

Anorectal Physiology

Key Concepts

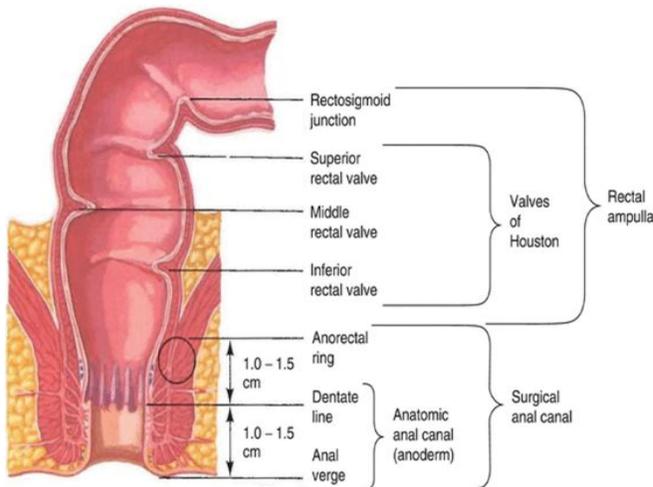
- **Maintenance of fecal continence and defecation** are complex processes requiring both **voluntary and involuntary reflexes** that have yet to be fully characterized.
- **Normal continence** is dependent on coordination between **neuronal reflexes, sensory and motor pathways, the rectum, anal sphincters, and pelvic floor** and requires adequate rectal compliance and competence of the anal sphincter.
- **During defecation:**
 1. sensory mechanisms allow the **rectum to stretch to accommodate feces.**
 2. The **pelvic floor muscles relax**, and **intraabdominal pressure increases.**
 3. Simultaneously, the **puborectalis relaxes and straightens the anorectal angle**, the **anal canal shortens**, and the **pelvic floor descends.**
 4. Finally, the **anal sphincters relax and evacuation is initiated.**
- Anatomy and physiology of the rectum and anus are intrinsically related, allowing physiologic testing to be exceedingly useful for diagnosis and management of anorectal pathologies.
- Disorders of continence can derive from deficits of mental, anatomic, and physiologic functions, including reflexes, sensory and motor nerves, and the muscles of the rectum, sphincters, and pelvic floor.

- Functional defecatory disorders frequently coexist with urogynecologic conditions likely due to the shared musculature of the pelvic floor and urogenital diaphragm, as well as from the overlap in peripheral innervation and spinal nerve roots.

Anatomy

- The **rectum** serves as a **reservoir for feces**, measuring approximately **12–15 cm in length**, yet its proximal and distal margins continue to be debated – particularly in light of differences in treatment approaches for lower gastrointestinal cancers.
- The rectum, which is **identified in the abdomen by the lack of haustra, taeniae, or epiploica**, is **located along the curve of the sacrum and coccyx** and **becomes the anal canal as it passes through the levators**.
- The rectal wall contains a **layer of longitudinal smooth muscle** and a **layer of circular smooth muscle** that are in continuity with the gastrointestinal tract.
- The rectum encompasses **three folds, known as the valves of Houston**, which **do not contain all the muscle wall layers and are not believed to serve any specific function**.

- **The middle valve corresponds to the anterior peritoneal reflection and is the most consistent with regard to location and its presence.**



- Like the rectum, the definition of the anus or anal canal is controversial and is distinguished by embryologic origin and mucosal histology or by its function.
- The **embryologic anal canal**, which does not incorporate anal function, is defined as **the area from the anal verge to the dentate line.**
- First described by Milligan and Morgan in 1934 in order to guide anorectal surgery, the **functional or surgical anal canal begins where the rectum enters the pelvic hiatus and passes through the puborectalis.**
- It encompasses **the area from the anal verge to the anorectal ring and is surrounded by the anal sphincters and the puborectalis.**

- On average, the functional or surgical anal canal measures approximately **2.5–5 cm in length and is shorter in females.**
- **The anal canal** is characterized by **columnar mucosa above the dentate line** and **squamous epithelia below**, which are important as they represent two separate inputs, supplied by different aspects of the arterial- venous, lymphatic, and nervous systems.
- **Above the dentate line**, the anal canal is **supplied and drained by the hypogastric vessels and innervated by the sympathetic and parasympathetic nervous systems.**
- **Below the dentate line**, the anal canal is **supplied by the inferior hemorrhoidal vessels and innervated by the somatic nervous system.**
- **The 1–2 cm area between these two regions** is known as the **transition or cloacogenic zone**, which is composed of **columnar, transitional, and stratified squamous epithelium.**

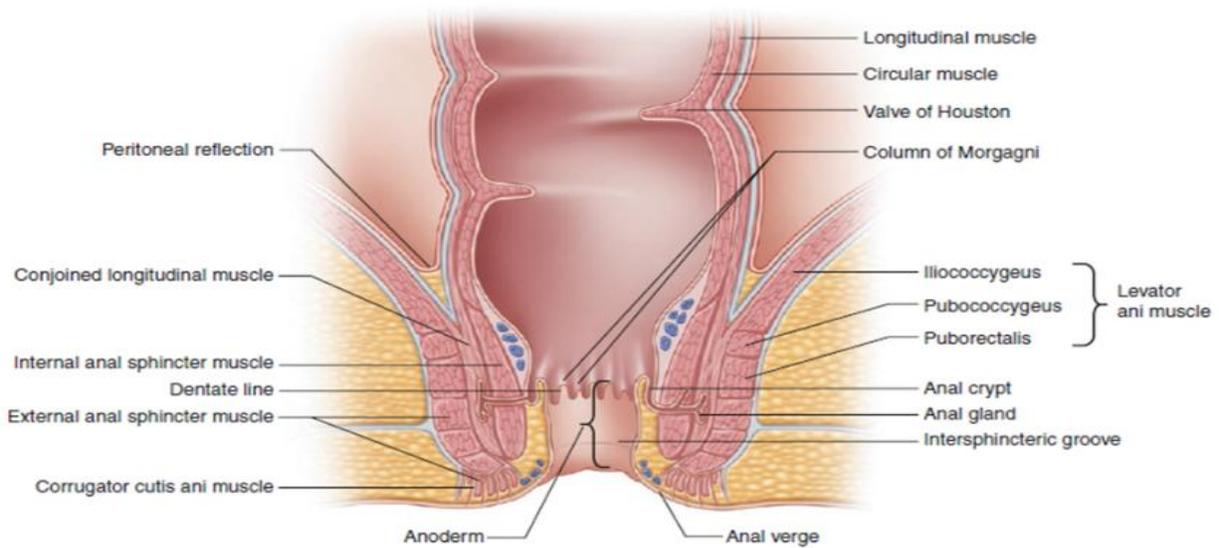
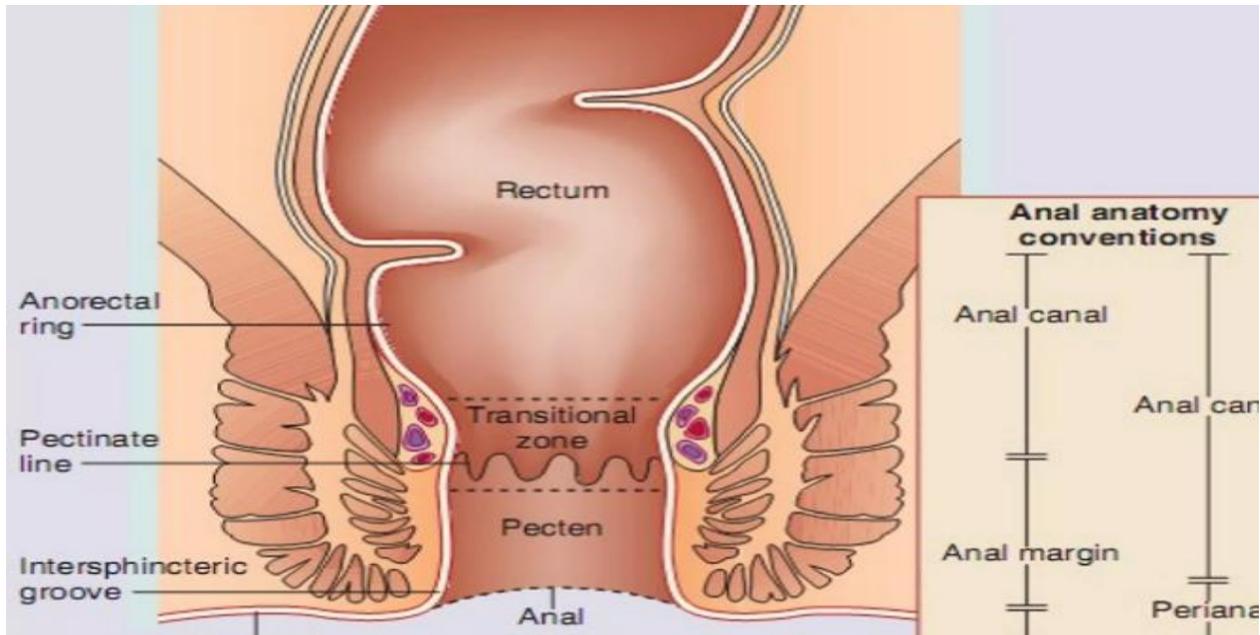


Fig. 1.1 Anal canal

Distinction	Above Pectinate line	Below Pectinate line
Destination of lymph drainage	Internal iliac lymph nodes (pararectal lymph nodes)	Superficial inguinal lymph nodes (Below Hilton's line)
Epithelium	Columnar epithelium	Stratified squamous epithelium, non keratinized
Embryological origin	Endoderm	Ecotoderm
Artery	Superior rectal artery > Inf. Mesenteric	Middle & inferior rectal arteries > Internal iliac
Vein	Superior rectal vein > Inf. Mesenteric	Middle & inferior rectal veins > Internal iliac
Hemorrhoids classification	Internal hemorrhoids (not painful)	External hemorrhoids (painful)
Nerves	Inferior hypogastric plexus Symp L1,L2 & parasymp S2,S3,S4	Inferior rectal nerves > pudendal nerve



- The **anal sphincter complex** consists of the **internal anal sphincter (IAS)**, the **conjoined longitudinal muscle (CLM)**, and the **external anal sphincter (EAS)**.
- The **IAS**:
 - is a **2–3 mm thick circular band** composed of the **distal inner circular smooth muscle layer** of the rectum.
 - is always **maximally contracted** to prevent involuntary loss of stool and flatus.
 - is encompassed proximally by the levator ani and distally by the **superficial external sphincter muscle** and **subcutaneous external straited anal sphincter muscle**.

- The **CLM**:
 - located **between the IAS and the EAS**.
 - is composed of the **fibers of the outer layer of the rectum at the level of the anorectal ring and runs distally to the puborectalis muscle**.
 - Its function are unclear, but it may **contribute minimally to maintaining continence and defecation**.
 - More importantly, the CLM may act as a **scaffolding for the entire anal sphincter complex**.

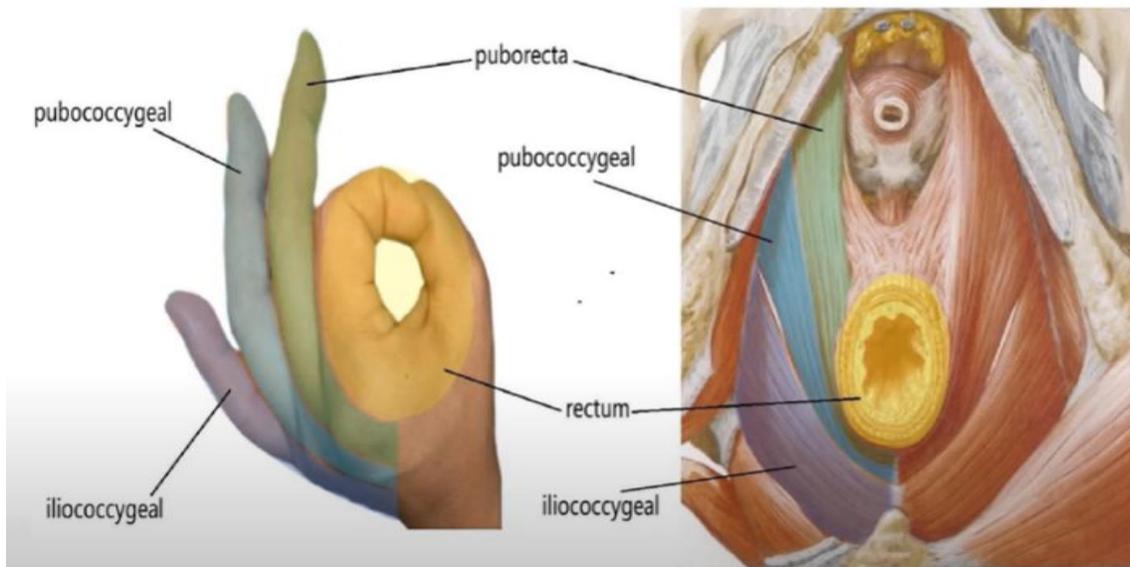
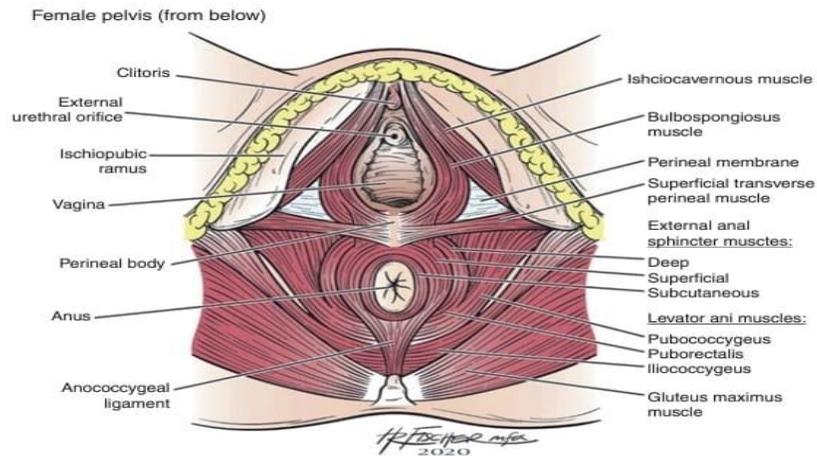
- The **EAS**:
 - comprises **striated muscle** as a **continuation of the puborectalis muscle** and is **attached anteriorly to the perineal body and posteriorly to the anococcygeal ligament**.
 - is in **constant state of tonic contractile activity, even at rest, and voluntarily contracts during any threat of incontinence**.

- The **pelvic floor muscles** include the **levator ani**, which consists of the **pubococcygeus, puborectalis, and iliococcygeus**.
 - These muscles function to **support the viscera** of the pelvic cavity and play a key role in **defecation**.

 - **The pubococcygeus** arises from the posterior pubis, travels alongside the anorectal junction, and inserts into the anococcygeus ligament and the coccyx.

- **The puborectalis** is a U-shaped muscle that slings the anorectal junction to the posterior pubis to pull the rectum anteriorly and forms the anorectal angle. It is palpable on digital rectal exam as the top of the anorectal ring.
- **The iliococcygeus** arises from the ischial spine and obturator fascia, travels inferiorly and medially, and inserts into the anococcygeal raphe and coccyx.

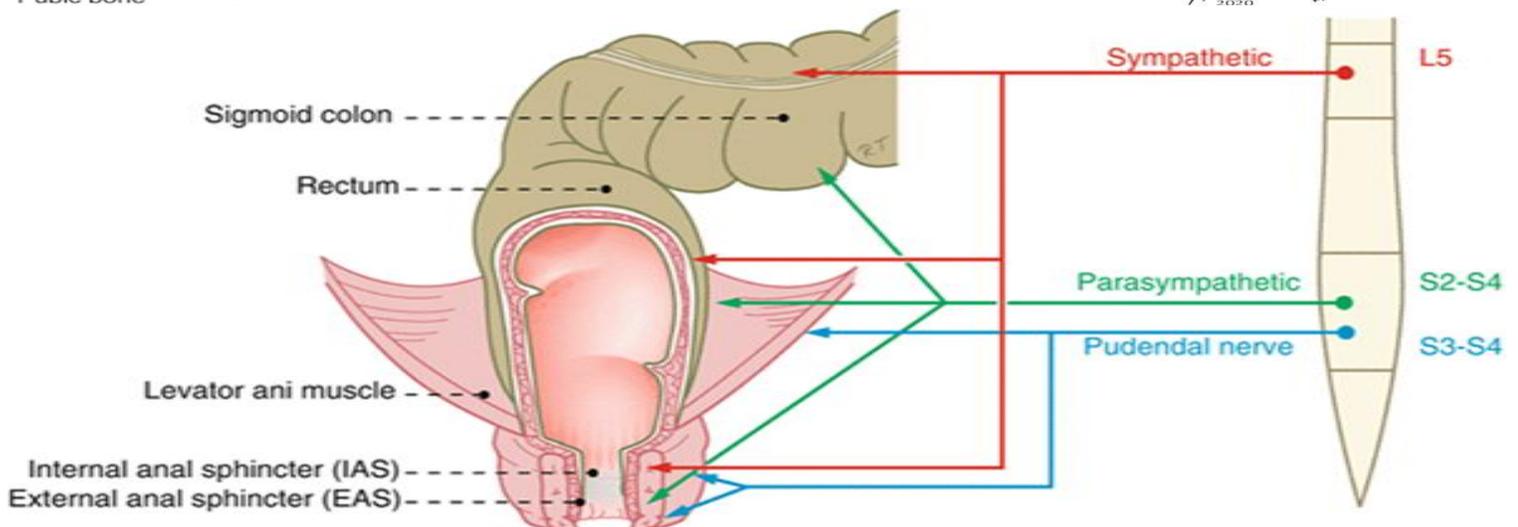
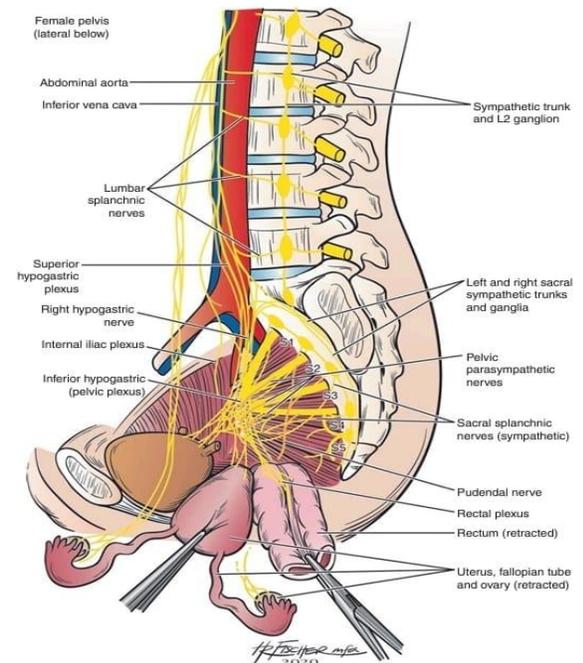
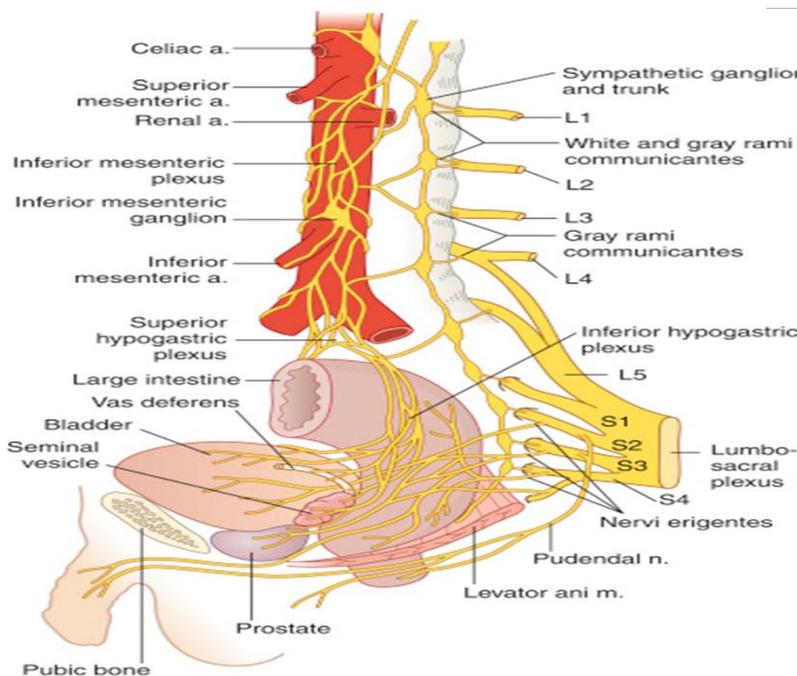
Fig. 3.1 Muscles of the pelvic floor. (Illustration created by H.R. Fischer, MFA)



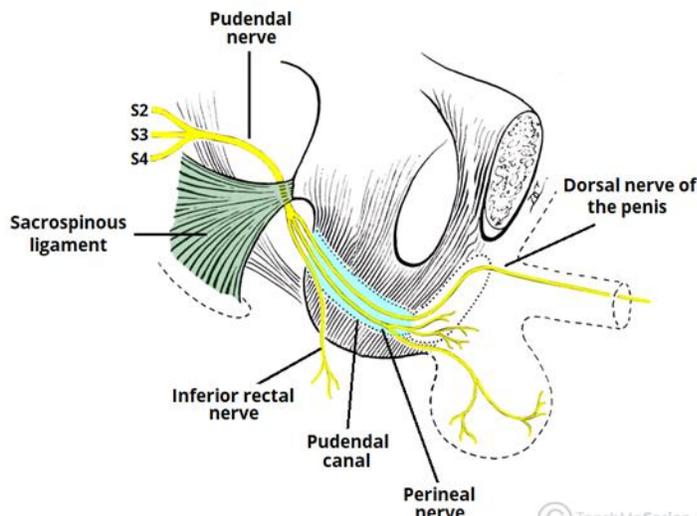
Physiology

- **Innervation of the Anus and Pelvic Floor**

- Sympathetic nerves derived from **L1, L2, and L3** join the **preaortic plexus**, which then extend to form the **hypogastric plexus** below the aorta.
- These then join **parasympathetic fibers called nervi erigentes (S2, S3, and S4)** to form the **pelvic plexus**.



- Motor innervation of the **IAS** is supplied by the **sympathetic (L5)** and **parasympathetic nerves (S2, S3, and S4)** from the autonomic nervous system.
- In contrast, the **EAS** is supplied by the **inferior rectal branch of the pudendal nerve (S2 and S3)** and by the **perineal branch of S4** from the somatic nervous system.
- **Unilateral transection of the pudendal nerve does not impact EAS function due to fiber crossover at the spinal cord level.**
- The sacral roots of **S3 and S4**, the **perineal branch**, and the **inferior rectal nerve** of the pudendal nerve innervate the **levator ani**.
- The **pudendal nerve branches** supply the **pubococcygeus** and **puborectalis**, whereas **direct sacral nerves S3 and S4** innervate the **iliococcygeus**.



- **Upper anal canal sensory innervation** is supplied by both free and organized sensory nerve endings, including **Meissner's corpuscles (touch)**, **Krause's bulbs (temperature)**, **Golgi-Mazzoni bodies (pressure)**, and **genital corpuscles (friction)**.
 - Within the transition zone of the anal canal, these organized nerve endings may play a role in sampling.
 - The inferior rectal branch of the pudendal nerve provides anal sensation and may provide some maintenance of fecal continence.
 - In addition, it may play a smaller role in **discriminating between solid and gas**.
-
- **Normal Continence**
 - Normal continence requires **adequate rectal compliance to accommodate fecal contents** and **competence of the anal sphincter to resist propulsive forces of the distal gastrointestinal tract, assess its contents, and release them under voluntary control**.
 - Although normal continence is incompletely understood, it is known to be dependent on complex coordination between:
 1. Neuronal reflexes.
 2. Sensory and motor pathways.
 3. The rectum.
 4. Anal sphincters.
 5. Pelvic floor.

- **Rectal Sensation and Compliance**

- **Rectal sensation** encompasses **the feeling of both rectal filling and anal reflexes**, which is distinct from the rest of the lower gastrointestinal tract where distension evokes pain.
- The **rectum's function** is to **store feces**, which requires the **ability to accommodate volumes of feces without substantially altering rectal pressures**.
- **Accommodation is reliant** on both **the content** and the **contractile state of the rectum**.
- **Baseline rectal pressure is low** (approximately **5 mmHg**) compared to **anal canal pressures**, which measure approximately **10–14 times that of the rectum**.
- This **pressure differential** may allow for **stool deferment, forcing stool back into the sigmoid and rectum, until defecation is initiated**.

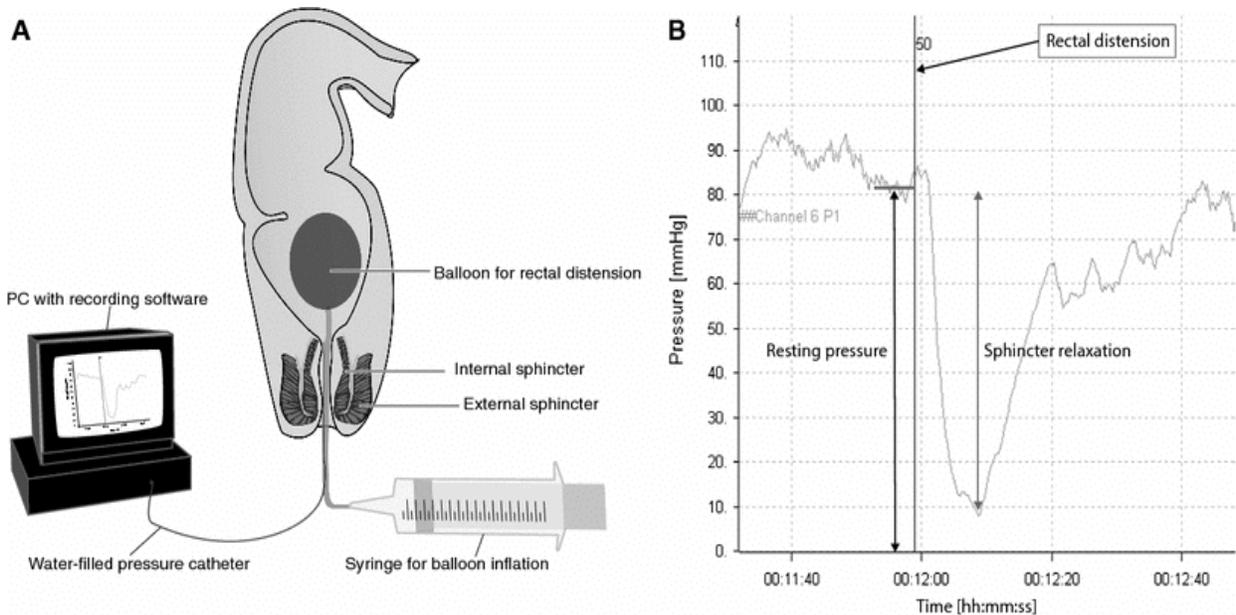
- Although the rectum does not have proprioceptive receptors, rectal compliance may be due to unique, slowly adapting mechanoreceptors that respond to tension and rapid distension, termed **rectal intra-ganglionic laminar endings (RIGLEs)**. This idea is consistent with the observation that rectal filling sensations coincide with increased rectal pressure during rectal distension.
- Instead, **defecation is sensed at the level of the levators and the anal canal**, which may underlie the **preserved sense of defecation among patients after proctectomy with ileoanal or coloanal anastomoses**.

-

- **Anorectal Reflexes**

1. **The recto-anal inhibitory reflex (RAIR) is an intrinsic intramural reflex critical to normal continence.**

- It occurs in **response to distension of the rectum, relaxing the upper IAS to allow fecal material or flatus to interact with specialized receptors in the upper anal canal.**
- This sampling **enables flatus to pass without fecal incontinence** as the lower IAS resting pressure, the contraction of the EAS, and puborectalis push feces to the upper rectum and delays defecation.



- The RAIR occurs **every 8–10 minutes** and **lasts less than 10 seconds.**
- The RAIR is **absent in those with Hirschsprung’s disease** due to the **absence of myenteric ganglia in the rectum.**

- Furthermore, injury or alteration to the RAIR may play a role in patients with poor functional outcome or incontinence after rectal resection.

2. The cutaneous anal sphincter reflex: The cutaneous anal sphincter reflex is defined as contractions of the EAS with touch or pain of the anal skin.

3. The bulbocavernosus reflex: is characterized by contractions of the EAS when squeezing the glans penis or clitoris. The bulbocavernosus reflex can also occur when a urethral catheter is removed.

4. The cough-anal reflex: is described as contractions of the EAS when coughing or sniffing. The cough-anal reflex is important in maintaining continence during sudden increases of intraabdominal pressures, such as coughing, sneezing, or laughing.

- **Internal and External Anal Sphincters**

- **The IAS** constitutes approximately **50–70% of resting tone** or pressure and is **maximally contracted at rest**, with the **hemorrhoid complexes** accounting for an **additional 15% of resting tone or pressure**.
- Hemorrhoid complexes contribute to continence by expanding to create a seal proximal to the anal opening.

- Due to the intrinsic function of smooth muscle, **most of the resting tone** is due to **myogenic tone**, which is characterized by **slow, constant waves of contraction**.
- The IAS receives additional excitatory sympathetic input and inhibitory parasympathetic input, which are mediated by nitric oxide.
- **Injury to the IAS leads to passive fecal incontinence or leakage**, whereas **injury to the EAS is associated with urge fecal incontinence**.
- Whereas the **EAS** plays a smaller role in resting tone, its primary contribution to continence involves **voluntary or reflexive contraction in response to rectal distention and threat of incontinence**, for example, during increases in intraabdominal pressure.
- Similarly, defecation may be deferred by contraction of the EAS to oppose increased rectal pressure.
- After EAS contraction, the sensation of urgency and tenesmus will diminish over a period of time that allows rectal adaptation to occur.
- The EAS differs from the IAS, however, in its fatigability, demonstrated by the deferment of large volumes of stool for more seconds or minutes, despite normal rectal compliance.

- **Puborectalis and the Pelvic Floor**

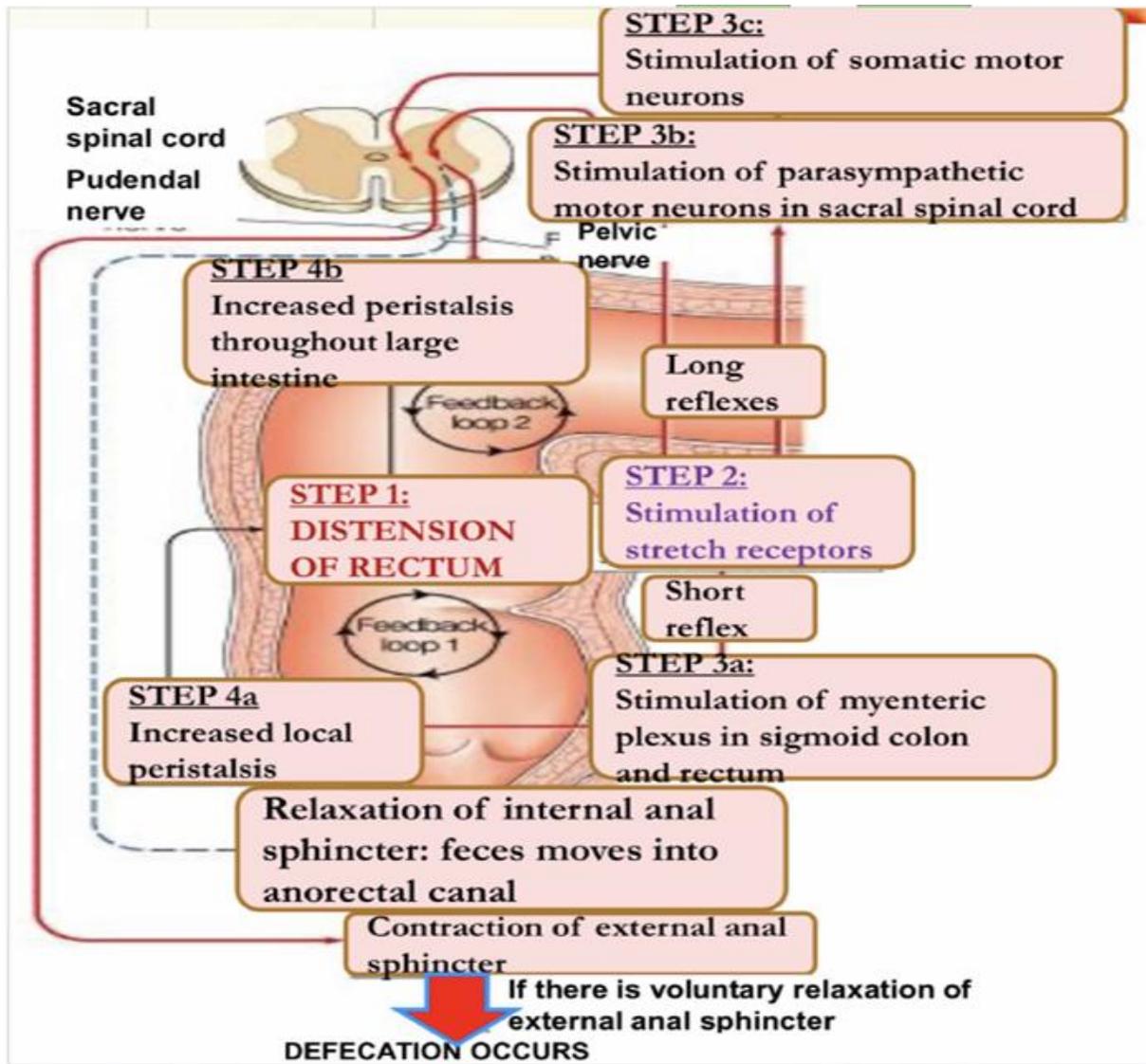
- The puborectalis is a striated muscle that acts as a sling located at the anorectal junction, from which a 90- to 100-degree angle is formed at rest.
- **Its critical role in continence** is believed to be due to this **anorectal angle**.
- **Theories** for its underlying mechanism include that the **puborectalis pushes the anterior rectal wall against the upper anal canal, preventing feces from passing distally**, particularly during times of increased intraabdominal pressure (known as **the flap-valve theory**), or that the **puborectalis acts as a deeper sphincter mechanism that works in coordination with the EAS**.

- **Normal Defecation**

- **Defecation requires:**
 1. Coordination between the colon and movement of its contents.
 2. Increases in intraabdominal and rectal pressures.
 3. Pelvic floor relaxation.
- First, **sensory mechanisms allow the rectum to stretch to accommodate feces once fecal material or flatus is sensed**.
- In response to distension of the rectum, **the IAS reflexively relaxes**.

- The **RAIR response** requires an intact subcutaneous nervous **plexus** in order to function and is under autonomic control.
- The **RAIR allows distinction between feces and flatus** as well as **solid and liquid waste, and the initiation of defecation.**
- **If defecation is not desired, the anal sphincters will contract and the rectum will continue to distend until the individual becomes aware.**
- However, the urge to defecate lasts only a few seconds and is controlled by continued **EAS contraction (conscious suppression).**
- Sampling may continue throughout this process even with a full rectum.
- During defecation, **the pelvic floor muscles relax** and the **intraabdominal pressure increases (Valsalva).**
- Several actions occur simultaneously:
 1. The puborectalis relaxes and lengthens, which straightens of the anorectal angle.
 2. The CLM contracts, which leads to shortening of the anal canal;
 3. The pelvic floor descends.
- Finally, the anal sphincters relax and evacuation is initiated by the rectosigmoid contractions, which propel feces through the anal canal.
- **A squatting or hip flexion position** facilitates this process by **optimally straightening the anorectal angle** and **increasing intraabdominal pressure.**
- Sensory input from the anus ensures that the contractions continue until the rectum is completely emptied.

- Anal closure at the end of defecation is termed the “**closing reflex**” and is described as an **exaggerated contraction of the EAS** and restoration of IAS resting tone.



- Most of the time the rectum is empty.
- Both internal & external anal sphincters are maintained in a state of tonic contraction.
- Defecation is a spinal reflex, influenced by higher centers.
- Gastrocolic & duodenocolic reflexes initiate a mass movement in the colon that pushes feces into the rectum.
- Rectal distension sends signals to cerebral cortex producing the desire to defecate.

● **Defecation reflex:**

1. Distention of rectum.

2. Stimulation of stretch receptors in rectum.

3. a. Short (local) reflex:

■ Stimulation of myenteric plexus in sigmoid colon and rectum. (But the intrinsic myenteric defecation reflex functioning by itself normally is relatively weak. To be effective in causing defecation, it usually must be fortified by parasympathetic defecation reflex).

b. Long reflex:

■ Stimulation of parasympathetic motor neurons in sacral spinal cord (it will increase peristalsis throughout large intestine).

c. Stimulation of somatic motor neurons.

4. Results in:

- Increases local peristalsis
- Relaxation of internal anal sphincter
- Contraction of external anal sphincter

- **Physiologic Testing**

- ❖ **Anal Manometry**

- Using a **pressure-sensitive catheter in the rectum and anal canal**, manometry is a test that **measures sphincter function** including:

1. Resting tone.
2. Maximum squeeze pressure.
3. Presence of RAIR.
4. Response to cough or Valsalva reflex.
5. Anal canal length.

- **Resting tone (normal 40–80 mmHg)** is due to **the resting pressure of the IAS and the length of the anal canal**, which is known as the **high-pressure zone (normal 2.0–4.0 cm)**.

- **Maximum squeeze pressure** reflects **EAS function (normal 40–80 mmHg)**.

- **Presence of the RAIR** is determined by **inflating a balloon in the distal rectum**.

The absence of RAIR is found in **impaired myenteric nerve plexus** such as **Hirschsprung's disease** or **following proctectomy** as described above.

- ❖ **Pudendal Nerve Terminal Motor Latency**

- Neurophysiological testing of the pudendal nerve, which again innervates the EAS, is **performed by stimulation at the site where the nerve enters the ischiorectal fossa at the level of the coccyx**.

- **Pudendal nerve terminal motor latency (PNTML)** measures the **time between the stimulation of the pudendal nerve and contraction of the EAS.**
- Normal values are approximately **2 ± 0.2 milliseconds.**
- **Prolonged or abnormal values** demonstrating **neuropathy** can be seen in those with **idiopathic fecal incontinence, rectal prolapse, or sphincter injuries.**
- However, PNTML testing is operator dependent and limited by low sensitivity and specificity.

❖ **Balloon Insufflation**

- Rectal sensation and compliance are tested by balloon insufflation, which measures the:
 1. First detectable sensation.
 2. The urge to defecate.
 3. The maximum tolerable volume.
- Urge to defecate is characterized by an increase in compliance, as indicated by volume increasing with pressure changes. This represents **“adaptive relaxation”** of the rectum.
- **Delayed sensation or hyposensitivity** manifests at higher volumes for these three parameters and **may be detected in those with neuropathies or altered rectal reservoirs.**
- **Hypersensitivity is characterized by reduced sensory threshold** to rectal distension, lower volumes for the three parameters, and complaints of urgency and frequency. Hypersensitivity is often demonstrated in those with **inflammatory bowel disease, proctitis, and functional bowel disorders.**

❖ Defecography

- Defecography is a **dynamic study to assess the defecatory process, specifically, the function of the pelvic floor during defecation.**
- The most common method to perform defecography involves the **instillation of liquid barium and air into the rectum followed by barium paste into the rectum and/or vagina depending on clinical indication.**
- With the patient sitting on a commode and attempting to recreate normal defecation, radiographs are obtained at: **rest, during squeeze, and during Valsalva.**
- The **anorectal angle** and **perineal descent** are commonly measured, as well as whether **paradoxical contraction of the puborectalis occurs.**

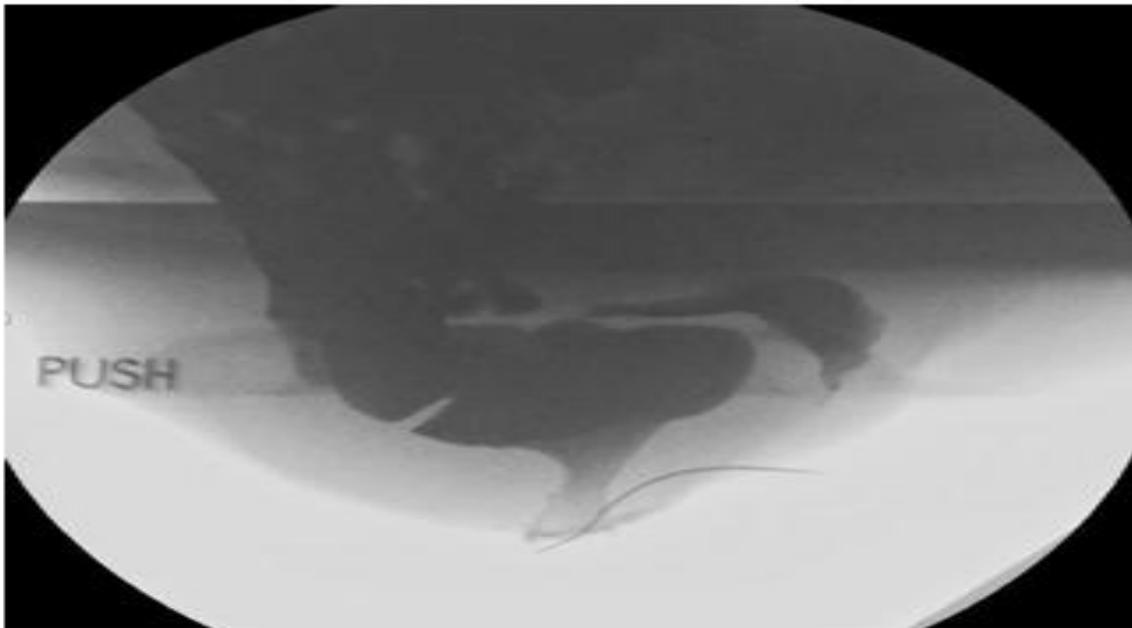


Fig. 3.3 Defecography demonstrating anterior rectocele. (Courtesy of G. Kwakye, MD, used with permission)

- **Functional Anorectal Disorders**

- ❖ **Fecal Incontinence**

- Anal continence requires integrated and coordinated mental, anatomic, and physiologic functions, including reflexes, sensory and motor nerves, and the muscles of the rectum, sphincters, and pelvic floor.
- Thus, disorders of continence can derive from deficits in any of these contributors, or as a result of high stool volume or liquid consistency, even in patients with normal anatomy and function.

- Yet, the various mechanisms of continence are likely somewhat redundant, as single, isolated deficits in any one of these functions may often be tolerated without symptomatic incontinence.

For example, the functional consequences of obstetric trauma suffered during childbearing years may not be experienced until decades later, as compensatory mechanisms are weakened or disrupted.

- These observations suggest that the physiologic etiology of fecal incontinence is most often **multifactorial**.

- Fecal incontinence due to **sphincter muscle defects** may result **from iatrogenic injury** associated with **sphincterotomy, fistula surgery, and hemorrhoidectomy** or from **obstetric injury** or other trauma.

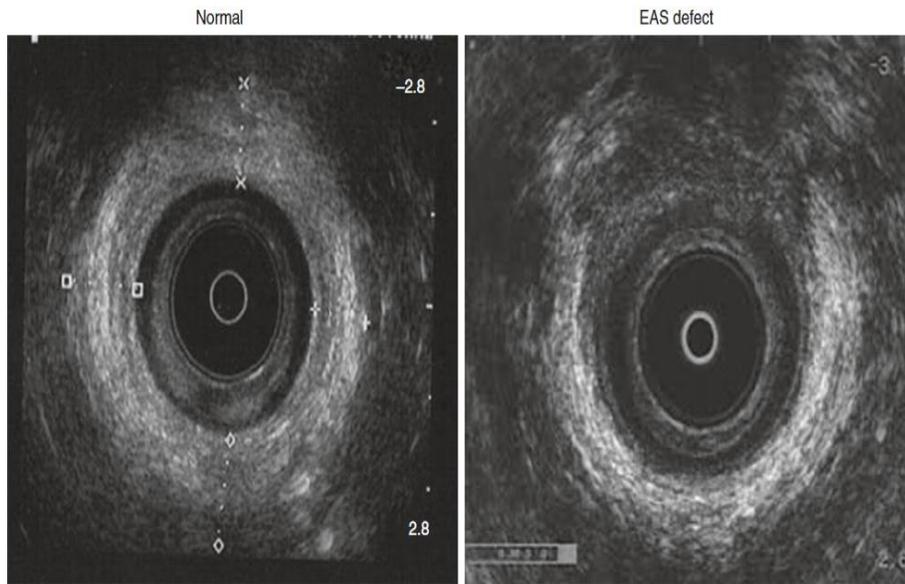


Fig. 3.4 Endorectal ultrasound. (Courtesy of S. Menees, MD, used with permission)

❖ Idiopathic fecal incontinence:

- In the absence of defined functional bowel disorder or anatomic deficit, is most commonly associated with **denervation of the pelvic floor and/or sphincter muscles**.
- This nerve dysfunction may itself be **idiopathic**, for example associated with **advanced age**, or may be secondary to **trauma** from obstetric injury, **chronic prolonged straining**, **distention from constipation**, or **outlet dysfunction**.
- There is evidence of **decreased sphincter pressures in older adults**, and in **women especially after menopause**.
- Pudendal nerve terminal motor latencies are likewise observed to be prolonged in older women.
- Compared to individuals with normal continence, patients with idiopathic fecal incontinence are more likely to have evidence of **pelvic floor motor neuropathy**, including **lower anal canal resting and voluntary contraction pressures**, **longer pudendal nerve**

terminal motor latency, and **higher thresholds to mucosal electro- sensitivity** in the anal canal.

- On average, these patients **have reduced anal resting pressures** and **reduced squeeze pressures**, as well as **lower volume and pressure thresholds for the urge to defecate**.
- patients with fecal incontinence tend to exhibit **significant impairment of anal sensation**.

- This combination of motor and sensory deficits may underlie the ameliorative effects of sacral nerve and posterior tibial nerve stimulation, which can influence neural innervation for both the sensory and motor functions of the anus and rectum.

- The etiology of this deficit has been proposed to be **repeated traction on the pudendal nerve** and **consequent denervation of the external anal sphincter and fibrous replacement**.

- **Loss of rectal sensation may contribute to deficits in RAIR**, while exaggerated, unopposed stimulation during distention may induce **involuntary sphincter relaxation**, and **impaired spinal reflex activity may reduce rectal compliance**.

- Incontinence in this setting may therefore derive from any combination of the following, depending on the level and completeness of injury: decreased anal sphincter resting tone, loss of voluntary control, or loss of anorectal reflexes.

- **Disorders of Defecation**

- In patients with constipation associated with anal outlet dysfunction, physiological abnormalities may include inadequate defecatory propulsion, dyssynergic defecation, or some combination thereof.
- Obstructed defecation can also be associated with pathologic anatomic conditions, including rectocele, intussusception, prolapse, or stricture.
- Patients with **idiopathic outlet dysfunction** may exhibit a variety of manometric anomalies, **including elevated anal resting pressures**, but this finding varies widely and may be normal in many of these patients.
- Some may have **impaired rectal sensation**, or **decreased RAIR**, which may reduce the autonomic emptying response, but these findings are also varied among numerous studies.
- The finding that women with new-onset constipation following a hysterectomy experienced decreased rectal sensory perception implies a role for the parasympathetic plexus of nerves, which reach the rectum via the lateral vaginal walls as they are susceptible to injury during lateral pelvic dissection.

- Some have suggested that **decreased rectal tone** and **intrarectal pressure with straining** are consistent with findings in those with idiopathic constipation, implying that diminished propulsion contributes to the outlet dysfunction.
- In other patients, obstructed defecation may result from **dyssynergic contraction of the external anal sphincter** and/ or **puborectalis muscle during efforts to evacuate the rectum.**
- Patients with obstructed defecation exhibit clinically significant limitation of emptying despite puborectalis activity, as demonstrated through electromyography (EMG), and adequate rectal pressure with straining.
- These patients will **exhibit paradoxical increase in puborectalis muscle contraction during EMG with straining and Valsalva maneuver, also known as anismus.**
- In one study, there was no difference in the degree of perineal descent or the manometric assessment of the external anal sphincter between patients with incontinence and patients with obstructed defecation.

- **Anorectal Pain**

- In the absence of identifiable anatomic source of pain from trauma, fissure, thrombosed hemorrhoid, abscess, tumor, or other finding, **idiopathic or functional anorectal pain disorders may be diagnosed.**

- These pain syndromes have been subclassified as either:

1. **Chronic proctalgia** (chronic or recurring pain lasting more than 20 minutes, without identifiable source).

Patients with chronic proctalgia may be considered to have levator ani syndrome if digital rectal exam with posterior traction on the puborectalis muscle reproduces the pain.

2. **Proctalgia fugax** (episodes lasting less than 20 minutes, with resolution between episodes).

- On occasion, either of these conditions may arise **following anorectal surgery**, but they are more commonly associated with **psychological disturbances**, including **anxiety and post-traumatic stress.**

- The physiologic findings from manometry or other testing are variable.

- **Urogynecological Considerations**

- Functional defecatory disorders, including fecal incontinence, obstructed defecation, rectal prolapse, rectocele, enterocele, sigmoidocele, and anorectal pain, frequently coexist with urogynecologic conditions such as urinary incontinence or retention, uterine prolapse or procidentia, and chronic pelvic pain.

- These relationships likely result from the **shared musculature of the pelvic floor and urogenital diaphragm**, as well as from the **overlap in peripheral innervation and spinal nerve roots**.