUTS] due to prostatic enlargement, there is a growing need for an easily available, cheap, safe, non invasive and precise monitoring procedure. Transabdominal sonographic evaluation of prostatic size and PVR can be repeated as often as necessary, as a consulting-room based procedure in monitoring progress of treatment without the risk of trauma or infection to the urinary tract.

RECOMMENDATION

We therefore recommend it as the best diagnostic option in patients on pharmacological or surgical management of prostate enlargement. It is however recommended that repeated PVR assessments should be made, for individual ‘test-reatest’ reliability to be maintained. This is because PVR cannot be determined reliably from a single measurement
SUMMARY

The aim of this study was to determine the sonographic volumes of the prostate and post void residual urine in patients with prostatic enlargement and to document any relevant relationship between the two values.

280 adult Nigerian male patients referred for ultrasonographic assessment of the clinically diagnosed prostatic enlargement were investigated by transabdominal ultrasonography. The age range of the patients were 48-92 years with a mean age of 69.8 years. The peak incidence of the prostatic enlargement was in the seventh decade of life. The prostate volume ranged from 25cm$^3$ to 248.8cm$^3$ with a mean of 68.3cm$^3$ while the post void residual urine volume ranged from 18.2cm$^3$ to 342cm$^3$ with a mean of 131.8cm$^3$. Statistically significant variation of the prostate volume was observed among various age groups.

The study showed positive but weak correlation between the post void residual urine volume and the prostate volume, significant PVR being associated with increase in the prostate volume.
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