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RESEARCH

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The role of pelvic floor ultrasound correlated with pelvic organ prolapse quantification in the assessment of anterior and apical compartments of pelvic organ prolapse

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Abstract

Background Pelvic organ prolapse (POP) is a gynecological disease significantly associated with older age. A higher prevalence of women with symptomatic POP showed physical and emotional distress, negatively affecting their quality of life (QoL). The most widespread tool used is the prolapse quantification system (POP-Q) of the International Continence Society (ICS). The aim of this study was to evaluate the role of ultrasound (U/S) compared to POP-Q for the detection and quantification of POP in the anterior (urinary bladder) and apical (cervix/vaginal vault) compartments of the pelvic floor in Egyptian women.

Results The current study revealed that among 83 women, 53 had POP with a mean age of 50.83 years, 96.2% had anterior compartment prolapse (either alone or with apical compartment prolapse), 52% had apical compartment prolapse (either alone or with anterior compartment prolapse), 47.2% had anterior compartment prolapse only, and 3.7% had apical compartment prolapse only. There was a strong agreement (almost linear) between (POP-Q) and U/S in detecting significant pelvic organ prolapse in the anterior compartment (Kappa value 0.925, $P < 0.001$) and the apical compartment (Kappa value 0.945 and $P < 0.001$). With higher value of sensitivity and specificity, our study assigned significant anterior compartment prolapse using a cutoff value of 0 for point Ba of POP-Q and −11.5 for bladder neck descent at valsalva using U/S.

Conclusions Pelvic floor ultrasound provides general and detailed anatomical overview of the pelvic floor as well as detection and assessment of the POP in anterior and middle compartments.

Keywords Pelvic organ prolapse, Pelvic floor ultrasound, Pelvic organ prolapse quantification, Anterior compartment of pelvis, Apical compartment of pelvis

Background

Pelvic organ prolapse (POP) is a gynecological disease where the pelvic organs herniate into the vagina as a result of ligamentous or muscular weakness. Pelvic organ prolapse is defined according to the affected section (i.e., cystocele in anterior vaginal wall herniation, rectocele in posterior vaginal wall descent, and vaginal vault prolapse of the uterus, cervix, or apex of the vagina in the middle/apical compartment) [1]. Although the causes of POP

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are multifactorial, it was found that the defects within the supporting connective tissue or muscles lead to variable pathological manifestations of the pelvic floor [2].

The incidence of POP is expected to increase by 46% from the current 3.3 million to 4.9 million by 2050 [3]. In a recent meta-analysis in Egypt, the prevalence of POP among 12 included studies with a final 9905 participants was 39% [4]. Another study revealed that 50% of the elderly patients (compared to 23% of the childbearing patients) had severe symptoms of POP. Furthermore, 66.7% and 13.3% showed higher level of impairment in their physical activities, respectively [5].

Although the majority of patients with POP are asymptomatic (usually until they reach the significant grade of prolapse; grade 2 according to POPQ), others may suffer significant symptomatic trouble [6].

Assessment of POP is done on valsalva, for the anterior compartment (urinary bladder), the middle/apical compartment (cervix or vaginal vault following hysterectomy), and the posterior compartment (anorectal junction). The most widespread tool used is the prolapse quantification system (POP-Q) of the International Continence Society (ICS) [7]. Several studies have shown the efficacy of ultrasound (U/S) in detecting POP and quantifying the associated clinical symptoms. In fact, U/S is an affordable, real time, non-invasive diagnostic tool that permits imaging in three-dimensional and four-dimensional (3D/4D) multiplanar and tomographic assessment, for assessment of the pelvic floor muscle condition and the state of the supporting connective tissue [8]. Volløyhaug et al., [9] revealed that POP-Q and U/S had moderate to strong correlation in the anterior and middle compartments in patients with symptomatic POP. Furthermore, both methods were substantially associated with the symptom "vaginal bulge." Consequently, our study aimed at assessing the diagnostic role of pelvic floor U/S in POP (anterior and apical compartments) in relation to POP-Q and highlights its superadded values in assessment of the levator ani muscle to achieve the best outcome for cases.

Methods

This study was a prospective analysis that was ethically approved from the ethics committee of the radiology department on November 2020. A written informed consent was obtained from each participant prior to study initiation.

Patients

The study included 53 female patients complaining of anterior and/or apical compartment prolapse symptoms, referred from the gynecological clinic, and 30 female controls who attended the gynecology clinic for symptoms other than prolapse e.g.: infertility, infection (Fig. 1).

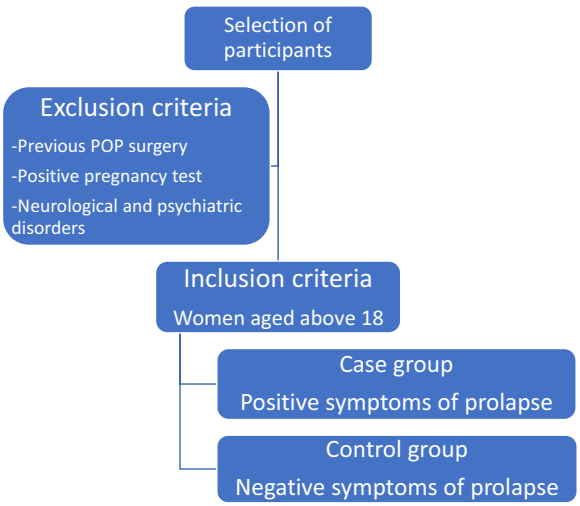

Fig. 1 Flow chart showing the exclusion and inclusion criteria

Inclusion criteria

We included in our study women aged above 18 whether in the case or control groups. Regarding the case group, the participants were the women who gave a prolapse relevant complaint such as seeing or feeling a vaginal lump, dragging sensation or urinary symptoms as stress or urge incontinence, the inability of complete voiding or the necessity of using fingers in the vagina to void. Owing to the fact that prolapse is rarely unicompartmental and weakness usually affects more than one compartment of the pelvic floor, we put special criteria in patients with multicompartmental prolapse (patients having anterior, apical, and posterior compartment prolapse detected by POP-Q and/or U/S) where rectal descent should not have exceeded 10 mm more than the bladder or cervical descent because our main scope in this study was to assess the anterior and apical compartmental prolapse and we did not put the third compartment, the posterior compartment under research in this study. For the control group, we included the patients coming to the gynecology clinic with symptoms other than prolapse as infection or infertility as long as they are aged above 18 as mentioned before.

Exclusion criteria

In our study, we intended to exclude from the start the patients who already had pelvic organ prolapse surgery even if they were experiencing symptoms of prolapse at time of selection of cases and those with positive

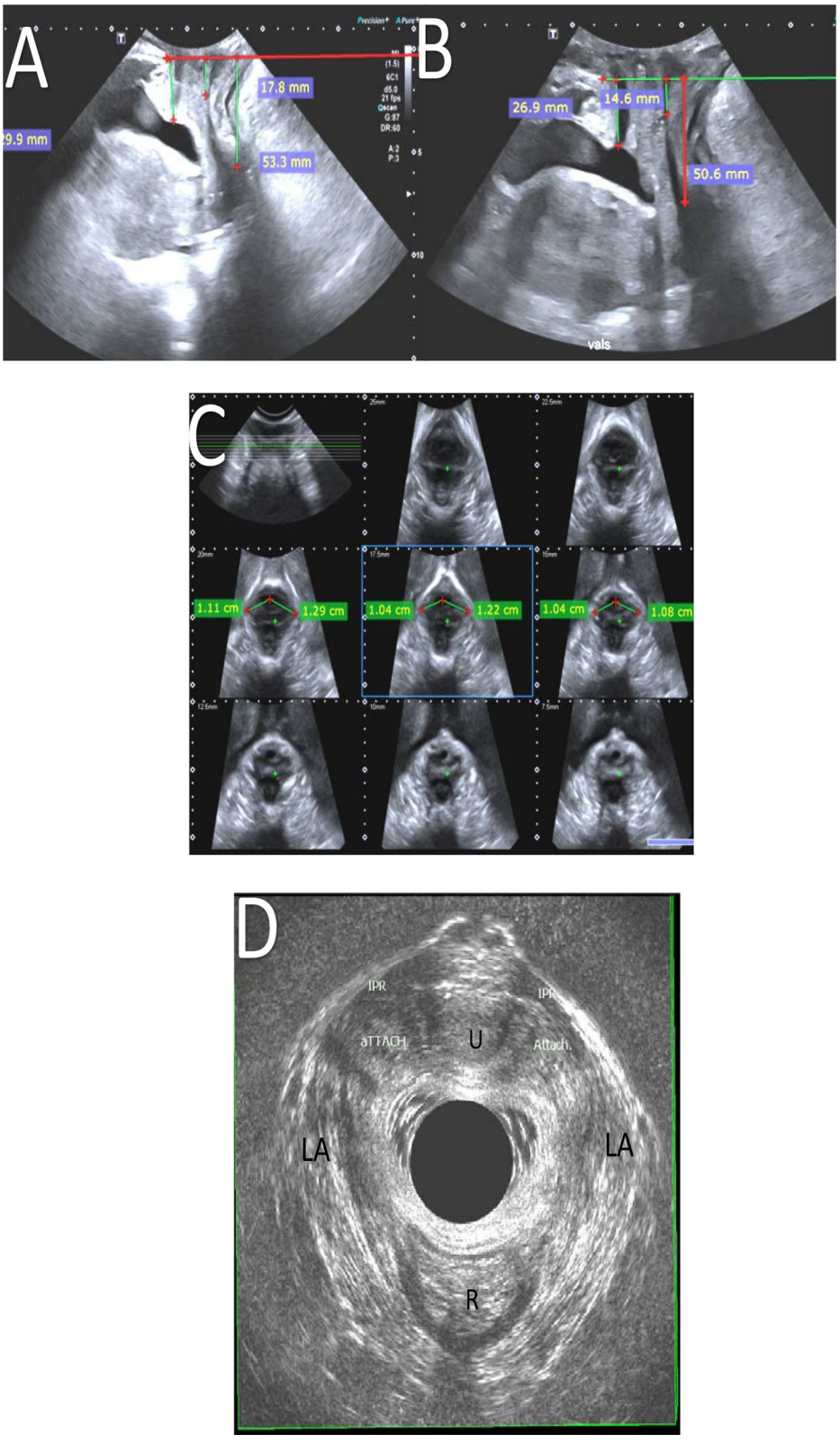

Fig. 2 (See legend on next page.)

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Fig. 2 Normal sonographic images of a 23-year-old female. A and B TPUS Sagittal view 2D images showing the position and the measurements of organs at rest and their descent upon valsalva, respectively (in relation to SP); urinary bladder neck: 29.9, 26.9 mm, cervix: 53.3, 50.6 mm, rectum:17.8, 14.6 mm. C TUI of the levator ani muscle on contraction showing the intact levator ani muscles on both sides and illustrating the levator urethral gap measurements in the central three slices bilaterally with calculated average value on both sides = 1.06 (Rt), 1.19 (Lt).D) Endocavitary 3D ultrasound shows intact attachments of the levator ani slings to the inferior pubic rami bilaterally. *IPR* inferior pubic ramus, *Attach* attachment of the levator ani to the inferior pubic ramus, *LA* levator ani, *U* urethra, *R* rectum

pregnancy test as pregnancy hormones lead to relaxation of the pelvic floor muscles and would have gave us incorrect data. We also omitted the patients with neurological and psychiatric disorders as these conditions would hinder obtaining correct information during POP-Q examination and ultrasound assessment as these patients would not be compliant enough with the orders of pelvic maneuvers as contraction and valsalva.

Assessment tools

All recruited patients were subjected to a Pelvic Floor Distress Inventory (PFDI-20) questionnaire. Also, patients were assessed by POP-Q to grade the severity of prolapse. In addition, patients were subjected to pelvic floor ultrasonography at rest and during contraction and valsalva. The data obtained from POP-Q system and pelvic floor ultrasound were compared.

POP-Q technique

Pelvic organ prolapse quantification (POP-Q) was done by the gynecologist with the patient in lithotomy position and her bladder was comfortably full. The six POP-Q coordinates (Aa, Ba, C, D, Ap, and Bp) were recorded on maximum valsalva. The three further descriptive measurements (Genital Hiatus (GH), Perineal Body (PB), and Total Vaginal Length (TVL)) were also taken during maximum valsalva apart from for the TVL. Two POP-Q points were mainly used for the analyses: the furthest descending point in the anterior vaginal wall (Ba) and the cervix (C) or vaginal vault in case of previous hysterectomy.

The above measurements were recorded on a 3 × 3 grid. Prolapse of each compartment was staged depending on the taken measurements according to Madhu et al. [10].

Pelvic Floor U/S technique and image analysis

A. Transperineal ultrasound (TPUS) (Fig. 2 A, B,C)

We used the Toshiba Aplio a550 ultrasound machine to perform real-time two-dimensional (2D) ultrasonography, via the transperineal approach, where the used probe was the convex transducer (frequency 1.5 to 6.1 Mega Hertz (MHz) put in the mid-sagittal plane at rest, during contraction and valsalva for the evaluation of the degree of pelvic organs descent. We also measured the retrovesical angle (RVS) on valsalva in cases of cystocele. Three-dimensional and four-dimensional ultrasonography was done using the 4D convex transducer (frequency 2.5–8 MHz) for tomographic or multislice imaging that was applied to assess the integrity of the levator ani muscle with assessment of levator urethral gap (LUG) bilaterally.

Levator Ani muscle assessment The multiplanar mode was used to illustrate the three orthogonal planes: midsagittal, axial, and coronal (taken during contraction). The tomographic ultrasound imaging (TUI) was also used defined as the presentation of the volumetric imaging data into eight axial images with 2.5-mm intervals adjusted from 5 mm below the plane of minimal hiatal dimension to 12.5 mm above it, where the plane of minimal hiatal dimension was the minimal distance between the posterior aspect of the symphysis pubis and the anterior border of the levator ani muscle just posterior to the anorectal angle. This plane is identified in the mid-sagittal orthogonal plane, which allows representation of this cross section of the volume in the axial plane for measurement of hiatal dimensions [11]. A special scoring system for assessment of the levator defects was adopted where the score was obtained according to the number of slices where the muscle discontinuity was identified; with a patient having no avulsion takes the score 0 and the patient with bilateral complete avulsion takes the score 16 (using the 6 slices that extends from the minimal hiatal dimension plane to 12.5 mm above it) [12]. This score was done for each side separately and then added. They assigned complete avulsion as the presence of abnormal muscle insertion present in at least the three central tomographic slices.

Levator urethral gap (LUG) The three central slices (the slice of the plane of minimal hiatal dimension, the previous, and the following ones) were especially used for evaluating the average levator urethral gap bilaterally where it is the distance between the urethral lumen and the levator's most medial insertion on the inferior pubic ramus. A cutoff value for LUG (2.5 cm), being very specific for the diagnosis of levator avulsion, was adopted [8].

Retrovesical Angle (RVA) Retrovesical angle is the angle between the bladder neck and the urethra posteriorly where we measured it on valsalva to differentiate the cystoceles in our study, according to the Green radiological classification, into Green II (open RVA (equal or more than 140 degrees)), mostly associated with stress urinary incontinence and Green III (intact RVA less than 140 degrees) associated with voiding dysfunction.

B. Endocavitary ultrasound (Fig. 2D)

For further levator ani muscle assessment, especially its attachment to the inferior pubic rami (IPR) bilaterally, this technique was adopted using the device "bk medical Flex Focus 400" ultrasound machine using type 2052 3D high-resolution 360° endocavitary transducer, of frequency 16–6 MHz.

In both techniques (A and B), the patient lied in dorsal lithotomy with a comfortably/moderately full bladder where in the TPUS, the probe was applied gently on the perineum with no pressure, while in the endocavitary technique, the probe was inserted in the vagina in a neutral position. 3-D data automatic acquisition covered the field of vision form the bladder neck to the external urethral meatus upon four standard levels of assessments. In this study, the third level was adopted to assess the levator ani slings and their attachments to IPR as introduced by Santoro et al. [13].

Post-processing and image analysis The ultrasound was done by two radiologists (the first with 11 years of experience and the second with 7 years of experience) in the same setting, and the final diagnosis was reached by their agreement (in consensus).

Sample size calculation Based on the data retrieved from Athanasiou et al. [14], a standard deviation (5.225) and effect size (5.86), a total sample size of 83 patients; 53 cases and 30 controls were determined.

Medcalc 19 tool was used by setting a 95% confidence level and 80% power.

Statistical analysis

Data were analyzed using IBM SPSS advanced statistics (Statistical Package for Social Sciences), version 23 (SPSS Inc., Chicago, IL). Qualitative data were described as numbers and percentages, while quantitative data were described as mean, standard deviation (SD), or median and range as appropriate. Chi-square test was done for categorical variable; Mann–Whitney test was done to independent nonparametric values. Sensitivity, specificity, and positive value of prediction and negative value of prediction were calculated for POP-Q and U/S with 95% confidence interval. A P value less than 0.05 was considered statistically significant. All tests were two-tailed.

The Gold standard of the study

We took POP-Q as the gold standard against which pelvic floor ultrasound was compared because POP-Q is the most widespread tool of quantification of pelvic organ prolapse performed by gynecologists.

Results

Among 83 included participants (53 in the case group and 30 in the control group), regarding the demographic factors, patients in the case group were older than those in the control group with a mean age of 50.83 and 28.77, respectively ($P=0.010$). Similarly, body mass index (BMI) assessment showed higher percentage among the cases compared to the control group where the mean value in the control group was 25.28 and, in the case, group was 32.55 ($P<0.001$) (Table 1).

The clinical background of the participants was studied. Worth to mention that 81.1% of the case group women gave history of heavy weightlifting of more than 10 kg for more than 3 months, while only 40% of the control group females gave such history. Also chronic cough and chronic constipation, as indicators of increased intra-abdominal pressure, was found in 50.9% and 60.4%, respectively, of the case group females, while this percentages declined significantly among the control group to be 10% and 16.7%, respectively ($P<0.001$) (Table 2).

Studying gynecological and obstetric characteristics among the studied population revealed a statistically positive correlation between the number of the vaginal deliveries in the cases and POP-Q ($rs=0.6$ and $P<0.001$), while a statistically negative correlation between the age at first vaginal delivery in the cases and the final POP-Q stage was detected ($rs=-0.4$ and $P=0.040$) (Table 3).

All the case group presented with seeing or feeling a vaginal bulge. Furthermore, POPDI (Pelvic Organ Prolapse Distress Inventory) score displayed a mean of 63.01 ± 22.84, while that of UDI (Urinary Distress Inventory) score was 53.54 ± 18.33. Moreover, a significant strong positive correlation between the summation of both POPDI and UDI score subdivisions of the PFDI-20 questionnaire and the final POPQ was detected ($P<0.001$) (Table 4).

Table 1 Demographic factors among the studied groups

Studied variable	Control		Case		*P* value of T test
Age					
Min. – Max	19–40		32–70		0.010*
Mean ± SD	28.77 ± 5		50.83 ± 8.3		
Median (IQR)	28.5 (7)		52 (12)		
	N	**%**	**N**	**%**	
Grades of obesity					
Healthy weight	17	56.7	1	1.9	< 0.001*(1)
Overweight	8	26.7	9	17	
Obesity I	4	13.3	30	56.6	
Obesity II	1	3.3	13	24.5	
Obesity III	0	0	0	0	
BMI					
Min.–Max	18.2–35.2		23.2–38.8		< 0.001*(2)
Mean ± SD	25.28 ± 4		32.55 ± 3.2		
Median (IQR)	23.7(6.2)		33.2(4.3)		

BMI Body mass index; *IQR* Inter-quartile range; *SD* Standard deviation

*Statistically *significant at P ≤ 0.05*

(1) *T* test; (2)Mann–Whitney U test

Table 2 General clinical background of the studied groups

Studied variables	Control		Case		*P* value
	N	**%**	**N**	**%**	
Hypertension					
No	26	86.7	28	52.8	0.002*
Yes	4	13.3	25	47.2	
DM					
No	27	90	33	62.3	0.007*
Yes	3	10	20	37.7	
Hypertension and DM					
No	30	100	42	79.2	< 0.001*
Yes	0	0	11	20.8	
Heavy weightlifting					
No	18	60	10	18.9	< 0.001*
Yes	12	40	43	81.1	
Smoking					
No	29	96.7	48	90.6	0.303
Yes	1	3.3	5	9.4	
Chronic cough					
No	27	90	26	49.1	< 0.001*
Yes	3	10	27	50.9	
Chronic constipation					
No	25	83.3	21	39.6	< 0.001*
Yes	5	16.7	32	60.4	
Family history of prolapse or hernia					
No	22	73.3	12	22.6	< 0.001*
Yes	8	26.7	41	77.4	

*Statistically significant at *P*

Assessing the symptoms in the studied population using POP-Q revealed that 51 cases (96.2%) had anterior compartment prolapse (either alone or with apical compartment prolapse), 52% had apical compartment prolapse (either alone or with anterior compartment prolapse), 47.2% had anterior compartment prolapse only, and 3.7% had apical compartment prolapse only. There was statistically significant difference between points Ba and C among the control and case groups ($P < 0.001$), given that the negative values are above the hymen, while the positive values are below the hymen (Table 5).

Studying the characteristics of valsalva using 2-D U/S revealed a significant difference between controls and cases in both bladder descent and cervix descent at valsalva, considering that the negative sign is assigned for any measurement taken below the symphysis pubis (Table 6; Figs. 3 and 4).

The retrovesical angle in the cases of cystocele ranged from 70 to 177 with a mean value of 111.3. Upon classifying the cystoceles according to the Green radiological classification using the RVA during valsalva, there were 14 cases of Green type II (29.16) and 34 cases of Green type III (70.83) (Table 7).

Assessing LUG and levator ani muscle revealed that the control group showed a mean of 1.27 and ranged from 1 to 2.1 with a mean value of 1.29 on the right and left sided, respectively. Among the case group, this variable ranged from 1 to 2.7 with a mean value of 1.46 and

Table 3 Gynecological and obstetric background among the studied

Studied variables	Control		Case		*P* value
	N	%	N	%	
Menopause					
No	30	100	23	43.4	< 0.001*(1)
Yes	0	0	30	56.6	
Mode of delivery					
Nullipara	15	50	0	0	< 0.001*(2)
C/S	10	33.3	0	0	
Vaginal	5	16.7	49	92.5	
Vaginal + C/S	0	0	4	7.5	
Number of delivery					
Min.–Max	0–2		1–7		< 0.001*(1)
Mean ± SD	0.87 ± 0.9		4 ± 1.4		
Median (IQR)	0.5(2)		4(2)		

No		Yes		Can't remember		*P* value
N	%	N	%	N	%	
Forceps use in vaginal delivery in cases (n = 53)						
49	92.5	1	1.9	3	5.7	1.000(1)
Age at first vaginal delivery in cases (n = 53)						
Min.–Max			14–32			
Mean ± SD			19.5 ± 3.5			
Median (IQR)			19(4)			

Chi-square test (2) Monte Carlo test

C/S Cesarean Section; *IQR* Inter-Quartile Range; *SD* Standard deviation

Table 4 Relevant history taking and PFDI-20 questionnaire (POPDI and UDI subdivisions):

Studied variables	Cases		*P* value
	N	%	
Seeing or feeling vaginal bulge			
No	0	0	< 0.001*
Yes	53	100	
POPDI score			
Min.–Max	20.8–95.8		–
Mean ± SD	63.01 ± 22.84		
Median (IQR)	66.6 (41.7)		
UDI score			
Min.–Max	20.8–87.5		–
Mean ± SD	53.54 ± 18.33		
Median (IQR)	50 (20.9)		
Final POP-Q stage			
Rs			***P***
POPDI score + UDI score			
0.9			< 0.001*

POPDI: Pelvic Organ Prolapse Distress Inventory; UDI: Urinary Distress Inventory IQR: Inter-Quartile Range

SD: Standard deviation Fisher exact test; *: Statistically significant at P ≤ 0.05

Table 5 Clinical perspective and POP-Q assessment

Type of prolapse in the case group according to POP-Q		
Type of prolapse (N = 53)	**N**	**%**
Anterior compartment prolapse	51	96.2
Apical compartment prolapse	28	52.8
Anterior compartment prolapse only	25	47.2
Apical compartment prolapse only	2	3.7

Points Ba and C (POPQ coordinates) and anterior and apical compartments (stratified clinically into POPQ stages) among the studied groups					
Studied variable*	**Control**		**Case**		***P* value**
Point Ba					
Min.–Max	−3 to −2		−2 to 7		< 0.001*(1)
Mean ± SD	−2.6 ± 0.498		1.75 ± 1.53		
Median (IQR)	−3(1)		2(1)		
Point C					
Min.–Max	−6 to −3		−5 to 8		< 0.001*(1)
Mean ± SD	−4.83 ± 1.02		−0.34 ± 3.43		
Median (IQR)	−5(2)		1(5)		
POP Q stage	**N**	**%**	**N**	**%**	***P* value**
Anterior compartment					
Stage 0	18	60	1	1.9	< 0.001*(2)
Stage 1	12	40	1	1.9	
Stage 2	0	0	22	41.5	
Stage 3	0	0	28	52.8	
Stage 4	0	0	1	1.9	
Apical compartment					
Stage 0	30	100	25	47.2	< 0.001*(2)
Stage 1	0	0	0	0	
Stage 2	0	0	6	11.3	
Stage 3	0	0	21	39.6	
Stage 4	0	0	1	1.9	
Final					
Stage 0	18	60	0	0	< 0.001*(2)
Stage 1	12	40	0	0	
Stage 2	0	0	19	35.8	
Stage 3	0	0	33	62.3	
Stage 4	0	0	1	1.9	

POPQ Pelvic organ prolapse quantification; *IQR* Inter-Quartile Range; *SD* Standard deviation (1)Mann–Whitney U test, Chi-square test

*The negative values are above the hymen, while the positive values are below the hymen

1 to 2.1 with a mean value of 1.44 on the right and left sides, respectively.

Moreover, a diabetic hypertensive 69-year-old female who had stage 3 prolapse, showed right levator ani tear which was evident on TPUS where the right average LUG was 2.67 cm, the left was 1.4 cm, and the tear was found in the three central tomographic images ($3 \times 2.5 = 7.5$ mm in thickness). The tear was also evident on endovaginal US (Fig. 5). This lady gave history of forceps use during vaginal delivery in two out of her seven births.

Table 6 Sagittal 2-D U/S findings on valsalva (bladder descent and cervical descent) among the studied groups:

Studied variable	Control	Case	*P* value
Bladder descent at valsalva			
Min.–Max	29.8 to 9.8	10 to −72	< 0.001*
Mean ± SD	18.19 ± 5.93	−20.7 ± 13.64	
Median (IQR)	16.85 (11.63)	−20(10.6)	
Cervix descent at valsalva			
Min.–Max	56.1 to 21.1	43.2 to −72	< 0.001*
Mean ± SD	41.59 ± 9.28	−1.41 ± 31.68	
Median (IQR)	43.1 (10.93)	−14 (49.35)	

Mann–Whitney U test

IQR Inter-Quartile Range; *SD* Standard deviation

*Statistically significant at $P \leq 0.05$

Transperineal U/S was able to differentiate prolapse among its mimickers where a 34-year-old female patient presented with seeing vaginal bulge for a year and urge incontinence where she was diagnosed as cystocele stage 3 by POPQ and turned out to be a mass by ultrasound, an aggressive angiomyxoma proven by pathology (Fig. 6).

A strong significant correlation is shown between bladder and cervix descent (relative to symphysis pubis) on U/S and point Ba and Point C at POP-Q, respectively (Table 8).

Studying the sensitivity and specificity of point Ba and those for bladder neck descent at valsalva in the detection of anterior compartment prolapse and cystocele in POP-Q, respectively, revealed a sensitivity of 98% and 95.9%, respectively, and a specificity of 97% and 10%, respectively (Table 9).

There was a strong agreement (almost perfect) between (POP-Q) and U/S in detecting significant pelvic organ prolapse in the anterior compartment (Kappa value 0.925, $P < 0.001$) and the apical compartment (Kappa value 0.945 and $P < 0.001$) (Table 10).

Discussion

Female POP is a widespread condition that has a major negative impact on QoL, affecting 10–20% of parous females [15, 16]. Better perception of the female pelvic floor anatomy has been achieved through 3-D U/S scanning [17]. Ultrasound comprises a safe, simple, cheap, and an easy technique for physicians and allows the evaluation of pelvic floor functional anatomy during maneuvers e.g., valsalva [18]. Although the POP-Q is used frequently to assess POP, it uses a moving structure (i.e., hymen) as the reference point to measure pelvic organ descent, based on expert opinion, with no information on primary organs or functional anatomy [19].

In this study, we aimed to compare the diagnostic efficacy of U/S correlated to POP-Q where we revealed a strong significant correlation between the measurements of the bladder and cervix descent on U/S and point Ba and point C at POP-Q, respectively. Similarly, a strong correlation between POP-Q and U/S measures in the anterior and apical compartments ($rs = 0.84$, $P < 0.001$) and ($rs = 0.78$, $P < 0.001$), respectively [20] was revealed. Also, a strong correlation regarding apical compartment prolapse, between point C and cervical descent in U/S ($r = 0.77$), was demonstrated as well as that between point Ba and the bladder descent on U/S ($r = 0.72$) [21]. Other study results have met same conclusion [22, 23]. On the contrary, a meta-analysis showed that pelvic floor U/S was a valued diagnostic tool for POP; nevertheless, it might show a weak precision compared to physical examination [24]. Worth to mention that they admitted that their results are opposite to many previous views due to the fact that many of the participants had undergone pelvic floor surgery, unlike our study where we excluded the women who underwent pelvic prolapse surgical correction. Also, Maheut et al. [25] revealed no correlation between POP-Q and U/S of bladder prolapse, putting into consideration that they mentioned that the ultrasound datasets were limited by an important number of

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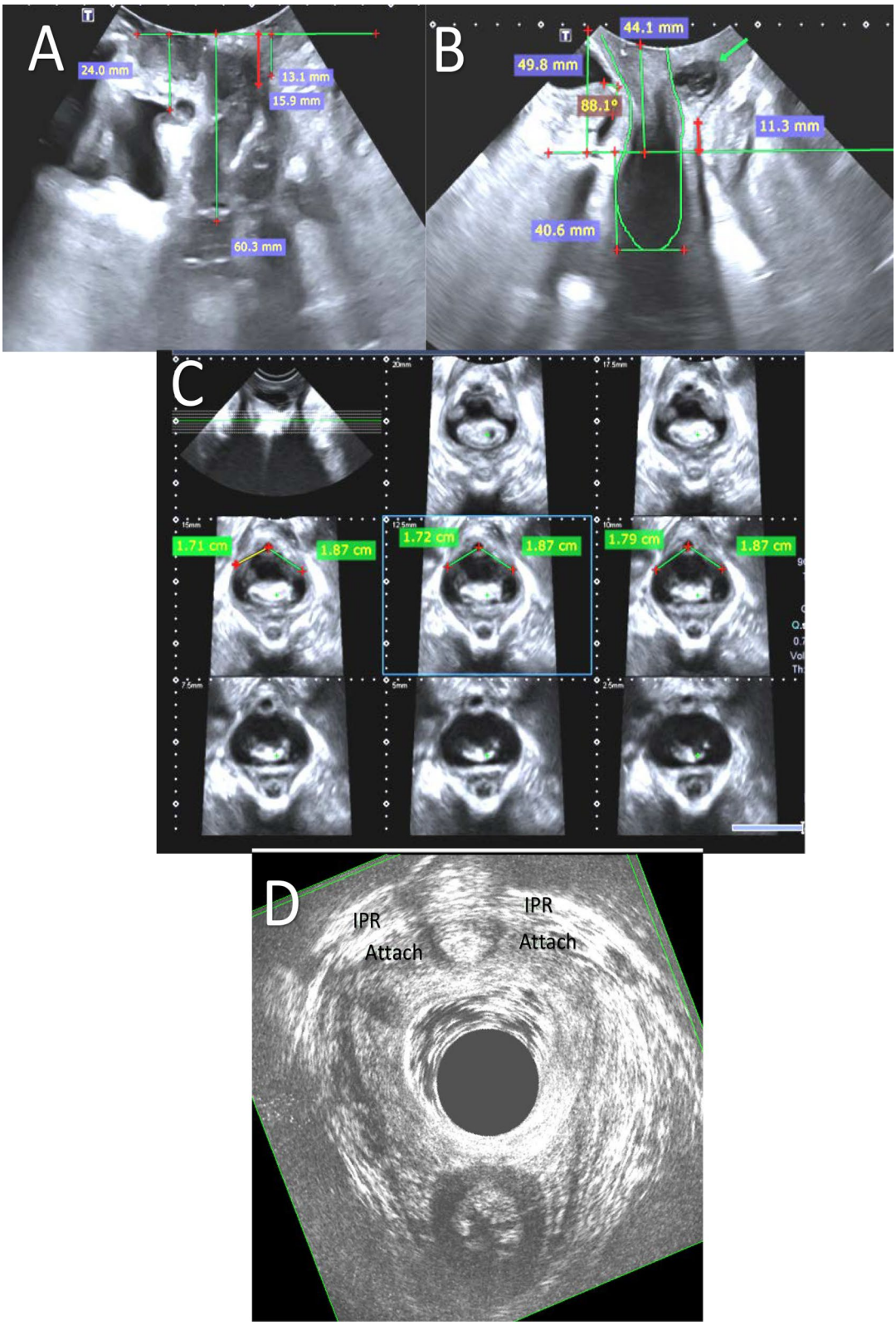
Fig. 3 A 52-year-old female patient with a complain of progressive vaginal bulge for 10 years. **A** and **B** TPUS Sagittal view 2D images showing the position and measurements of organs at rest and their descent upon valsalva, respectively (in relation to the SP), as well as the RVA;urinary bladder:24, −49.8 mm, cervix: 15.9, −44.1 mm, rectum: 13.1, −11.3 mm. RVA:86.3 degrees. Note the posterior vaginal wall cyst (green arrow). **C** TUI of the levator ani muscle on contraction showing the levator urethral gap measurements in the central three slices with calculated average value on both sides = 1.74 (Rt), 1.87 (Lt). **D** Endocavitary 3D ultrasound shows intact attachment of the levator ani slings to the inferior pubic rami bilaterally



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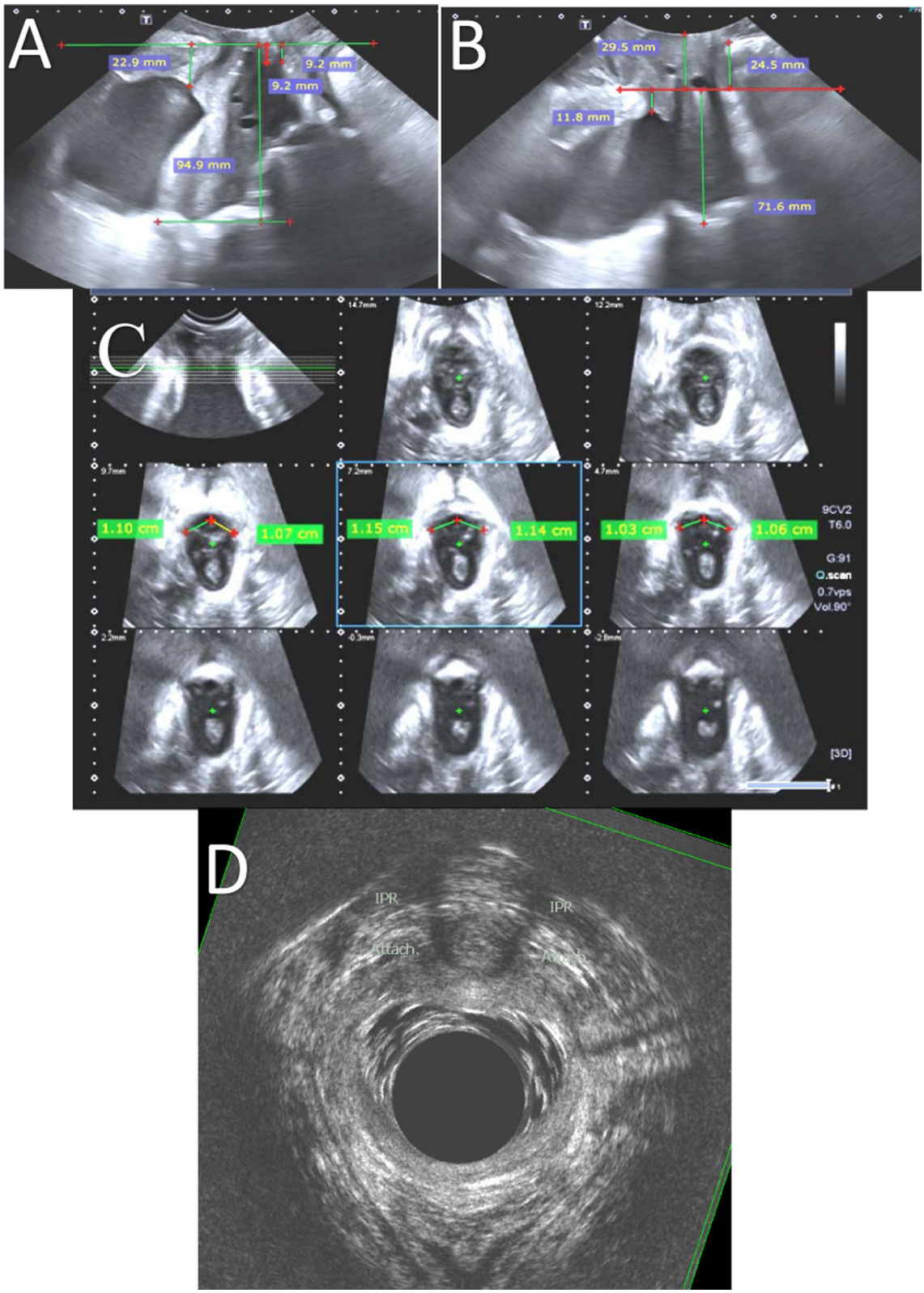

Fig. 4 (See legend on next page.)

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Fig. 4 A 48-year-old diabetic female patient with a complain of progressive vaginal bulge for 2 years. **A** and **B** TPUS Sagittal view 2D images showing the position and measurements of organs at rest and their descent upon valsalva, respectively (in relation to SP), as well as the RVA; urinary bladder: 22.9,11.8 mm, cervix: 9.2, −29.5 mm (notice the nabothian cysts; white arrow), rectum: 9.2, −24.5 mm. **C** TUI of the levator ani muscle on contraction showing the intact levator ani muscles on both sides and illustrating the levator urethral gap measurements in the central three slices bilaterally with calculated average value on both sides = 1.09 (Rt),1.09 (Lt). **D** Endocavitary 3D ultrasound shows intact attachment of the levator ani slings to inferior pubic rami bilaterally

missing data. From our side we suggested that this deficiency was probably due to inexperience with ultrasound machinery to obtain the optimum data.

In our study, the proposed cutoff values of point Ba in POP-Q and bladder neck descent in U/S were 0 and −11.5, respectively, which showed high sensitivity and specificity (Figs. 7 and 8). This is consistent with Dietz et al. [15] where in their study a bladder descent to ≥ 10 mm beneath the symphysis pubis (−10) was strongly correlated to symptomatology and they adopted this value as cutoff for the diagnosis of significant prolapse. Similarly, Dietz and Mann [19] suggested a cutoff value of −0.5 for Ba point with (sensitivity 69%, specificity 71%). A similar conclusion was retrieved by Kamisan et al. [26]. Furthermore, Dietz and Lekskulchai [27] displayed a cutoff of ≥ 10 mm descent beneath the symphysis pubis for the bladder which was strongly correlated with the symptoms.

Despite the previously reported cutoff value of 15 mm above symphysis pubis on maximum valsalva [28] to predict prolapse symptoms due to uterine descent, we did not propose a cutoff value for point C of POP-Q or the cervical descent on ultrasound. We only consider significant prolapse to be clinically important, as early stages present mostly with vague symptoms such as back pain or fullness and heaviness which are objective and nonspecific to this type of prolapse (apical compartment prolapse). However, seeing or feeling a mass protruding from the vulva (when it is at the level of the hymen or below) was considered clinically significant by Volløyhaug et al. [9] as well as our study results. Additionally, Dietz and Lekskulchai [27] agreed with our perspective where the unspecific symptoms and the descent of the pelvic organs were not as clear for uterine descent when compared to cystocele and rectocele.

Another study defined -5 cm above the hymen as a cutoff for uterine prolapse based on the feeling of "vaginal lump" or even "dragging sensation" of the vagina [19], yet this could be criticized as "dragging" and "lump" are rather nonspecific complaints and could be present in a myriad of clinical scenarios. On the contrary, Kamisan et al. [26] found that the previously proposed cutoffs of C = −5 (POP-Q) and a uterine location of 15 mm above the symphysis pubis (in U/S) are mutually consistent, even if somewhat counterintuitive, given that C = −5 would commonly be considered as normal as they described. Similarly, Volløyhaug et al. [9] acknowledged that C-5 was not counted as clinically relevant by most urogynecologists. Thus, they chose to use a cutoff of 0 mm, which corresponded to C-1 and prolapse grade 2. Out of this, we were concerned to identify the correlation between point C of POPQ and cervical descent on ultrasound as well as the agreement of both methods upon the term significant prolapse, taking into consideration that this significant POP is generally defined as POP-Q stage ≥ 2.

Table 7 Retrovesical angle assessment in cystocele cases (*N* = 48)

	Cystocele	
Retro vesical angle	Min.–Max	70–177
	Mean ± SD	111.3 ± 27.88
	Median (IQR)	106.75(41.28)
	N	**%**
Green radiological classification of cystocele		
Green II	14	29.16
Green III	34	70.83

IQR Inter-quartile range ; *SD* Standard deviation

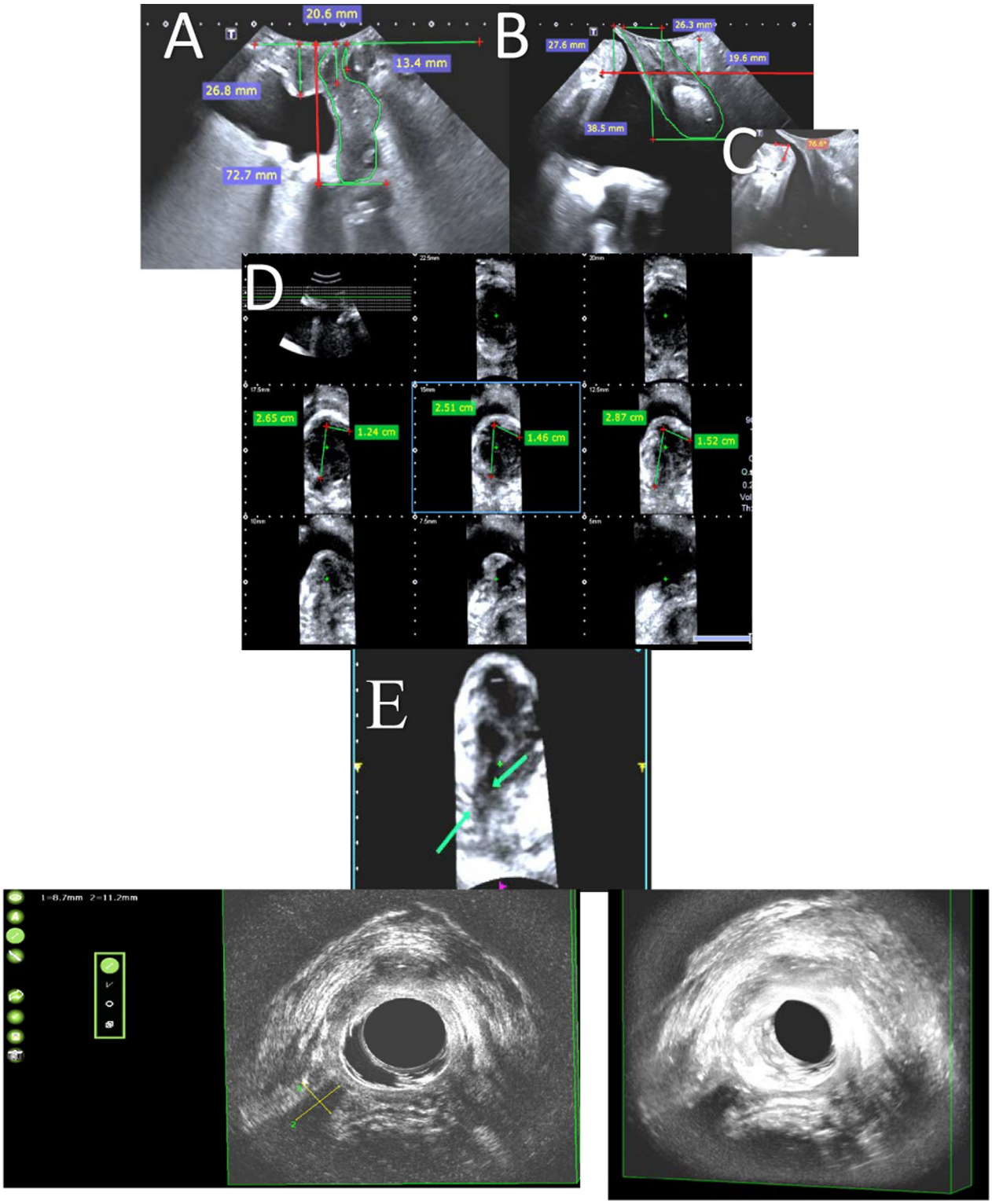

Fig. 5 A 69-year-old female patient complained of vaginal bulge for 20 years and voiding dysfunction. **A** and **B** TPUS Sagittal view 2D images showing the position and measurements of organs at rest and their descent upon valsalva, respectively (in relation to SP); urinary bladder:26.8, −27.6 mm cervix: 20.6, −26.3 mm rectum: 13.4, −19.6 mm. **C** RVA measured 76.6 degrees. **D** TUI of the levator ani muscle on contraction showing the levator urethral gap measurements in the central three slices bilaterally with calculated average LUG on both sides = 2.67(rt), 1.4 (lt). **E** axial image of the levator ani muscle on contraction showing the right levator ani tear/gap (green arrows). **F** Endocavitary 3D ultrasound. **G** Its volume-rendered mode showing the right levator ani defect measured 8.7 × 11.2 mm

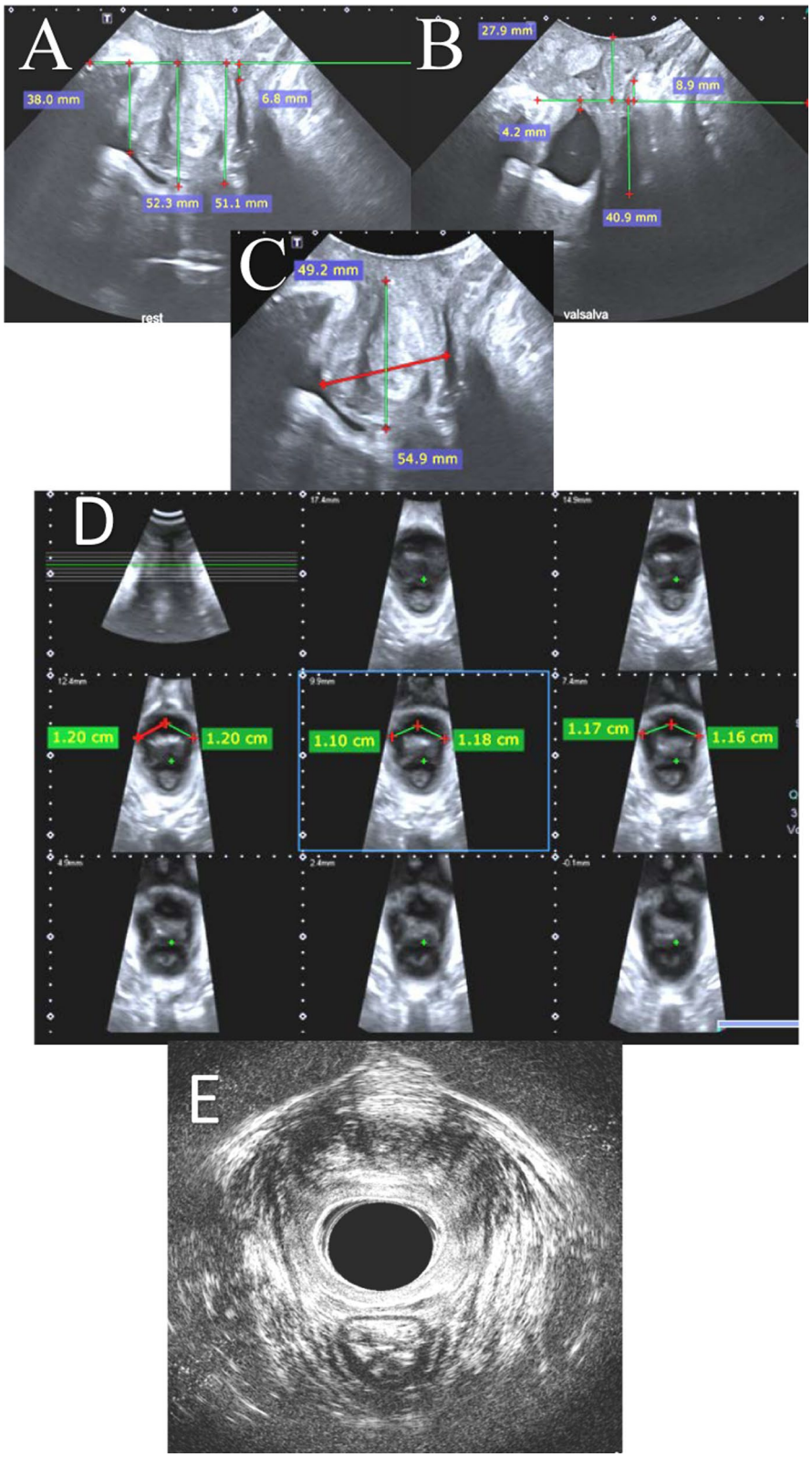

Fig. 6 (See legend on next page.)

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Fig. 6 A 34-year-old female patient with a complain of seeing a vaginal bulge for a year and urge incontinence. **A** and **B** TPUS Sagittal view 2D images showing the position and the measurements of organs at rest and their descent upon valsalva, respectively (in relation to SP); urinary bladder: 38, 4.2 mm, cervix: 51.1, 40.9 mm, rectum: 6.8, −8.9 mm, prolapsing mass: 52.3, −27.9 mm. **C** The heterogeneous mass measured 49.2 × 54.9 mm in maximum dimensions. **D** TUI of the levator ani muscle on contraction showing the intact levator ani on both sides and illustrating the levator urethral gap measurements in the central three slices bilaterally with calculated average value on both sides = 1.15 (Rt),1.14 (Lt). **E** Endocavitary 3D ultrasound shows intact attachment of the levator ani slings to inferior pubic rami bilaterally

Table 8 Correlation between bladder and cervix descent on U/S and point Ba and Point C at POP-Q, respectively:

	Rs	*P*
POP_Q (Point Ba)		
Bladder descent in U/S	0.971	< 0.001*
POP_Q (Point C)		
Cervix descent in U/S	0.984	< 0.001*

Regarding the agreement, generally, between POP-Q and U/S in detecting significant POP in the anterior and apical compartments (Kappa value 0.925, 0.945; $P < 0.001$), respectively, were retrieved in our study. Similarly, high agreement was obtained between POP-Q and U/S staging systems in anterior and apical compartments by Arian et al. [20] where the Kappa coefficient of agreement was 0.73 and 0.69, respectively. However, Volløyhaug et al. [9] and Dietz et al. [15] determined the agreement between POP-Q and U/S in the anterior and apical compartments as follows; Cohen's kappa (κ) were 0.56 and 0.51, respectively, for the anterior compartment (moderate agreement) and 0.31 and 0.37, respectively, for the apical compartment (fair agreement).

From our point of view, what made our study unique in comparison with the others (which correlated the efficacy of pelvic floor ultrasound to POP-Q studies) that we added more information in form of assessment of the levator ani status of each participant by the 3D/4D transperineal ultrasound and the endovaginal ultrasound as well. We not only detected bladder descent (cystocele), but also we targeted identifying its type according to the

Table 9 Sensitivity and specificity for point Ba and bladder neck descent (U/S) in detection of cystocele:

AUC	P	Cutoff point	Sensitivity	Specificity	95% CI	
Sensitivity and specificity for point Ba of POPQ in the detection of anterior compartment prolapse						
0.982	< 0.001*	0	98%	97%	0.948	1
Sensitivity and specificity for bladder neck descent at valsalva measured by ultrasound in the detection of cystocele						
0.99	< 0.001*	11.5	95.9%	100%	0.967	1

AUC Area under the curve; *CI* confidence interval

*Statistically significant at $P \leq 0.05$

Table 10 Agreement between sonographic and POP-Q data upon the clinical definitions of "significant prolapse":

Ultrasound diagnosis	POP-Q diagnosis				Kappa value	*P* value
	No		Yes			
	N	%	N	%		
Anterior prolapse						
No	32	91.4	3	8.6	0.925	< 0.001*
Yes	0	0	48	100		
Apical prolapse						
No	55	96.5	2	3.5	0.945	< 0.001*
Yes	0	0	26	100		

POP-Q Pelvic organ prolapse quantification

*Statistically significant at $P \leq 0.05$

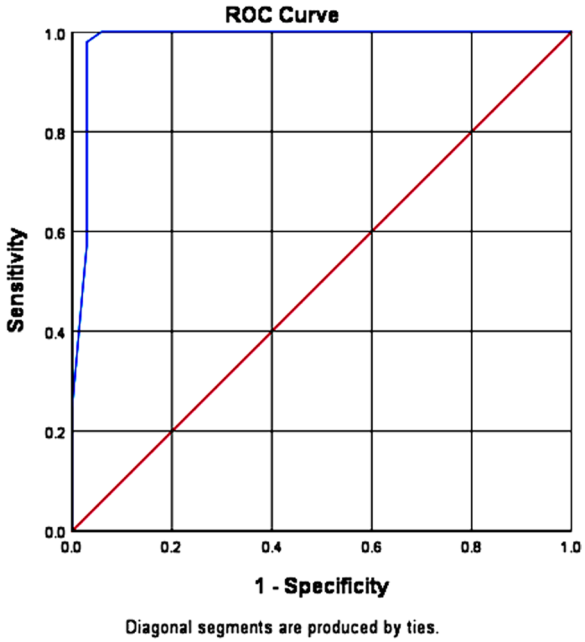

Fig. 7 ROC curve and the performance of POP-Q for the diagnosis of significant anterior compartment prolapse (cystocele)

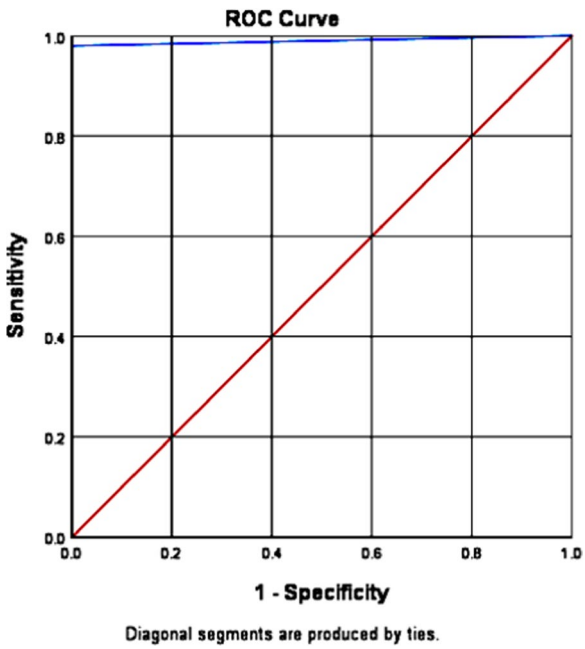

Fig. 8 ROC curve and the performance of ultrasound in bladder decent on valsalva for the "diagnosis of significance"

Green radiological classification of cystocele which surely affected the surgical management of these patients. Worth to mention that we did not include any patients who underwent POP intervention/surgery, which gave us adequate assessment of the pelvic floor anatomy.

Limitation

The control group did not include old aged or menopausal women as we targeted this group mainly from the patients who came for infertility or complaining of genital tract infection, while the females with prolapse, in most cases, belong to a higher age group.

Conclusion

Our study revealed that U/S is an indispensable diagnostic tool for full diagnosis of POP, especially the anterior and apical compartments. Transperineal U/S provides general and detailed anatomical overview of this region and allows documentation of findings as well. Levator ani muscle assessment was done efficiently by U/S. Moreover, levator avulsion and levator ani defects were documented with measurement of the gap (tear) and assessing its depth. Furthermore, assessing cystocele type could be done according to the Green radiological classification using mainly the RVA on valsalva.

Abbreviations

2-D	Two-dimensional
3-D	Three-dimensional
BMI	Body mass index
C	Cervix
GH	Genital hiatus
ICS	International Continence Society
IPR	Inferior pubic rami
LUG	Levator urethral gap
MHz	Mega Hertz
MRI	Magnetic resonance imaging
PB	Perineal body
POP	Pelvic organ prolapse
POPDI	Pelvic Organ Prolapse Distress Inventory
POP-Q	Prolapse quantification system
PVDI-20	Pelvic Floor Distress Inventory
QoL	Quality of life
ROC	Receiver operating characteristic
RVS	Rectovesical angle
SD	Standard deviation
TUI	Tomographic ultrasound imaging
TVL	Total vaginal length
UDI	Urinary distress inventory
U/S	Ultrasound

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Author contributions

All authors have read and approved the manuscript. TG, SH, HE, HH, and HA contributed equally to this work. TG and SH designed research. HA and HE performed research. HE and HH analyzed data. TG and HA wrote the paper.

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Availability of data and materials

All the datasets used and analyzed during this study are available with the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the research ethics committee of the radiology department of the Faculty of Medicine Cairo University on 10/11/2020, Reference number of approval (MD-289-2020). All patients included in this study gave a written informed consent to participate in the research. If the patient was less than 16 years old, or unconscious at the time of study, written informed consent was given by their parent or legal guardian.

Consent for publication

All patients included in this study gave a written informed consent to publish the data contained in this study. If the patient was less than 16 years old, or unconscious at the time of study, written informed consent was given by their parent or legal guardian.

Competing interests

The authors declare that they have no competing interests.

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