Comparative Analysis Of Pelvic Floor Imaging In Women With Pelvic Organ Prolapse Versus Controls Using Two-Dimensional and Three-Dimensional Transperineal Ultrasound*

by Katrina Fidelina C. Adan, MD and Melissa DL. Amosco, MD, FPOGS, FPSUOG
Section of Ultrasound, Department of Obstetrics and Gynecology, Philippine General Hospital

ABSTRACT

Background: Pelvic organ prolapse (POP) is a condition characterized by the failure of various anatomic structures to support the pelvic viscera. There has been a growing interest in the understanding of the underlying structural alterations in the pelvic floor, and the use of 2D and 3D transperineal ultrasound has recently been shown to be able to determine biometric indices of the levator hiatus and pubovisceral muscle.

Objective: To compare the morphological features and biometric parameters of the pelvic floor of patients with pelvic organ prolapse with age-matched controls using 2D and 3D transperineal ultrasound.

Methodology: In a prospective case control study, 35 patients with prolapse and 25 asymptomatic controls were assessed. Bladder symphyseal distance (BSD), bladder neck descent, angle of urethral inclination, retrovesical angle, bladder wall thickness and quantification of prolapse were measured on rest and valsalva maneuver on 2D ultrasound. Anteroposterior and lateral diameters, as well as pubovisceral muscle thickness was measured on rest and valsalva on 3D ultrasound.

Results: BSD was significantly lower in the prolapse group (p=0001), while bladder wall thickness was significantly higher (p=0024). AP and lateral diameters were significantly higher in the prolapse group both at rest and on valsalva, showing that there is significant correlation with increased diameters at rest and pelvic organ descent. Pubovisceral muscle thickness was lower in the prolapse group compared to controls both at rest and on valsalva.

Conclusion: Levator hiatal dimensions and biometry indices of the pubovisceral muscle can be determined using 2D and 3D transperineal ultrasound. There is significant correlation between anteroposterior and lateral diameters, as well as pubovisceral thickness, with pelvic organ descent.

Keywords: pelvic organ prolapse, levator hiatus, pubovisceral muscle, 2D transperineal ultrasound, 3D transperineal ultrasound

INTRODUCTION

Pelvic organ prolapse (POP) is a condition characterized by the failure of various anatomic structures to support the pelvic viscera.[1] It is common among parous women, with a lifetime prevalence of 30-50% worldwide. In our institution, which is the largest tertiary referral center in the country, pelvic organ prolapse remains to be the most common pelvic floor disorder seen in the outpatient department, with a yearly average of 286 newly diagnosed patients in the last 5 years.[2]

However, despite its high prevalence, the underlying pathophysiology of pelvic organ prolapse still has not been fully elucidated. Because of this, there has been a growing interest in the understanding of the underlying structural alterations in the pelvic floor which may eventually lead to pelvic organ prolapse.

The pelvic organs are maintained in their position by a combination of connective tissue, and smooth and striated muscle. Complex interactions between these elements are responsible for normal support. Damage to any of them may contribute to pelvic organ prolapse and pelvic floor dysfunction.[3]

Furthermore, the levator ani complex plays a significant role in pelvic organ support. This muscle has two major components, the pubovisceral (pubococcygeus and puborectalis muscles) and the iliococcygeal muscles. However, assessment of the integrity of pelvic organ support is difficult. The value of clinical examination alone is limited and has not been validated.[4]

* First Place, 2013 Philippine Society of Ultrasound in Obstetrics and Gynecology (PSUOG) Research Paper Contest, Novembe 21, 2013, Philippine Columbian Association Sports Complex, Manila

Magnetic resonance imaging (MRI) studies have provided a detailed insight into the anatomy of the levator ani complex. However, although MRI has provided valuable insights into pelvic floor anatomy and function, its use is limited because it is not universally available and is expensive.[5]

Because of this, ultrasound imaging is rapidly replacing radiological methods in the investigation of pelvic organ disorders. In a landmark study by Dietz published in 2004, he demonstrated that the position and mobility of the bladder neck, bladder wall thickness, pelvic floor muscle activity, and uterovaginal prolapse may be quantified using two-dimensional gray scale ultrasound.[5]

Ultrasound imaging of the pelvic floor has its advantages over MRI. It is safer, more economical, and enables visualization in real time. This would allow assessment of the levator function and dynamic changes during pelvic floor muscle contraction and Valsalva. Due to its non-invasive nature, ready availability and absence of distortion, perineal and translabial two-dimensional ultrasound is the most widely used imaging method due to ease of use and availabilty of equipment.[6]

Further investigation in the use of ultrasound as an imaging modality in the assessment of the pelvic floor is not limited to gray scale two-dimensional sonography alone. The advent of three dimensional (3D) pelvic floor ultrasound enables evaluation of the levator ani with much less cost to the health care provider and minimal discomfort to the patient. Recordings in real time can be easily made, making assessment of the pelvic floor structures during movement possible. Improved ability to describe prolapse by visualizing the functional pelvic anatomy should make it possible to avoid unnecessary surgery and futile conservative management. Likewise, while spatial resolution may be inferior, ultrasound adds a degree of dynamic multiplanar imaging, which is almost impossible using current MRI technology.[7, 8]

Yang et al in 2006 explored the possible ethnic differences between previously published data on biometric measurements of nulliparous Caucasian women, with their measurements in nulliparous Chinese women. This study showed that ethnicity can be a factor affecting the biometry of the levator hiatus in chinese nulliparous women, showing a significant difference in average pubovisceral muscle thickness between nulliparous Chinese and Caucasian women.[11] This fact supports further investigation among other ethnic groups, such as in Filipinos.

Despite these advantages of the use of ultrasound imaging in the investigation of pelvic floor disorders, there is still no local study published in the Philippines using two-dimensional or three-dimensional ultrasound in the assessment of pelvic floor biometry. There is likewise no local data on biometric indices of the pelvic floor of asymptomatic Filipino women with no pelvic organ prolapse. This may due to the fact that in the Philippines, the field of Urogynecology is still in its infancy stage, and the use of ultrasound in imaging of the pelvic floor is not widely practiced.

This study aims to compare the morphological features and biometry of the pelvic floor muscles of patients with pelvic organ prolapse with controls using real time two-dimensional and three-dimensional transperineal ultrasound. This study also aims to compare biometric measurements of the pelvic floor in Filipinos with measurements in previously published studies on Caucasian and Asian (Chinese) women.[8,11] Data on the morphologic features and pelvic floor biometry will enhance our understanding of pelvic floor biomechanics as well as observing functional anatomy and examining muscular and fascial structures of the pelvic floor, which will lead to a greater understanding of pelvic floor disorders.

METHODS

STUDY DESIGN: Prospective, Case control

Study Subjects - The computed minimum sample size was 25 subjects for the control group and 35 subjects for the pelvic organ prolapse group. This was computed by setting the power at 80% and a significance of 5%, using the computation for the minimum sample size for the difference between the two means, to detect a minimum difference of 0.5.

Study Population

The study included 2 study arms:

1. Patients with pelvic organ prolapse – included 35 patients who consulted at the general gynecology clinic of our institution and diagnosed to have pelvic organ prolapse (Stage 1-4), from 19 to 75 years of age, who are referred to the Section of Ultrasound for transvaginal scan.

Inclusion Criteria:

- Patients diagnosed to have pelvic organ prolapse Stage 1-4 using the International Continence Society (ICS) Pelvic Organ Prolapse Quantification system (POP-Q)
- Patients whose pelvic organ prolapse may be manually reduced
- Patients who have signed the informed consent form
- Patients who are willing to undergo two-dimensional

and three-dimensional transperineal ultrasound and are willing to abide with the study protocol

Exclusion Criteria:

- Patients diagnosed with pelvic organ prolapse whose prolapse cannot be manually reduced
- Pregnant patients
- Patients with concomitant uterine, ovarian or adnexal masses, benign or malignant (gynecologic oncology patients)
- Patients who underwent hysterectomy

2. Patients with no pelvic organ prolapse (Control group) – included 25 patients who consulted at the general gynecology clinic in a tertiary hospital with no clinical evidence of pelvic organ prolapse, 19 to 75 years of age, and who are referred to the Section of Ultrasound for transvaginal scan.

Inclusion Criteria:

- Patients with no demonstrable pelvic organ prolapse by clinical examination
- Patients who are age-matched with the pelvic organ prolapse group using a range of ages
- Patients who are asymptomatic (no urinary incontinence or fecal incontinence)
- Patients who have signed the informed consent form
- Patients who are willing to undergo two-dimensional and three-dimensional transperineal ultrasound and are willing to abide with the study protocol

Exclusion Criteria:

- Pregnant patients
- Patients with concomitant uterine, ovarian or adnexal masses, benign or malignant (including gynecologic oncology patients)
- Patient who underwent hysterectomy

A prospective case-control study involving patients with pelvic organ prolapse versus controls seen at the ultrasound section was done in our institution.

Women were recruited by the primary investigator from the general gynecology clinic at the outpatient department (for both the pelvic organ prolapse group and the control group) of a tertiary hospital from April to June 2013.

Oral and written consent was obtained by the primary investigator using the WHO Informed Consent Form.

All women included in the study were interviewed using a structured symptom questionnaire regarding urinary, bowel, and prolapse symptoms (P-QOL questionnaire) and was recorded.

Demographic characteristics (age, gravidity/parity, height, weight, and body mass index (BMI) were recorded in the data collection form.

After complete and thorough history and systemic physical examination by the residents-in-charge at the outpatient department, all women underwent a vaginal examination with an empty bladder to grade the severity of the prolapse using the International Continence Society (ICS) pelvic organ prolapse quantification system (POP-Q). The maximum descent of the leading organ was noted. All patients with pelvic organ prolapse were referred to the urogynecology clinic for assessment by the urogynecology fellow.

Women with no organ prolapse was enrolled in the control group, while those with pelvic organ prolapse Stage 1-4 was enrolled in the pelvic organ prolapse group by the primary investigator (should meet the inclusion/exclusion criteria set).

All patients then underwent a baseline transvaginal ultrasound which was done by the primary investigator. After this, real time two-dimensional and three-dimensional transperineal ultrasound was performed by the primary investigator with the supervision of the consultant supervising investigator for both study arms. Each measurement was done twice and the average of the two measurements was noted to ensure reproducibility of results.

For women in the pelvic organ prolapse group, the prolapse was manually reduced prior to the treatment procedure.

The following methodology was done based on the previous study of Dietz, et al.[6]

Two-Dimensional Transperineal Ultrasound:
(For both controls and pelvic organ prolapse group)

1. Patients were placed on dorsal lithotomy position with hips flexed and slightly abducted after voiding, with the bladder nearly empty. The examination was done using Aloka SSD 4000 system with a 3.5 MHz curved 3D/4D ultrasound transducer.

2. A midsagittal view was obtained by placing the transducer on the perineum after covering the transducer with a glove for hygienic reasons.

3. Two images of the midsagittal view were taken first at rest, and then another two images on maximal Valsalva maneuver, to ensure intraobserver reproducibility of results. The images included the pubic symphisis anteriorly, the urethra and bladder neck,

the vagina, cervix, rectum and anal canal and will be documented. (Figure 1)

4. From these images, the following quantitative parameters were recorded both at rest and on maximal Valsalva maneuver. These parameters focus on the position of the bladder neck and the proximal urethra:

   a. Bladder-neck symphyseal distance (BSD) – distance between the inferoposterior margin of the symphysis pubis and the bladder neck. The difference of BSD at rest and at Valsalva will determine bladder neck descent.

   b. Angle of urethral inclination – angle between the proximal urethra and a fixed axis. This measures the extent of rotation of the proximal urethra.

   c. Retrovesical angle – angle between the proximal urethra and bladder trigone (Figure 2)

   d. Bladder wall thickness – measured at three points: anterior wall, trigone, and bladder dome and the mean thickness was obtained.

   e. Quantification of prolapse (Figure 3) – at rest and after obtaining maximum descent on Valsalva maneuver, images were taken and the maximal descent of the bladder, uterus, cul de sac, and rectum were measured relative to the inferoposterior margin of the symphysis pubis.

The following images are 2D transperineal images at rest and at Valsalva of a patient enrolled in the pelvic organ prolapse group (Figures 4 & 5).

5. Other incidental findings noted on transperineal ultrasound were recorded (e. g. presence of urethral diverticulum, bladder/urethral masses, gartner's duct cyst, etc).

All ultrasound images were retrieved and stored in a computer for further reference and analysis.

After performing two-dimensional transperineal ultrasound and all data were recorded, the investigators proceeded with three-dimensional transperineal ultrasound.

Three-Dimensional Transperineal ultrasound: (For both controls and pelvic organ prolapse group) [7, 8]

1. Patients were placed on dorsal lithotomy position with hips flexed and slightly abducted after voiding with the bladder nearly empty. Examination was done using Aloka SSD - 4000 system with a 3.5 MHz curved 3D/4D ultrasound transducer.

2. A midsagittal view was obtained by placing the transducer on the perineum after covering the transducer with a glove for hygienic reasons.

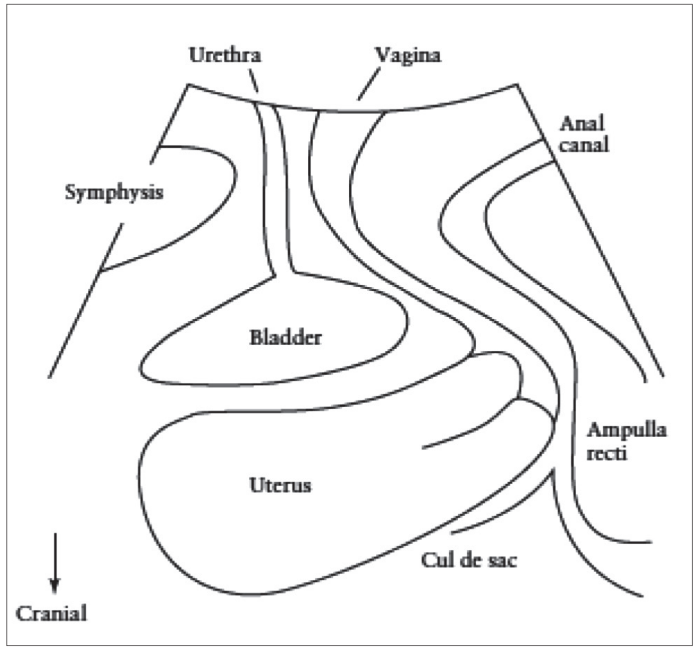

Figure 1. Translabial ultrasound in the midsagittal plane. Image taken from Dietz HP. Ultrasound imaging of the pelvic floor. Part I: two-dimensional aspects

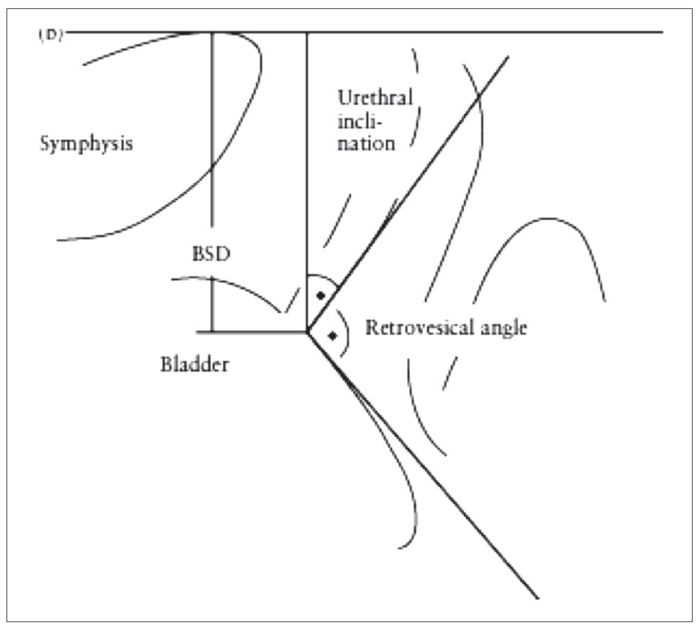

Figure 2. Measured parameters. BSD (bladder neck-symphyseal distance). Image taken from Dietz HP. Ultrasound imaging of the pelvic floor. Part I: two-dimensional aspects.

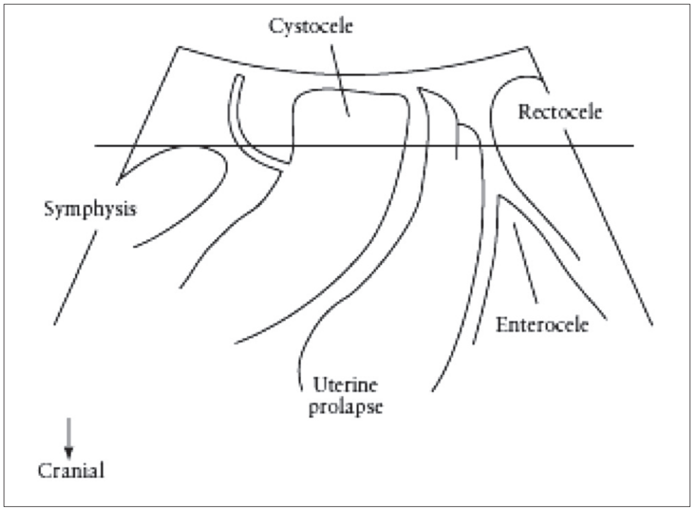

Figure 3. Ultrasound quantification of uterovaginal prolapse. The inferior margin of the symphysis pubis serves as the line of reference against which the maximal descent of the bladder, uterus, cul de sac, and rectum will be measured. Image taken from Dietz HP, Haylen BT, Broome J. Ultrasound in the quantification of female pelvic organ prolapse.

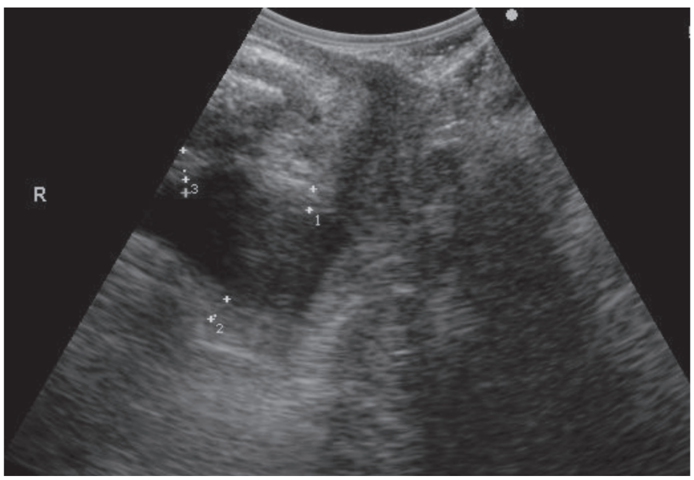

Figure 4. Two-dimensional transperineal ultrasound of a patient with pelvic organ prolapse Stage IV (cystocoele) at rest.

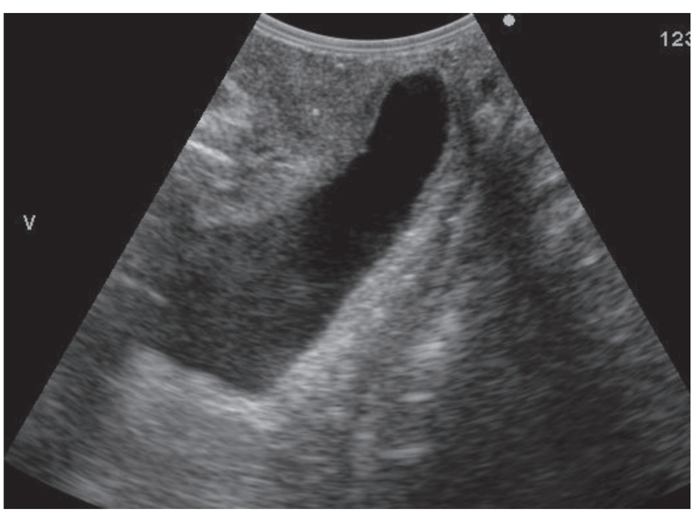

Figure 5. Two-dimensional transperineal ultrasound of the same patient on Valsalva maneuver.

3. Two images of the midsagittal view were taken at rest and another two images were taken on maximal Valsalva to ensure intraobserver reproducibility of results. Images were obtained at rest with an acquisition angle of 70 degrees. All images were retrieved and stored for subsequent analysis.

4. Each retrieved sonographic record was processed to obtain a mid-sagittal view in the multiplanar display. This view was then manipulated until an imaginary line from the puborectalis muscle behind and below the anorectal junction to the inferior border of the symphysis pubis was positioned according to the section line of the region of interest (ROI). The reconstructed image, an axial view, will be in the plane of minimal hiatal dimensions. (Figure 6)

5. The section line of the region of interest (ROI) in the mid-sagittal view was moved slowly upwards on the screen until the thickness of the pubovisceral muscle will be maximal, the reconstructed image will now be the plane of maximal muscle thickness.

The following quantitative parameters was measured in the rendered images:

In the plane of minimal hiatal dimensions: AP and lateral diameters

In the plane of maximal muscle thickness: Thickness of the pubovisceral muscles bilaterally (right and left), and the average of these measurements was recorded.

The following are 3D images of a patient in the pelvic organ prolapse group in the plane of minimal hiatal dimensions and maximal muscle thickness (Figures 7 & 8).

For each patient, each scan (from the baseline transvaginal scan, and including the two-dimensional and three-dimensional transperineal scans) lasted for a total of 10 to 20 minutes. All measurements were done at one visit, and no follow up scans were required.

Statistical Analysis

The data for the different morphological features and pelvic floor biometry for both pelvic organ prolapse and control groups were tabulated and encoded in the appropriate Excel tables. The summary measures that were computed are the proportion for the categorical data, while the median and range for the continuous data. The measurements from the two groups were compared using the Mann-Whitney U test (for continuous data) and the test of independence (for categorical data). The necessary

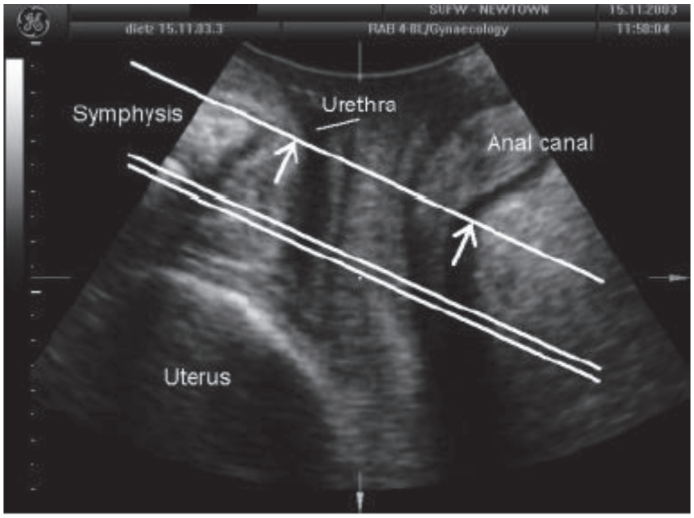

Figure 6. Mid-sagittal translabial two-dimensional pelvic floor ultrasound showing the location of planes used for determining hiatal diameters and areas, as well as pubovisceral muscle thickness and area. (Image taken from Dietz, et al. Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound. Ultrasound Obstet Gynecol 2005;25: 580-85)

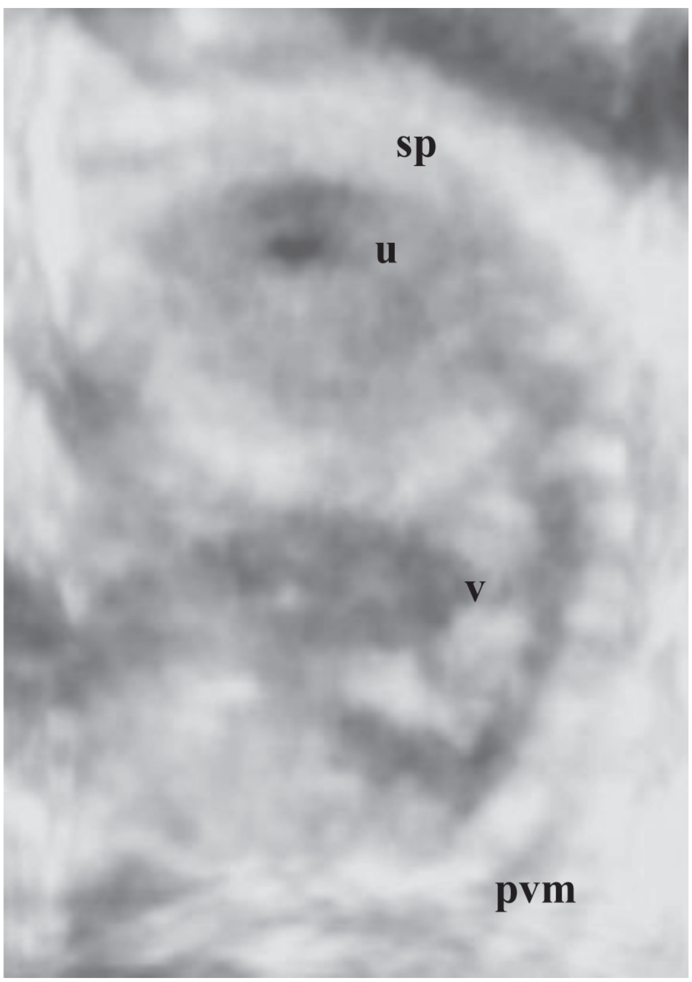

Figure 7. Three-dimensional transperineal ultrasound of a patient with pelvic organ prolapse. At the plane of maximal muscle thickness, the thickness of the pubovisceral muscle (pvm) is measured. (sp - symphysis pubis, u - urethra, v - vagina)

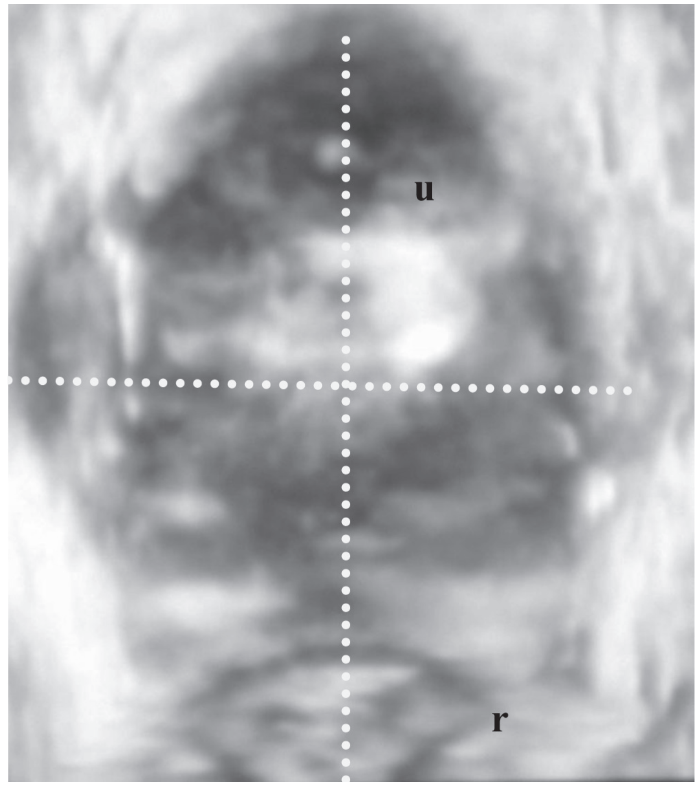

Figure 8. At the plane of minimal hiatal dimensions, the antero-posterior and lateral diameters are measured. (u - urethra, r - rectum)

p-value was also computed to determine which characteristics are different for the two groups. The same thing was done to the demographic characteristics of the group. Correlations between different characteristics will be done using Spearman's correlation. All the statistical tests were done using STATA 10 statistical software.

The study protocol was submitted and approved by the Research Ethics Board of this institution. Standard medical and gynecological care was rendered on all subjects. The principal investigator has no conflict of interest with the study, or with the co-investigator.

RESULTS AND DISCUSSION

Demographic Characteristics

For the 25 patients enrolled in the control group, their ages ranged from 40-64 years, with a mean of 48.72 years (SD = 8.00). Majority of the patients (22/25) or 88% were married. Seventy six percent (19/25) were unemployed or housewives, while the rest of the occupations noted were the following: laundrywoman, businesswoman, canteen helper, barangay health worker, vendor and a saleslady (see Table 1)

As for the pelvic organ prolapse group, the patients' ages ranged from 43 to 75 years, with a mean of 61.97 years (SD = 8.84). Almost all patients were married

(33/35 or 94.3%), while 1 patient was single, and 1 was a widow. Twenty-four patients (68.9%) were unemployed or housewives, 4 patients (11.4%) were vendors, 2 (5.7%) were cooks, while the rest of the occupations noted were the following: laundrywoman, teacher, messenger, nurse, and a manicurist (see Table 2).

Clinical Characteristics

Of the 25 patients in the control group, 12 (48%) of them were within normal limits of body mass index (BMI 19-24.9), 11 patients (44%) were overweight, and 2 patients (8%) were obese class I. Majority of the patients had a gravidity and parity of 2 to 5 (48% for gravidity and 52% for parity) respectively. With regards to their past medical history, 18 (72%) patients had unremarkable history, followed by 5 patients (20%) who had hypertension. The most common reason for consult was abnormal uterine bleeding which was the presenting symptom in 16 or 62% of the patients (see Table 3).

On the other hand, for the pelvic organ prolapse group, majority were also within normal limits of body mass index (16 patients or 45.7%) and 13 patients (37.1%) were overweight. Majority of the patients also had a gravidity and parity of 2 to 5 (65.7%) respectively. With regards to their past medical history, 22 (74.3%) patients had unremarkable history which was similar with the control group, followed by 8 patients (22.9%) who had hypertension, and 5 patients (14.3%) had diabetes mellitus. The most common reason for consult was a palpable introital mass which was present in 31 patients or 88.6% of the patients (see Table 4).

Table 1: Demographic Characteristics (Control) - Descriptive Analysis

Age: 40 – 64 years (Mean = 45.1, SD = 8.0)		
Variable	**Number**	**Percent**
Civil Status		
Single	1	4.0
Married	22	88
Separated	1	4.0
Widow	1	4.0
Occupation		
Unemployed/Housewife	19	76
Barangay Health worker	1	2.86
Laundrywoman	1	2.86
Businesswoman	1	2.86
Canteen helper	1	2.86
Vendor	1	2.86
Saleslady	1	2.86

Table 2: Demographic Characteristics (Pelvic Organ Prolapse Group) - Descriptive Analysis

Age: 43 – 75 years (Mean = 61.97, SD = 8.84)		
Variable	**Number**	**Percent**
Civil Status		
Single	33	94.2
Married	1	2.86
Widow	1	2.86
Occupation		
Unemployed/Housewife	24	68.6
Vendor	4	11.4
Cook	2	5.7
Laundrywoman	1	2.86
Teacher	1	2.86
Messenger	1	2.86
Nurse	1	2.86
Manicurist	1	2.86

Table 3 – Clinical Characteristics (Control) - Descriptive Analysis

Variable	Number	Percent
Body Mass Index (BMI)		
19-24.9 (Normal)	12	48
25-29.9 (Overweight)	11	44
30-34.9 (Obese Class I)	2	8
Gravidity		
Nulligravid	5	20
Primigravid	2	8
Gravida 2 to 5	12	48
Gravida 6 and above	6	24
Parity		
Nulliparous	6	24
Para 1	2	8
2 to 5	13	52
6 and above	4	16
Past Medical History		
None	18	72
Hypertension	5	20
Breast Cancer	1	4
Diabetes Mellitus	1	4
Chief Complaint		
Abnormal uterine bleeding	16	64
Asymptomatic/routine	6	24
Abdominal pain	3	12

The demographic and clinical characteristics of the two study groups were compared using the mean (standard deviation), and proportion of the characteristics were computed when appropriate. The statistics were also compared for the two groups using the t-test or the Chi-square test, when applicable (see Table 5). From the table we can see that ages of the two groups are significantly different from each other (p-value 0.000001). As stated in the methodology, the ages of the controls were matched with the ages of the prolapse group by utilizing a range of ages. This however, still resulted in a relatively younger control group. A more appropriate age matching by using each individual age instead of a range of ages could have resulted in a more homogenous data set. We can also see from the data table that both study groups are homogenous, save for the gravidity and parity, which is statistically significant and slightly higher in the prolapse group (p-value 0.0035 and 0.0059 respectively). Previous studies have shown that increasing parity is a risk factor for the occurrence of pelvic organ prolapse. Further investigation in this area may benefit from further matching both gravidity and parity, aside from the age alone, in both control and prolapse groups, to achieve a homogenous data set. All the subjects in both the control and prolapse groups delivered by spontaneous vaginal delivery.

Table 4 – Clinical Characteristics (Pelvic Organ Prolapse) - Descriptive Analysis

Variable	Number	Percent
Body Mass Index (BMI)		
18 and below (Underweight)	3	8.6
19-24.9 (Normal)	16	45.7
25-29.9 (Overweight)	13	37.1
30-34.9 (Obese Class I)	3	8.6
Gravidity		
Nulligravid	0	-
Primigravid	0	-
Gravida 2 to 5	23	65.7
Gravida 6 and above	12	34.3
Parity		
Nulliparous	0	-
Para 1	2	5.7
2 to 5	23	65.7
6 and above	10	28.6
Past Medical History		
None	22	62.9
Hypertension	8	22.9
Diabetes Mellitus	5	14.3
Chief Complaint		
Introital mass	31	88.6
Difficulty in urination	4	11.4

Table 5. Comparative Analysis of Demographic and Clinical Characteristics of the Control Group and the Prolapse Group

Charateristics	Control Group	Prolapse Group	Difference (p-value)
Age	45.1 (8.007)	61.97 (8.84)	11.29 (0.0000001)
BMI	24.79 (3.644)	24.05 (4.25)	0.74 (0.435)
Medical History	25.71%	31.42%	5.71% (0.597)
Employment	12.28%	28.57%	14.29% (0.145)
Gravidity	3.11 (2.99)	5.09 (2.43)	1.97 (0.0035)
Parity	2.83 (2.87)	4.60 (2.30)	1.77 (0.0059)

Two-Dimensional Trasperineal Ultrasound Measurements

This study measured the following biometric parameters on 2D ultrasound: bladder symphyseal distance (BSD), bladder neck descent, angle of urethral inclination, retrovesical angle, and bladder wall thickness at rest, which are all parameters to determine the position and mobility of the bladder neck and proximal urethra.

For the control group, the BSD at rest had a range of 1.6 – 3.7 cm, with a mean of 2.5 cm. On valsalva, the range was 1.1 – 3.0 cm, with a mean of 1.91 cm. The bladder neck descent was taken as the numerical difference between the BSD values and rest and at valsalva. For the control group, the bladder neck descent ranged from 0.1 cm to 1.7 cm with a mean of 0.6 cm. This value is comparable to the bladder neck descent reference measurements published in literature (0.51 to 0.53 cm) in continent nulliparous women, which can range up to an average of 1.5 to 1.7 cm, which is also comparable to our results.[16] Although the sample population for our control group had varied parity, our data shows that the data published in literature may also apply to continent asymptomatic women of varied parity.

The angle of urethral inclination at rest ranged from 7 to 85 degrees, with a mean of 22.8 degrees. On valsalva, the range was 2 to 100 degrees, with a mean of 17.1 degrees. The rectovesical angle at rest ranged from 91 to 190 degrees, with a mean of 123.4 degrees. On valsalva, the range was 112 to 200 degrees, with a mean of 135 degrees. Limited studies have been done measuring the angle of urethral inclination, which can be used to measure the extent of the rotation of the proximal urethra in the postero-inferior direction. Our findings showed a wide range of rotation among asymptomatic continent women, from up to 85 degrees at rest, which opens up to 100 degrees at valsalva. On the other hand, the rectovesical angle or the angle between the proximal urethra and the bladder trigone, showed a value of up to 190 degrees at rest which opens up to 200 degrees on valsalva. Our results varied from published data which shows that the retrovesical angle opens up to 160-180 degrees from a normal value of 90-120 degrees.[6] This variation in measurements may have likely arised from methodological differences such as patient positioning, bladder filling during the exam, and the quality of the Valsalva maneuver may account for the above discrepancies.

The quantification of bladder wall thickness was measured in 3 sites: the anterior wall, trigone, and dome and the average of the 3 values were calculated. For the control group, this ranged from 0.2 to 0.6 cm, with a mean of 0.4 cm. This is consistent with the cut-off of 5 mm published in literature for asymptomatic patients.

The following table is a summary of the two-dimensional transperineal ultrasound measurements of the control group (see Table 6).

Table 6. Two-Dimensional Transperineal Ultrasound Measurements (Control)

2D Measurements	Rest (Mean)	Valsalva (Mean)
BSD	1.6-3.7 cm (2.5)	1.1 – 3.0 cm (1.91)
Bladder neck descent	0.1-1.7 cm (0.6 cm)	
Angle of urethral inclination	7 – 85 degrees (22.78)	2 – 100 degrees (17.1)
Retrovesical angle	91 – 190 degrees (124.6)	112 – 200 degrees (135)
Bladder wall thickness	0.2 - 0.6 cm (0.4 cm)	

On the other hand, for the prolapse group, the BSD at rest had a range of 0.7 – 3.0 cm, with a mean of 1.9 cm. On valsalva, the range was 0.8 – 2.4 cm, with a mean of 1.1 cm. The bladder neck descent ranged from 0.1 cm to 3.0 cm with a mean of 0.9 cm. There is still no definition of a normal value for bladder neck descent although a cut-off of 2.5 cm has been proposed to define hypermobility.[6] Although there were measurements > 2.5 cm for bladder neck descent (up to 3 cm) in the prolapse group, the mean was not significantly different from the mean of the bladder neck descent values of the control group. This could be explained by fact that bladder neck descent has been proposed to have the strongest association with stress incontinence, and not pelvic organ prolapse, and from the prolapse sample population, only 3 patients were diagnosed with stress incontinence, and these 3 patients had bladder neck descent values 2.5 cm and greater (2.5-3.0 cm). The etiology of increased bladder neck descent is likely to be multifactorial. Previous studies have looked into the role of a congenital component, as well as the role of vaginal birth, long second stage of labor and vaginal operative delivery in increased bladder neck descent. These may be points of interest in future studies involving 2D transperineal ultrasound of the pelvic floor.

Furthermore, the angle of urethral inclination at rest ranged from 5 – 45 degrees, with a mean of 19.5 degrees. On valsalva, the range was 27 – 60 degrees, with a mean of 22 degrees. This is significantly different from the values of urethral inclination of the control group on valsalva (p = 0.482). This means that the angle of urethral inclination in the prolapse group is significantly lower than the control group, supporting the theory of hypermobility of the proximal urethra, causing a smaller angle of inclination on Valsalva maneuver in patients with pelvic organ prolapse.

The rectovesical angle at rest ranged from 89 – 180 degrees, with a mean of 132.5 degrees and on valsalva, the range was 108 – 185 degrees, with a mean of 112 degrees. There was no significant difference of the rectovesical angle between the control and the prolapse group, both at rest and on valsalva. Among the parameters, this appeared to be the least reliable due to the wide variation in measurement.

Bladder wall thickness values for the prolapse group ranged from 0.3 to 1.0 cm, with a mean of 0.5 cm, which is significantly higher than in the control group (p = 0.0024). Bladder wall thickness of > 0.5 cm seems to be associated with detrusor instability according to Khullar, et al in 1996. In their paper, they said that increased bladder wall thickness likely signifies hypertrophy of the detrusor muscle, and this may be cause of symptoms or simply the effect of an underlying abnormality.[17] While bladder thickness on its own seems only moderately predictive of detrusor instability, the method may be clinically highly useful when combined with symptoms of overactive bladder. Looking at our data, among the 10 patients diagnosed with overactive bladder in the prolapse group, 7 of them had bladder wall thickness values of 0.5 – 1.0 cm, which can support this theory.

The following table summarizes the two-dimensional transperieneal ultrasound measurements of the pelvic organ prolapse group (see table 7).

This table shows the comparison of measured variables on 2D transperineal ultrasound between the control group and the prolapse group using sample means and the standard deviations. To check if the difference between the two means is significant, a two-tailed t-test was used. From the table, we see that there is significant difference in the BSD readings at rest and at valsalva. Bladder wall thickness and the angle of urethral inclination at valsalva were also statistically significant (see Table 8).

Quantification of prolapse on valsalva was also measured using the inferior margin of the symphysis pubis as a line of reference against which the maximal descent

Table 7. Two-Dimensional Transperineal Ultrasound Measurements (Prolapse)

2D Measurements	Rest (Mean)	Valsalva (Mean)
BSD	0.7-3.0 cm (1.9)	0.8 – 2.4 cm (1.1)
Bladder neck descent	0.1-3.0 cm (0.9 cm)	
Angle of urethral inclination	5 – 45 degrees (19.5)	27 – 60 degrees (22)
Retrovesical angle	89 – 180 degrees (132.5)	108 - 185 degrees (112)
Bladder wall thickness	0.3 – 1.0 cm (0.5 cm)	

of the bladder, uterus, cul de sac and rectal ampulla can be measured. Four patients had Stage I prolapse, and the values ranged from 0 – 1.5 cm (mean of 0.4 cm). Thirteen patients had clinical Stage II prolapse, with a range of values from 0.5 – 2.0 cm (mean of 1.4 cm). Eleven patients had clinical Stage III prolapse, with values ranging from 1.1 – 2.3 cm (mean of 1.8 cm), while the remaining seven patients had clinical Stage IV with values ranging from 1.0 – 2.5 cm (mean of 1.9 cm). We can see from the data that there is an increasing trend in the numerical distance of the leading compartment of prolapse as the clinical stage increased. In a study by Dietz in 2001, ultrasound findings were compared to clinical staging and ICS scoring, with good correlations of anterior and central compartments.15 The disadvantages of this method would include incomplete imaging of the cervix and vault with large rectocoeles and a possible underestimation of severe prolapse due to the transducer pressure. This comparison however was not analyzed in this study. The future use of this technique may prove to be in outcome assessment after prolapse and incontinence surgery, which can be further validated in future studies.

Three-Dimensional Transperineal Ultrasound

In this present study, we wanted to establish if 3D transperineal ultrasound may be used as a method for assessing biometric indices of the pubovisceral muscle and the levator hiatus, not only for asymptomatic women, but for women with pelvic organ prolapse as well. Previous studies have demonstrated that 3D ultrasound is reliable and comparable to the gold standard MRI in imaging the pelvic floor in asymptomatic nulliparous women[7,8] however, there is limited information on its use for patients with pelvic organ prolapse.

Using a 3D transabdominal volume probe, at the plane of minimal hiatal dimensions, the anteroposterior and lateral diameters were measured. The maximal levator thickness was determined by moving the plane of minimal hiatal dimensions cranially until the plane of maximal thickness of the pubovisceral muscle is reached.

For the control group, the anteroposterior diameters at rest ranged from 2.8 – 5.8 cm (mean of 4.9 cm), while on valsalva the anteroposterior diameters ranged from 3.0 – 6.0 cm (mean of 4.2 cm). The lateral diameters at rest ranged from 2.8 – 5.1 cm (mean of 3.8 cm), and on valsalva the lateral diameters ranged from 3.0 – 5.2 cm (mean of 4.2 cm). This is comparable to published data on mean levator hiatal dimensions both on nulliparous Caucasian and Chinese asymptomatic women.[8, 11] In the initial study by Dietz, et al on 52 asymptomatic Caucasian women in 2005, the mean levator hiatal AP diameter was 4.5 cm at rest, while the lateral diameter had a mean of 3.75 cm. This was followed by a similar study by Yang, et al. in 2006, this time on 59 asymptomatic Chinese women to determine if there was a difference in levator hiatal 3D measurements among different ethnic groups. Their findings showed no significant difference from the Caucasian group, with a mean levator hiatal AP diameter of 4.29 +/- 0.60 cm, and a mean lateral diameter of 3.92 +/- 0.7 cm.

Furthermore, the pubovisceral muscle thickness was measured at the right and left, and the average of the 2 values was taken. The pubovisceral muscle thickness ranged from 1.2 – 2.1 cm with a mean of 1.7 cm. Our measurement of pubovisceral muscle thickness however is significantly higher than the mean thickness in the caucasian group in the study of Dietz (mean 0.73 cm).[8] This is compatible with the chinese group in the study of Yang, wherein they noted a significant difference in the pubovisceral thickness, and they found that the chinese had thicker pubovisceral muscle measurements (mean 0.84 +/- 0.17 cm) than their caucasian counterparts. This suggests that it appears there may be ethnic differences between caucasian and asian women, but only in the average pubovisceral muscle thickness. The rest of the parameters appear to have no significant difference among different ethnic groups.

For the pelvic organ prolapse group, the anteroposterior diameters at rest ranged from 4.5 – 6.0 cm (mean of 5.3 cm), while on valsalva the anteroposterior diameter ranged from 4.8 – 7.0 cm (mean of 6.0 cm). The lateral diameters at rest ranged from 3.2 – 5.6 cm (mean of 4.2 cm), while on valsalva the lateral diameters ranged from 4.0 – 7.0 cm (mean of 4.9 cm). The pubovisceral muscle thickness ranged from 1.2 – 1.9 cm with a mean of 1.4 cm.

Table 9 shows that all measurements of the levator hiatus at the plane of minimal hiatal dimensions (both AP and lateral diameters) are statistically significantly higher

Table 8. Comparison Between Two-Dimensional Measurements of the Control and Prolapse Groups

2D measurements	Control Group Mean/(SD)	Prolapse Group Mean/(SD)	Difference (p-value)
Rest			
BSD (cm)	2.5 (0.49)	1.89(0.59)	*0.0001*
Bladder neck descent (cm)	0.6 (0.41)	0.83(0.81)	0.1474
Angle of urethral inclination (degrees)	22.8 (14.73)	19.51(11.57)	0.5240
Retrovesical angle (degrees)	123.4 (29.31)	132.43(20.79)	0.2002
Bladder wall thickness (cm)	0.4 (0.09)	0.5(0.17)	0.0024
Valsalva			
BSD (cm)	1.91 (0.45)	1.11(0.72)	*0.0000*
Angle of urethral inclination (degrees)	17.1 (19.12)	26.59(13.59)	*0.0482*
Retrovesical angle (degrees)	135 (22.92)	145.37(22.74)	0.5504

Table 9. Comparison Between Three-Dimensional Measurements of the Control and Prolapse Groups

3D measurements (cm)	Control Group Mean/(SD)	Prolapse Group Mean/(SD)	Difference (p-value)
Plane of minimal hiatal dimensions			
Rest			
AP	4.9 (0.68)	5.08 (0.66)	*0.0000*
Lateral	3.92 (0.54)	4.24 (0.58)	*0.0198*
Valsalva			
AP	4.2 (0.79)	6.01 (0.66)	*0.0000*
Lateral	4.2 (0.62)	4.86 (0.68)	*0.0003*
Plane of maximal muscle thickness			
Pubovisceral thickness (average)	1.71 (0.26)	1.42 (0.30)	*0.0001*

in the prolapse group than the control group, both at rest and at valsalva. This means that we will expect greater diameters in pelvic organ prolapse patients which may be due to the opening of the hiatus during pelvic descent (as downwards displacement of organs may push the levator laterally). This is not surprising for measurements taken on valsalva maneuver – the increase in levator hiatal dimensions may be either the cause or effect of pelvic organ descent. But for the measurements taken at rest, significant correlations between the anteroposterior and lateral diameters at rest and pelvic organ descent was demonstrated, wherein the wider the measurements were at rest, the more that the descent of pelvic organs on valsalva occurred.

The pubovisceral muscle thickness however, showed a significantly lower diameter in the prolapse group than the control group, which may suggest a correlation between thinned out muscle fibers and development of prolapse. Although we have to keep in mind that other factors may also cause thinning out of muscle fibers, wherein the muscle fibers' diameters decrease significantly with age and menopause, and majority of the prolapse group population were elderly menopausal women.

Another parameter of importance is the levator hiatal area, which is measured in the plane of minimal hiatal dimensions. Published literature has shown that significant correlations were documented between levator hiatus area and pelvic organ descent. However due to volume software limitations, this parameter was not measured in this study. Further research on 3D transperineal ultrasound of the pelvic floor must include levator hiatal area to complete the assessment.

CONCLUSIONS AND RECOMMENDATIONS

Our study was able to demonstrate that 2D and 3D transperineal ultrasound may be reliably used for determining the pelvic floor morphology and biometry. Bladder symphyseal distance (BSD) was significantly lower in the prolapse group compared to the control group (p=0.0001), while bladder wall thickness was significantly higher in the prolapse group than the controls (p=0.0024). With regards to the use of 2D ultrasound, our data is comparable with previous studies published. Bladder symphyseal distance, bladder neck descent, and bladder wall thickness are the most consistent parameters, while the angle of urethral inclination and rectovesical angles yielded the most varied and less reliable measurements. Although there was no significant difference in bladder neck descent between the control and prolapse group, this parameter may be significant in patients diagnosed with stress incontinence as proposed in previous literature. A larger sample population in future studies will have to be undertaken to validate this theory.

Biometrics of the pubovisceral muscle and the levator hiatus can be determined by 3D ultrasound, and our study looked into its role not just among asymptomatic controls, but also in patients with pelvic organ prolapse. The anteroposterior, and lateral diameters measured on the plane of minimal hiatal dimensions are significantly higher at rest and at valsalva in the pelvic organ prolapse group compared to the control group, showing that an increase in diameters correlate significantly with pelvic organ descent. The data presented supports the hypothesis that the levator ani anatomy (specifically the levator hiatus and pubovisceral muscle) plays a role in determining pelvic support. These data are compatible with published studies on both Caucasian and Asian (Chinese women). The only difference would be the thickness of the pubovisceral muscle which we found to be thicker than the mean thickness in the Caucasian population, and compatible with the Asian (Chinese) population. This may suggest that ethnicity may also affect the biometry of the levator hiatus and pelvic organ descent.

In our data, the pubovisceral muscle thickness data however was significantly lower in the prolapse group compared to the control group, which may be attributed to the thinning out muscle fibers secondary to trauma, increased age, or menopausal status. Future work in this area of research should include levator hiatal area measurement to complete the assessment of the levator hiatus biometry.

REFERENCES

1. Lentz G, Lobo R, Wharton T, Katz V (eds): Comprehensive Gynecology. 6th ed. USA: CV Mosby Co., 2012.
2. Department Annual Reports, Department of Obstetrics and Gynecology, Philippine General Hospital. Unpublished.
3. Swift S, Woodman P, O'Boyle A, et al. Pelvic organ support study (POSST): the distribution, clinical definition, and epidemiologic condition of pelvic organ support defects. *Am J Obstet Gynecol* 2005; 192:795-806.
4. Bo K., Finckenhagen HB. Vaginal palpation of pelvic floor muscle strength: inter – test reproducibility and comparison between palpation and vaginal squeeze pressure. *Acta J Obstet Gynecol Scand* 2001; 80:883-887.
5. Athanasiou S, Chaliha C, Toozs-Hobson P, Salvatore S, Khullar V, Cardozo L. Direct imaging of the pelvic floor muscles using two-dimensional ultrasound: a comparison of women with urogenital prolapse versus controls. *BJOG* 2007;114:882-888.
6. Dietz HP. Ultrasound imaging of the pelvic floor. Part I: two-dimensional aspects. *Ultrasound Obstet Gynecol* 2004; 23: 80-92.
7. Dietz HP. Ultrasound imaging of the pelvic floor. Part II: three-dimensional or volume imaging. *Ultrasound Obstet Gynecol* 2004; 23: 615-625.
8. Dietz HP, Shek K, Clarke B. Biometry of the pubovisceral muscle and levator hiatus by three-dimensional pelvic floor ultrasound. *Ultrasound Obstet Gynecol* 2005; 25:580-85.
9. Majida M, Brakken IH, Umek W, Bo K, Saltyte Benths J, Ellstrom Engh M. Interobserver repeatability of three- and four-dimensional transperineal ultrasound assessment of pelvic floor muscle anatomy and function. *Ultrasound Obstet Gynecol* 2009;33:567-573.
10. Majida M, Brakken IH, Umek W, Bo K, Saltyte Benths J, Ellstrom Engh M. Validation of three-dimensional perineal ultrasound and magnetic resonance imaging measurements of the pubovisceral muscle at rest. *Ultrasound Obstet Gynecol* 2010;35:715-22.
11. Yang JM, Yang SH, Chuang W. Biometry of the pubovisceral muscle and levator hiatus in nulliparous chinese women. *Ultrasound Obstet Gynecol* 2007; 30:346-50.
12. Dietz HP, Shek C, De Leon J, Steensma AB. Ballooning of the levator hiatus. *Ultrasound Obstet Gynecol* 2008; 31:676-80.
13. Digesu G, Khullar V, Cardozo L, Robinson D, Salvatore S. P-QOL: a validated questionnaire to assess the quality of life of women with urogenital prolapse. *Int Urogynecol J* 2005; 16:176-181.
14. Bump R, Mattiasson A, Bo K. Brubaker L, DeLancey J, Klarskov P, et al. The standardization of female pelvic organ prolapse and pelvic floor dysfunction. *Am J Obstet Gynecol* 1996; 175:10-7.
15. Dietz HP, Haylen BT, Broome J. Ultrasound in the quantification of female pelvic organ prolapse. *Ultrasound Obstet Gynecol* 2001; 18:511-14.
16. Reed H, Waterfied A, Freeman RM, Adekanmi OA. Bladder neck motility in continent nulliparous women: normal references. *Int Urogynecol J* 2002; 13:S4.
17. Khullar V, Cardozo LD, Salvatore S, Hill S. Ultrasound: a noninvasive screening test for detrusor instability. *BJOG* 1996;103:904-8.
18. World Health Organization Research Ethics Review Committee, Informed Consent Form
19. Philippine Obstetrical and Gynecological Society Clinical Practice Guidelines on Urogynecology 2010.