Ultrasound Obstet Gynecol 2022
Published online in Wiley Online Library (wileyonlinelibrary.com). **DOI:** 10.1002/uog.24957.

Comparison of diagnostic criteria for significant anal sphincter defects between endoanal and transperineal ultrasound

N. A. OKEAHIALAM[1], R. THAKAR[1,2] and A. H. SULTAN[1,2]

[1]*Urogynaecology and Pelvic Floor Reconstruction Unit, Croydon University Hospital, Croydon, UK;* [2]*St George's University of London, London, UK*

KEYWORDS: endoanal ultrasound; OASI; obstetric anal sphincter injury; severe perineal trauma; sphincter defect; third/fourth-degree tear; transperineal ultrasound

CONTRIBUTION

What are the novel findings of this work?
Transperineal ultrasound (TPUS) had excellent agreement with endoanal ultrasound in diagnosing the presence of anal sphincter defects. However, there was poor-to-moderate agreement between the two modalities in the measurement of defect angle, with a standard error of measurement of 16° and 27° for external and internal anal sphincter defects, respectively.

What are the clinical implications of this work?
A cut-off angle of 30° should not be used for the diagnosis of a significant residual anal sphincter defect on TPUS. Further research is required to determine the cut-off angle for a significant defect on TPUS.

ABSTRACT

Objective *To evaluate the agreement between three-dimensional endoanal ultrasound (EAUS) and four-dimensional transperineal ultrasound (TPUS) in measuring anal sphincter defect angle.*

Methods *This was a secondary analysis of the PERINEAL study, which evaluated the effect of perineal wound infection on anal sphincter integrity. Women were reviewed once a week, until their perineal wound had healed or for up to a maximum of 16 weeks. At each review, both EAUS and TPUS (the latter at rest and on maximum pelvic floor muscle contraction (PFMC)) were performed to evaluate the presence of external (EAS) and internal (IAS) anal sphincter defect and measure the defect size. The largest angle size of a defect at the same sphincter level was analyzed. A defect was deemed significant if it was > 30°. Kappa coefficient (κ), intraclass correlation coefficient and standard error of measurement (SEM) were calculated, using EAUS as the reference standard.*

Results *In 73 women scanned at weekly intervals, a total of 250 EAUS and 250 TPUS scans were performed. An EAS defect was found in 55 (22.0%) EAUS images and 47 (18.8%) TPUS images. An IAS defect was found in 26 (10.4%) images on both modalities. There was excellent agreement (κ = 0.87) between TPUS and EAUS in diagnosing the presence of an EAS defect and perfect agreement (κ = 1.00) in diagnosing the presence of an IAS defect. TPUS performed at rest had poor and moderate agreement with EAUS in measuring EAS and IAS defect size, respectively, with respective SEMs of ± 16.1° and ± 27.9°. TPUS performed during maximum PFMC had poor and moderate agreement with EAUS in measuring EAS and IAS defect size, respectively, with respective SEMs of ± 16.5° and ± 26.4°. Based on the SEMs, if the diagnostic cut-off of 30° for defect size on TPUS was used, an incorrect diagnosis of significant EAS defect could occur in approximately 9–36% of women and an incorrect diagnosis of a significant IAS defect could occur in approximately 4–15% of women, using EAUS as the reference.*

Conclusions *This is the first study to compare directly anal sphincter defect angle measurements obtained on EAUS and TPUS. A cut-off angle of 30° should not be used for the diagnosis of a significant residual anal sphincter defect during TPUS examination. Further research is*

Correspondence to: Mr A. H. Sultan, Consultant Obstetrician and Urogynaecologist, Croydon University Hospital, 530 London Road, Thornton Heath, Croydon CR7 7YE, UK (e-mail: abdulsultan@nhs.net)

Accepted: 23 May 2022

required to determine the optimal defect cut-off angle for TPUS. © 2022 The Authors. Ultrasound in Obstetrics & Gynecology published by John Wiley & Sons Ltd on behalf of International Society of Ultrasound in Obstetrics and Gynecology.

INTRODUCTION

Endoanal ultrasound (EAUS) and transperineal ultrasound (TPUS) can be used to evaluate the anal sphincter after obstetric anal sphincter injury (OASI)[1]. EAUS has been validated using histology as the reference standard and findings have been shown to correspond with external anal sphincter (EAS) defects, which appear hypoechoic or have mixed echogenicity, and also internal anal sphincter (IAS) defects, which appear as a hyperechoic disruption within the hypoechoic muscular ring[2,3]. Therefore, EAUS is the agreed gold standard modality to evaluate the anal sphincter[4]. Unlike EAUS, TPUS has not been validated against histology[5]. As EAUS probes measure 17 mm in diameter, it is agreed that due to the probe being placed within the anal canal, this may result in stretching and possible distortion of anatomy[6,7]. In comparison, TPUS allows analysis of the anal sphincter in an undisturbed state as the probe is placed exoanally[6].

The diagnostic criteria for a significant residual anal sphincter defect seen on TPUS have been validated mathematically, based on the EAUS criteria used to diagnose a significant sphincter defect[5]. Specifically, on EAUS, a significant anal sphincter defect is defined as a discontinuity of $> 30°$ in at least two-thirds of the length of the anal sphincter[8]. This is because it is difficult to decipher whether defects $\leq 30°$ are secondary to a scar formed as part of the normal healing process following surgical repair or due to a defect secondary to the sphincter muscles being unopposed[8]. In addition, the function of the sphincter muscle, which can be demonstrated using anal manometry[9], has been shown to be significantly worse[10] in women with an anal sphincter defect $> 30°$ in comparison to those with a defect of $\leq 30°$. However, defects less than 30° are considered significant if anal manometry pressures are substantially reduced, indicating compromised function[8].

Despite this potential difference in the appearance of the anal sphincter anatomy between EAUS and TPUS, it is assumed that a defect on TPUS should also be $> 30°$ to be considered significant[1]. We aimed to establish the agreement between EAUS and TPUS in measuring anal sphincter defect angle, using EAUS as the gold standard.

METHODS

This was a secondary analysis of a previous clinical study completed at Croydon University Hospital, London, UK, which explored the effect on anal sphincter integrity of perineal wound infection following childbirth-related perineal injury. This primary study was registered with ClinicalTrials.gov (NCT 04480684) and was approved by the National Health Service (NHS) Health Research Authority, London–Surrey Research Ethics Committee (20/LO/0304)[11]. All study participants provided written informed consent.

To explore the differences between EAUS and TPUS, we analyzed the data of the primary study population, including only women who underwent both EAUS and TPUS ($n = 73$). Women were reviewed once a week, until their perineal wound had healed, or for up to a maximum of 16 weeks. EAUS and TPUS were performed on the same day at each visit. Three-dimensional (3D) EAUS was performed at rest with the patient lying in the left lateral position using the Flex-focus 500 or BK 3000 ultrasound system (BK Medical, Herlev, Denmark). An anal sphincter defect was defined as a discontinuity in the ultrasound appearance of the IAS or the EAS. Figure 1 shows the measurement of an EAS and IAS defect in the same patient on EAUS and TPUS at rest. Anal sphincter defect sizes were measured using a three-point angle with images taken at the deep (proximal), superficial (mid) and subcutaneous (distal) levels of the EAS. Four-dimensional (4D) TPUS was performed at rest and on maximum pelvic floor muscle contraction (PFMC) with the patient in the supine position, using a 2–8-MHz convex-array volume probe (GE Voluson S10, RAB6-RS; GE Healthcare, Zipf, Austria). The anal sphincter was reviewed on tomographic ultrasound imaging (TUI). On TUI, the entire length of the anal sphincter from the puborectalis to the subcutaneous level of the EAS was captured in eight transverse slices. The anal sphincter was then evaluated on slices 2–7 with the interslice interval adjusted to include the entire length of the anal sphincter. Again, anal sphincter defect sizes were measured using a three-point angle. To allow direct comparison of EAUS and TPUS, the largest angle size of any identified defect (including defects $< 30°$) was taken into account, ensuring that this was measured at the same level of the anal sphincter. A defect of any size, of partial or full thickness, was measured for the EAS and IAS. Anal sphincter defects identified on both modalities were also scored using the validated Starck score[12], which accounts for depth, length and size of the defect for both the IAS and EAS, with a range from 0 (no defect) to 16 (maximum defect, involving the whole length and depth of the anal sphincter). All image volumes were reviewed independently offline by a single investigator experienced in imaging of the anal sphincter (A.H.S. analyzed EAUS, and K.W.W. analyzed TPUS images). As participants were scanned weekly, ultrasound volumes were analyzed with a week interval and each investigator was blinded to the results of the previous scan to avoid bias due to repeated measurements.

Study outcomes

The primary study outcome was the agreement in anal sphincter defect three-point radial angle measured on TPUS *vs* EAUS (reference standard). The secondary outcomes included agreement between the two methods in diagnosing the presence of anal sphincter defect and

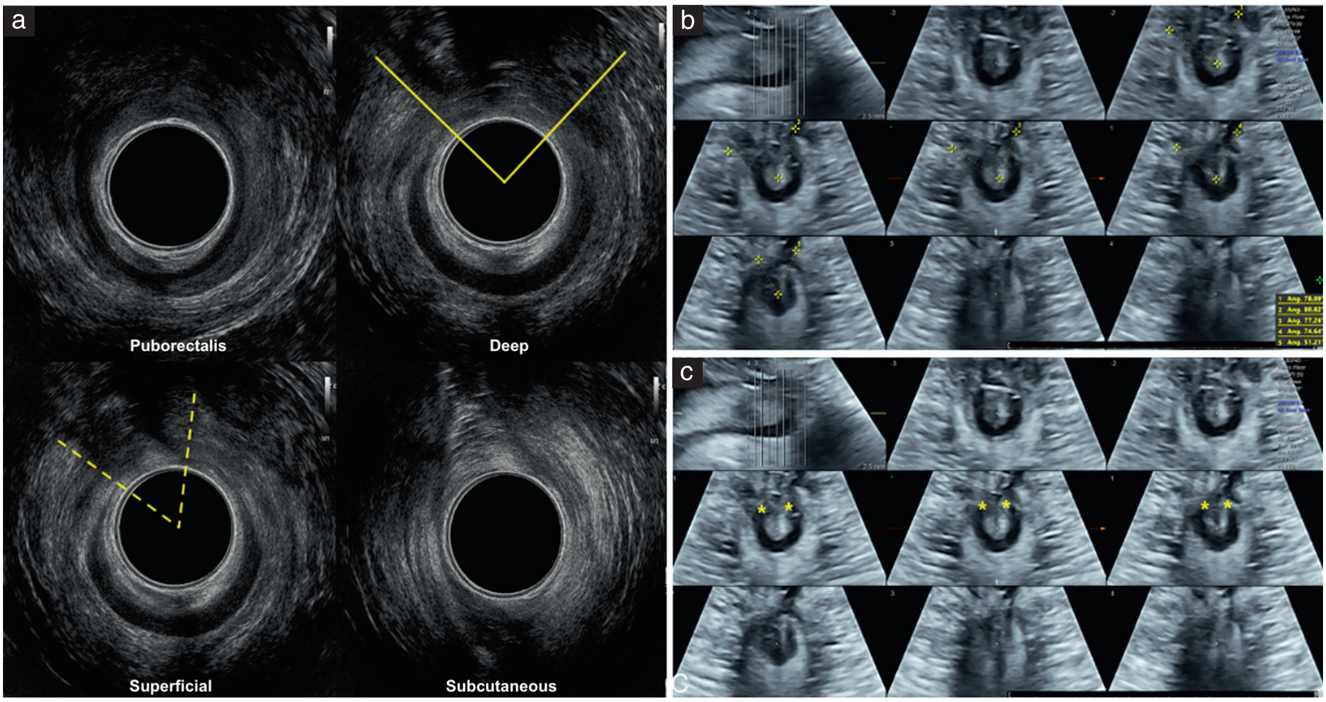

Figure 1 Endoanal ultrasound (a) and transperineal tomographic ultrasound (b,c) images obtained in the same patient at rest, showing measurement of external anal sphincter (EAS) and internal sphincter (IAS) defect using a three-point angle. (a) On endoanal ultrasound, EAS defect is indicated by solid-line angle and IAS defect by dashed-line angle. (b) On transperineal ultrasound, EAS defect is indicated by calipers in slices 2–6. (c) On transperineal ultrasound, IAS defect is indicated by stars in slices 3–5.

the Starck score, using EAUS as the reference standard. This observational study was reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[13].

Statistical analysis

Data were analyzed using SPSS version 26.0.0.0 (IBM Corp., Armonk, NY, USA). Categorical data were expressed as n (%). The Shapiro–Wilk test was used to check the normality of continuous variables and continuous data were then reported as mean ± SD if normally distributed and as median (interquartile range) if not. Differences between two measurements were analyzed using the paired-sample t-test or the Wilcoxon-signed rank test as appropriate. Intraclass correlation coefficients (ICC) were calculated to assess the interinstrument agreement in defect angle and Starck score between EAUS and TPUS. Values of < 0.50 indicated poor, 0.50–0.75 moderate, 0.75–0.90 good and > 0.90 excellent reliability[14]. Standard error of measurement (SEM) was calculated to measure the range of error of each measurement. SEM was calculated as follows: $SEM = SD \times \sqrt{(1 - ICC)}$. The defect angle measured at that timepoint and the relevant SEM was subtracted and added to this value to calculate the number of women that would be incorrectly diagnosed with a significant sphincter defect on TPUS, using a diagnostic cut-off of 30°. Kappa coefficient (κ) was calculated to assess the agreement between diagnosing a defect using EAUS and TPUS at the end of the wound-healing process. Values of ≤ 0 indicated no agreement, 0.01–0.20 none to slight, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial and 0.81–1.00 almost perfect agreement[15]. EAUS was considered the reference standard.

RESULTS

Of the 80 women that participated in the primary study, 73 agreed to undergo both EAUS and TPUS. In the 73 women included, a total of 500 scans were performed over the course of the follow-up period, comprising 250 TPUS and 250 EAUS scans. The grade of perineal injury diagnosed at delivery and ultrasound findings in the 73 participants are described in Table 1. Five (6.3%) women were diagnosed with an OASI and underwent primary OASI repair. However, an additional five women (6.8%) had a missed third-degree tear, identified either on EAUS or TPUS. All five women had an instrumental delivery (ventouse, $n = 2$; forceps, $n = 1$; sequential instrumental delivery (ventouse plus forceps), $n = 2$) and four (80%) had mediolateral episiotomy. At the end of the wound-healing process, 10 (13.7%) and eight (11.0%) women were diagnosed with an EAS defect on EAUS and TPUS, respectively. An IAS defect was also found in three (4.1%) of these women on both EAUS and TPUS. There was almost perfect agreement between TPUS and EAUS in diagnosing the presence of an EAS defect (κ = 0.87 (95% CI, 0.70–1.05)) and perfect agreement in diagnosing the presence of an IAS defect (κ = 1.00).

The median number of ultrasound scans performed each week until complete perineal wound healing was

2 (range, 1–16). On TPUS, an EAS defect was found in 47 (18.8%) images, and the defect was > 30° in 42/47 (89.4%) images at rest and in 34/47 (72.3%) images on maximum PFMC (Table 2). On EAUS, an EAS defect was found in 55 (22.0%) images and was > 30° in 30/55 (54.5%) images. An IAS defect was found in 26 (10.4%) images on both TPUS and EAUS (Table 2). On TPUS the IAS defect was > 30° in 22/26 (84.6%) images at rest and on maximum PFMC. On EAUS the IAS defect was > 30° in all images.

The angle of EAS and IAS defects and the Starck score on TPUS and EAUS are shown in Table 3. EAS defects measured on TPUS at rest were significantly larger than those measured on EAUS (51.7° *vs* 40.5°, $P < 0.001$). However, there was no significant difference in the size of EAS defects measured on EAUS *vs* during maximum PFMC on TPUS. In comparison to EAUS, IAS defects measured on TPUS in a resting state (86.1° *vs* 112.4°, $P < 0.001$) and on maximum PFMC (78.9° *vs* 112.4°, $P < 0.001$) were significantly smaller. No significant difference was found in the resulting Starck score as assessed on EAUS *vs* on TPUS at rest and during maximum PFMC. Sensitivity analysis was performed using only measurements obtained at the end of the wound-healing process ($n = 73$ women). No significant difference was found between the two modalities (Table S1).

TPUS performed at rest had a moderate agreement with EAUS in the measurement of EAS defect size (ICC, 0.64 (95% CI, 0.40–0.80)) and poor agreement in the measurement of IAS defect size (ICC, 0.34 (95% CI, −0.10 to 0.67)), with a SEM of ± 16.1° and ± 27.9°, respectively. TPUS performed during maximum PFMC had a moderate agreement with EAUS in the measurement of EAS defect size (ICC, 0.67 (95% CI, 0.50–0.80)) and poor agreement in the measurement of IAS defect size (ICC, 0.29 (95% CI, −0.07 to 0.60)), with a SEM of ± 16.5° and ± 26.4°, respectively. There was excellent agreement in the Starck score between EAUS and TPUS performed at rest and on maximum PFMC, with a SEM of 1 (Table 4).

Based on the SEMs, using EAUS as the reference standard, the number of women that would be incorrectly diagnosed with a significant anal sphincter defect on TPUS, if the diagnostic cut-off of 30° was used to indicate significant defect, is shown in Figure 2. For TPUS performed at rest, underdiagnosis of a significant

Table 1 Perineal injury diagnosed at delivery and on follow-up three-dimensional endoanal ultrasound (EAUS) and four-dimensional transperineal ultrasound (TPUS) in 73 women who underwent both imaging modalities

Parameter	n *(%)*
At delivery	
First-degree tear	1 (1.4)
Second-degree tear only	13 (17.8)
Episiotomy only	47 (64.4)
OASI only	2 (2.7)
Episiotomy and additional tear	
Second-degree tear	7 (9.6)
OASI	3 (4.1)
OASI grade	
3a	3 (4.1)
3b	1 (1.4)
3c	0 (0)
4	1 (1.4)
On EAUS	
EAS defect	10 (13.7)
IAS defect	3 (4.1)
On TPUS	
EAS defect	8 (11.0)
IAS defect	3 (4.1)

EAS, external anal sphincter; IAS, internal anal sphincter; OASI, obstetric anal sphincter injury.

Table 2 Anal sphincter defects diagnosed on three-dimensional endoanal ultrasound (EAUS; $n = 250$ scans) and on four-dimensional transperineal ultrasound (TPUS; $n = 250$ scans) at rest and on maximum pelvic floor muscle contraction (PFMC) during perineal wound healing

Parameter	*Value*
Number of scans per week*	2 (1–4)
EAUS	
EAS defect	55 (22.0)
Defect angle > 30°	30/55 (54.5)
IAS defect	26 (10.4)
Defect angle > 30°	26/26 (100.0)
TPUS at rest	
EAS defect	47 (18.8)
Defect angle > 30°	42/47 (89.4)
IAS defect	26 (10.4)
Defect angle > 30°	22/26 (84.6)
TPUS on maximum PFMC	
EAS defect	47 (18.8)
Defect angle > 30°	34/47 (72.3)
IAS defect	26 (10.4)
Defect angle > 30°	22/26 (84.6)

Data are given as median (interquartile range), *n* (%) or *n*/*N*(%). *Until complete perineal wound healing or up to 16 weeks of follow-up. EAS, external anal sphincter; IAS, internal anal sphincter.

Table 3 Angle size of external anal sphincter (EAS) and internal anal sphincter (IAS) defects and Starck score assessed on three-dimensional endoanal ultrasound (EAUS; $n = 250$ scans) and on four-dimensional transperineal ultrasound (TPUS; $n = 250$ scans) at rest and during maximum pelvic floor muscle contraction (PFMC)

Parameter	*EAUS*	*TPUS at rest*	P	*TPUS on maximum PFMC*	P
EAS defect angle (°)	40.5 ± 18.6	51.7 ± 35.6	< 0.001*	45.6 ± 33.3	0.09*
IAS defect angle (°)	112.4 ± 19.5	86.1 ± 35.4	< 0.001*	78.9 ± 38.0	< 0.001*
Starck score	5 (4–12)	5 (4–12)	0.70†	5 (4–12)	0.45†

Data are given as mean ± SD or median (interquartile range). *Paired *t*-test. †Wilcoxon signed-rank test.

Table 4 Agreement between three-dimensional endoanal ultrasound (EAUS; $n = 250$ scans) and four-dimensional transperineal ultrasound (TPUS; $n = 250$ scans) at rest and during maximum pelvic floor muscle contraction (PFMC) in measurement of external anal sphincter (EAS) and internal anal sphincter (IAS) defect angle size and assessment of Starck score, using EAUS as reference standard

	TPUS at rest			*TPUS on maximum PFMC*		
Parameter	*ICC (95% CI)*	*SEM (°/score)*	P	*ICC (95% CI)*	*SEM (°/score)*	P
EAS defect angle	0.64 (0.40 to 0.80)	± 16.1	< 0.001	0.67 (0.50 to 0.80)	± 16.5	0.02
IAS defect angle	0.34 (−0.10 to 0.67)	± 27.9	0.02	0.29 (−0.07 to 0.60)	± 26.4	0.02
Starck score	0.95 (0.92 to 0.97)	± 1.0	< 0.001	0.95 (0.91 to 0.97)	± 1.0	< 0.001

ICC, intraclass correlation coefficient; SEM, standard error of measurement.

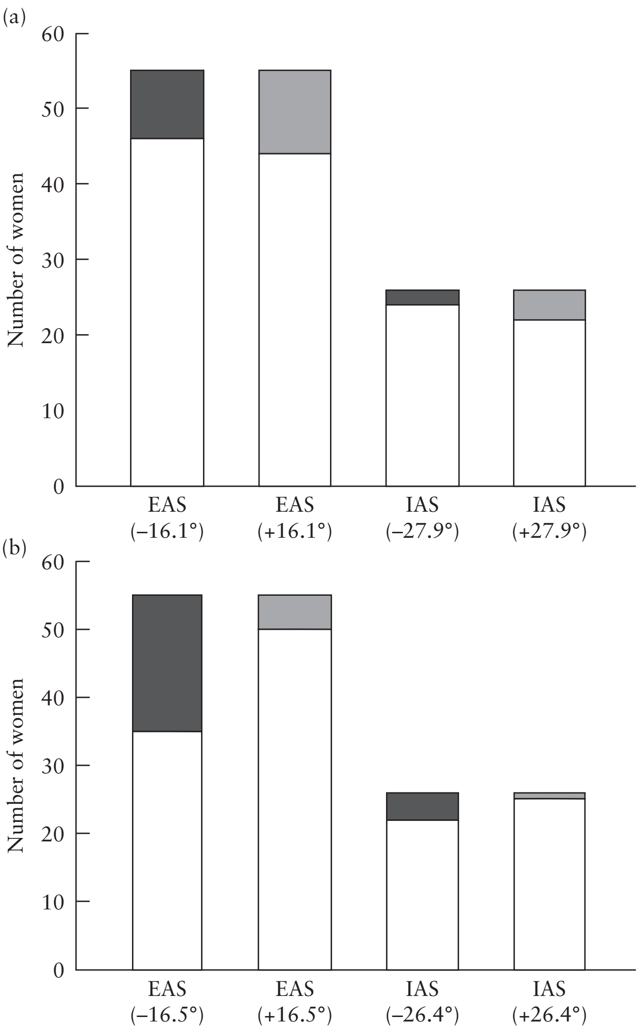

Figure 2 Number of women that would be diagnosed incorrectly with a significant external (EAS) or internal (IAS) anal sphincter defect on transperineal ultrasound performed at rest (a) and during maximum pelvic floor muscle contraction (b) if diagnostic cut-off of 30° was used to indicate significant defect, using endoanal ultrasound as the reference standard. □, Correct diagnosis; ▩, overdiagnosis; ■, underdiagnosis.

EAS defect ($n = 55$ images on EAUS) would occur in 16.4% ($n = 9$) of cases, and overdiagnosis would occur in 20% ($n = 11$). Underdiagnosis of a significant IAS defect ($n = 26$ images on EAUS) would occur in 7.7% ($n = 2$) of cases and overdiagnosis would occur in 15.4% ($n = 4$) (Figure 2a). For TPUS performed during maximum PFMC, underdiagnosis of a significant EAS defect would occur in 36.4% ($n = 20$) of cases, and overdiagnosis would occur in 9.1% ($n = 5$). Underdiagnosis of a significant IAS defect would occur in 15.4 % ($n = 4$) of cases, and overdiagnosis would occur in 3.8% ($n = 1$) (Figure 2b).

DISCUSSION

This original study compared directly the anal sphincter defect angle measurements taken using EAUS and TPUS. We showed that TPUS has excellent agreement with EAUS in the detection of a sphincter defect. However, there is poor-to-moderate agreement in the measurement of IAS and EAS defect angles between TPUS at rest or during maximum PFMC and EAUS. Moreover, the SEM was approximately ± 16° for EAS and ± 27° for IAS defect angle measured on TPUS. Therefore, if TPUS was performed using the diagnostic cut-off of 30°, incorrect diagnosis of a significant EAS defect could occur in approximately 9–36% of women and incorrect diagnosis of a significant IAS defect could occur in approximately 4–15% of women.

Strengths of this study include that a validated scoring system was used to assess scan findings and that all scans were reviewed offline and independently by two reviewers who were blinded to the other scan results and clinical history, at a weekly interval. Limitations include that, with both TPUS and EAUS, suture material, edema and hematoma may affect the image quality and therefore assessment of the defect angle[6,12]. This may have affected the defect angles measured at the beginning of the wound-infection process. We acknowledge that, as this was a secondary analysis, the primary outcome of this study was not powered to assess a difference between EAUS and TPUS measurements. Although our sample size was large ($n = 500$ ultrasound volumes), only 10 women had a defect (10 EAS and three IAS) on ultrasound, this equated to 102 ultrasound scans (55 EAUS and 47 TPUS). As the rate of OASI[16] is only approximately 3% and the risk of wound infection in the group has been reported to affect up to 20% of women[17], this small sample size was expected. However, as a difference of 30° is clinically relevant, based on this study findings, for EAS defect angle, assuming a SD of 21.52 for the differences, 5% significance level and 90% power, a future study would need a sample size of eight women. For IAS defect angle, assuming a SD of 28.89 for the differences, 12 women would be required.

A cut-off angle of 30° is used in the diagnosis of significant defects and is taken into account when making recommendations regarding the mode of delivery in subsequent pregnancies after OASI[18,19]. The Royal College of Obstetricians and Gynaecologists recommends that women who are symptomatic or have abnormal EAUS and/or manometry should be counseled regarding the option of elective Cesarean delivery[20]. We found that, when defect angle was measured on TPUS and the diagnostic cut-off of 30° was used, underdiagnosis of a significant anal sphincter defect could occur in up to 36% of cases. This would therefore lead to an improper recommendation of vaginal birth, and so, potentially compromise anal sphincter function in a future delivery. Additionally, using TPUS, overdiagnosis of a sphincter defect could occur in up to 15% of cases, leading potentially to an improper recommendation of Cesarean birth, which is not without short- or long-term risk[21].

In a prospective study, Taithongchai *et al.*[22] compared the diagnostic accuracy of 3D-EAUS and 3D-TPUS for OASI in 250 women, using EAUS as the reference standard. They found that TPUS had a low positive predictive value of 51% and 37% in diagnosing EAS and IAS defects, respectively. However, TPUS had a high negative predictive value of 85% and 93% in diagnosing EAS and IAS defects, respectively, meaning that although TPUS could diagnose accurately an intact anal sphincter, it could not accurately diagnose a sphincter defect. We found that there was substantial agreement between 3D-EAUS and 4D-TPUS in diagnosing EAS and IAS defects. The difference between this study findings and those of Taithongchai *et al.*[22] may be due to the difference in TPUS ultrasound systems used. We used a newer generation system, which may have led to better volume acquisition and image quality, and ultimately to better agreement in the diagnosis of an anal sphincter defect.

As we analyzed EAUS and TPUS at rest, we can suggest the effect distention from the endoanal probe has on the anal sphincter complex, without additional change in anatomy from PFMC. It was unsurprising that, in comparison to EAUS, IAS defects were significantly smaller by 26° at rest on TPUS. However, EAS defects on TPUS at rest were significantly larger by 11° compared with EAUS. A plausible explanation for this is that, despite their contractile ability, in comparison to the smooth muscle of the IAS, the striated skeletal muscle of the EAS has lower elastic capability and therefore is less affected by stretching forces[23]. With TPUS, it is advised that volume acquisition is performed on maximum PFMC to improve defect visualization[24]. However, if sufficient PFMC cannot be achieved, images can be taken at rest and there is no significant difference in diagnostic performance[25]. With regard to EAS defect angle, this study agrees with the recommendation by Dietz[24] that TPUS should be performed during maximum PFMC as no significant difference was found with EAUS measurements. However, when TPUS measurements were performed at rest, the EAS defect angle was significantly larger by about 11° in comparison to EAUS.

The correlation between TPUS and EAUS in assessing defect severity scores such as the Norderval score has been shown to be good[22]. With regard to defect angle size, the Norderval score uses 90° as a cut-off[26]. We used the Starck score[12] to evaluate the extent of anal sphincter defects, which uses cut-off values of 90°, 91–180° and 180°. We found an excellent correlation between EAUS and TPUS in assessing the Starck score, which is unsurprising as the SEMs were smaller than 90°. This is in keeping with a previous prospective study of 59 women with primary OASI repair, which found that EAUS and TPUS had moderate-to-good correlation in assessing the Starck score[27].

In conclusion, we found that TPUS has excellent agreement with EAUS in the detection of anal sphincter defects. However, there was poor-to-moderate agreement between EAUS and TPUS when measuring IAS and EAS defect size. TPUS may therefore incorrectly diagnose significant sphincter defects when using a diagnostic cut-off of 30° and lead to inappropriate management. This highlights the need for exercising caution when using TPUS for this purpose in subsequent pregnancy management. Therefore, the diagnostic criteria for significant anal sphincter defects require reappraisal in the setting of TPUS. Future studies with larger sample size, powered specifically to assess differences between EAUS and TPUS would be required to detect a true difference and to calculate a new cut-off for the diagnosis of significant defect on TPUS.

ACKNOWLEDGMENTS

We thank Dr Ka Woon Wong (Urogynaecology Subspecialty Trainee at Croydon University Hospital, London, UK) for her support with the independent analysis of the TPUS volumes. We also thank P. Bassett at Statsconsultancy Ltd for support with the statistical analysis. We thank the Croydon Childbirth Charitable Trust for providing an educational grant for N.A.O..

REFERENCES

1. AIUM/IUGA Practice Parameter for the Performance of Urogynecological Ultrasound Examinations: Developed in Collaboration with the ACR, the AUGS, the AUA, and the SRU. *J Ultrasound Med* 2019; **38**: 851–864.
2. Sultan AH, Kamm MA, Talbot IC, Nicholls RJ, Bartram CI. Anal endosonography for identifying external sphincter defects confirmed histologically. *Br J Surg* 1994; **81**: 463–465.
3. Sultan AH, Kamm MA, Nicholls JR, Bartram CI. Prospective study of the extent of internal anal sphincter division during lateral sphincterotomy. *Dis Colon Rectum* 1994; **37**: 1031–1033.
4. Sultan AH, Monga A, Lee J, Emmanuel A, Norton C, Santoro G, Hull T, Berghmans B, Brody S, Haylen BT. An International Urogynecological Association (IUGA)/International Continence Society (ICS) joint report on the terminology for female anorectal dysfunction. *Int Urogynecol J* 2017; **28**: 5–31.
5. Guzmán Rojas RA, Kamisan Atan I, Shek KL, Dietz HP. Anal sphincter trauma and anal incontinence in urogynecological patients. *Ultrasound Obstet Gynecol* 2015; **46**: 363–366.
6. Dietz HP. Exoanal Imaging of the Anal Sphincters. *J Ultrasound Med* 2018; **37**: 263–280.
7. Bartram CI, Sultan AH. Imaging of the Anal Sphincter. In: *Perineal and Anal Sphincter Trauma*. Sultan AH, Thakar R, Fenner DE (eds). Springer: London, 2007.
8. Scheer I, Thakar R, Sultan AH. Mode of delivery after previous obstetric anal sphincter injuries (OASIS): a reappraisal? *Int Urogynecol J* 2009; **20**: 1095–1101.
9. Scott SM, Lunniss PJ. Investigations of Anorectal Function. In: *Perineal and Anal Sphincter Trauma: Diagnosis and Clinical Management*. Sultan AH, Thakar R, Fenner DE (eds). Springer: London, 2009; 102–122.

10. Okeahialam NA, Thakar R, Sultan AH. Effect of a subsequent pregnancy on anal sphincter integrity and function after obstetric anal sphincter injury (OASI). *Int Urogynecol J* 2021; **32**: 1719–1726.
11. Sultan AH. The Effect of Perineal Wound Infection on the Anal Sphincter. ClinicalTrials.gov Identifier: NCT04480684. https://clinicaltrials.gov/ct2/show/NCT04480684?term=04480684&draw=2&rank=1.
12. Starck M, Bohe M, Valentin L. Results of endosonographic imaging of the anal sphincter 2–7 days after primary repair of third- or fourth-degree obstetric sphincter tears: Endosonographic imaging after anal sphincter tear repair. *Ultrasound Obstet Gynecol* 2003; **22**: 609–615.
13. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; **370**: 1453–1457.
14. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med* 2016; **15**: 155–163.
15. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012; **22**: 276–282.
16. Thiagamoorthy G, Johnson A, Thakar R, Sultan AH. National survey of perineal trauma and its subsequent management in the United Kingdom. *Int Urogynecol J* 2014; **25**: 1621–1627.
17. Lewicky-Gaupp C, Leader-Cramer A, Johnson LL, Kenton K, Gossett DR. Wound complications after obstetric anal sphincter injuries. *Obstet Gynecol* 2015; **125**: 1088–1093.
18. Jordan PA, Naidu M, Thakar R, Sultan AH. Effect of subsequent vaginal delivery on bowel symptoms and anorectal function in women who sustained a previous obstetric anal sphincter injury. *Int Urogynecol J* 2018; **29**: 1579–1588.
19. Taithongchai A, Thakar R, Sultan AH. Management of subsequent pregnancies following fourth-degree obstetric anal sphincter injuries (OASIS). *Eur J Obstet Gynecol Reprod Biol* 2020; **250**: 80–85.
20. RCOG. The Management of Third and Fourth-degree Perineal Tears. Green-Top Guideline No. 29. https://www.rcog.org.uk/media/5jeb5hzu/gtg-29.pdf.
21. Sandall J, Tribe RM, Avery L, Mola G, Visser GH, Homer CS, Gibbons D, Kelly NM, Kennedy HP, Kidanto H, Taylor P, Temmerman M. Short-term and long-term effects of caesarean section on the health of women and children. *Lancet* 2018; **392**: 1349–1357.
22. Taithongchai A, van Gruting IMA, Volløyhaug I, Arendsen LP, Sultan AH, Thakar R. Comparing the diagnostic accuracy of 3 ultrasound modalities for diagnosing obstetric anal sphincter injuries. *Am J Obstet Gynecol* 2019; **221**: 134.e1–9.
23. Jaslove JM, Nelson CM. Smooth muscle: a stiff sculptor of epithelial shapes. *Philos Trans R Soc Lond B Biol Sci* 2018; **373**: 20170318.
24. Dietz HP. Ultrasound imaging of maternal birth trauma. *Int Urogynecol J* 2021; **32**: 1953–1962.
25. Subramaniam N, Robledo KP, Dietz HP. Anal sphincter imaging: better done at rest or on pelvic floor muscle contraction? *Int Urogynecol J* 2020; **31**: 1191–1196.
26. Norderval S, Markskog A, Røssaak K, Vonen B. Correlation between anal sphincter defects and anal incontinence following obstetric sphincter tears: assessment using scoring systems for sonographic classification of defects. *Ultrasound Obstet Gynecol* 2008; **31**: 78–84.
27. Stuart A, Ignell C, Örnö A. Comparison of transperineal and endoanal ultrasound in detecting residual obstetric anal sphincter injury. *Acta Obstet Gynecol Scand* 2019; **98**: 1624–1631.

SUPPORTING INFORMATION ON THE INTERNET

The following supporting information may be found in the online version of this article:

Table S1 Sensitivity analysis of final angle size of external (EAS) and internal (IAS) anal sphincter defect and Starck score, assessed on 3D endoanal ultrasound (EAUS) and on 4D transperineal ultrasound (TPUS) at rest and during maximum pelvic floor muscle contraction (PFMC)