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Comparing the diagnostic accuracy of three ultrasound modalities for diagnosing obstetric anal sphincter injuries

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Condensation

Endoanal ultrasound remains the reference standard for diagnosing sphincter defects, but three-dimensional introital or transperineal ultrasound can screen for an intact sphincter when advising mode of delivery in a subsequent pregnancy after obstetric sphincter injury.

Short version of title:

Ultrasound diagnosis of anal sphincter defects

AJOG at a Glance (130)

- A. Endoanal ultrasound is regarded as the reference standard for imaging the anal sphincter morphology. Alternatives which are more widely available and accepted by patients include three-dimensional introital and transperineal ultrasound. However, it is unknown whether they are accurate enough to replace endoanal ultrasound.
- B. Three-dimensional introital and transperineal ultrasound provide suitable screening tools for an intact anal sphincter, but are not sensitive enough to accurately detect defects. Onward referral for endoanal ultrasound would be required if a defect is seen, as this remains the reference standard and correlates best with symptoms.
- C. The cut-off for an external anal sphincter defect on tomographic ultrasound imaging is ≥3/7 slices and for an internal anal sphincter defect is ≥2/7 slices, providing standardization within the field for reporting and clinical use.

C. Abstract

Background: The optimal imaging modality of obstetric anal sphincter injuries (OASIs) needs to take into consideration convenience, availability and ability to assess the sphincter morphology. Endoanal ultrasound is currently regarded as the reference standard but is not widely available in obstetric units. Exoanal alternatives exist, such as three-dimensional (3D) introital or transperineal ultrasound, which are already readily available in most obstetrics and gynecology units.

Objectives: The primary objective was to evaluate the diagnostic accuracy of 3D introital and 3D transperineal ultrasound compared to 3D endoanal ultrasound as the reference standard for the detection of anal sphincter defects in women who sustained obstetric anal sphincter injuries. The secondary objective was to correlate diagnosis of anal sphincter defect on imaging to symptoms of anal incontinence, and to assess patient discomfort experienced for each imaging modality

Study Design: A cross-sectional study of 250 women who sustained OASIs, all underwent 3D introital, transperineal and endoanal ultrasound. Introital and transperineal ultrasound were assessed using tomographic ultrasound imaging. All completed a validated modified St Mark's Score and Visual Analogue Score for discomfort. Optimal cut-off values for a significant defect on tomographic ultrasound imaging were defined as those with the greatest sensitivity and specificity based on Receiver Operating Characteristic curves with endoanal ultrasound as reference standard. Diagnostic test characteristics of introital and transperineal ultrasound using these optimal cut-offs were calculated.

Results: Optimal cut-off for a significant external anal sphincter defect was ≥3/7 slices; sensitivity and specificity were 0.65 and 0.75 on introital and 0.70 and 0.69 on transperineal ultrasound respectively. Optimal cut-off for a significant internal anal sphincter defect was ≥2/5 slices; sensitivity and specificity were 0.59 and 0.84 on introital and 0.43 and 0.97 on transperineal ultrasound. The Area Under the Curve for diagnosing external and internal anal sphincter defects ranged from 0.70 - 0.74 ($p<0.001$) for introital and transperineal. Positive predictive value for external and internal sphincter defects ranged from 0.37-0.63 and negative predictive value ranged from 0.85-0.93 for transperineal and introital ultrasound.

Endoanal ultrasound was the only modality for a defect to correlate with symptoms; mean modified St Mark's score 2.4 (SD 4.1) for defect sphincter and 0.9 (SD 2.7) for intact sphincter ($p<0.01$). Introital and transperineal ultrasound were associated with less discomfort than endoanal ultrasound.

Conclusion: Endoanal ultrasound remains the most accurate diagnostic imaging modality. With low positive predictive values, introital and transperineal ultrasound are not suitable for identifying sphincter defects; however high negative predictive values show a good ability to detect an intact sphincter. The optimal cut-off number of slices on tomographic ultrasound imaging for external and internal anal sphincters allows for standardisation of a significant defect. In women with a history of OASI, introital and transperineal ultrasound are suitable to screen for an intact sphincter if endoanal ultrasound is not available. Women with defects seen should then have endoanal ultrasound to verify the diagnosis.

Key words: Anal canal, diagnostic test accuracy, endoanal ultrasound, gynecology, introital ultrasound, obstetrics, obstetric anal sphincter injury, OASI, ROC curve,

sensitivity and specificity, transperineal, ultrasonography

D. Text

Introduction:

Obstetric anal sphincter injury (OASI) is one of the main causes of anal incontinence, occurring in up to 35% of vaginal deliveries.[1-3] It can significantly impact women's social, psychological and physical quality of life, and is increasingly associated with litigation.[4] Endoanal ultrasound (EAUS) assessment of the anal sphincters following OASI has been shown to be useful particularly in counselling regarding mode of delivery in a subsequent pregnancy.[5-7] Clinical examination is associated with poor detection of sphincter damage[8]; ultrasound diagnostic accuracy is better. [9]

There has been increasing interest in the optimal imaging modality of OASIs, taking into account convenience, availability and ability to assess the sphincter morphology. To date, most research has been carried out using the EAUS technique,[1,3,10] currently regarded as the reference standard.[9,11] However, it requires a trained operator, expensive specialised equipment and it is relatively intrusive to the patient. Furthermore, it may distend the muscular anatomy of the anal canal.[12] Alternative exoanal approaches include introital (IUS)[12,13] and transperineal ultrasound (TPUS)[14-17], visualising the sphincter in an undisturbed state. Moreover, the equipment for these scans is readily available in most obstetric and gynecology units.

With ultrasound advances, three and four dimensional (3D/4D) technology is also becoming increasingly popular. Advantages include multiplanar imaging, short examination times and digital volume storage allowing for later re-analysis.[16,17]

The primary aim of this study was to evaluate the diagnostic test accuracy of 3D IUS and 3D TPUS compared to 3D EAUS as reference standard for the detection of anal sphincter defects in women who sustained OASIs. The secondary aim was to correlate diagnosis of anal sphincter defect on imaging to symptoms of faecal incontinence, and to assess patient discomfort experienced for each imaging modality.

Materials and Methods

This was a cross-sectional study of 250 consecutive women who had sustained OASIs and undergone primary repairs of the anal sphincter. They were recruited from the perineal clinic of the tertiary urogynaecology centre of Croydon University Hospital (CUH), United Kingdom. All the women were referred from within CUH or the surrounding regions for assessment 6 to 12 weeks post-partum or seen in a subsequent pregnancy for counselling regarding mode of delivery. Women were recruited prospectively from October 2013 to August 2015. Women aged 18 years or older who could read and understand English were eligible. The study was approved by the National Research Ethics Service South East London Committee (REC number 13/LO/0232), and local research and development department; IRAS project number 122213 and registered in clinicaltrials.gov (NCT 02655900). All study participants gave written informed consent.

Demographic data (age, BMI, ethnicity and parity) of each patient was collected. Each patient completed a validated modified St Mark's score[18], this is a 24-point scoring system for anal incontinence symptoms; accounting for faecal urgency, flatal incontinence, liquid and solid faecal incontinence, impact on lifestyle as well as the use of incontinence pads or constipating medication. For each patient all ultrasound assessments were performed on the same day. EAUS was performed at rest using the Pro-focus 2202 and Flex-focus 500 ultrasound systems (BK medical, Herlev, Denmark) fitted with a 12 - 16 MHz anorectal transducer (type 2052; focal point up to 20 mm and focal range 5 - 45 mm, with 360° acquisition). With the patient lying in the left lateral position, the probe was inserted along the axis of the anal canal and the 3D cube imaged the full length of the anal sphincter; starting proximally at the puborectalis muscle to the most distal aspect of the subcutaneous level of the external anal sphincter (EAS). IUS and TPUS were performed using the GE Voluson I system (GE medical systems, Zipf, Austria). Both were performed at rest with the patient in the supine position. IUS was performed using a 3D 5-9 MHz endocavity probe placed with low pressure on the posterior fourchette in a vertical axis towards the anal sphincter complex. TPUS was performed using a 3D 4-8.5 MHz curved array abdominal probe. The probe was placed transversely on the perineum and inclined to visualize the “U” shape of the puborectalis muscle and angulated to visualize the full length of the sphincter. Both modalities had an acquisition angle of 85°. All ultrasound examinations were performed by an investigator experienced in imaging of the anal sphincter (IvG).

The 3D image volumes of all three modalities were stored for off-line assessment. Image analysis was performed using the 3D BK viewing programme (version 5.19, BK Medical) for EAUS and the 4D View software (version 10.2, GE Medical Systems) for IUS and TPUS by three independent investigators who were blinded to clinical and other imaging findings. Every investigator analysed 30 volumes of each modality, and intra-class correlation analysis was performed to assess agreement. After substantial agreement was found, the remaining volumes were analysed by a single investigator independently (AT analysed EAUS, IV IUS and LA TPUS).

The 3D EAUS cube was assessed by rating the sphincter complex integrity at three levels starting after the "U" shape of the puborectalis muscle; (1) the deep level, up to where the EAS muscle forms anteriorly in the midline, (2) the superficial level, where the IAS (hypoechoic) and EAS (hyperechoic) should be seen as complete rings and (3) the subcutaneous level of the EAS, where the IAS is no longer present (Figure 1a).

IUS and TPUS were both assessed using tomographic ultrasound imaging (TUI). The TUI was adjusted to have 8 slices, with the inter-slice interval varying according to individual sphincter length. EAS (slices 2-8) and IAS (slices 2-6) were evaluated in the same TUI. Slice 1 corresponds with the puborectalis level. Slice 2 was adjusted to be the most cranial aspect of the EAS (deep level), where the muscle comes together in the midline, with the superficial level ending at slice 6. Slices 7 and 8 covered the subcutaneous level (Figure 1b and 1c).

Defect sizes were measured for all three modalities using a 3-point angle, with the angle vertex in the middle of the anal canal. The 3D EAUS cube was assessed in the deep, superficial and subcutaneous levels for defects, with manipulation of the cube in the axial, coronal and sagittal planes to aid diagnosis. Any defect of ≥30 degrees of partial or full thickness was measured for IAS and EAS and considered significant if present at ≥1 level[17] (figure 2a). The same cut-off angle for EAS and IAS defect was also used for IUS and TPUS for consistency in analysis (figure 2b and 2c). The EAS was evaluated both with and without the subcutaneous level to assess whether diagnostic performance would be affected by the inclusion of this level. In addition, we looked at the deep level independently and calculated sensitivity and specificity of IUS and TPUS in detecting a defect at this level, as this can be the most challenging level to diagnose defects accurately in view of anatomical variations.

Norderval score was calculated for all three ultrasound modalities (Table 1), accounting for the length, depth and size of both EAS and IAS defects, with 0 being no defect and 7 maximal defect.[19]

Following each scan, women were asked to complete a visual analogue pain assessment tool to determine the discomfort of each modality, ranging from 0 (no discomfort) to 10 (severe discomfort).

Statistical Analysis

The mean values for demographic variables were calculated. Inter class correlation (ICC) analysis (absolute agreement between the mean of k raters, 2-way random-effects model) between the three investigators was performed for the Norderval scores of 30 volumes for each imaging modality. Based on the 95% confident interval of the ICC estimate, values less than 0.50 indicate poor, 0.50 to 0.75 moderate, 0.75 to 0.90 good, and greater than 0.90 excellent reliability.[20,21]

Spearman's rank correlation was used to test correlation of Norderval scores between different imaging methods. The sensitivity and specificity of IUS and TPUS was calculated using EAUS as the reference standard and receiver operating characteristic (ROC) curves were created.[22] The area under the ROC curve (AUC) was calculated, where 0.50 denotes no clinical application as a test, 0.60-0.70 poor, 0.70-0.80 fair, 0.80-0.90 good and >0.90 an excellent test.[23] This was done including all levels for the EAS (slices 2-8) and IAS (slices 2-6) and subsequently excluding the subcutaneous level of the EAS (slices 2-6). The number of slices with the best diagnostic performance was selected to define the best cut-off value for the detection of a significant EAS and IAS defect within a population of known OASI. Diagnostic test characteristics for these cut-offs were calculated. Mann-Whitney U test was used to test the modified St Mark's Score against intact or defect sphincters for each imaging modality using the new cut-off values. Mann-Whitney U test was used to assess the difference in visual analogue scores of discomfort for IUS and TPUS compared to EAUS.

Sample size calculation was based on the assumption of a 30% prevalence of anal sphincter defects in the population of interest.[16] A sample size of 200 women would provide 60 women with sphincter defects. 60 women with a sphincter defect would give a confidence interval of 0.50 to 0.75, assuming a true rate of sensitivity of 0.64. 140 women with an intact sphincter would provide a confidence interval of 0.78 to 0.90 when assuming a specificity of 0.85. Recruiting 250 women would allow for unusable volumes for analysis or incomplete data sets.

Statistical analysis was performed with IBM SPSS statistics version 23 software (IBM SPSS, Armonk, NY, USA). A p-value <0.05 was considered statistically significant for all analyses.

Results

In total, 250 women were examined at a median of 5 (range 1-137) months after the index (OASI) delivery of whom 88 were pregnant with a subsequent pregnancy at the time of examination. Average age was 31.5 years (SD 4.5), mean BMI was 25.3 kg/m^2 (SD 4.7) and 183/248 (74%) had a parity of 1. The main ethnic group was Caucasian 116 (46%) with other ethnicities being: Indian 55 (22%), other Asian 35 (14%), black 27 (11%) and 17 (7%) of mixed or unknown ethnicity.

The ICC of the Norderval score among the 3 analysers for 30 volumes showed a significant correlation: 0.83 (95% CI 0.70-0.92, $p<0.01$) for EAUS, 0.76 (95% CI 0.57-0.88, $p<0.01$) for IUS and 0.86 (95% CI 0.74-0.93, $p<0.01$) for TPUS.

A defect of ≥30 degrees in ≥1 level was present in 79/248 (32%) women on EAUS, in 134/246 (55%) on IUS and in 118/243 (49%) on TPUS. Two volumes were missing for different women, and not all volumes had complete data to fully assess the EAS or IAS for IUS or TPUS. The mean (SD) Norderval scores for EAUS, IUS and TPUS were 1.2 (2.0), 1.8 (1.9) and 1.1 (1.5) respectively. The correlation of Norderval scores was moderate; between EAUS and IUS it was r_s= 0.42, $p<0.001$ and between EAUS and TPUS it was r_s= 0.47, $p<0.001$.

The AUC for IUS and TPUS and the sensitivities and specificities for each number of TUI slices for diagnosing EAS and IAS defects are indicated in Table 2. The number of slices with the best diagnostic performance for a significant EAS defect was ≥3 of 7 slices; sensitivity and specificity 0.65 and 0.75 on IUS and 0.70 and 0.69 on TPUS. Optimal cut-off for significant IAS defect was ≥2 of 5 slices; sensitivity and specificity 0.59 and 0.84 on IUS and 0.43 and 0.97 on TPUS. The ROC curves for diagnosis of EAS and IAS defects on IUS and TPUS are presented in Figure 3a and 3b. The AUC for EAS defects (with subcutaneous level included) on IUS was 0.74 (95% CI 0.66-

0.81, $p<0.001$) and on TPUS 0.72 (95% CI 0.64-0.79, $p<0.001$). The AUC for IAS defects on IUS was 0.72 (95% CI 0.62-0.83, $p<0.001$) and on TPUS 0.70 (95%CI 0.57-0.82, $p=0.001$). Both IUS and TPUS had greater AUC for EAS defects when the subcutaneous level was included, although not statistically significant. Table 3 shows a summary of the diagnostic test characteristics of both IUS and TPUS using the optimal cut-off values.

Sixty-one women had anal incontinence symptoms, of whom 30 had a defect on EAUS. Endoanal ultrasound was the only modality for a defect to correlate with the modified St Mark's Score; mean score 2.4 (SD 4.1) for defect sphincter and 0.9 (SD 2.7) for intact sphincter ($p<0.01$). There was no difference in mean modified St Mark's Score between intact or defect sphincter for either IUS or TPUS; 1.1 (SD 2.5) vs 1.8 (SD 3.8) $p=0.40$ and 1.1 (SD 2.6) vs 1.6 (SD 3.5), $p=0.17$ respectively.

Discomfort scores of the imaging technique were documented for 238/250 patients. The median discomfort scores for IUS (1.0, SD 1.8) and TPUS (0.0, SD 1.3) were significantly lower when compared to EAUS (4.0, SD 2.3) (both $p<0.001$).

Comment:

The study aim was to assess diagnostic test accuracy of 3D IUS and TPUS compared to 3D EAUS as reference standard for the detection of anal sphincter defects in women who sustained OASIs. Optimal cut-off for a significant EAS defect was ≥3 of 7 slices and for significant IAS defect ≥2 of 5 slices on TUI. Both IUS and TPUS had AUC showing fair ability to diagnose EAS and IAS defects. Both had high NPV suggesting good ability to identify an intact sphincter; but low PPV indicating poor detection of sphincter defects. EAUS was the only modality to correlate with anal incontinence symptoms. IUS and TPUS were associated with less discomfort than EAUS.

When first described, IUS suggested good correlation with EAUS.[24] Later, a larger study showed in fact low sensitivity, with high specificity [25]; comparable to our findings. 2D IUS and TPUS have been compared to EAUS in a large study; concluding that 2D TPUS could identify an intact sphincter, but lacked sensitivity to detect defects.[16] Our study found higher sensitivity values using 3D, suggesting 3D can offer improved detection compared to 2D. The only other study comparing all 3D modalities had 55 patients; they substantiated that 3D technology with TPUS improves the test accuracy compared to 2D and that 3D TPUS has potential in screening,[26] similar to other studies.[27, 28] With our significantly larger study, we confidently agree that (with AUC values between 0.70-0.74) 3D IUS and TPUS are not suitable diagnostic tests to substitute EAUS.

The development of optimal cut-off values for a significant EAS and IAS defect on TUI allows for standardized reporting, in clinical and research settings. Although a cut-off of ≥4/6 slices on TUI has been validated against symptoms in urogynaecology patients[29], we are aiming for a cut-off to detect a sphincter defect in women known to have OASI. We know the majority of women with OASI will not have symptoms until later in life, if at all, and therefore a defect can be significant even if not associated with symptoms. There has been debate about whether the subcutaneous component of the EAS should play a part in defining a defect.[29] We found that its inclusion led towards improved diagnostic performance, although not statistically significant. The subcutaneous part of the EAS contributes to a significant proportion of the sphincter and thus should be included. In the deep level it was more difficult to accurately diagnose a defect on IUS or TPUS compared to EAUS, indicated by lower AUC for this level when isolated. This demonstrates the poor ability of distinguishing a defect from anatomical variation at this level.

We believe that this is the most adequately powered study to date comparing these three 3D imaging modalities to be able to draw firm conclusions. We also used validated scoring systems for symptoms and scan findings. In addition, the study population is generalizable and there is low risk of detection bias as all examiners were blinded to other scan results and clinical history. However, using three examiners, even with good ICC, may have introduced bias. We acknowledge that the quality of the scanning machine for EAUS was superior to that used for IUS and TPUS. It is possible that accuracy could be improved with a new generation scanner. We also acknowledge the heterogeneity of this study population, as some women were pregnant. In addition there was a large range in follow-up time. Although presence of anal incontinence symptoms may change with time and pregnancy status, these two confounders have no effect on sphincter defects or morphology.[3, 30] Therefore as all scans were performed on the same day for each woman, the diagnostic accuracy of each modality or correlation with symptoms should not be affected.

Patient acceptability should be considered. As expected, the less intrusive nature of IUS and TPUS led to reduced discomfort. The IUS probe requires pressure on the posterior fourchette, this and hence tissue proximity could result in reduced visibility of distal defects at 12 o'clock. This may support the use of TPUS over IUS.

When evaluating applicability, cost and equipment availability are important. IUS and TPUS probes are already used widely by obstetricians and gynaecologists; providing a cheaper alternative to the more specialised endoanal probe. However, one must appreciate that the interpretation of all techniques requires training and expertise.

This study was carried out in a cohort with a high prevalence of sphincter defects, therefore the NPV would be expected to be even higher in an unselected cohort of postpartum women. This would support their use to screen for an intact sphincter on labour ward, immediately after delivery. Although likely to be highly accepted by patients and reduce undetected OASI, it would require widespread training of obstetricians, instead of improving examination skills. Likely, the most appropriate place for these modalities is in the antenatal setting, assessing women in subsequent pregnancies after OASI to advise mode of delivery.

In conclusion, 3D EAUS remains the most accurate method for the diagnosis of anal sphincter defects, correlating best with symptoms, and cannot be substituted by IUS or TPUS. High NPV indicate that, in women with a history of OASI, IUS and TPUS are useful for screening an intact sphincter in situations where EAUS is not available. However, with a low PPV, women with defects on IUS or TPUS would need referral for EAUS to verify the diagnosis.

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F. Tables

Table 1 Norderval scoring system for anal sphincter defects.[19]

	Score 0	**Score 1**	**Score 2**	**Score 3**
External anal sphincter				
Length of defect	≤50%	≥50%		
Depth of defect	None	Partial	Total and ≤90^o radial extension	Total and > 90^o radial extension
Internal anal sphincter				
Length of defect	≤50%	≥50%		
Depth of defect	None	Total and ≤90^o radial extension	Total and > 90^o radial extension	

Total score is calculated from adding the total length and depth score for both external and internal anal sphincter.

Table 2

Sensitivity and specificity per number of tomographic ultrasound imaging slices for detection of external and internal anal sphincter defects using introital and transperineal ultrasound compared to endoanal ultrasound as the reference standard using Receiver Operator Characteristic curves.

	Number of TUI slices	Sensitivity	Specificity	AUC	95% CI	p
EAS without subcutaneous level						
IUS	1	0.76	0.63			
	2	0.68	0.69			
	3	0.53	0.76			
	4	0.41	0.81	0.70	0.63-0.77	<0.001
	5	0.18	0.90			
	1	0.69	0.63			
	2	0.66	0.65			
	3	0.64	0.69			
TPUS	4	0.61	0.73	0.68	0.61-0.76	<0.001
	5	0.54	0.78			
EAS with subcutaneous level included						
	1	0.82	0.61			
	2	0.77	0.65			
	3	0.65	0.75			
IUS	4	0.55	0.80	0.74	0.66-0.81	<0.001
	5	0.34	0.86			
	6	0.23	0.89			
	7	0.13	0.93			
	1	0.73	0.63			
	2	0.73	0.66			
	3	0.70	0.69			
TPUS	4	0.66	0.73	0.72	0.64-0.79	<0.001
	5	0.61	0.76			
	6	0.49	0.82			
	7	0.37	0.87			
IAS						
IUS	1	0.63	0.81			
	2	0.59	0.84			
	3	0.47	0.88			
	4	0.19	0.94	0.72	0.62-0.83	<0.001
	5	0.30	0.99			
	1	0.43	0.96			
	2	0.43	0.97			
	3	0.39	0.98			
TPUS	4	0.29	0.98	0.70	0.57-0.82	0.001
	5	0.21	0.99			
ANY EAS and/or IAS defect in the deep level (slice 2)						
IUS		0.36	0.84	0.60	0.52-0.69	0.02
TPUS		0.64	0.69	0.67	0.59-0.75	<0.001

TUI, tomographic ultrasound imaging; EAS, external anal sphincter; IAS, internal anal sphincter; IUS, introital ultrasound; TPUS transperineal ultrasound; AUC, area under the curve

Table 3

Diagnostic test characteristics of introital and transperineal ultrasound for diagnosis of external and internal anal sphincter defects using endoanal ultrasound as reference standard in 250 women who sustained obstetric anal sphincter injury.

Anal sphincter	**Imaging Modality**	**Defect**[§] *n/N (%)*	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**LR+**	**LR-**
EAS	EAUS N=248*	73/248 (29.4)	n/a	n/a	n/a	n/a	n/a	n/a
	IUS N=248*	80/223[‡] (35.9)	0.65	0.75	0.50	0.86	2.60	0.47
	TPUS N=246*	96/227[†] (42.3)	0.70	0.69	0.51	0.85	2.26	0.43
IAS	EAUS N=248*	34/248 (13.7)	n/a	n/a	n/a	n/a	n/a	n/a
	IUS N=248*	52/241[‡] (21.6)	0.59	0.84	0.63	0.93	3.69	0.49
	TPUS N=246*	19/238[†] (8.0)	0.43	0.97	0.37	0.93	14.33	0.59

EAS, external anal sphincter; IAS, internal anal sphincter; EAUS, endoanal ultrasound; IUS, introital ultrasound; TPUS transperineal ultrasound; PPV, positive predictive value; NPV, negative predictive value; LR+, positive likelihood ratio; LR-, negative likelihood ratio; n/a, not applicable.

[§]Using the cut off values of ≥ 1 level for EAUS, ≥3/7 slices for EAS or ≥2/5 slices for IAS on IUS/TPUS * Two volumes for different women were missing

[‡]22 volumes had incomplete data to fully assess EAS and or IAS

[†] 23 volumes had incomplete data to fully assess EAS and or IAS

G. Figure Legends

Figure 1 – Intact anal sphincter

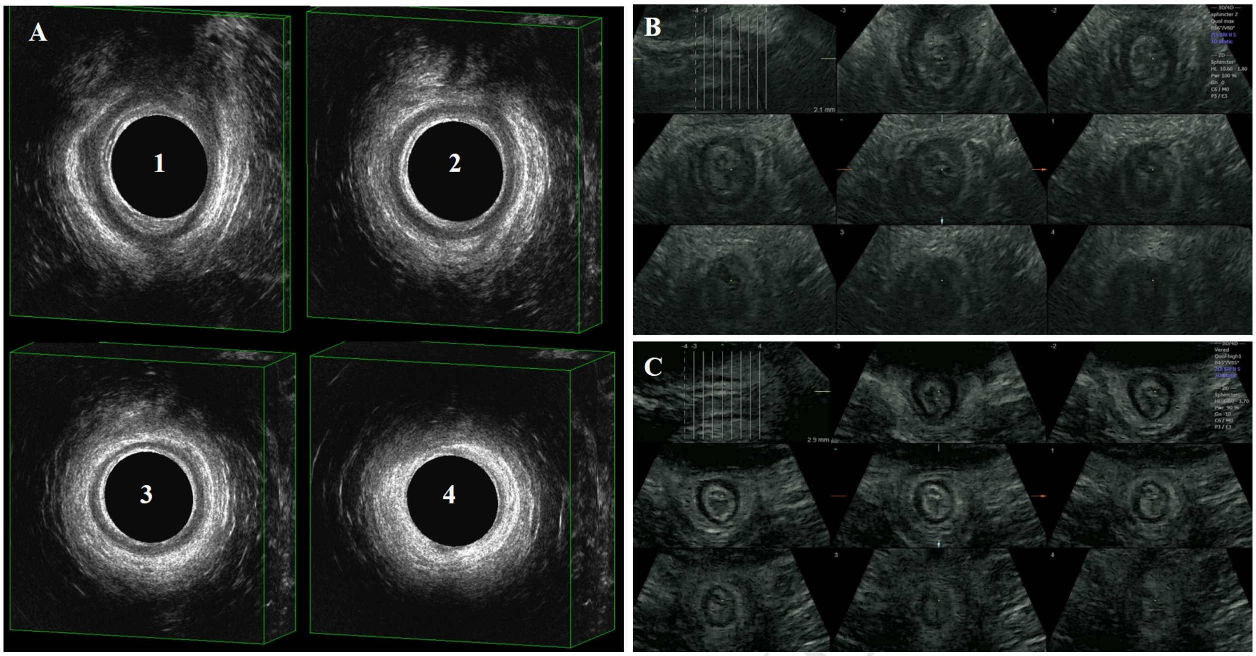
A. Three-dimensional endoanal ultrasound images of an intact sphincter with the external anal sphincter seen as the complete hyperechoic ring encircling the complete hypoechoic ring of the internal anal sphincter. The puborectalis (1), deep (2), superficial (3) and subcutaneous (4) levels are shown.
B. Introital Tomographic ultrasound imaging (TUI) demonstrating an intact external (slices 2-9) and internal (slices 2-7) anal sphincter.
C. Transperineal TUI demonstrating an intact external (slices 2-9) and internal (slices 2-7) anal sphincter.

Figure 2 – Defect anal sphincter

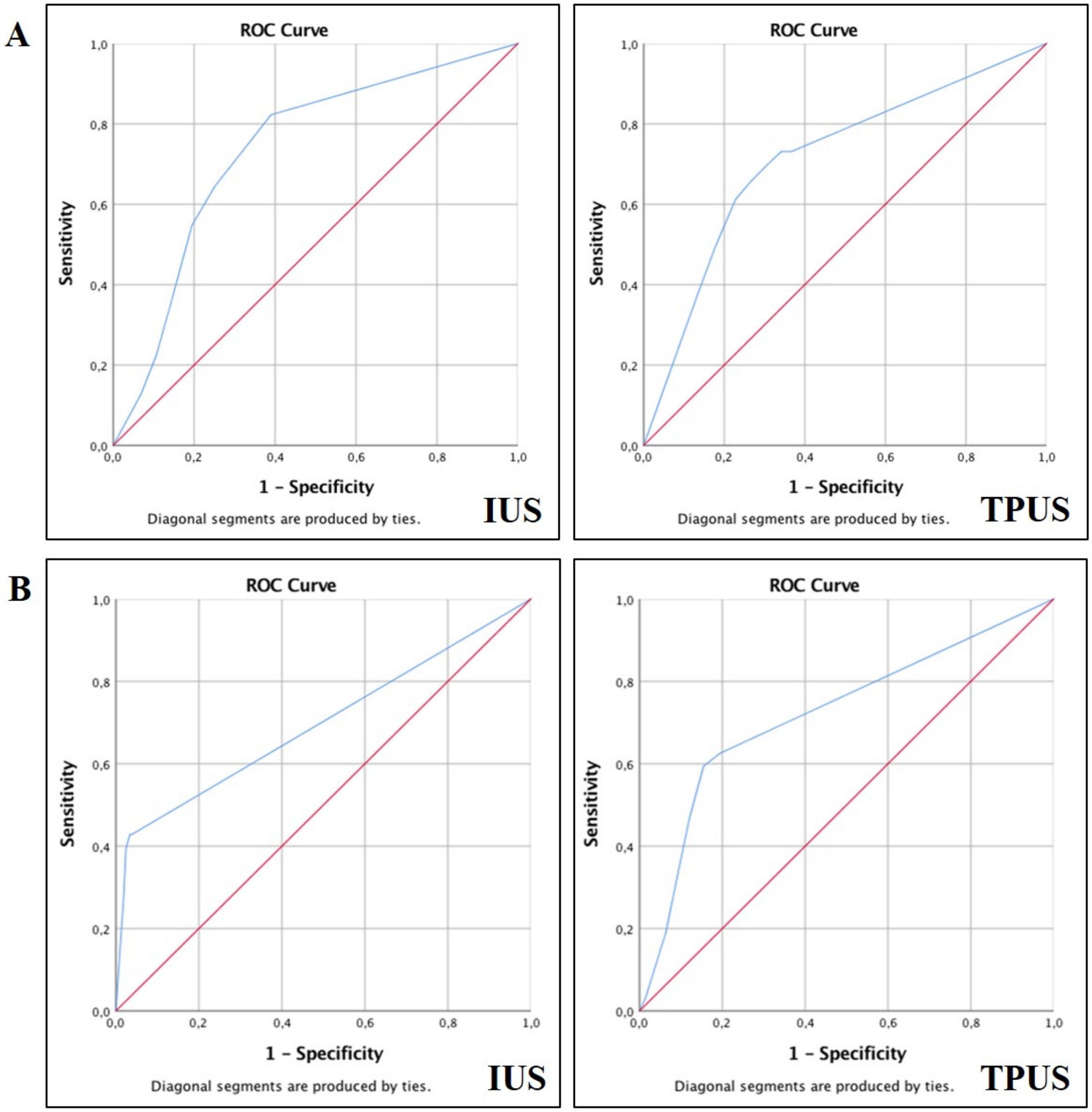
A. Superficial level of Endoanal ultrasound demonstrating a defect in the external (shown by the angles) (EAS) and internal anal sphincter (shown by the arrows) (IAS).
B. Superficial level (slice 4) of introital tomographic ultrasound imaging (TUI) demonstrating a defect in the EAS (shown by the angles) and IAS (shown by the arrows).
C. Superficial level (slice 4) of transperineal TUI demonstrating a defect in the EAS (shown by the angles) and IAS (shown by the arrows).

Figure 3 – Receiver operator characteristic (ROC) curves

A. ROC curves for 3D introital tomographic ultrasound imaging (TUI) (left) and 3D transperineal TUI (right) for diagnosis of external anal sphincter defects (with inclusion of subcutaneous level).
B. ROC curves for 3D introital TUI (left) and 3D transperineal TUI (right) for diagnosis of internal anal sphincter defects.


A
1
2
3
4
B
C


A
B
C


A
ROC Curve
Sensitivity
1,0
0,8
0,6
0,4
0,2
0,0
0,0
0,2
0,4
0,6
0,8
1,0
1 - Specificity
Diagonal segments are produced by ties.
IUS
ROC Curve
Sensitivity
1 - Specificity
Diagonal segments are produced by ties.
TPUS
B
ROC Curve
Sensitivity
1 - Specificity
Diagonal segments are produced by ties.
IUS
ROC Curve
Sensitivity
1 - Specificity
Diagonal segments are produced by ties.
TPUS