Has 4D transperineal ultrasound additional value over 2D transperineal ultrasound for diagnosing obstructed defaecation syndrome?

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Plain language summary

Two-dimensional and four-dimensional transperineal ultrasound are equally good in diagnosis of posterior pelvic floor disorders and could both be used to screen women with obstructed defaecation syndrome.

Abstract

Objective

To establish the diagnostic test accuracy of both two-dimensional (2D) and four-dimensional (4D) transperineal ultrasound, to assess if 4D ultrasound imaging provides additional value in the diagnosis of posterior pelvic floor disorders in women with obstructed defaecation syndrome.

Methods

In this prospective cohort study, 121 consecutive women with obstructed defaecation syndrome were recruited. Symptoms of obstructed defaecation and signs of pelvic organ prolapse were assessed using validated methods. All women underwent both 2D transperineal ultrasound (Pro-focus, 8802 transducer, BK-medical) and 4D transperineal ultrasound (Voluson i, RAB4-8-RS transducer, GE). Imaging analysis was performed by two blinded observers. Pelvic floor disorders were dichotomised into presence or absence according pre-defined cut-off values. In the absence of a reference standard a composite reference standard was created from a combination of results of evacuation proctogram, magnetic resonance imaging and endovaginal ultrasound. Primary outcome measures were diagnostic test characteristics of 2D and 4D transperineal ultrasound for diagnosis or rectocele, enterocele, intussusception and anismus. Secondary outcome measures were interobserver agreement, agreement between the two techniques and correlation of signs and symptoms to imaging findings.

Results

For diagnosis of all four posterior pelvic floor disorders there was no difference in sensitivity and specificity between 2D and 4D TPUS (p= 0.131 – 1.000). A good agreement between 2D and 4D TPUS was found for the diagnosis of rectocele (κ 0.675) and a moderate agreement for diagnosis of enterocele, intussusception and anismus (κ 0.465 – 0.545). There was no difference in rectocele depth measurements between both TPUS techniques (19.9 mm vs 19.0 mm, p=0.802). Inter-observer agreement was comparable for both techniques, however 2D TPUS had an excellent interobserver agreement for diagnosis of enterocele and rectocele depth measurements. Diagnosis of rectocele and enterocele on both 2D and 4D TPUS correlated well with presence of posterior vaginal wall prolapse on clinical examination (OR 1.89 - 2.72). In this group of ODS patients, the imaging findings on both techniques did not correlate with severity of symptoms of ODS (OR 0.82 - 1.08).

Conclusions

There is no evidence of a superiority of 4D ultrasound acquisition to dynamic 2D ultrasound acquisition for the diagnosis of posterior pelvic floor disorders. Both 2D and 4D TPUS could be used interchangeably to screen women with symptoms of obstructed defaecation.

Introduction

Obstructed defaecation syndrome (ODS) is caused by posterior pelvic floor disorders, which are responsible for the sensation of incomplete emptying, excessive straining or the need to manually assist evacuation.[1] In current practice, diagnosis is made either using evacuation proctography (EP) or dynamic magnetic resonance imaging (dynamic MRI).[2,3] Transperineal ultrasound (TPUS) has been suggested as an alternative to address disadvantages such as ionising radiation, bowel preparation, and embarrassment of the evacuation phase, in addition to high costs and waiting lists.[4] TPUS could be used as the initial examination or screening method in patients with ODS suspected to have a rectocele, enterocele or intussusception.[5-8]

TPUS can be performed using a two-dimensional (2D) or a four-dimensional (4D) method. 2D TPUS acquires still images and dynamic cineloops in the mid-sagittal plane only, whereas 4D TPUS has the ability to acquire still images (3D) and dynamic cineloops (4D) simultaneously in three planes (axial, sagittal and coronal). This real-time acquisition of 4D ultrasound volumes enables offline assessment of rendered volumes in all orthogonal planes.[7]

The diagnostic accuracy of both 2D TPUS and 4D TPUS have been assessed compared to EP,[5,9-14] however it has not been established if 4D data acquisition improves diagnostic accuracy over 2D by assessing both 2D and 4D TPUS in the same population. We hypothesised that 2D and 4D TPUS are equally good for the diagnosis of posterior pelvic floor disorders, as the mid-sagittal plane used in both techniques provides the most diagnostic information.

EP is considered to be the reference standard, however it is known to over diagnose pelvic floor disorders[15] and has a significant inter-observer variability;[16,17] therefore its use as a reference standard is questionable. It has been proven that dynamic MRI and endovaginal ultrasound (EVUS) have a similar diagnostic accuracy as EP.[8,18]

The objective of this study was to establish the diagnostic test accuracy of both 2D TPUS and 4D TPUS, using a combination of the results of MRI, EP and EVUS as reference standard, with the aim to determine if 4D imaging provides additional diagnostic information in the assessment of women with ODS.

Methods

Patient recruitment

In this prospective cohort study, between January 2014 and January 2015 consecutive women with symptoms of ODS were recruited from urogynaecology and colorectal surgery clinics in Croydon University Hospital. This current study is part of a large cohort study, which aimed to assess the accuracy of MRI, EP and pelvic floor ultrasound for the detection of posterior pelvic floor disorders.[8] For this primary study ethical approval was obtained from the National Research Ethics Service (REC 13/LO/1665). Exclusion criteria were inability to understand English, age under 18 years and lacking mental capacity. Women with previous pelvic floor surgery were not excluded. All women gave written informed consent. Demographic data were collected and symptoms were assessed using validated ODS questionnaires.[19,20] Pelvic organ prolapse (POP) was assessed using the validated ICS-POP-Q.[21] Time difference between all imaging techniques was kept as short as possible.

Image acquisition

Both 2D and 4D TPUS were performed in the supine position with the knees semi flexed. The women were asked to have a comfortably full bladder. No vaginal or rectal contrast was used. 2D TPUS was performed with the BK Medical pro-focus using a 2D curved array transducer (type 8802, 3.5-6.0 MHz, focal range 10-135 mm, BK medical, Denmark). 4D TPUS was performed with the GE Voluson i system using a 3D/4D curved array transducer with an acquisition angle of 85° (type RAB4-8-RS, 4-8.5 MHz, GE Medical Systems, Zipf, Austria). For both techniques the probe was placed gently on the perineum in a vertical position. In the mid-sagittal plane, the following structures were identified: symphysis pubis, bladder, urethra, vaginal walls, anal canal, rectum and the levator ani muscle sling. For 2D TPUS still images and cineloops were acquired in the mid-sagittal plane at rest, squeeze and maximum pelvic floor strain. For 4D TPUS still images and dynamic cineloops were acquired simultaneously in all three planes (axial, sagittal and coronal) at rest, squeeze and maximum pelvic floor strain. For each technique three cineloops of maximum pelvic floor strain were recorded and the best was used for evaluation. Both 2D and 4D TPUS were performed by the same operator (I.v.G.) experienced in pelvic floor ultrasound (> 200 ultrasound scans performed).

Image analysis

The ultrasound volumes were saved anonymously and exported for offline analysis. Two-dimensional BK TPUS cineloops were analysed in the mid-sagittal plane using Windows software. For rectocele depth measurements, the cineloop was stopped at the point of maximum Valsalva using VirtualDub© and measurements were taken with the aid of the Meazure© software. Four-dimensional GE TPUS cineloops were analysed by manipulating the 4D volume in the mid-sagittal, coronal and axial planes using 4D-view software (version 10.2, GE Medical Systems). All cineloops were assessed by two independent observers (I.v.G. and K.K.) who were blinded to clinical findings and results of the other imaging techniques. The 2D and 4D TPUS cineloops were assessed at least 3 months after acquisition and at least 3 months from each other to avoid recognition bias. Possible discrepancies were resolved by a third observer (R.T.), who is an urogynaecologist with more than 10 years' experience in pelvic floor ultrasound. The four posterior pelvic floor disorders were dichotomised in to presence or absence of the condition. A rectocele was defined as a diverticulum of the anterior rectal wall at Valsalva with a depth of at least 15 mm.[8,22] The rectocele depth was measured perpendicular to the line drawn parallel to the anterior border of the anal canal, which is the expected contour of the rectal wall (Figure 1a). An enterocele was present at Valsalva if small bowel loops extended below the posterio-inferior border of the symphysis pubis (Figure 1b).[23] An intussusception was present if a full-thickness circumferential invagination of the rectum was visualised at maximum Valsalva (Figure 1c).[5,15] Anismus was present if a paroxysmal pelvic floor contraction was visualised at Valsalva (Figure 1d).[11,13]

Reference standard

All patients underwent EP, dynamic MRI and EVUS, of which the results served in the derivation of the composite reference standard. EP was performed with the patient in the upright position with the use of small bowel (liquid barium) and rectal contrast (barium paste). Dynamic MRI was performed with a closed 1.5 T magnet MRI scanner (Siemens Avanto) in which the patient was lying in a supine position and rectal contrast (ultrasound gel) was used. T2-weighted fast acquisition (TRUFI) images were obtained simultaneously in the mid-sagittal and coronal plane. EVUS was performed with the patient in the supine position with the legs semi flexed and no contrast was used. A linear probe (Type 8838, 12–6 MHz, BK Medical) was placed into the vagina facing the posterior pelvic floor in the mid-sagittal plane visualising the anal canal, rectum and the hump of the levator ani muscle. EP, dynamic MRI and EVUS were performed by an experienced radiologist, radiographer and sonographer respectively. Images for all techniques were acquired at rest, squeeze and maximum Valsalva. For EP and dynamic MRI, an evacuation phase was included.

Imaging analysis of EP and MRI was performed by two observers (I.v.G and A.St.) and discrepancies were solved by a consultant radiologist (H.B.) with more than 30 years' experience in pelvic floor imaging. EVUS was analyses by two observers (I.v.G. and K.K.) and discrepancies were solved by a consultant in urogynaecology (R.T.) with more than 10 years' experience in pelvic floor ultrasound. All observers were blinded to clinical findings and results of the other imaging techniques.

Findings for each condition were dichotomised into presence or absence. A rectocele was present on EP and MRI if its depth was > 20 mm[24] and > 10 mm on EVUS[8]. Enterocele was defined as present if small bowel loops dropped below the pubococcygeus line (PCL) on EP or MRI[18,24] and on EVUS if small bowel loops were visible between the rectum and vagina[8]. Intussusception was defined as present if a full thickness circumferential invagination of the rectal wall was seen during straining, corresponding with Grade 4-7 according Shorvon et al.[15] Anismus was defined as present if a paradoxical contraction of the puborectalis muscle during straining was visualised.[25]

Statistical Analysis

EP is not the best available imaging technique for the diagnosis of all posterior pelvic floor disorders.[8,18] In the absence of a reference standard, a composite reference standard (CRS) is the preferred method for the assessment of diagnostic test accuracy.[26] A CRS is constructed as a combination of the results of different tests, which are all able to diagnose posterior pelvic floor disorders. Here, the CRS was positive for the condition if the majority (2 out of 3) of the findings on EP, MRI or EVUS were positive and negative if the majority (2 out of 3) of the findings on EP, MRI or EVUS were negative. When MRI results were missing due to contra-indications, both EP and EVUS (2 out of 2) needed to be positive for the CRS to be positive. Diagnostic test accuracy of both TPUS techniques were individually assessed compared to the CRS. Diagnostic test characteristics with 95% confidence intervals were calculated; sensitivity, specificity, positive predictive value, negative predictive value and likelihood ratio. The

McNemar test was used to assess statistical differences in sensitivity and specificity between the two methods. Inter-observer agreement and agreement between the two imaging techniques for presence of the condition were assessed using the Cohen's Kappa. Inter-observer agreement for rectocele depth measurements was assessed using the intra-class correlation coefficient (ICC). Statistical difference in rectocele depth between the two imaging techniques was assessed using the paired sample t-test and agreement of measurements was assessed using Bland-Altman limits of agreement. Correlation of 2D and 4D TPUS imaging findings to symptoms of ODS and signs of POP were assessed using binary logistic regression analysis, taking imaging findings as dependent variable and symptoms and signs as independent variable. Odds ratios (ORs) with 95% confidence interval (CI 95%) were calculated. Sample size calculation was performed for the initial study based on the expected prevalence, expected sensitivity and specificity with a precision (half width of 95% CI) of 0.1, and the expected kappa with a precision of 0.2 and a power of > 80% to detect a kappa > 0. Statistical analyses were performed using SPSS (version 22) and R (version 3.3.1). A *p*-value of <0.05 was considered statistically significant.

Results

As part of the parent study, 131 women with ODS were recruited and underwent 2D TPUS.[8] Of those, seven did not agree to have the 4D transperineal ultrasound scan, two were excluded as they underwent surgery before having the 4D transperineal ultrasound scan and in one patient no Valsalva cineloops were captured, leaving 121 women for comparison of 2D and 4D TPUS (Figure 2). Mean age was 53 years (range 25-90, 14.5 SD), body mass index 27 (4.9 SD) and parity 2.3 (range 0-6). Ethnicity was 77% Caucasian, 8% Asian and 15% Black. Previous POP surgery was performed in 20 (17%) women, 34 (28%) had a hysterectomy and 12 (10%) had previous surgery for ODS (6 STARR, 4 rectopexy and 2 had both). The mean Renzi questionnaire total score was 8.95 (range 0-18) and the mean Altomare questionnaire total score was 10.18 (range 0-22). On clinical examination the leading edge of posterior vaginal wall prolapse (POP-Q Bp) was average -2.12 cm (range -3 to +4) above the introïtus. The mean time difference between 2D TPUS and 4D TPUS was 65 days (SD 90).

The prevalence of the posterior pelvic floor disorders on both TPUS techniques and the CRS are presented in Table 1. The estimated prevalence of enterocele was lower on both TPUS techniques as compared to the prevalence diagnosed with the CRS ($p=0.001$), with no differences in prevalence between index tests and reference standard for the other posterior pelvic floor disorders. A good agreement between 2D TPUS and 4D TPUS was found for the diagnosis of rectocele (κ 0.675) and a moderate agreement for enterocele, intussusception and anismus (κ 0.465-0.545)(Table 1).

The sensitivity of both 2D and 4D TPUS was moderate for diagnosis of rectocele (0.609; 0.522), and fair for enterocele (0.350; 0.350), intussusception (0.211; 0.263) and anismus (0.200; 0.400) with no significant difference between the two ultrasound techniques (respectively p=0.131, p=1.000, p=1.000 and p=1.000)(Table 2). The specificity of both TPUS techniques was good for rectocele (0.787; 0.760) and excellent for the other pelvic floor disorders (0.912-1.00), with no significant difference between the two techniques (respectively *p*= 1.000, *p*=NaN, *p*=0.343, *p*=1.000)(Table 2).

Interobserver agreement for diagnosis of the four posterior pelvic floor disorders was comparable for 2D and 4D TPUS, except for diagnosis of enterocele which had an excellent interobserver agreement on 2D TPUS (κ 0.919), but a moderate on 4D TPUS (κ 0.524) (*p*=0.076)(Table 3). Mean rectocele depth on 2D TPUS was 19.9 mm (8.0 SD) and on 4D TPUS 19.0 mm (7.4 SD) (*p*=0.802). Mean difference of rectocele depth measurements between the two TPUS techniques was 0.2 mm (6.0 SD) with limits of agreement of +- 11.8 mm. The interobserver agreement for measuring the size of the rectocele was excellent using 2D TPUS (ICC 0.946, 95% CI 0.903 - 0.988) and good using 4D TPUS (ICC 0.726, 95% CI 0.562 – 0.890) (*p*=0.107).

No significant correlation was found between symptoms of ODS and presence of posterior pelvic floor disorders on 2D (OR 0.90 - 1.05) and 4D TPUS (OR 0.82 - 1.13)(Table 4). Posterior vaginal wall prolapse on clinical examination correlated with diagnosis of rectocele (OR 2.72-2.02) and enterocele (OR 2.45-1.89) on both 2D and 4D TPUS, with no significant difference between the two TPUS techniques.

Discussion

This study showed that manipulation of 4D TPUS in coronal, axial and midsagittal planes had no additional value over standard 2D TPUS in the midsagittal plane, as they have similar diagnostic test accuracy for the diagnosis of posterior pelvic floor disorders in women with ODS. Good agreement between 2D and 4D TPUS was found for diagnosis of rectocele and moderate agreement for diagnosis of enterocele, intussusception and anismus. There was no difference in rectocele depth measurements between both TPUS techniques. Interobserver agreement was comparable for both techniques, however 2D TPUS had an excellent interobserver agreement for diagnosis of enterocele and rectocele depth measurements. Diagnosis of rectocele and enterocele on both 2D and 4D TPUS correlated well with presence of posterior vaginal wall prolapse on clinical examination, but imaging findings on both techniques did not correlate with symptoms of ODS.

These results confirm our hypothesis that 2D TPUS is as good as 4D TPUS for the diagnosis of posterior pelvic floor disorders in women with ODS. For most conditions sensitivity, specificity and interobserver agreement were comparable between 2D and 4D TPUS, suggesting 4D ultrasound volume acquisition and analysis by manipulating the volume in any free-definable plane does not add a benefit of diagnosing posterior pelvic floor disorders over standard 2D assessment in the midsaggital plane only. For the majority of conditions diagnosis is only possible in the mid-sagittal plane; for rectocele its depth needs to be measured from its expected anterior (ventral) border, for enterocele its relation to the symphysis pubis needs to be assessed and for anismus the maximum contraction of the levator muscle is presented mid-sagittally; therefore assessment in axial and coronal planes was not often of added value. Compared to 4D TPUS, 2D TPUS showed an excellent interobserver agreement for diagnosis of enterocele and rectocele depth measurements, which could be explained by difference in ultrasound physics. For 2D TPUS a 3.5-6 MHz convex transducer was used, which provides excellent detail and soft tissue discrimination. Furthermore, capturing 4D data requires more storage space, thereby reducing the quality of the 4D volumes in contrast to the relatively low size 2D cineloops. The difference in symptoms in patients with or without target conditions was relatively small and did not reach statistical significance as only patients with symptoms of ODS were selected. We acknowledge that correlation of symptoms to imaging findings is better assessed in a case-control setting.

Other studies assessing rectocele on 4D TPUS found a higher sensitivity when a lower cut-off value (10 mm) was used and a lower sensitivity when a higher cut-off (20 mm) was used as compared to the current study (15 mm).[5,10,12] Differences in test accuracy are caused by using different cut-off values; the higher the cut-off the more likely rectoceles will be missed on TPUS. A study assessing rectocele on 2D TPUS found a lower sensitivity for diagnosis of rectocele[9], which could be explained by the use of a linear probe as compared to a curved array transducer. Sensitivity for diagnosis of enterocele and intussusception was comparable to others when using 4D TPUS[10,12], however lower than others when using 2D TPUS[27,13]. The latter studies made use of rectal contrast, which might have improved the discrimination of the rectal wall, hence improving diagnosis. Specificity of rectocele, enterocele and intussusception in the current study were comparable to other studies.[5,9,10,12,13,27] Brusciano et al showed an excellent agreement for diagnosis of anismus on 2D TPUS as compared to anal and vaginal ultrasound, but diagnostic test characteristics were not provided by lack of reference standard for anismus.[9] Inter-observer agreement of rectocele depth measurement on 2D and diagnosis of rectocele, enterocele and intussusception on 4D were similar as compared to others.[12,28,29] Dietz at al found women with ODS symptoms to have larger rectocele measurements compared to women without ODS[22], whereas in this current study all women had a degree of ODS, and hence we did not find a significant correlation. Broekhuis et al found a poor correlation and Lone et al found a significant correlation between TPUS and POPQ Bp measurements[30,31], however these studies measured rectocele descent on TPUS against a horizontal reference line which does not correct for rectal descent, as opposed to a true rectocele depth measured perpendicular to the expected contour of the anterior rectal wall. Overall, our results are comparable with other published work supporting the generalizability of this study.

A strength of this study is its prospective design and appropriate sample size. We used a combination of results of three imaging techniques as a reference standard, which is more reliable than using only one non-perfect technique (e.g. EP), a drawback of previously published studies. Another strength is that all measurements were performed by two blinded observers using pre-defined cut-off values. Furthermore, we have used validated methods for assessment of symptoms of ODS and signs of POP. A limitation of this study is that 8 % of the recruited women did not undergo 4D TPUS. In some patients the scans where a few months apart due to logistical reasons, however half the population had both scans on the same day. It is possible that the acquisition of 4D images on the ultrasound machine we used is of inferior quality. Newer models are now available with more sophisticated beam formation and power processing which provides images with more clarity, speed and flexibility. Moreover, the Valsalva manoeuvre was not standardised, hence the patient’s effort might have varied; however this is most likely to be at random.

In clinical practice 2D and 4D TPUS could be used interchangeably based on the availability of ultrasound scanners on hospital premises. TPUS has a high specificity for all conditions so it would be a good screening tool and could be used as initial assessment of women with ODS, which is in agreement with others.[5-8] However, the low sensitivity of TPUS for enterocele, intussusception and anismus suggests that additional imaging is required if abnormalities are suspected. The moderate interobserver agreement for all conditions on TPUS suggests that a substantial experience is required before diagnosis can be made by a single clinician. This highlights the need for a multidisciplinary approach to pelvic floor disorders particularly before any surgical intervention.[32]

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Table 1 Prevalence of posterior pelvic floor disorders on 2D TPUS, 4D TPUS and composite reference standard (*n*= 121)

Target condition	**Prevalence of target conditions**			**Difference in prevalence between TPUS and CRS†**		**Agreement between 2D and 4D TPUS††** κ *(95% CI)*
	2D TPUS *n (%)*	4D TPUS *n (%)*	CRS # *n (%)*	2D TPUS *p-value*	4D TPUS *p-value*	
Rectocele	44 (36)	42 (35)	46 (38)	0.626	0.291	0.675 (0.538 – 0.812)
Enterocele	7 (6)	7 (6)	20 (17)	0.001*	0.001*	0.545 (0.222 – 0.868)
Intussusception	13 (11)	10 (8)	19 (16)	0.307	0.066	0.472 (0.207 – 0.737)
Animus	9 (7)	7 (6)	5 (4)	0.343	0.752	0.465 (0.151 – 0.779)

2D, two-dimensional; 4D, four-dimensional; TPUS, transperineal ultrasound; CRS, composite reference standard; *n*, number

† Mc Nemmar test: significant difference means not able to identify the true prevalence of the condition as indicated with the CRS

†† Cohen's kappa: >0.200 = poor agreement; 0.200-0.400 = fair agreement; 0.400-0.600 = moderate agreement; 0.600-0.800 = good agreement; 0.800-1.000 = excellent agreement

Composite reference standard is positive if majority (at least 2 of 3) of evacuation proctography, MRI and endovaginal ultrasound are positive for the condition

* statistically significant

Table 2 Diagnostic test characteristics of 2D TPUS and 4D TPUS as compared to a composite reference standard*.

n=121	**Modality**	**Cohen's Kappa**	**Sensitivity (95% CI)**	**Specificity (95% CI)**	**PPV (95% CI)**	**NPV (95% CI)**	**LR+ (95% CI)**	**LR- (95% CI)**
Rectocele	2D TPUS	0.399	0.609 (0.46-0.75)	0.787 (0.69-0.88)	0.636 (0.49-0.78)	0.766 (0.67-0.86)	2.853 (1.82-5.19)	0.497 (0.32-0.70)
	4D TPUS	0.287	0.522 (0.38-0.67)	0.760 (0.66-0.85)	0.571 (0.42-0.72)	0.722 (0.62-0.82)	2.174 (1.35-3.79)	0.629 (0.43-0.85)
Enterocele	2D TPUS	0.473	0.350 (0.15-0.56)	1 (1.00-1.00)	1 (1.00-1.00)	0.886 (0.83-0.94)	Inf (Inf-Inf)	0.650 (0.44-0.85)
	4D TPUS	0.473	0.350 (0.14-0.57)	1 (1.00-1.00)	1 (1.00-1.00)	0.886 (0.82-0.94)	Inf (Inf-Inf)	0.650 (0.43-0.86)
Intussusception	2D TPUS	0.140	0.211 (0.05-0.42)	0.912 (0.85-0.96)	0.308 (0.07-0.58)	0.861 (0.79-0.92)	2.386 (0.43-7.07)	0.866 (0.64-1.07)
	4D TPUS	0.265	0.263 (0.07-0.48)	0.951 (0.90-0.99)	0.500 (0.17-0.83)	0.874 (0.81-0.93)	5.368 (1.26-24.47)	0.775 (0.55-0.98)
Anismus	2D TPUS	0.246	0.400 (0.00-1.00)	0.940 (0.89-0.97)	0.222 (0.00-0.54)	0.973 (0.94-1.00)	6.629 (0.00-23.80)	0.639 (0.00-1.08)
	4D TPUS	0.124	0.200 (0.00-0.67)	0.948 (0.91-0.98)	0.143 (0.00-0.50)	0.965 (0.93-0.99)	3.867 (0.00-21.19)	0.844 (0.35-1.09)

2D, two-dimensional; 4D, four-dimensional; TPUS, transperineal ultrasound; PPV, Positive predictive value; NPV, Negative predictive value; LR, Likelihood ratio.

*Composite reference standard: combination of results of evacuation proctography, MRI and endovaginal ultrasound. CRS was positive for a condition if the majority of imaging techniques (at least 2 of 3) was positive and negative if majority was negative.

Table 3 Interobserver agreement for diagnosis of the four posterior pelvic floor disorders using 2D and 4D TPUS

	2D TPUS		**4D TPUS**		**Difference in κ 2DTPUS and 4DTPUS**
	n	κ *(95% CI)*	*n*	κ *(95% CI)*	*p-value*
Rectocele	*Obs. 1* 46 *Obs. 2* 42	0.822 (0.716 – 0.927)	*Obs. 1* 45 *Obs. 2* 36	0.723 (0.597 – 0.849)	0.224
Enterocele	*Obs. 1* 7 *Obs. 2* 6	0.919 (0.744 – 1.000)	*Obs. 1* 6 *Obs. 2* 5	0.524 (0.113 – 0.935)	0.076
Intussusception	*Obs. 1* 4 *Obs. 2* 4	0.224 (-0.172 – 0.621)	*Obs. 1* 5 *Obs. 2* 7	0.124 (-0.158 – 0.407)	0.715
Anismus	*Obs. 1* 13 *Obs. 2* 26	0.372 (0.160 – 0.583)	*Obs. 1* 8 *Obs. 2* 7	0.503 (0.155 – 0.850)	0.492

2D, two-dimensional; 4D, four-dimensional; TPUS, transperineal ultrasound; n, number; κ, Cohen's kappa value; Obs 1, Observer 1; Obs 2, Observer 2

Table 4 Correlation of imaging findings to symptoms of ODS and signs of pelvic organ prolapse

Target condition	**Imaging**	**n** 121	**Total Renzi questionnaire** (Range 0-20)		**Total Altomare questionnaire** (Range 0-31)		**POP-Q Bp** (Range -3 to +9)	
			Mean (SD)	OR (95% CI)	Mean (SD)	OR (95% CI)	Mean (SD)	OR (95% CI)
Rectocele	2D TPUS + 2D TPUS -	44 77	9.55 (4.05) 8.61 (4.50)	1.05 (0.96 – 1.15)	10.89 (4.72) 9.78 (4.83)	1.05 (0.97 – 1.14)	-1.30 (1.29) -2.58 (1.08)	2.72 * (1.77 – 4.18)
	4D TPUS + 4D TPUS -	42 79	9.81 (4.02) 8.49 (4.46)	1.08 (0.98 – 1.18)	11.31 (4.64) 9.58 (4.81)	1.08 (0.99 – 1.17)	-1.43 (1.27) -2.48 (1.19)	2.02 * (1.40 – 2.92)
Enterocele	2D TPUS + 2D TPUS -	7 114	8.57 (3.69) 8.97 (4.39)	0.98 (0.82 – 1.16)	10.29 (3.68) 10.18 (4.87)	1.01 (0.86 – 1.18)	0.0 (2.52) -2.28 (1.01)	2.45 * (1.40 – 4.28)
	4D TPUS + 4D TPUS -	7 114	9.43 (3.3) 8.92 (4.42)	1.03 (0.86 – 1.23)	12.71 (4.23) 10.03 (4.81)	1.13 (0.96 – 1.34)	-0.57 (1.90) -2.25 (1.14)	1.89 * (1.20 – 2.98)
Intussuscep-tion	2D TPUS + 2D TPUS -	13 108	8.00 (3.65) 9.06 (4.43)	0.95 (0.3 – 1.08)	8.85 (4.24) 10.34 (4.85)	0.94 (0.82 – 1.06)	-2.38 (0.87) -2.12 (1.29)	0.81 (0.46 – 1.43)
	4D TPUS + 4D TPUS -	10 111	9.00 (2.9) 8.95 (4.46)	1.00 (0.86 – 1.16)	10.00 (3.30) 10.20 (4.93)	0.99 (0.87 – 1.14)	-1.80 (1.87) -2.18 (1.19)	1.22 (0.79 - 1.87)
Anismus	2D TPUS + 2D TPUS -	9 112	7.89 (4.26) 9.04 (4.36)	0.94 (0.81 – 1.10)	7.89 (4.20) 10.37 (4.81)	0.90 (0.77 – 1.04)	-2.78 (0.44) -2.10 (1.28)	0.40 (0.12 – 1.33)
	4D TPUS + 4D TPUS -	7 114	6.29 (4.19) 9.11 (4.32)	0.86 (0.72 – 1.03)	6.29 (4.39) 10.42 (4.74)	0.82 (0.68 – 0.99)	-2.43 (0.79) -2.13 (1.28)	0.78 (0.36 – 1.72)

ODS, obstructed defecation syndrome; 2D, two-dimensional; 4D, four-dimensional; TPUS, transperineal ultrasound; n, number

Footnote: Dependent variable: Imaging abnormality Y/N. Independent variable: Symptoms (ordinal), Rectocele clinical examination (Y/N and ordinal)

POP-Q Bp = leading edge of posterior vaginal wall prolapse on clinical examination (measurement in centimetres above or below introitus)

* = Statistically Significant

Figure 1: Diagnosis of rectocele, enterocele, intussusception and anismus on 2D TPUS and 4D TPUS.

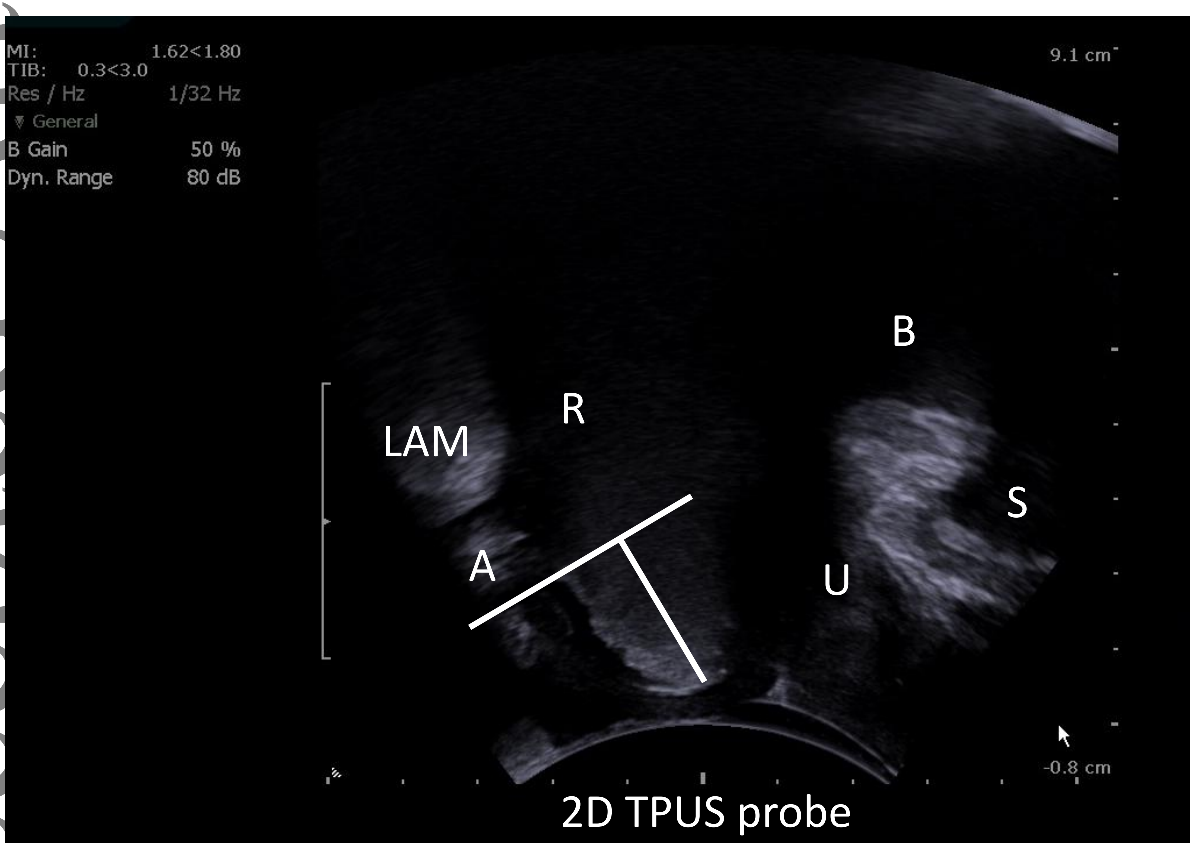
Disclaimer:

Please note all figures are presented as a static 2D image in the midsaggital plane at the point of maximum Valsalva, however diagnosis of the four conditions are made using the entire cineloop during Valsalva and not only from a single static image as presented below. Moreover for 4D TPUS also the axial and coronal planes are examined.

Figure 1a:

Diagnosis of rectocele using 1) 2D TPUS and 2) 4D TPUS

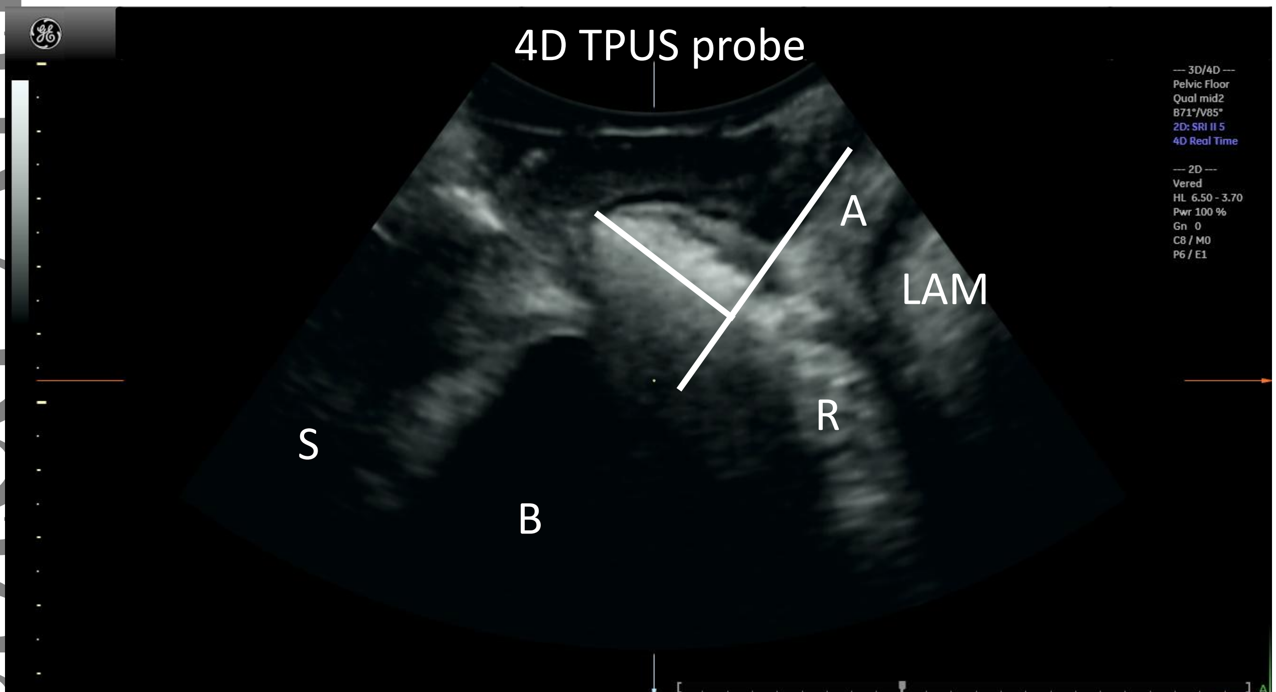
1



A = Anal canal
R = Rectum
LAM = Levator ani muscle
B = Bladder
U = Urethra
S = Symphysis pubis

Rectocele depth is measured perpendicular to the expected contour of the anterior rectal wall

2

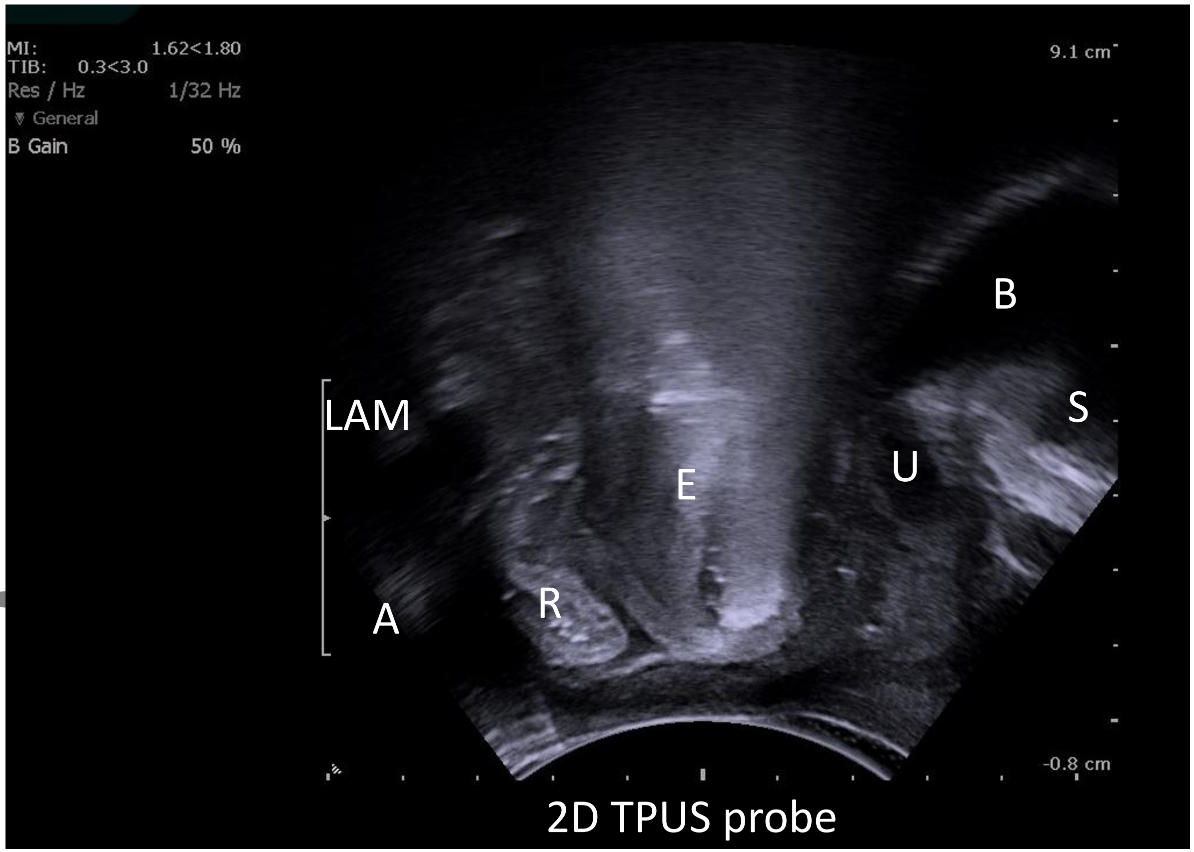


A = Anal canal
R = Rectum
LAM = Levator ani muscle
S = Symphysis pubis
B = Bladder

Rectocele depth is measured perpendicular to the expected contour of the anterior rectal wall

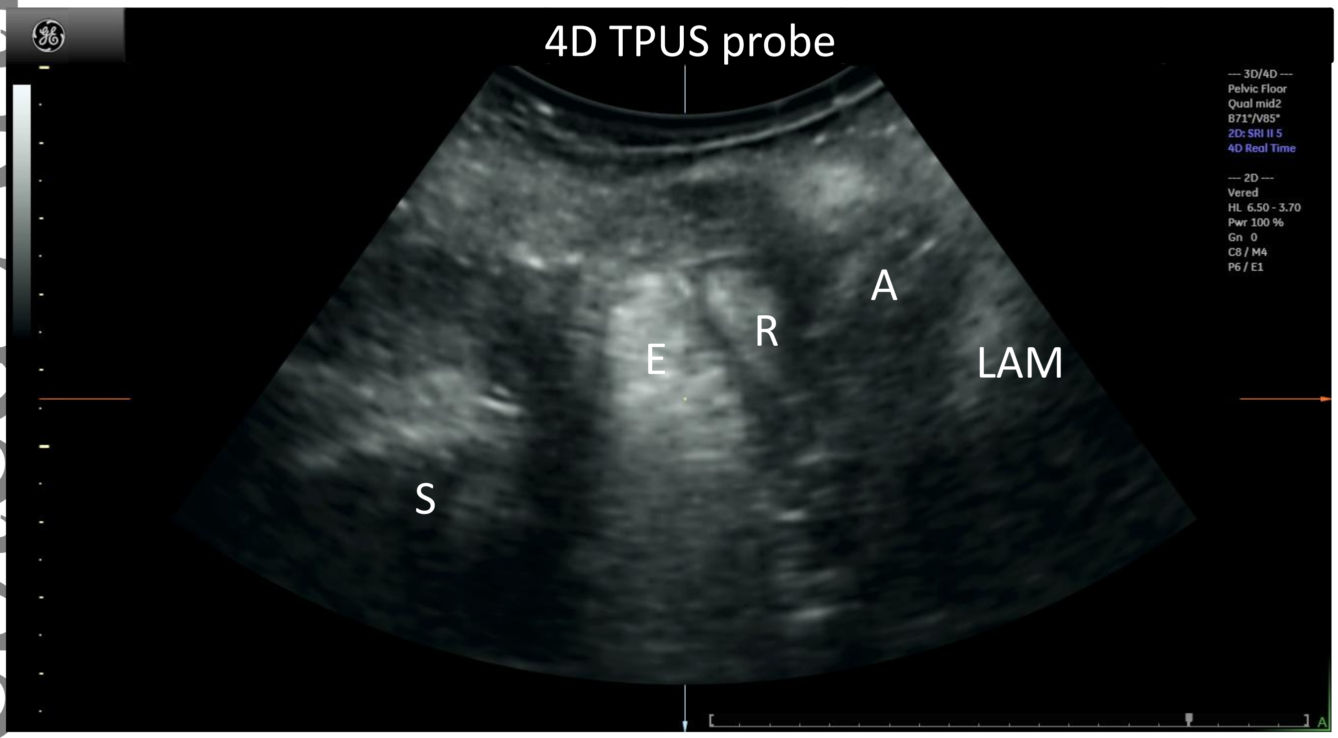
Figure 1b:
Diagnosis of enterocele using 1) 2D TPUS and 2) 4D TPUS

1



A = Anal canal
R = Rectum
LAM = Levator ani muscle
B = Bladder
U = Urethra
S = Symphysis pubis
E = Enterocele

2



A = Anal canal

R = Rectum

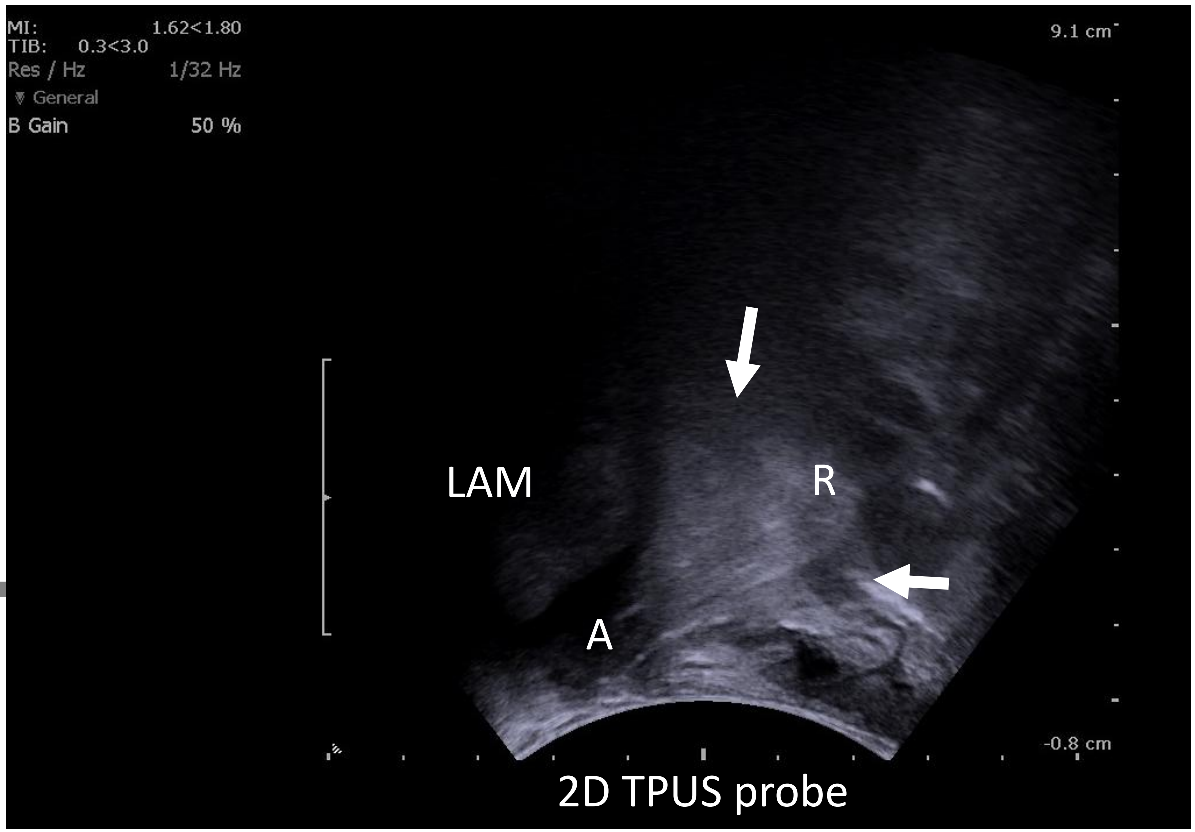
LAM = Levator ani muscle

S = Symhpysis pubis

E = Enterocele

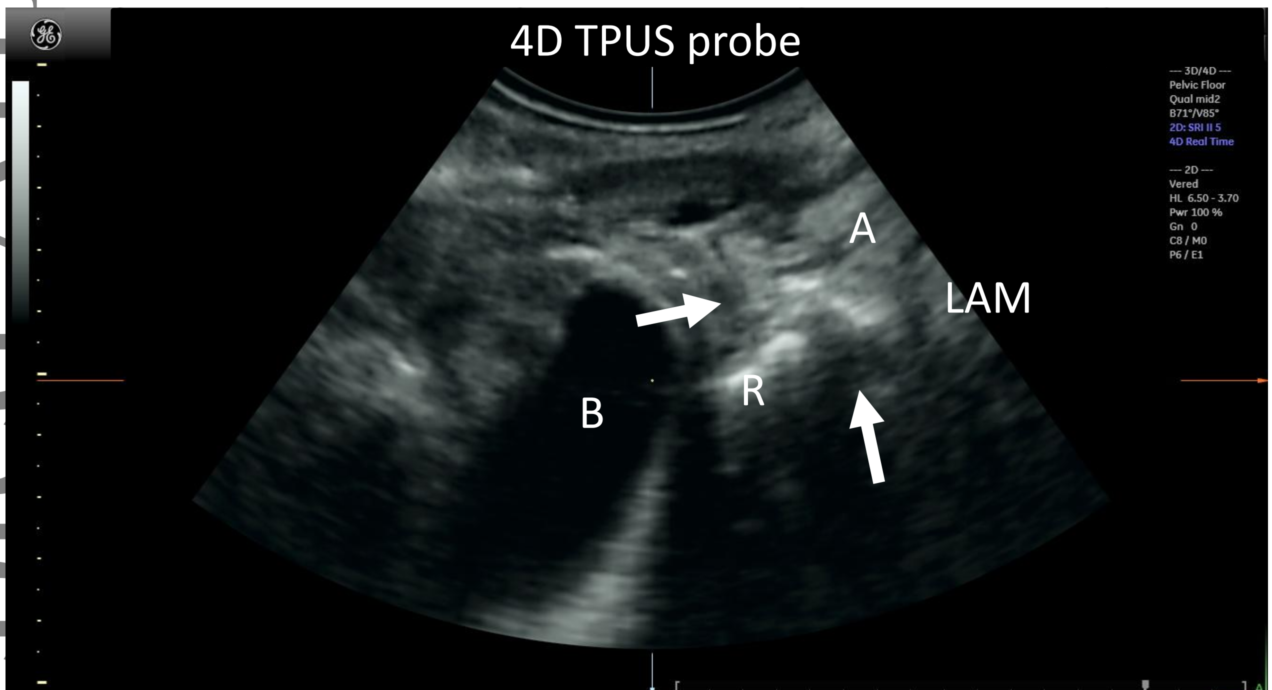
Figure 1c:
Diagnosis of intussusception using 1) 2D TPUS and 2) 4D TPUS

1



A = Anal canal
R = Rectum
LAM = Levator ani muscle
Arrows = Intussusception

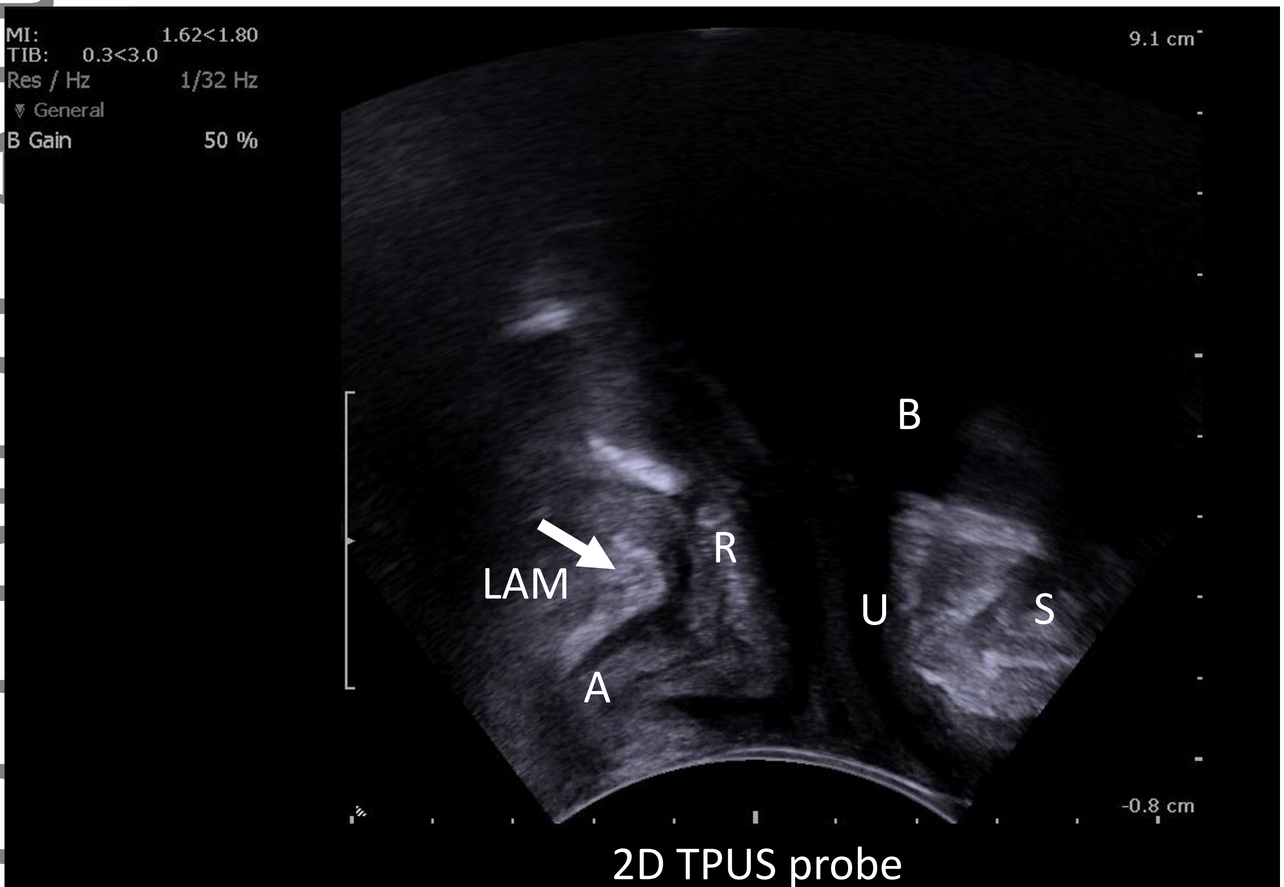
2



A = Anal canal
R = Rectum
B = Bladder
S = Symhpysis pubis
LAM = Levator ani muscle
Arrows = Intussusception

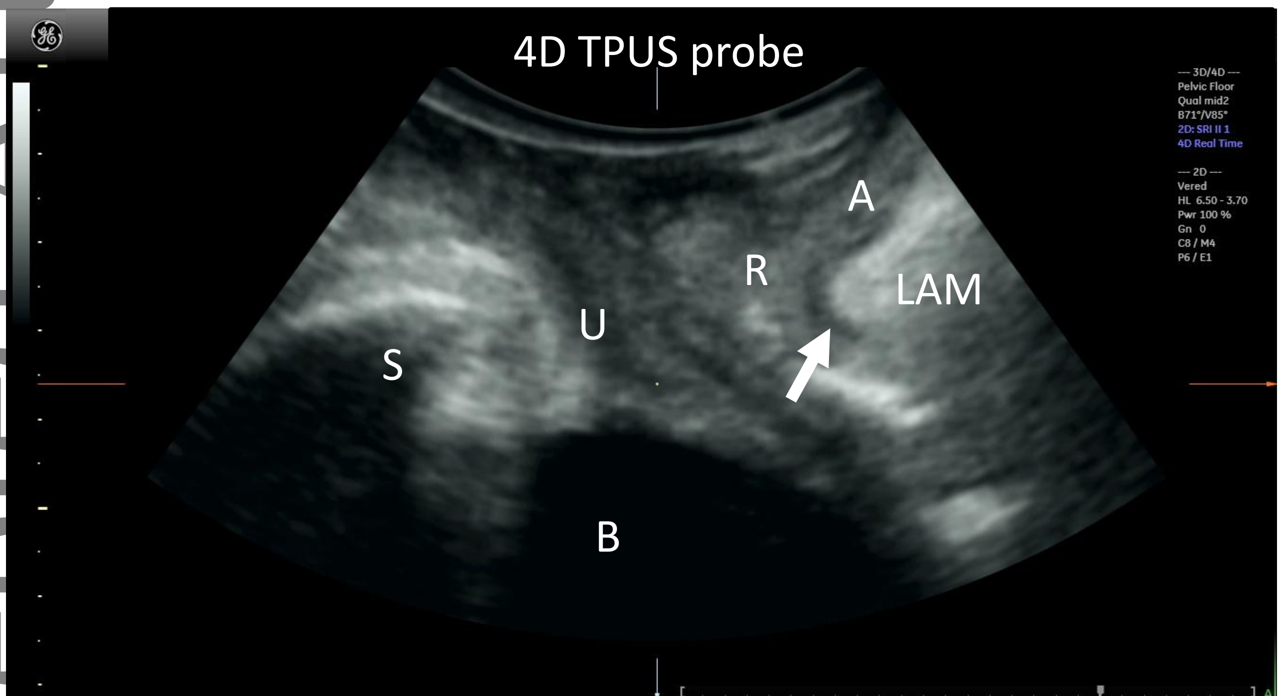
Figure 1d:
Diagnosis of anismus using 1) 2D TPUS and 2) 4D TPUS

1



A = Anal canal
R = Rectum
LAM = Levator ani muscle
B = Bladder
U = Urethra
S = Symphysis pubis
Arrow = Anismus

2



A = Anal canal
R = Rectum
LAM = Levator ani muscle
B = Bladder
U = Urethra
S = Symphysis pubis
Arrow = Anismus

Figure 2: Recruitment flowchart