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Relationship Among Anal Sphincter Injury, Patulous Anal Canal, and Anal Pressures in Patients with Anorectal Disorders

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Abstract

Background & Aims—The anal sphincters and puborectalis are routinely imaged with an endoanal magnetic resonance imaging (MRI) coil, which does not assess co-aptation of the anal canal at rest. Using a MRI torso coil, we identified a patulous anal canal in some patients with anorectal disorders. We aimed to evaluate the relationship between anal sphincter and puborectalis injury, a patulous anal canal, and anal pressures.

Methods—We performed a retrospective analysis of data from 119 patients who underwent MRI and manometry analysis of anal anatomy and pressures, respectively, from February 2011 through March 2013 at the Mayo Clinic. Anal pressures were determined by high-resolution manometry, anal sphincter and puborectalis injury was determined by endoanal MRI, and anal canal integrity was determined by torso MRI. Associations between manometric and anatomical parameters were evaluated with univariate and multivariate analyses.

Results—Fecal incontinence (55 patients, 46%) and constipation (36 patients, 30%) were the main indications for testing; 49 patients (41%) had a patulous anal canal, which was associated with injury to more than 1 muscle (all $P < .001$) and internal sphincter ($P < .01$), but not puborectalis ($P = .09$) or external sphincter ($P = .06$) injury. Internal ($P < .01$) and external sphincter injury ($P = .02$) and a patulous canal ($P < .001$), but not puborectalis injury, predicted anal resting pressure. A

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DH - collecting data

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patulous anal canal was the only significant predictor ($P<.01$) of the anal squeeze pressure increment.

Conclusions—Patients with anorectal disorders commonly have a patulous anal canal, associated with more severe anal injury, anal resting pressure, and squeeze pressure increment. It is therefore important to identify patulous anal canal because it appears to be a marker of not only anal sphincter injury but disturbances beyond sphincter injury, such as damage to the anal cushions or anal denervation.

Keywords

Anorectal imaging; diagnosis; risk factor; anal sphincter defects

BACKGROUND

Anorectal imaging with endoanal ultrasound or magnetic resonance imaging (MRI) is recommended to identify anal injury in patients with fecal incontinence (FI) and anal weakness.¹ Anorectal imaging also guides surgical therapy, for example, surgical repair of anal sphincter defects, in patients with FI.² Atrophy of the external sphincter was associated with a worse outcome after anal sphincteroplasty in some³ but not all⁴ studies. While patients with large anal sphincter defects were excluded from multicenter trials of sacral nerve stimulation,⁵ smaller studies suggest that these patients may also benefit from this modality.⁶

The application of anorectal imaging to investigate anal weakness is underpinned by the premise that structural abnormalities (ie, anal sphincter injury) explain anal weakness. Indeed, internal anal sphincter (IAS) and external anal sphincter (EAS) injuries are associated with reduced anal resting and squeeze pressures respectively in older women with FI.^{7–10} Anal weakness is also associated with anal sphincter defects in postpartum women.^{11, 12} Moreover, women with IAS and EAS defects have more severe anal weakness and FI than women with isolated EAS defects.¹³ Puborectalis injury has also been associated with anal weakness in FI.^{8, 14}

There are 3 important questions regarding the relationship between anal sphincter injury and pressures in FI. First, the sensitivity and specificity of manometry to identify sphincter injury has not been evaluated. Second, most studies that evaluated the relationship between sphincter injury and weakness focused on injury affecting a single rather than multiple muscles. Third, with MRI using a torso rather than an endoanal coil, we have observed that the anal canal is often patulous (ie, not closed), even at rest in some patients with anorectal disorders. While a gaping anal canal, which is associated with reduced anal resting pressure, can be identified by physical examination,¹⁵ prior imaging studies have not described a patulous anal canal, perhaps because they were conducted with an endoanal coil, which distorts the anal canal. A MEDLINE literature search for “patulous anal canal” identified only 2 articles in the past 100 years that described a patulous canal, ie, in association with fecal impaction in children and surgical repair.^{16, 17} Conceivably, a patulous anal canal results from anal sphincter injury and should predispose to FI. However, the relationship between a patulous anal canal, anal sphincter injury, and anal weakness is unclear.

Prompted by these questions, the objectives of this study were to investigate the relationship between anal sphincter and puborectalis injury, anal canal integrity, and anal weakness in patients with anorectal symptoms.

METHODS

Study Subjects

This was a retrospective audit of all consecutive patients in whom anal anatomy and pressures were evaluated by MRI and manometry, respectively, between February 2011 and March 2013. Of 122 patients, 3 patients with a history of anorectal surgery, which was the only exclusion criterion, were excluded. Of the remaining 119 patients, 107 were females with a median age (interquartile range [IQR]) of 58 (43–65) years. This audit was approved by the Mayo Clinic Institutional Review Board. All patients had consented to use of their medical records for research.

Assessment of Clinical Features

The demographic and clinical features were abstracted from the medical records by a gastroenterologist (D.P.). Among individuals had more than 1 indication for anorectal testing, the primary indication for anorectal testing for the analysis was determined by a hierarchy (ie, FI, constipation, rectal prolapse without FI or constipation, and other indications [ie, anal fissures, fistulae, rectal urgency or rectocele without constipation or FI]), which was based on the recognition that constipation and FI are the main indications for anorectal testing. Among patients with constipation and FI, FI is more likely to be associated with anal injury and weakness than patients with constipation alone. FI severity was graded by the Fecal Incontinence and Constipation Assessment (FICA) system.^{18, 19}

Anorectal Manometry

Anal pressures were assessed by a high-resolution anorectal manometry catheter (Sierra Scientific Instruments; Los Angeles, CA) that has 8 sensors at 6 mm intervals along the anal canal and 2 sensors in the rectal balloon. At each level, pressures are averaged across 36 circumferentially-oriented, pressure-sensing elements which detect pressure over a length of 2.5 mm. Rectoanal pressures were evaluated at rest and during squeeze.^{20, 21}

Magnetic Resonance Imaging of Anal Sphincters, Puborectalis, and Anal Canal

Patients underwent endoanal imaging of the anal sphincters followed by MR proctography. After a 3-plane scout, the anal sphincters were imaged orthogonally with respect to anal canal in three planes using a disposable endorectal coil (MRInnervu®, Medrad, Inc, Indianola, PA) in conjunction with a torso phased-array coil.⁸ Anal sphincter imaging parameters are detailed in Supplementary Methods.

Consistent with previous studies, the appearance of the EAS and IAS was characterized as normal or abnormal (injury). The designation of abnormal includes 1) mild focal thinning; 2) marked focal thinning, scar or tear; 3) atrophy; 4) atrophy and tear; or 5) global thickening.^{8, 22, 23} Puborectalis abnormalities were characterized as follows: 1) asymmetry, 2) unilateral atrophy, 3) bilateral atrophy, or 4) tear.

After removing the endoanal coil, 180 cc of ultrasound gel was instilled in the rectum. Using only the external torso phased array coil and a 3 plane scout, an oblique mid-sagittal plane bisecting the anorectum that included the pubis and sacrococcygeal junction was identified. Anal canal integrity was evaluated on dynamic true-FISP images (5 mm slice, 24 x 30 cm FOV over 30 seconds) at rest in the mid-sagittal plane. A patulous canal was defined by separation of the anterior and posterior anal mucosa by ultrasound gel for the entire length of the anal canal. The narrowest distance between the anterior and posterior walls of the anal canal, usually near the midpoint of the anal canal, was measured on an image obtained at rest.²⁴

Statistical Analysis

The associations between anorectal parameters and clinical features, or between sphincter injury for 2 muscles (eg, IAS versus EAS) was evaluated by the Fisher exact test, Kruskal-Wallis test or Wilcoxon rank sum test. The association between indication for the procedure and anal pressures was assessed by an analysis of variance based on ranks.

Multiple variable logistic regression models evaluated whether 1) IAS and EAS and puborectalis injury and 2) the number of muscles affected could explain a patulous canal. A multiple variable linear regression model was used to assess whether sphincter injury and a patulous canal explained anal resting pressure and the squeeze pressure increment, which were rank transformed for this analysis. A *P*-value of <.05 was considered significant. Unless stated otherwise, all summary data refer to median (IQR).

RESULTS

Demographic Features and Anal Pressures

The primary indications for anorectal testing in the 119 patients were FI (55 patients[46%]), constipation (36 patients[30%]), rectal prolapse (18 patients[18%]) and other conditions (7 patients [6%]; ie, rectocele [2 patients], fissures [4 patients] and rectal urgency [1 patient]). Forty-seven patients (40%) had more than 1 indication for testing. Only 2 patients had FI and constipation. Patients with FI were older than patients with constipation and other indications; the association between age and group status was significant (*P* .001) (Table 1). Among FI patients, the FICA score indicated that 10 patients had mild, 27 had moderate and 18 had severe FI. The sex distribution and body mass index were not significantly different among indications for testing. Anal resting pressure was also associated (*P*<.001) with group status, being lower in patients with FI. However the anal squeeze pressure and squeeze pressure increment was not significantly different among groups.

Anal Sphincter and Puborectalis Injury

In 45 patients (38%), all 3 muscles (ie, IAS, EAS, and puborectalis) were normal with MRI (Table 1). Sixty-one patients (51%) had IAS injury, 34 (29%) had EAS injury, and 36 (30%) had puborectalis injury (Table 1, Figures 1 and 2). EAS (*P*=.02), IAS (*P*=.03) and puborectalis (*P*=.03) injury were associated with group status and were more common in patients with FI (Table 1).

Pelvic floor injury affected 1 muscle in 32 patients (27%), 2 muscles in 27 patients (23%), and all 3 muscles in 15 patients (13%). Indeed, among patients with anal sphincter and puborectalis injury, injury to 1 muscle was associated with injuries to other muscles (all $P < .001$).

Relationship Between Anal Sphincter Injury and a Patulous Anal Canal

Forty-nine patients (41%) had a patulous anal canal (Figure 2). A patulous anal canal was associated ($P < .01$) with the primary symptom and was more common in patients with FI (32 patients, 58%) than constipation (9 patients, 25%) (Table 1). Among the 49 patients with a patulous canal, 5 patients (10%) had no sphincter or puborectalis injury, 38 (78%) had IAS injury, 26 (61%) had EAS injury, and 25 (51%) had puborectalis injury (Figure 3); this total exceeds 100% because 32 patients (65%) had injury affecting 2 or more muscles.

A patulous anal canal was univariately associated with IAS injury ($P = .001$), EAS injury ($P = .001$), and puborectalis injury ($P = .001$). In a multiple variable logistic regression model, IAS injury ($P < .01$), but not puborectalis ($P = .09$) or EAS injury ($P = .06$), was associated with a patulous canal on MRI.

Relationship Between Anal Sphincter Injury, Patulous Anal Canal, and Anal Pressures

By univariate analysis, IAS injury was associated with a lower median (IQR) anal resting pressure (45[27–62] vs 62[44–75] mm Hg; $P = .002$). However, the squeeze pressure increment was not different ($P = .06$) in patients with (39[16–72] mm Hg) versus without (47[26–102] mm Hg) anal injury. External sphincter injury was associated with a reduced anal squeeze pressure increment (33[14–52] vs 47[24–97] mm Hg; $P = .005$) but not with reduced resting pressure (data not shown, $P = .15$). Puborectalis injury was associated with a reduced squeeze pressure increment (30[15–49] vs 47[23–106] mm Hg; $P = .006$) but not lower resting pressure.

A patulous canal was also associated with a lower median resting pressure (36 [23–58] vs 61[48–75] mm Hg; $P < .001$) and a lower squeeze pressure increment (26[15–45] vs 59[33–106] mm Hg; $P < .001$). Moreover, the diameter of the anal canal was inversely correlated with anal resting pressure ($r = 0.44$, $P = .0016$) (Figure 4).

In multiple linear regression models, IAS injury ($P < .01$), EAS injury ($P = .02$), and a patulous canal ($P < .001$) but not puborectalis injury ($P = .49$) predicted anal resting pressure ($P < .001$). However, a patulous anal canal was the only predictor ($P < .01$) of the anal squeeze pressure increment ($P < .01$) after adjusting for IAS, EAS, and puborectalis injury.

Consequences of Anal Injury to Multiple Anal Muscles

A patulous anal canal was observed in only 11% of patients with no anal injury, 38% with injury to one, 70% with injury to two, and 87% with injury to three muscles (IAS, EAS, and puborectalis). Relative to the reference group (ie, no sphincter injury), the risk of a patulous canal was greater when more muscles were injured; the ORs were 4.8 (95% CI, 1.5–15.5), 19.0 (95% CI, 5.5–65.9), and 52.2 (95% CI, 9.0–300.8) when 1, 2, and 3 muscles were injured, respectively.

Likewise, the number of injured muscles was associated with the mean resting pressure ($P=.03$) and the squeeze pressure increment ($P=.001$). Among patients with no injury, the median (IQR) anal resting pressure was 62(48–75) mm Hg. However, anal resting pressure was 55(25–67), 25(28–58), and 39(28–70) mm Hg when 1, 2, and all 3 muscles were injured, respectively. The median (IQR) anal squeeze pressure increment was 49(24–112), 60(32–100), 36(11–47), and 16(14–39) mm Hg among patients in whom none, 1, 2, and 3 muscles were injured, respectively.

Utility of Anal Pressures for Predicting Anal Sphincter Injury

Anal weakness is the commonest indication for anal imaging in patients with FI. In this study, reduced anal resting pressure had a sensitivity of 51% and a specificity of 70% for identifying IAS injury or a patulous canal. Reduced anal squeeze pressure had a sensitivity of 58% and a specificity of 79% for identifying EAS or puborectalis injury or a patulous canal. For this analysis, reduced resting and squeeze pressures were less than the 10th percentile value in age- and sex-matched asymptomatic patients.

DISCUSSION

Current guidelines recommend anal manometry to be followed, when pressures are reduced, by anorectal imaging in patients who fail conservative management of FI.^{25–27} The anal sphincters and puborectalis muscle are imaged with endoanal MR and ultrasound probes because endoanal probes provide a better signal to noise ratio than transcutaneous probes. Reduced anal resting and squeeze pressures are associated with IAS and EAS injury, respectively.^{7–9} However, endoanal probes distort the anal canal, precluding an assessment of the anal seal. In this study, MRI with a torso coil identified a patulous anal canal in 41% of all patients and 58% of patients with FI. The relationship between anal sphincter and puborectalis injury, a patulous anal canal, and anal pressures was analyzed; anal pressures were evaluated as continuous and separately, as ordinal variables (ie, normal or low). The findings, in particular, shed light on the pathophysiology of a patulous anal canal, the relationship between a patulous anal canal and anal weakness, and the consequences of injury to multiple anal muscles.

The diameter of a patulous anal canal was inversely correlated with anal resting pressure, confirming that a patulous canal reflects anal weakness at rest. To our surprise, the squeeze pressure increment was also lower in patients with a patulous canal. Indeed, while internal and external sphincter injury and a patulous canal independently explained anal resting pressure, a patulous anal canal was the only independent predictor of a reduced squeeze pressure increment. These observations underscore the contribution of the IAS and EAS to anal resting tone. The IAS and EAS maintain approximately 55% and 35% of anal resting tone, respectively, and the remainder (15%) is generated by the hemorrhoidal plexus.²⁸ Moreover, a patulous anal canal independently predicted anal resting and squeeze pressure even after adjusting for IAS and EAS injury, suggesting that a patulous canal may represent a surrogate marker for disturbances other than sphincter injury that can disrupt the anal seal, such as damage to the anal cushions, perhaps to a hemorrhoidectomy²⁹ or anal

denervation,³⁰ or even, because a patulous canal was identified when the rectum was distended with ultrasound gel, an exaggerated rectoanal inhibitory reflex.³¹

Anal resting pressures were lower in FI than constipation. A higher proportion of patients with FI than constipation had IAS, EAS, and puborectalis injury. Reduced anal resting and squeeze pressures were relatively insensitive for identifying sphincter injury or a patulous anal canal perhaps because small sphincter defects may not cause anal weakness. However, the specificity of reduced anal pressures for predicting sphincter defects or a patulous canal was higher, ie, 79% for identifying EAS or puborectalis injury or a patulous anal canal. These observations reinforce the current approach wherein imaging is not recommended when anal pressures are normal.

Sixty-five percent of patients who had a patulous anal canal had anal injury to 2 or more muscles; over 25% had injury to all 3 muscles. On average, the likelihood of a patulous canal was 4.8-, 19-, and 52-fold higher in patients with injury to 1, 2, and 3 muscles, respectively. Anal squeeze, and to a lesser extent, anal resting pressure, were also significantly lower when more muscles were damaged. These findings highlight the limitations of therapeutic approaches (eg, EAS repair) that address only 1 deficit in patients who have injury to 2 or more muscles. Conversely, nearly 30% of patients with reduced anal resting pressure did not have anal sphincter or puborectalis injury or a patulous anal canal.

It is conceivable that a patulous canal predisposes to FI, particularly of flatus and liquid stool. Indeed, FI is more likely when anal weakness is associated with lower rectal compliance, heightened rectal sensitivity, and less formed stool³² or an evacuation disorder.³³ Therapeutic trials in FI have not compared responses in patients with versus without a patulous anal canal. Conceptually, anal plugs, perianal bulking agents, and anal sphincteroplasty may be useful for managing FI in patients with a patulous anal canal. A Cochrane review of data from 4 studies with a total of 136 participants concluded that “anal plugs can be difficult to tolerate.”³⁴ However, if they are tolerated they can be helpful in preventing incontinence.” Moreover, “the review showed that the selection of the type of plug can impact on its performance.”³⁴ Perianal dextranomer in stabilized hyaluronic acid is approved for treating FI³⁵ but its therapeutic efficacy has been questioned.³⁶ It is conceivable but unknown if perianal bulking agents restore the anal seal. Finally, a modified external anal sphincteroplasty, designed to restore the purse string morphology of this muscle,³⁷ may be more likely to close a patulous anal canal.

The risk factors for a patulous anal canal (eg, obstetric trauma) and the utility of a digital rectal examination for identifying a patulous anal canal were not assessed in this study. Endoanal ultrasonography is less expensive and more widely available than MRI. Hence the clinical utility of identifying a patulous anal canal needs to be clarified before using this rationale for choosing between these tests in clinical practice. In summary, MRI with a torso coil identified a patulous anal canal in 41% of all patients with anorectal disorders and 58% of patients with FI. A patulous canal was associated with injury to more muscles and independently predicted (ie, even after adjusting for IAS and EAS injury) anal resting and squeeze pressures. A patulous canal may represent a surrogate marker for disturbances other than sphincter injury that can disrupt the anal seal, such as damage to the anal cushions,

perhaps to a hemorrhoidectomy, anal denervation, or even an exaggerated rectoanal inhibitory reflex. Targeted therapeutic trials in patients with FI and a patulous anal canal are warranted.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1B

Figure 1C

Figure 1D

Figure 1. MRI of the pelvis in a patient with normal anal sphincter muscles and anal canal
 The sagittal image (A) that was acquired with a torso phased coil demonstrates ultrasound gel in the rectum (R) and an intact anal seal (small arrows). Axial images in the mid anal canal (B), which were acquired with an endoanal coil (EC), demonstrate normal internal (IAS) and external anal sphincters (EAS). In the upper anal canal (C), the IAS and puborectalis muscle (PR) appear normal. Coronal images (D) thru the anal canal demonstrate normal levator Ani (LA) and sphincter complex.

Figure 2A

Figure 2B

Figure 2C

Fig. 2D

Figure 2. MRI of the pelvis in a patient with anal sphincter injury and a patulous anal canal
 In contrast to Figure 1, the anal canal (between arrows) is patulous (A), with leakage of ultrasound gel (arrowhead) from the rectum (R) even before evacuation. Axial images in the lower (B) and upper anal canal (C), with an endoanal coil (EC) in situ, demonstrate marked focal thinning of the IAS from the 4:00 to 10:00 positions and diffuse atrophy of the EAS. The fibers of the internal anal longitudinal muscle (LM) are visible in cross-section. In the upper anal canal (Panel C) the puborectalis muscle (PR) is normal. Coronal images (Panel D) demonstrate the thinned IAS and EAS below the PR.

Figure 3.

Prevalence of anal sphincter and puborectalis injury in patients with a patulous anal canal
IAS = internal anal sphincter, EAS = external anal sphincter and PR = puborectalis muscle

Figure 4. Relationship between patulous anal canal diameter and anal resting pressures
Observe the inverse correlation ($r = 0.44$, $P = .0016$) between anal diameter and resting pressure.

Table 1

Demographic Features, Anal Pressures, and Anal Sphincter Abnormalities

Variable	All (n = 119)	Fecal Incontinence (n = 55)	Constipation (n = 36)	Rectal Prolapse (n = 21)	Other (n = 7)	P value ^x
Age (range), y ¹	58 (43–65)	62 (55–70)	45 (30–59)	61 (49–69)	33 (30–62)	<.001
Female sex, No (%)	107 (90%)	48 (87%)	33 (92%)	19 (90%)	7 (100%)	.96
Hysterectomy, No (%)	42/107 (39%)	19/48 (40%)	14/33 (42%)	8/19 (42%)	1/7 (14%)	.62
Body mass index ¹	24.8 (21.8–29.1)	25.7 (21.8–29.2)	26.0 (22.7–29.7)	23.4 (21.7–26.0)	23.1 (21.7–29.7)	.60
Anal manometry						
Rest pressure (mm Hg) ¹	53 (33–69)	43 (27–62)	66 (45–89)	56 (37–66)	68 (58–127)	<.001
Maximum squeeze pressure (mm Hg) ¹	98 (67–142)	91 (61–135)	114 (78–157)	98 (62–138)	119 (76–204)	.24
Squeeze pressure increment (mm Hg) ¹	41 (21–78)	36 (16–93)	46 (20–75)	39 (22–92)	52 (15–77)	.91
Magnetic resonance imaging						
Internal anal sphincter injury	61 (51%)	36 (65%)	15 (42%)	7 (33%)	3 (43%)	.03
External anal sphincter injury	34 (29%)	23 (42%)	5 (14%)	5 (24%)	1 (14%)	.02
Puborectalis injury	36 (30%)	24 (44%)	6 (17%)	5 (24%)	1 (14%)	.03
Patulous anal canal (%)	49 (41%)	32 (58%)	9 (25%)	7 (33%)	1 (14%)	.004
¹ Median (IQR)						