Two-dimensional Endoanal Ultrasound Scan Correlates with External Anal Sphincter Structure and Function, but not with Puborectalis

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KEYWORDS
anal sphincter, anorectal physiology, endoanal ultrasound, fecal incontinence, perineal dynamometer, puborectalis

Abstract  Background: To investigate the relevance of two-dimensional (2D) endoanal ultrasonic (EAUS) assessment of anal sphincter and puborectalis morphology by comparison to functional measures derived from patient symptoms and anorectal physiology.

Methods: Thirty women (mean age 44 years, mean parity 2) with anal incontinence underwent 2D EAUS, anorectal pull-through manometry, anorectal electosensitivity and sensation to rectal distension, pelvic floor dynamometry, and completed Wexner incontinence scores. EAUS images were reported blind to physiological assessments by a single experienced observer. The external and internal sphincters, and puborectalis were measured and scored for integrity and atrophy, and correlated with symptom load (Wexner score) and physiological data.

Results: The mean Wexner score was 10 (range 1–20). The puborectalis could not be accurately measured in 12 patients (44%) on EAUS. Anal squeeze pressure correlated with integrity of the external sphincter ($r = -0.4, p = 0.02$) but not integrity or atrophy of the puborectalis. There were no other significant correlations between EAUS features and patient symptom load or anorectal physiology ($r$ range, $-0.42$–$0.26$, $p > 0.05$).

Conclusion: Two-dimensional EAUS can define sphincter integrity, has a limited role for assessment of muscular quality but is not useful for assessment of the puborectalis.

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Conflicts of interest: The authors report no conflicts of interest.

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Introduction

Fecal incontinence (FI) is a life-altering and debilitating health condition which is more prevalent in women. This predilection is thought to be the result of child birth injuries [1,2]. The mechanical maintenance of continence has been largely attributed to the function of the anal sphincters, the internal anal sphincter (IAS) being largely responsible for preventing passive leakage [3], while the external anal sphincter (EAS) reinforces the action of the IAS during voluntary squeeze in order to defer the urge to defecate and prevent urge incontinence.

Improved understanding of pelvic floor musculature has however led to a greater appreciation of their role in maintaining continence, in particular the puborectalis muscle. It is postulated that the puborectalis blends into the fibers of the EAS and provides occlusion over the upper canal, augmenting anal sphincter function. This muscle also forms a sling around the anorectum playing an important role in maintaining the anorectal angle of ~90° to help maintain continence [4,5]. It is increasingly recognized that there is a large cohort of women with FI who have intact external and internal sphincters, and puborectal deficiency is hypothesized as a cause in this group. Assessment of this muscle is therefore important.

Assessment of sphincter morphology in patients with FI is routinely performed using two-dimensional (2D) endoanal ultrasound (EAUS), which is well-established for assessment of sphincter integrity. Its utility beyond this is less clear cut. Notably its value for assessment of muscular quality is less defined, and its ability to evaluate structures beyond the main sphincter complex, such as the puborectalis, is unclear [6,7]. Sultan et al [8] suggested that puborectalis can be visualized on EAUS, although assessment of this muscle is not routine in most centers.

Attempts to validate EAUS findings against anorectal physiological parameters and symptom load in incontinent patients have been attempted [9], although the literature is relatively sparse. Furthermore, there is little data validating the ability of ultrasonography (USS) to assess the pelvic floor muscles, particularly against a reference standard of muscle function.

The aim of this study was to investigate the effectiveness of 2D EAUS assessment of anal sphincter and puborectalis morphology by comparison with functional measures based on patient symptoms and anorectal physiology.

Methods

Design

This prospective cohort study was conducted over a 9 month period within the Physiology and Radiology units at a tertiary referral center. Full ethical approval was obtained from the Joint University College London (UCL) and University College London Hospitals (UCLH) Ethics Committee (London, UK). Women with anal incontinence or severe urgency, attending a colorectal, gastroenterology, or postnatal clinic were recruited. Informed consent was obtained from all participants. Data was gathered by history and examination, symptom questionnaire, anorectal physiology testing, and by EAUS (see below), all of which were carried out on the same day. Exclusion criteria included previous anorectal surgery, patients younger than 18 years, irritable bowel syndrome (ROME III criteria), or those who were suffering from medical illnesses affecting bowel function.

Endoanal ultrasound

EAUS was performed by one of two experienced gastrointestinal radiologists using a Hitachi machine (Zug, Germany) with a 10 MHz radial transducer. The probe was inserted into the anal canal and a standard 2D ultrasonic assessment made. In particular the structures at the level of puborectalis sling, mid canal (anterior external sphincter bar), and distal canal (below termination of internal sphincter) were interrogated. Representative images were stored on a picture archive and communication systems (PACS) for subsequent analysis.

A single radiologist with 15 years’ experience of EAUS recalled the static images onto a medical image review workstation and identified the puborectalis, external anal sphincter, and internal anal sphincter using standard definitions [10,11]. Using electronic callipers, representative thickness measurements of puborectalis, internal and external anal sphincter were made.

The observer also scored sphincter integrity using the criteria proposed by Fletcher et al [12] as follows: Scores for left and right of the midline were given for each muscle group; internal sphincter (1 = intact, 2 = focal thinning, and 3 = defect/scar), external sphincter (1 = intact, 2 = focal thinning, and 3 = defect/scar), and puborectal sling (1 = intact, 2 = focal thinning, and 3 = defect/scar). Specifically, focal thinning was defined as diminished muscular thickness but with fibers in continuity. A defect/scar was defined as clear discontinuity of muscle fibers with or without replacement by lower echogenicity scar tissue (Figures 1–3).

A score for muscular atrophy was also assigned, again using literature based definitions [6,7,12,13]. Representative

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**Figure 1** An endoanal ultrasound image of a patient who had previously sustained an obstetric injury. The image demonstrates an external anal sphincter scar (thick arrow) and an intact internal anal sphincter (D1).
scores for left and right of the midline were given for each muscle group: internal sphincter (1 = normal, 2 = mild atrophy, and 3 = severe atrophy), external sphincter (1 = normal, 2 = mild atrophy, and 3 = severe atrophy), puborectalis (1 = normal, 2 = mild atrophy, and 3 = severe atrophy). Specifically, mild internal sphincter atrophy was defined as abnormal increased echogenicity and/or a thickness of between 1.5 mm and 2 mm [6,12] (Figures 4 and 5). Severe internal sphincter atrophy was defined as measurement < 1.5 mm. Mild external/puborectalis atrophy was defined when the muscle structure was visible but abnormal high echogenicity was suggestive of fatty replacement. Severe external/puborectalis atrophy was defined as present when the muscle structure was very poorly or not defined, suggestive of marked fatty replacement (Figure 3).

Assessment parameters

Patient symptom load
A validated symptom questionnaire (Wexner Incontinence scores) was used to determine the severity of anal incontinence [14]. The Wexner incontinence score ranges from 0 to 20, with a score > 9 believed to correlate with moderate to severe symptoms [15].

Anorectal physiology

Dynamometer. A dynamometer was used to objectively assess puborectalis strength (in grams) [4]. With the patient in the decubitus position, a latex balloon was inserted into the rectum and inflated with 25 mL of water. The balloon was attached via an inelastic rope to an electronic isometric dynamometer, perpendicular to the anal canal [4]. The dynamometer was calibrated with 100 g and 500 g weights prior to testing. The patient was asked to contract their pelvic muscle three times and the maximum force of each contraction was recorded and the average calculated [4].

Anorectal manometry. All patients underwent detailed standard anorectal physiological investigations, which included station pull-through manometry of the anal canal, evaluation of rectal sensory thresholds using a volumetric

Figure 2 Complete disruption of the internal anal sphincter (thin arrows) and external anal sphincter (thick arrows).

Figure 3 Puborectalis defect (thick arrow) with Grade III atrophy of the puborectalis. The thin arrow indicates the internal anal sphincter.

Figure 4 Grade II atrophy of both the internal anal sphincter (thick arrow) and external anal sphincter (thin arrows). Note the increased echogenicity in both muscles.

Figure 5 Intact internal (between crosses) and external (arrow) anal sphincters. Both muscles are scored as having Grade II atrophy.
based balloon distension technique, and assessment of pudendal nerve terminal motor latencies.

Manometry was performed using an eight channel catheter linked to an MMS-eight channel pneumohydraulic water perfusion system; a pullback technique allowed assessment of functional anal canal length. Maximum resting tone, and maximum voluntary squeeze and involuntary squeeze pressures were taken once the high pressure zone was identified [2]. Anal resting tone and squeeze pressures were considered abnormal if they were below 60 cmH2O and 50 cmH2O, respectively, based on standard criteria used in our unit [16].

Rectal distension thresholds. Rectal sensation was tested by inflating a latex balloon with air at 1 mL/s and determining the threshold volumes for first constant sensation, defecatory urge volume (DDV), and maximum tolerable volume (MTV) [17]. Normal values for first constant sensation, urge to defecate, and maximum tolerated volume are 20–70 mL, 35–120 mL, and 100–260 mL, respectively [16].

Anorectal electrosensitivity thresholds. A bipolar electrode catheter (Gastec, Freiburg, Germany) was placed in the anal canal first and then in the rectum to measure anal and rectal sensitivities respectively. Electrical stimulation in the anal canal was applied at 5 Hz with a pulse width of 0.1 ms. The current was then incrementally increased (analogue dial) to 20 mA or until the patient reported a change in sensation. In the rectum, electrical stimulation was applied at 10 Hz with a width of 0.5 ms and increased to 50 mA or until the patient reported a change in sensation [18]. Normal ranges for anal and rectal sensation were 9.4 mA and 34 mA, respectively [16].

Statistical analysis

For each patient the highest atrophy and integrity score (between the left and right side) for each muscle was taken and used for analysis. Data were entered into Graphpad Prism 10 (GraphPad Software, Inc, San Diego, CA, USA).

The primary outcome was the degree of linear correlation between findings on EAUS and symptom load, and physiological parameters. A Kolmogorov–Smirnov test was carried out to determine whether data was normally distributed. Correlations were compared using a Spearman’s (for nonparametric data) or Pearson’s (for Gaussian distributed) test where appropriate. Significance was set at 5%.

Results

Patient cohort

Over a 9-month period, 30 women were recruited consecutively (age range, 27–69 years; mean age, 44 years). Mean parity was 2 (range, 0–4). All women completed symptom questionnaires and underwent EAUS. Three women did not undergo full physiological assessment: two women failed to attend their anorectal physiology appointment and one patient refused perineal dynamometry.

2D endoanal ultrasound

Accurate measurement of internal and external anal sphincter thickness could not be made in five patients and four patients, respectively, due to obstetric related traumatic injury of the sphincter complex which in the opinion of the radiologist was too extensive to allow a reliable estimate of true muscle thickness. A further six patients and eight patients, respectively, had limited defects of their internal and external sphincters which allowed thickness measurements of the remaining muscle. Of the 30 patients one had IAS focal thinning and none had focal EAS thinning of the sphincter.

In 12 patients, it was not possible to identify the borders of the puborectalis muscle sufficiently well to confidently measure muscle thickness. In five of the 30 patients, puborectalis muscle visualization was sufficiently poor as to preclude assessment of integrity or atrophy. Of the patients who had puborectalis well-visualized, one had evidence of puborectalis injury.

Mean IAS thickness was 2.4 mm (range, 1.2–4.2 mm), EAS was 3.6 mm (range, 1.6–6.5 mm) and puborectalis was 3.9 mm (2.1–6.1 mm). Mean integrity score (range, 1–3) of IAS was 1.71, EAS was 1.75 and puborectalis was 1.02. Mean atrophy score (range, 1–3) for IAS was 1.3, for EAS was 1.3 and for puborectalis was 1.23. Six patients had evidence of IAS atrophy (3 of whom scored Grade 2), nine had evidence of EAS atrophy (6 of whom scored Grade 2 atrophy), and two had evidence of puborectalis atrophy (1 scored Grade 3 atrophy, 1 scored Grade 2 atrophy).

Symptom load

Across the cohort, the mean Wexner score was 10 [range, 1–20, standard deviation (SD), 6.0]. Anal incontinence symptom load correlated with parity (r = 0.56, p < 0.002) but not with patient age (r = 0.31, p = 0.08). Eighteen women had severe incontinence, achieving a Wexner score of >10.

Correlation of symptoms with USS findings

There was no statistically significant correlation between thicknesses, integrity or atrophy of, puborectalis, external or internal anal sphincters, and Wexner incontinence scores (Table 1).

Dynamometer

The mean dynamometer score was 390 g (normal range being >477 g) [4]. Dynamometer readings did not correlate significantly with symptoms scores, age or parity.

Correlation of USS and dynamometer findings

There was no significant correlation between atrophy, integrity or thickness of the anal sphincters and puborectalis and dynamometry measurements (Table A1 in Appendix 1).

Anorectal manometry

Anorectal manometry revealed mean anal sphincter pressures at rest of 64 cmH2O (SD 26), voluntary squeeze 76
cmH2O (SD 41), and involuntary squeeze of 62 cmH2O (SD 30). Values for resting and squeeze pressure fell within the normal ranges used within the department (normal resting pressure 60–160 cmH2O and squeeze pressure 50–180 cmH2O). These values did not significantly correlate with age or parity.

**Correlation of resting pressure with thickness of external sphincter**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Correlation of resting pressure with thickness of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puborectalis</td>
<td>0.74 (0.006)</td>
</tr>
<tr>
<td>Internal sphincter</td>
<td>0.35 (0.18)</td>
</tr>
<tr>
<td>External sphincter</td>
<td>0.14 (0.28)</td>
</tr>
</tbody>
</table>

**Correlation of involuntary squeeze pressure with atrophy of external sphincter**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Correlation of involuntary squeeze pressure with atrophy of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puborectalis</td>
<td>0.18 (0.26)</td>
</tr>
<tr>
<td>Internal sphincter</td>
<td>0.03 (0.41)*</td>
</tr>
<tr>
<td>External sphincter</td>
<td>0.50 (0.12)</td>
</tr>
</tbody>
</table>

**Correlation of involuntary squeeze pressure with integrity of external sphincter**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Correlation of involuntary squeeze pressure with integrity of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puborectalis</td>
<td>0.76 (0.06)</td>
</tr>
<tr>
<td>Internal sphincter</td>
<td>0.99 (0.001)</td>
</tr>
<tr>
<td>External sphincter</td>
<td>0.02 (0.42)*</td>
</tr>
</tbody>
</table>

Data are presented as *p* (r). * Significant value, *p* < 0.05.

This study attempted to validate ultrasound findings with a robust standard of reference based on patient symptoms and comprehensive anorectal physiology. We found that the only ultrasound measurement that had any correlation with manometric findings was the degree of EAS disruption, and squeeze pressure.

There is some debate as to the accuracy of the EAUS for assessment of anal sphincter integrity [13,19–21]. It is known that changes in the direction of the external sphincter muscle fiber results in a change in echogenicity and the resulting hypoechoic areas may be mistaken for defects [12]. However, Deen et al [11] found that in experienced hands ultrasound had sensitivities and specificities of 100% for detecting external sphincter defects and 100% and 95.5%, respectively, for internal anal sphincter defects, when compared to intraoperative findings. Given the reliance of squeeze pressure on an intact external sphincter, our data supports the ability of ultrasound to assess external sphincter integrity accurately.

Beyond this, no ultrasonic finding had any relationship to either symptom load or anorectal physiology. Since only a proportion of patients with a loss of anal sphincter integrity suffer fecal incontinence, it can be assumed that other factors must be involved for maintenance of continence. Sphincter atrophy is likely to be one factor. For example, Breil et al [22] found that patients with sphincter atrophy fared poorly after sphincter reconstruction, and data has linked anal sphincter and puborectalis muscle atrophy with idiopathic fecal incontinence [6,7]. The accuracy of atrophy assessment using ultrasound is unclear however. In particular, there is no universally accepted ultrasound criterion for external anal sphincter atrophy. In general, atrophy is established by measuring sphincter thickness and by evaluating subjectively the degree of fatty infiltration. Using definitions based on these factors, we found no correlation between our assessment of muscle atrophy and any parameters of symptom or function. This concurs with a larger study by Sultan et al [8]: In 114 patients thickness of neither the internal nor external sphincter had any correlation with manometry. Williams et al [23], also did not find any relationship between atrophy of anal sphincters and anorectal function. In part this may be due to the limitations of EAUS to delineate accurately muscular planes, in
particular those of the external anal sphincter [24]. It is suggested that magnetic resonance imaging (MRI) provides more clearly defined images of the external sphincter which are more easily measured [19], and most experienced radiologists would recommend MRI over ultrasound for assessment of sphincter atrophy. Our data certainly reinforces the limitations of ultrasound and newer MRI techniques such as pelvic MR spectroscopy may indeed further strengthen the role of MRI [25].

We also attempted to define the ability of ultrasound to assess the integrity and quality of the puborectalis sling. Historically, the principle role of the pelvic muscles was assumed to be support of pelvic organs. However, initial clinical observations found that patients were able to maintain passive continence with divided anal sphincters if the puborectalis was intact. This suggested a role for these pelvic floor muscles (in particular puborectalis) in maintaining continence. Introduction of the dynamometer, which assesses puborectal strength, has reinforced the concept that the muscle plays an active role in maintaining continence; correlation between anal incontinence and puborectal weakness has been demonstrated [4]. We did find anal sphincter squeeze pressure was related to pelvic floor strength when assessed by dynamometry. This may be due to puborectalis merging with the cranial fibers of the external sphincter and therefore augmenting squeeze pressure [26].

With a realization of the contribution from the levator ani, in particular puborectalis, there is growing interest in assessing its structural morphology. Cross sectional imaging using MRI has revealed tears or avulsions of the puborectalis muscle in 20–36% of primigravidas [27,28], and the use of MRI for pelvic floor assessment is increasing. Conversely we found little evidence that EAUS can fulfil this role. Indeed it was not possible to accurately measure the puborectalis in just under half of our patients and in 23% image quality was such that no firm comment could be made regarding atrophy and integrity. Perhaps unsurprisingly, in those patients in whom measurements were possible, there was no correlation with either symptom load or pelvic floor strength measured by dynamometry.

EAUS has proven to be an effective and cheap tool to determine sphincter integrity. It therefore plays an important role in reparatory surgery of the sphincters or assessment of anal sphincters in patients who have sustained obstetric injury. MRI is a comparatively expensive technology and is unlikely to replace ultrasound when sphincter integrity is the main clinical concern. However it is becoming more apparent that assessment of the pelvic floor is essential for management of patients with FI and defecation disorders, as continence is not just a function of the anal sphincters but also a function of the anorectum and pelvic floor. Our data confirms that 2D ultrasound has a limited role for assessment of anal sphincter muscle quality, and essentially cannot assess the puborectalis reliably.

Our study has limitations. Our cohort was relatively small, but our applied standard of reference was comprehensive and for the first time compared ultrasound to pelvic floor strength measured using dynamometry. Increasing data suggests 3D ultrasound may be superior to 2D and we can speculate that assessment of the puborectalis may have been improved if a 3D dataset had been acquired [29,30]. However, although 3D acquisition technology is increasingly disseminated, its higher costs and need for specially trained operators means 2D ultrasound is still the more readily available option worldwide, especially in less wealthy nations. We used a single highly experienced observer so our results may not be applicable to all users. However for the purposes of the study we wished to test the intrinsic ability of ultrasound to assess sphincter morphology and a highly experienced observer is most appropriate in this context. In any event, given the lack of correlation with our reference standard, extrapolation of our findings to less experienced readers is now of less relevance.

In conclusion, 2D ultrasound has a limited role in assessing anal sphincter muscle quality, and assessment of the puborectalis is largely unreliable.

References


Appendix 1

Table A1 Correlation of Wexner incontinence scores and dynamometer readings with ultrasonography findings of thickness, atrophy, and integrity for the three muscles: puborectalis, internal anal sphincter, and external anal sphincter.

<table>
<thead>
<tr>
<th></th>
<th>Puborectalis</th>
<th>Internal sphincter</th>
<th>External sphincter</th>
<th>Puborectalis</th>
<th>Internal sphincter</th>
<th>External sphincter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>0.27 (−0.21)</td>
<td>0.40 (0.15)</td>
<td>0.38 (0.17)</td>
<td>0.67 (0.07)</td>
<td>0.58 (−0.09)</td>
<td>0.48 (0.14)</td>
</tr>
<tr>
<td>Integrity</td>
<td>0.55 (−0.05)</td>
<td>0.74 (−0.05)</td>
<td>0.15 (0.25)</td>
<td>0.90 (0.03)</td>
<td>0.91 (0.03)</td>
<td>0.07 (−0.03)</td>
</tr>
<tr>
<td>Atrophy</td>
<td>0.95 (0.01)</td>
<td>0.95 (0.01)</td>
<td>0.39 (0.45)</td>
<td>0.17 (0.26)</td>
<td>0.30 (0.21)</td>
<td>0.94 (−0.01)</td>
</tr>
</tbody>
</table>

Data are presented as $r$.

Table A2 Correlation of age and parity with ultrasound findings of thickness, integrity, and atrophy for the three muscles: puborectalis, internal anal sphincter, and external anal sphincter.

<table>
<thead>
<tr>
<th></th>
<th>Puborectalis</th>
<th>Internal sphincter</th>
<th>External sphincter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation of parity with thickness of</td>
<td>0.43 (−0.20)</td>
<td>0.47 (0.19)</td>
<td>0.66 (0.11)</td>
</tr>
<tr>
<td>Correlation of parity with integrity of</td>
<td>0.40 (0.3)</td>
<td>0.40 (0.20)</td>
<td>0.60 (0.14)</td>
</tr>
<tr>
<td>Correlation of parity with atrophy of</td>
<td>0.60 (0.12)</td>
<td>0.30 (0.22)</td>
<td>0.74 (−0.38)</td>
</tr>
<tr>
<td>Correlation of age with thickness of</td>
<td>0.90 (0.02)</td>
<td>0.70 (−0.08)</td>
<td>0.45 (−0.17)</td>
</tr>
<tr>
<td>Correlation of age with integrity of</td>
<td>0.96 (−0.01)</td>
<td>0.90 (0.01)</td>
<td>0.90 (−0.012)</td>
</tr>
<tr>
<td>Correlation of age with atrophy of</td>
<td>0.11 (0.34)</td>
<td>0.10 (0.006)</td>
<td>0.50 (0.14)</td>
</tr>
</tbody>
</table>

Data are presented as $r$. 

170 K. Thiruppathy et al.