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ORIGINAL ARTICLE

Usefulness of anorectal and endovaginal 3D ultrasound in the evaluation of sphincter and pubovisceral muscle defects using a new scoring system in women with fecal incontinence after vaginal delivery

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Abstract
Purpose This study aims to evaluate pubovisceral muscle and anal sphincter defects in women with previous vaginal delivery and fecal incontinence and to correlate the findings with the severity of symptoms using the combined anorectal and endovaginal 3D ultrasonography with a new ultrasound scoring system.
Methods Consecutive female patients with previous vaginal delivery and fecal incontinence symptoms were screened. Fecal incontinence was assessed with the Cleveland Clinic Florida fecal incontinence scale, and the extent of defects was assessed by an ultrasound score based on results of anorectal and endovaginal 3D ultrasound. Fecal incontinence was assessed with the Cleveland Clinic Florida fecal incontinence scale.
Results Of 84 women with previous vaginal delivery and fecal incontinence, 21 (25%) had intact pubovisceral muscles and anal sphincters; 63 (75%) had a pubovisceral muscle or anal sphincter defect, or both. Twenty-eight (33%) had a pubovisceral muscle defect [23% with an external anal sphincter (EAS) defect or combined EAS/internal anal sphincter defects; 11% with intact anal sphincters]. Thirty-five (42%) had intact pubovisceral muscles and an anal sphincter defect. Compared with women with intact pubovisceral muscles/anal sphincter defects, patients with pubovisceral muscle defects had significantly higher incontinence scores and significantly higher ultrasound scores indicating more extensive defects. Incontinence symptoms correlated positively with the ultrasound score, measurements of sphincter defects, and area of the levator hiatus.
Conclusions Evaluation of both pubovisceral muscles and anal sphincters is important to identify defects and determine treatment for women with fecal incontinence after vaginal delivery. The severity of fecal incontinence symptoms is significantly related to the extent of defects of the pubovisceral muscles and anal sphincters.

Keywords Pelvic floor · Physiology · Incontinence · Ultrasound · Imaging

Anorectal ultrasonography is an established method for pretreatment assessment of benign and malignant diseases of the anal canal and rectum [1–4]. It is especially useful for evaluating anal canal anatomy and diagnosing sphincter defects [5–7]. The increasing availability of three-dimensional (3D) acquisition has opened new possibilities for research on anatomy and disorders of the anal canal, rectum, and pelvic floor [8–12]. The endovaginal approach [10, 12] provides visualization of the pelvic floor muscles, including the pubovisceral portion of the levator ani. We use the term *pubovisceral muscle* synonymously with *pubococcygeus* and *puborectalis muscles*, as defined by DeLancey et al., because the

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components cannot be distinguished on endovaginal imaging [13]. The pubovisceral muscle, which is visualized as a multilayer highly echoic sling lying posteriorly to the anal canal and attaching to the pubic bone, supports the pelvic organs (bladder, urethra, vagina, uterus, and anal canal) and borders the lateral and posterior parts of the levator hiatus and the anterior part of the symphysis pubis. The pubovisceral muscle limits the levator hiatus and plays an important role in sustaining continence and/or preventing pelvic organ prolapse [14].

Vaginal delivery is the most frequent risk factor for anatomic and innervation damage in the anal canal [1, 6–8, 15]. Several studies using nuclear magnetic resonance imaging and ultrasound have shown pubovisceral muscle injury in 15 to 55% of women after vaginal delivery, with corresponding pelvic organ prolapse (POP) and enlargement of the levator hiatus [15–20]. However, the relationship between pubovisceral muscle defects and fecal incontinence remains unclear. In a previous study using 3D endovaginal and anorectal ultrasonography [21], we found pubovisceral muscle defects in 27% of women with previous vaginal delivery and fecal incontinence and observed that severity of incontinence was related to the presence and extent of the pubovisceral muscle defect as well as to anal sphincter damage. In contrast, Chantarasorn et al. found no correlation between fecal incontinence symptoms and pubovisceral muscle defects [22]. Therefore, we decided to further investigate the relationship between fecal incontinence and pubovisceral muscle and anal sphincter defects in women with fecal incontinence who had previously undergone vaginal delivery. The aim of this study was to use combined anorectal and endovaginal 3D ultrasonography with a new ultrasound scoring system to evaluate pubovisceral muscle and anal sphincter defects in women with previous vaginal delivery and fecal incontinence, and to investigate the relationship between anatomic and functional findings and the severity of symptoms.

Methods

Patients

Consecutive female patients with previous vaginal delivery and fecal incontinence symptoms were screened between August 2013 and September 2014 at the Walter Cantídio University Hospital of the Federal University of Ceara and São Carlos Hospital–Ceara, Fortaleza, Brazil. Patients with a history of previous colorectal, anorectal, or gynecological surgery were excluded, as were those with inflammatory bowel disease, HIV infection, obesity, diabetes, or neurologic disorders. Patients underwent anorectal and endovaginal 3D ultrasound and anal manometry. Patients with defects of the anal sphincters and/or pubovisceral muscle were included in analyses of the relationships between these defects and fecal incontinence.

The clinical protocol was approved by the Research Ethics Committee of the Walter Cantídio University Hospital, and all patients gave written informed consent.

Three-dimensional ultrasonography

All patients underwent 3D endovaginal and anorectal ultrasonography. The examination was performed by a single colorectal surgeon with experience in 3D ultrasonography (S.M.M.R.). A rectal enema was administered 2 h before the scan. A 3D ultrasound endoprobe was used (Pro-Focus 2052; 12–16 MHz; 3.0–5.2 cm focal distance; B-K Medical, Herlev, Denmark). Images up to 6.0 cm long were captured along the proximal-distal axis for up to 55 s by moving two crystals (axial and longitudinal) on the extremity of the transducer automatically, without moving the probe. The examination involved a series of transaxial microsections up to 0.20 mm thick, producing a high-resolution digitalized volumetric image. Volume was displayed as a 3D cube image and recorded and analyzed in multiple planes.

For the endovaginal approach, patients were placed in the dorsal lithotomy position. A transducer using 12 MHz with a focal distance of 5.2 cm was placed in the vagina in the neutral position, and the endoprobe was introduced as far as the bladder. The endovaginal ultrasound examination identified pubovisceral defects, defined as complete or partial detachment (discontinuity) of the pubovisceral muscle from its insertion on the pubic rami. Complete detachment of the pubovisceral muscle involved the entire length of the muscle; partial detachment (partially compromised length of the muscle) was either unilateral (involving just one side) or bilateral (both sides). Endovaginal ultrasound was also used to measure the area of the levator hiatus, comparing the area at rest and during the Valsalva maneuver.

For the anorectal approach, patients were placed in the left lateral position for examination. After digital rectal examination, the endoprobe using 16 MHz and a focal distance of 3.0 cm was introduced as far as the upper anal canal. The ultrasound examination identified the presence of sphincter defects, including combined defects involving both the external anal sphincter (EAS) and the internal anal sphincter (IAS) and defects of the EAS alone. Defects were considered to be partial (partially compromised length of the muscle) or total (whole length of the muscle compromised). The radial angle of the anterior EAS defect was considered to be either minor (≤180°) or major (>180°). Anorectal ultrasound was also used to measure the lengths of the anterior EAS, the anterior IAS, and the gap between the proximal edge of the anterior EAS and the anorectal junction.

Anorectal manometry

Anorectal manometry was performed using a flexible, water-perfused polyethylene catheter with an eight-channel manometer with ProctoMaster software (Dynamed, São Paolo, Brazil) to calculate the length of the anal canal, anal canal pressure at rest, maximum anal squeeze pressure, and capacity required to sustain squeeze pressure, and to evaluate pressure during straining and the rectoanal inhibitory reflex. Rectal sensitivity (corresponding to the first sensation of rectal filling) and the maximum tolerable volume were also measured.

Evaluation

The extent of the anal sphincter and pubovisceral muscle defects identified by ultrasound examination was described by a score ranging from 0 to 10, based on the longitudinal involvement (none, partial, or total length) of the EAS and IAS, the radial angle of the anterior EAS defect (≤180 or >180°), and the longitudinal involvement (none, partial, or total length) of the left and right lateral pubovisceral muscle. One point is allotted for partial length detachment and two points for total length detachment of PV muscle in each side, so that combined and extended lesions result in a high ultrasound score (Table 1; Figs.1, 2, 3, and 4). The evaluation of the 3D image volume was done by a single colorectal surgeon (S.M.M.R.) who analyzed the images of the sphincter muscles and pubovisceral muscles at different times.

The severity of fecal incontinence was assessed by means of the Cleveland Clinic Florida (CCF) incontinence scale [23], which addresses the type and frequency of leakage (gas, liquid, and solid stool), need for pads, and extent of alterations in lifestyle on a scale from 0 (perfect continence) to 20 (complete incontinence).

Table 1 Scoring system for anal sphincter and pubovisceral muscle defects detected with anorectal and endovaginal 3D ultrasound

Defect	Score		
	0	1	2
External anal sphincter			
Length of defect	None	Partial	Whole
Size of defect (angle)	None	≤180°	>180°
Internal anal sphincter			
Length of defect	None	Partial	Whole
Pubovisceral muscle			
Length of left lateral defect	None	Partial	Whole
Length of right lateral defect	None	Partial	Whole

Statistical analysis

Characteristics of patients with pubovisceral muscle defects were compared with those with intact pubovisceral muscles. Differences between groups were assessed by means of the Student t test for continuous data or the Mann-Whitney U test for ordinal data. The Spearman rank correlation coefficient (ρ) was calculated to evaluate the relationship between severity of fecal incontinence symptoms (CCF score) and anal manometry anal pressures (resting pressure and maximum anal squeezing), anorectal ultrasound findings [length of the anterior external anal sphincter (EAS) and anterior internal anal sphincter (IAS)], the gap between the proximal edge of the anterior EAS and the anorectal junction, and the area of the levator hiatus.

Results

Prevalence of pubovisceral muscle and anal sphincter defects

A total of 84 women with previous vaginal delivery and fecal incontinence were eligible: 21 (25%) had intact pubovisceral muscles and anal sphincters, and 63 (75%) had a pubovisceral muscle defect or an anal sphincter defect, or both. Table 2 shows the number of patients with anal sphincter defects in relation to pubovisceral muscle defects. Twenty-eight women (33.3%) had a pubovisceral muscle defect (bilateral in 8 patients), including 19 women (22.6%) who also had an anterior EAS defect or combined anterior EAS and IAS defects and 9 women (10.7%) with intact anal sphincters. Thirty-five women (41.7%) had intact pubovisceral muscles and an anal sphincter defect.

Patient characteristics

Data from the 63 women with a pubovisceral muscle defect and/or an anal sphincter defect were further analyzed. The mean age was 61 (SD, 12.8; range, 18–87) years; the median number of vaginal deliveries was 2 (range, 1–8). The median CCF incontinence score was 6 (range, 2–16). The median ultrasound score was 3 (range, 1–10). On anal manometry, the mean resting pressure was 34 (SD, 14.2; range, 10–67) mmHg, and the mean maximal squeeze pressure was 85 (SD, 38.2; range, 20–190) mmHg. The mean area of the levator hiatus was 18 (SD, 3.6; range, 13–29) cm^2 at rest, with a significant increase during Valsalva to 20 (SD, 5.2; range, 13–40) cm ($p = 0.01$).

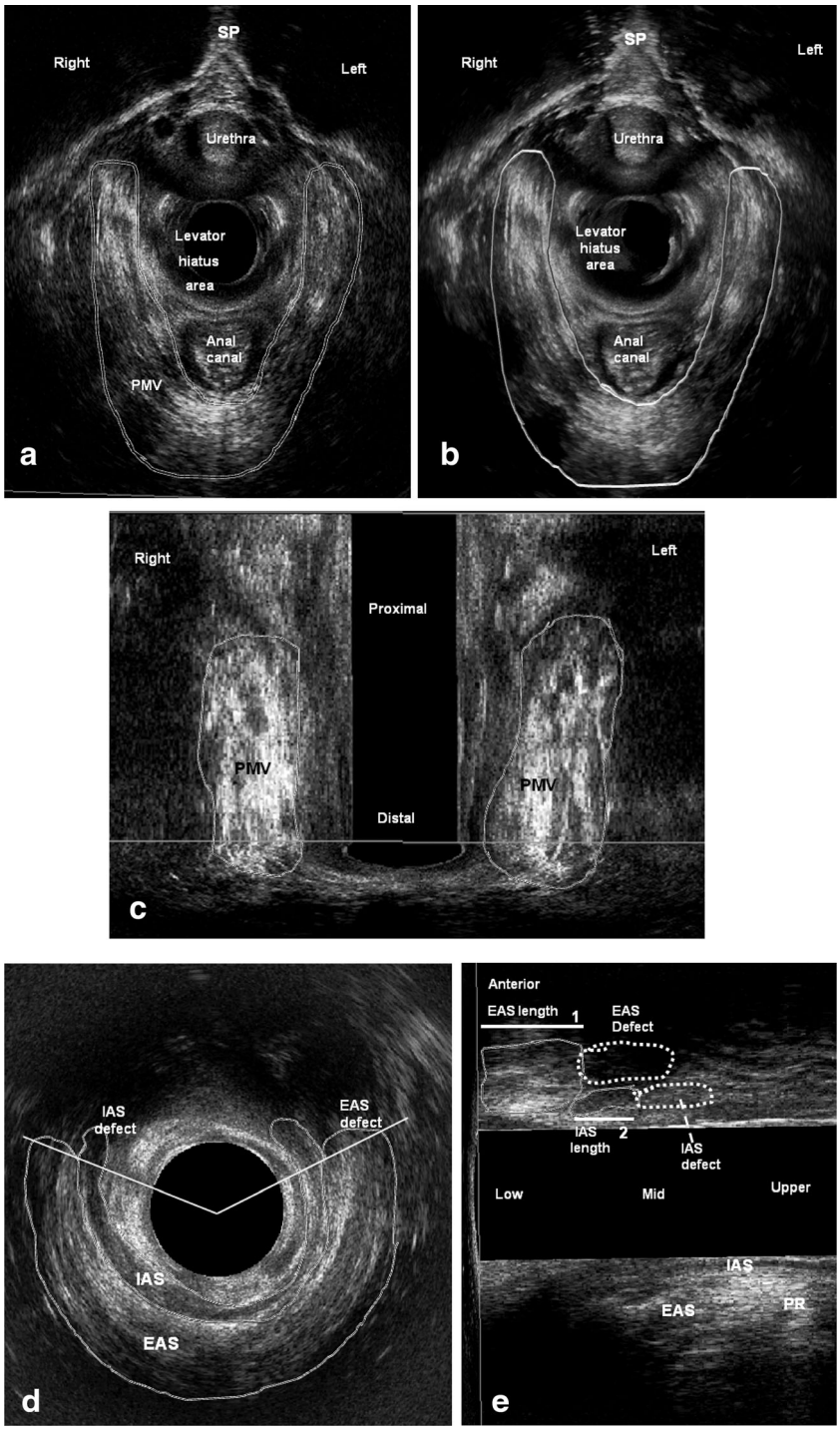

Fig 1 Representative three-dimensional ultrasonography images of combined partial external anal sphincter and internal anal sphincter defects with intact pubovisceral muscle after vaginal delivery. **a** Endovaginal approach showing intact pubovisceral muscle (axial plane). **b** Rendered mode of image (**a**). **c** Entire length of pubovisceral muscle intact (coronal plane). **d** Anorectal approach showing partial external and internal anal sphincter defects with an external anal sphincter angle less than 180° (axial plane). **e** Measurement of the residual external (line 1) and internal (line 2) anal sphincter length (sagittal plane). Ultrasound score = 3. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PMV* pubovisceral muscles, *PR* puborectalis muscle, *SP* symphysis pubis

Pubovisceral muscle defect versus intact pubovisceral muscles

Patients with pubovisceral muscle defects were compared versus those who had intact pubovisceral muscles and an anal sphincter defect (Table 3). Patients with pubovisceral muscle defects had more severe incontinence (significantly higher CCF scores; $p = 0.001$) and more extensive defects (significantly higher ultrasound scores; $p = 0.001$). Age and number of vaginal deliveries did not differ significantly between groups. On anal manometry, no significant differences were observed in mean resting pressure ($p = 0.39$), but the mean maximum anal squeeze pressure was significantly lower in patients with pubovisceral muscle defects ($p = 0.03$). Patients with pubovisceral muscle defects also had a significantly greater mean area of the levator hiatus at rest ($p = 0.01$)

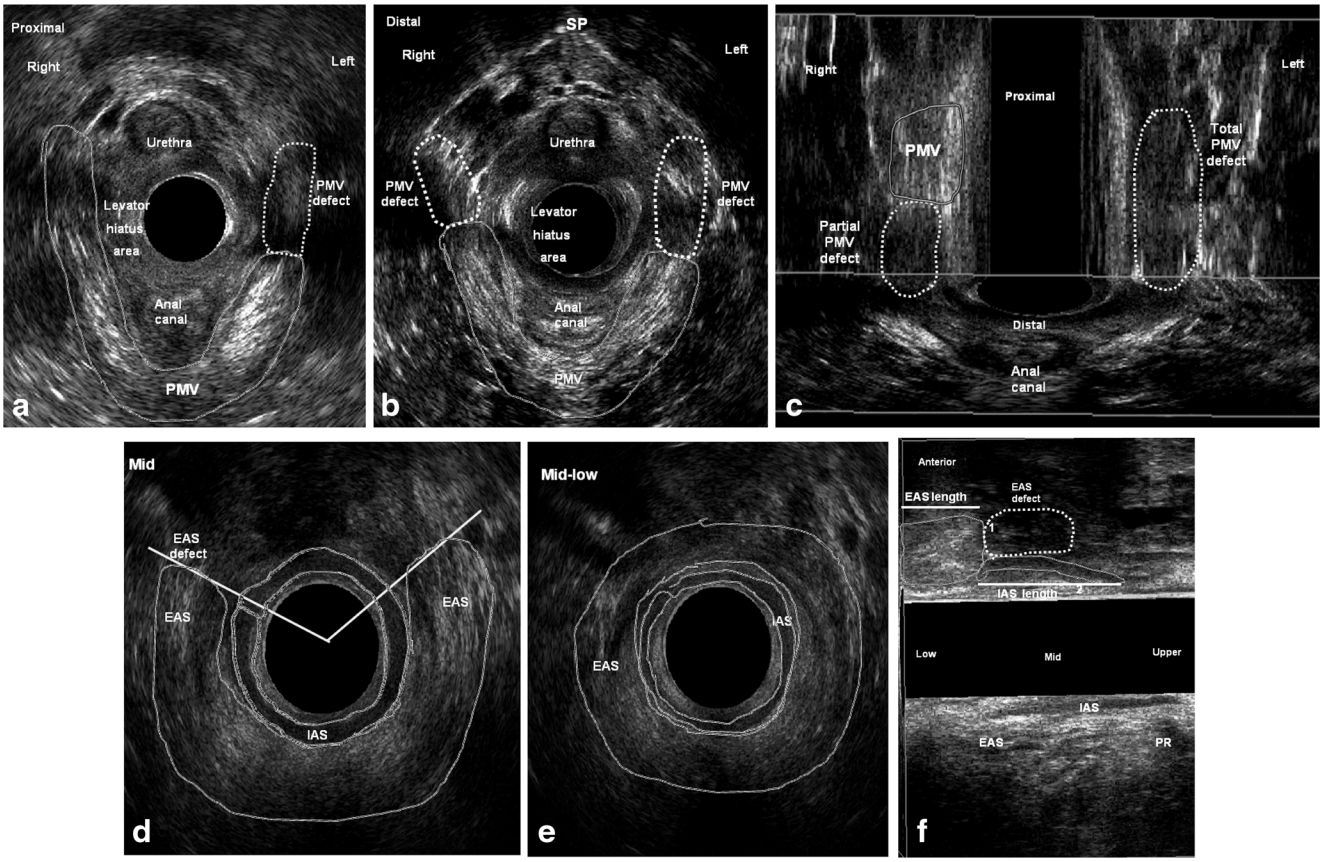

Fig 2 Representative three-dimensional ultrasonography images of bilateral pubovisceral muscle and partial external anal sphincter defects after vaginal delivery. **a** Endovaginal approach (axial plane) showing the pubovisceral muscle defect on the left side (proximal part). **b** Bilateral lesions of the pubovisceral muscle (distal part). **c** Complete defect of the pubovisceral muscle on the left and partial defect on the right side (coronal plane). **d** Mid anal canal, **e** mid-low anal canal. Anorectal approach (axial plane) showing a partial defect of the external anal sphincter with an angle less than 180°. **f** Measurements of the residual length of the external anal sphincter (sagittal plane). The internal anal sphincter is intact. Ultrasound score = 5. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PMV* pubovisceral muscles, *PR* puborectalis muscle, *SP* symphysis pubis

and during the Valsalva maneuver ($p = 0.02$). The mean area of the levator hiatus increased significantly during the Valsalva maneuver in patients with pubovisceral muscle defects ($p = 0.03$) but not in patients with intact pubovisceral muscles ($p = 0.08$).

Correlation between fecal incontinence and pelvic floor defects

A significant correlation was found between CCF incontinence and ultrasound scores ($\rho = 0.71$, $p < 0.001$). CCF incontinence scores also correlated significantly with the lengths of the anterior EAS ($\rho = -0.35$, $p < 0.001$) and IAS ($\rho = -0.40$, $p < 0.001$) as well as the area of the levator hiatus ($\rho = 0.26$, $p = 0.03$). No significant correlations were observed between CCF incontinence scores and the gap measurement ($\rho = 0.09$, $p = 0.46$) or the resting ($\rho = -0.08$, $p = 0.54$) or squeeze pressure ($\rho = -0.12$, $p = 0.34$) values on anal manometry.

Discussion

In our study, 33% of women with previous vaginal delivery and fecal incontinence had pubovisceral muscle defects, comparable to the 27% found in our previous study [21]. In both studies, median CCF incontinence scores were significantly higher in patients with pubovisceral muscle defects than in patients with anal sphincter defects and intact pubovisceral muscles. To aid the evaluation of the relationship between pelvic floor defects and fecal incontinence in this study, we used a new ultrasound score to quantify the extent of the lesions, taking into consideration anal canal circumference with measurement of the radial angle of the anterior EAS in addition to extent (partial or whole length) of the anterior EAS and IAS defects and pubovisceral muscle defects (unilateral and bilateral). High ultrasound scores indicate extensive defects, involving the complete length of at least one muscle. The ultrasound score was positively correlated with the CCF incontinence scores.

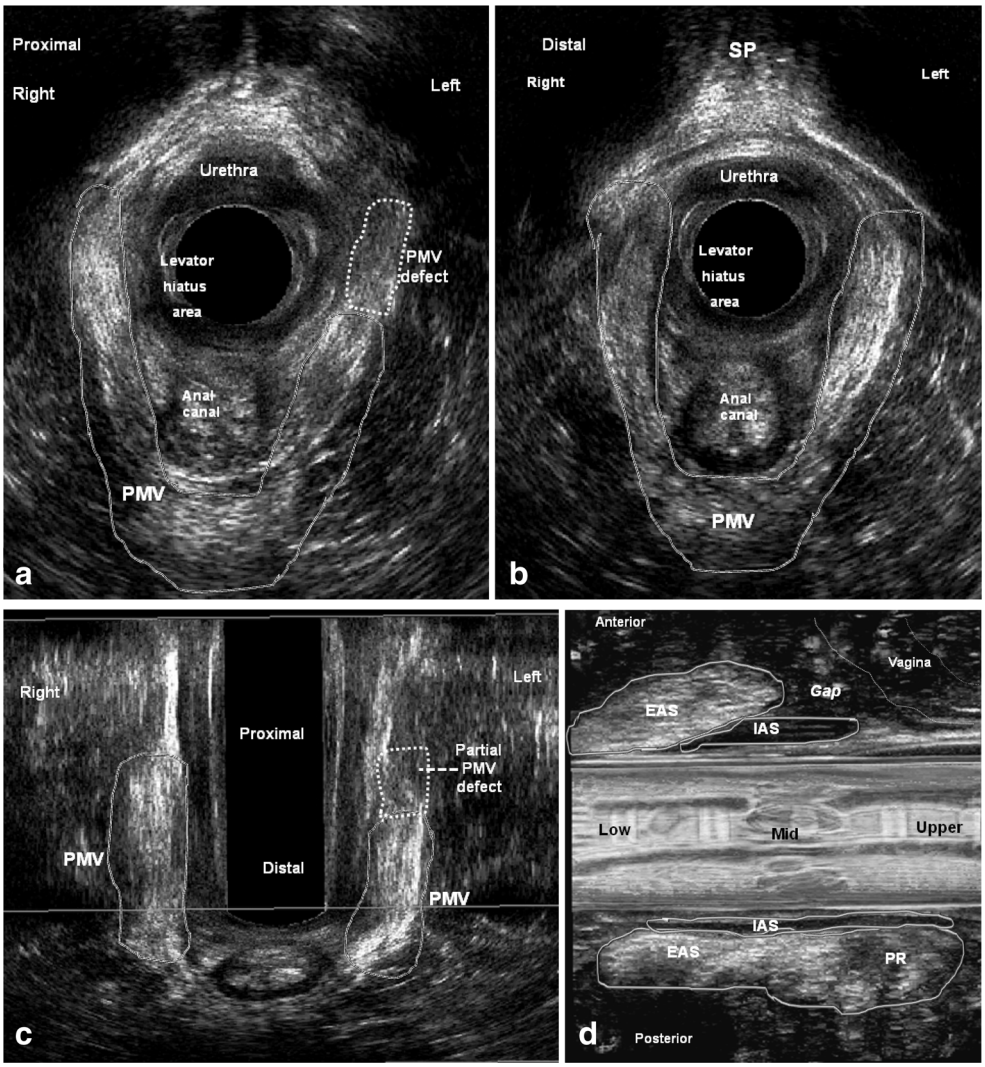

Fig. 3 Representative three-dimensional ultrasonography images of unilateral pubovisceral muscle and intact anal sphincter muscles after vaginal delivery. **a** Endovaginal approach (axial plane) showing the partial pubovisceral muscle defect on the left side (proximal part). **b** Bilateral intact pubovisceral muscle in the distal part. **c** Partial defect of the pubovisceral muscle on the left side and intact pubovisceral muscle on the right side (coronal plane). **d** Anorectal approach showing distribution of intact sphincter muscles in the anal canal. Ultrasound score = 1. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PMV* pubovisceral muscles, *PR* puborectalis muscle, *SP* symphysis pubis

Risk factors for fecal incontinence may include anatomic lesions of the anal sphincter [1, 6], damage to the innervation of the pelvic floor muscles [15], as well as age and diabetes [24, 25]. However, in some patients with fecal incontinence symptoms, no defect can be found, whereas other patients have a sphincter defect but no fecal incontinence symptoms [7]. The results of our current study and those of our previous study [21] suggest that pubovisceral muscle defects may represent an additional risk factor for fecal incontinence. Heilbrun et al. evaluated primiparous women with EAS injuries and found more symptoms of fecal incontinence in women with major levator ani injuries on magnetic resonance imaging 6 to 12 months after vaginal delivery compared with women without major levator ani injuries (35.3 vs. 16.7%) [26]. However, the difference was not significant. In contrast to our data, Chantarasorn et al. found no association between pubovisceral muscle damage and the presence of fecal incontinence in a retrospective study of 397 women who had attended a tertiary urogynecological clinic [22]. These authors concluded that their findings argued against a major role of the puborectalis muscle in anal continence. Lammers et al. evaluated 189 women with POP who were referred to a urogynecological clinic for magnetic resonance imaging and found that pubovisceral avulsion was associated with episiotomy and previous anterior vaginal wall reconstructive surgery [20].

Several studies found no correlation between incontinence symptoms and length of the sphincter muscles in patients with incontinence [11, 27]. In contrast, we found CCF incontinence scores to be positively correlated with the length of the anterior EAS and IAS in the present study. The differences in results may be due to differences in the populations studied, as those studies included patients with or without sphincter defects, whereas most patients in our analyses had defects of the anal sphincters. For example, Bordeianou et al. studied women with severe incontinence and/or history of vaginal delivery, traumatic injury, or perineal surgery, and only 42% had sphincter defects [27]. Wasserberg et al. studied

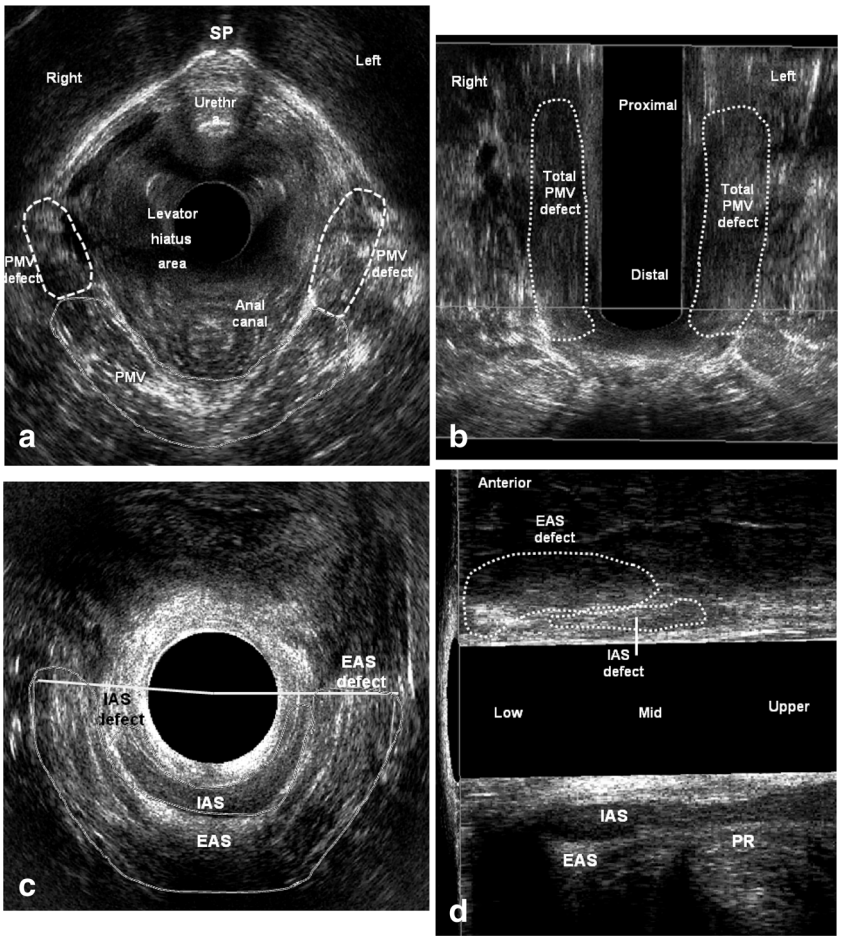

Fig. 4 Representative three-dimensional ultrasonography images of bilateral and complete pubovisceral muscle defects and complete external and internal anal sphincter defects after vaginal delivery. **a** Endovaginal approach showing bilateral pubovisceral muscle defect on the left and right sides (axial plane). **b** The entire length of the pubovisceral muscle lesion (coronal plane). **c** Anorectal approach showing complete external and internal anal sphincter defects with an external anal sphincter angle greater than 180° (axial plane). **d** External anal sphincter defect (sagittal plane). Ultrasound score = 10. *EAS* external anal sphincter, *IAS* internal anal sphincter, *PMV* pubovisceral muscles, *PR* puborectalis muscle, *SP* symphysis pubis

unselected consecutive patients with fecal incontinence. Consistent with these studies, we found no correlation between extent of defects as measured by ultrasound scores and anal manometric pressures [11, 27]. However, our patients with pubovisceral muscle defects had significantly lower mean maximum anal squeezing pressure compared with patients with intact pubovisceral muscles. This result may at least partially explain the role of pubovisceral muscle in the anatomy and function of anal continence.

The levator hiatus is the largest potential hernial portal in the human body and is delimited by the pubovisceral muscle and the pubic bone (rami pubis). Vaginal delivery leads to enlargement of levator hiatus, even without lesion of the muscles [28], and the area of the levator hiatus is correlated with POP [16, 19, 21]. In our current study, the area of the levator hiatus was significantly greater in women with pubovisceral muscle defects than in those with intact pubovisceral muscles and anal sphincter defects, both at rest and during the Valsalva maneuver. Patients with pubovisceral muscle defects also had a significant increase in the area of the levator hiatus during the Valsalva maneuver.

A strength of our study was the use of 3D ultrasonograph with automatic scanning, high-frequency, high-resolution imaging, which made it possible to measure in real time without moving the position of the transducer and to review the images as many times as necessary. The study was limited by the lack of data on the prevalence of pubovisceral muscle defect in a control group of women without fecal incontinence symptoms. Furthermore, it was not possible to evaluate patients before and after vaginal delivery. However, the study is relevant in that it simultaneously analyzed and correlated

Table 2 Distribution of anal sphincter defects in relation to pubovisceral muscle defects in women with incontinence after vaginal delivery (n = 84)

	Pubovisceral muscles	
	Defect (n = 28)	Intact (n = 56)
Anal sphincter defect		
Anterior EAS alone	7 (8.3)	23 (27.4)
Anterior EAS and IAS	12 (14.3)	12 (14.3)
Anterior EAS and IAS intact	9 (10.7)	21 (25.0)

Data are n (%)

EAS external anal sphincter, *IAS* internal anal sphincter

Table 3 Characteristics of 63 women with previous vaginal delivery and incontinence in relation to presence of pubovisceral muscle defects

	Pubovisceral muscles				
	Intact $n = 35$[a]		Defect $n = 28$[b]		p
Age, years					
Mean (SD)	61	(10.8)	60	(15)	0.83
Range	40–77		18–87		
Number of vaginal deliveries, median (range)	3	(1–8)	2	(1–8)	0.07
CCF incontinence score, median (range)	5	(2–11)	7	(3–17)	0.001
Ultrasound score, median (range)	2	(2–6)	4	(1–10)	0.001
Anal manometry, mmHg					
Resting pressure					
Mean (SD)	35	(13.7)	34	(12.8)	0.39
Range	16–67		10–64		
Maximal squeeze pressure					
Mean (SD)	94	(38.4)	72	(35.0)	0.03
Range	28–190		20–174		
Levator hiatus area (cm^2)					
At rest					
Mean (SD)	17	(3)[c]	20	(3.9)[d]	0.01
Range	13–23		15–29		
Valsalva maneuver					
Mean (SD)	19	(3.6)[c]	23	(6.1)[d]	0.002
Range	13–26		15–40		

CCF Cleveland Clinic Florida, *SD* standard deviation

[a] 23 patients with an anterior EAS defect alone; 12 with defects of the anterior EAS and IAS

[b] 9 patients with a pubovisceral muscle defect alone; 19 also with anal sphincter defects

[c] The difference in mean levator hiatus area between resting and the Valsalva maneuver was not significant in patients with intact pubovisceral muscles ($p = 0.08$)

[d] The mean levator hiatus area was significantly greater during the Valsalva maneuver than at rest in women with pubovisceral muscle defects ($p = 0.03$)

defects of the anal sphincter and pubovisceral muscle and function in a sample of women with fecal incontinence symptoms.

The results of this study suggest that complete anatomic and functional evaluation of patients with fecal incontinence should include combined evaluation of the anal sphincters and pubovisceral muscles. The strong correlation between the ultrasound score and CCF incontinence scores suggests that the ultrasound score can serve as a useful aid in choosing the best treatment for individual patients. For patients with a low score indicating defects of the sphincter muscles and/or pubovisceral muscles that involve only the partial length of the muscles, the recommended treatment might follow a sequence of clinical management including diet, medication, biofeedback, tibial nerve stimulation, and/or sacral nerve stimulation [29]. High scores indicating a complete defect involving the whole length of the muscle, especially the pubovisceral muscle, might be treated with a minimally invasive procedure such as the transobturator posterior anal sling (TOPAS). Recent publication of the 1-year results of a prospective, multicenter study showed that the TOPAS procedure provided significant improvements in symptoms of fecal incontinence and quality of life [30]. Further studies are needed to gain more information about the potential role of pubovisceral muscles in preserving continence and to develop new surgical repair techniques that will achieve good results.

Conclusions

Severity of fecal incontinence symptoms is significantly related to extent of defects of the pubovisceral muscles in addition to defects of the anal sphincters. Thus, evaluation of both the anal sphincters and the pubovisceral muscles is important in order to identify defects and determine a strategy for treatment in women with fecal incontinence after vaginal delivery. The 3D ultrasound score incorporating measurements of both defects represents a useful tool in assessing these patients.

Compliance with ethical standards

Financial disclosure None.

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