Physiology of Defecation and Mechanisms of Constipation

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Aims

At the end of this lecture students should be able to

• locate anatomical elements that are crucial for defecation;
• outline the hierarchy of control systems for defection;
• recognise the unconscious and voluntary control elements involved in defecation;
• explain the sequence of events that initiate, maintain and end defecation;
• discuss what constipation is; and
• list some mechanisms that might lead to constipation.
Contents

• Role of colon
• Facts about faeces
• Colonic mass movements
• Anatomical elements involved in defecation
• Hierarchy of control systems
• Phases of defecation
• Constipation including some pathophysiology
Physiological Role of Colon

• Reservoir for intestinal content.
• Fluid absorption: 500 - 1500 mL of chyme entering colon is reduced to 100 - 200 mL.
• Electrolyte absorption: $\text{Na}^+$, $\text{HCO}_3^-$, $\text{Cl}^-$ (same concept as in kidney; in colonic crypt cells, $\text{HCO}_3^-$ exchange for $\text{Cl}^-$ largely aldosterone-dependent): pH > 7.4.
• Bacterial flora “useful” for host: $10^{11} - 10^{12}$ bact/mL. Production of vitamin K and $\text{B}_12$; fermentation vs. putrescence; gas production (flatus: swallowed air; methane, $\text{H}_2$ and $\text{CO}_2$).
• Not necessary for life (colectomy…); consequences though for volume and electrolyte regulation.
Composition of Feces

- ~3/4 is water
- Of remainder, ~1/3 food residue (8%); rest produced “locally” (bacteria, epithelia).
- Quantity dependent on various factors like
  - food intake (quality and quantity), water content, and drugs, etc.
Colonic Motility

- Chyme is propelled towards sigmoid, ultimately to anus.
  - Motility: Segmentation (not peristalsis).
- “Normal” passage time: 10 - 20 h (highly variable).
- Mass movements 2 - 3 x / day (postprandial), starting in transverse colon.
  - Associated with defecation
- Initiated by food intake:
  - Gastrin (hormone)
  - Gastrocolic reflex (ANS)
  - Duodenocolic reflex (ANS)
Colonic Mass Movements

- Food intake stimulates colonic movements.
- Mass movements start in transverse colon.
- Contraction is “long”-lasting (few minutes).
- Within few minutes, sigmoid is filled: urge as prelude to defecation.

Despopoulos & Silbernagl 2003
Defecation in a Wider Context

- Hierarchy of reflexes coupled with learnt behaviour.
- At interface between voluntary and autonomic (uncontrollable) nervous control; prime target for psychological and psycho-social interference:
  - Stress increases frequency of voiding.
  - Shortly before going into action, a large number of soldiers in war involuntarily void (Patton report after WWII; “shit scared” - angst).
  - Coupled with urogenital reflexes (share control system in sacral cord).
- Psycho-socially often associated with “rituals”.
- Often compromised in disease: neurological, muscular, neoplastic, *etc*.
- Most people in hospitals have defecation difficulties…
Four Phases of Defecation

• In between defecation sessions, **continence ①** is crucial.

• Act of defecation consists of:
  - **Initiation of reflex ②**: urge caused by mass movement.
  - **Defecation reflex ③** (or voiding reflex): opening of the anus.
  - **Closure reflex ④**: closing of the anus.

• All systems have to work in conjunction with each other to accomplish efficient voiding: **all 3 nervous systems** have to participate (Enteric, Autonomic and Central NS).

• Higher-order control systems are there to **amplify/synchronize** ENS response.

• Under pathological conditions, synchronization might be hard to achieve.
• Most control systems are out of reach of voluntary control.
• Inclusion of several control systems guarantees sufficient amplification and synchronization of efferent response to initiate voiding.
1. **Anatomical Elements of Continence**

- **1<sup>st</sup> line of defence**: controlled by ENS.
  - Kohlrausch’s fold together with upright position.
  - Circular smooth muscles.

- **2<sup>nd</sup> line of defence**: controlled by ENS / ANS.
  - Internal anal sphincter (smooth muscle): 70 - 85% of sphincter pressure.
  - Venous spongy body (haemorrhoids): 10 - 20% of sphincter pressure.

- **3<sup>rd</sup> line of defence**: controlled by CNS (spinal reflexes).
  - External anal sphincter (striated muscle).
  - Puborectal muscles (*levator ani*; striated muscle).
**Physiology of Anal Continence**

- ENS constricts internal sphincter and relaxes sigmoid (reservoir).
- To keep anus closed, both internal and external sphincters are tonically active; most force is produced by internal sphincter.
② Initiation of Defecation: Filling

- Initiation of defecation is accomplished by
  - mass movements (gastrocolic reflex, hormones), or
  - small movements in sigmoid (distension/enema), or
  - emptying of sigmoid (increase in abdominal pressure).

- Result is filling of ampulla recti.

- Touch and/or pressure receptors signal via n. erigentes (plexus pelvicus - sympathetic; S₂ - S₄) a feeling of urge.

- Elicits either
  - recto-anal inhibitory reflex (B; ENS & ANS; leads to defecation), or
  - recto-anal contractile reflex (C; CNS; suppresses defecation).
Rectal filling (threshold is ~20 mL) causes
- recto-anal inhibitory reflex (ENS & ANS) with increase in smooth muscle tone in sigmoid (ENS); and
- urge, perceived in CNS: anorectal sampling via Krause end-bulbs, Golgi-Mazzoni bodies, genital corpuscles, Pacinian and Meissner’s corpuscles; gas - fluid - solid discrimination.

Initiation of Defecation
• Circular contraction of sigmoid (ENS) and relaxation of internal (ENS and ANS; ) and external sphincters (CNS): amplification/synchronization of response.

• Behavioural response to urge:
  – Relaxation of external sphincter.
  – Straining: abdominal pressure↑, closure of glottis, etc.; change in position (crouching).
• Upon voiding, receptor relief/adaptation in *ampulla recti* removes inhibitory drive to internal sphincter (ENS, ANS indirectly): contraction of internal sphincter.
• Voluntary contraction of external sphincter closes anus off.
• Smooth muscles in sigmoid relax (ENS; re-establishing reservoir function).
Dynamics of Defecation (①-④)
Special Notes

• **Babies**: Control of Onuf’s nucleus ($S_2-S_4$) only established after ~2 years (maturation of spino-thalamic, cortico-spinal tracts and local networks): feeling of “urge” required for efficient “potty training”.

• **Paraplegic patients**
  – Can often perceive rectal filling as a vague sensation and discomfort (parasympathetic afferents?).
  – High spine lesions (tetraplegia) do not allow for any sensation.
  – Patients with spinal injuries typically suffer from **constipation**; to stimulate “uncontrolled” defecations, reflex might have to be initiated via enema, manual opening, etc.
Constipation

What is YOUR definition of constipation?
Perception of Constipation

• Very individual

• Objective criteria
  – Frequency
  – Stool weight: difficult to measure routinely; varies widely.
  – Consistency: difficult to assess objectively

• Subjective criteria (invaluable, hard to quantify)
  – Straining, difficulty
  – Sense of incomplete voiding
  – Discomfort, pain
  – Perception of “ideal” voiding
Constipation

- Definition: Constipation is passage of small amounts of hard, dry bowel movements, usually fewer than three times a week. After NIH 1999.

- People who are constipated may find it difficult and painful to have a bowel movement.

- Other symptoms of constipation include feeling bloated, uncomfortable, and sluggish.

- Prevalence:
  - Very high incidence of females (young adult).
  - Often a result of iatrogenic action (side effects of drugs).
  - Often associated with other underlying illnesses (diabetes, etc.; secondary constipation).
Common Causes of Constipation

• Not enough liquids.
• Poor diet; i.e. insufficient fibre in diet (< 20 g/d).
• Lack of exercise (mechanisms not well understood).
• Changes in life or routine such as pregnancy, old age, and travel.
• Particular foods (chocolate, etc.)
• Ignoring urge to have a bowel movement.
• Abuse of laxatives (chronic use).
• Medications (most common side effect).
• Irritable bowel syndrome.
• Anorectal disease.
• Problems with intestinal function (chronic idiopathic constipation.)
• Specific diseases such as multiple sclerosis and lupus.
Properties of Constipation

- With a few exceptions, transit times in proximal regions of GI tract normal: disease of the colon.
- Results in various degrees of subjective symptoms.
- Is associated with abnormalities secondary to increase in colonic luminal pressure and intravascular pressure in haemorrhoidal venous cushions: colonic diverticular disease, haemorrhoidal disease, anal fissures.
Causes of Constipation

• Secondary causes (most common)
  – Insufficient water and/or fibre: Dry/hard stool with sliding difficulties.
  – Side effects of drugs: Analgesics, anticholinergics, cation containing agents (Fe, Ca, etc.), neurally active substances (opiates, antihyper-tensives, ganglion blockers, etc.): biggest problem in hospitals.
  – Metabolic and endocrine: Diabetes, hypoparathyroidism, hypokalemia, porphyria, pheochromocytoma.

• Primary causes (rare - but not to be forgotten)
  – Myogenic:
    • Smooth muscle: some endocrine disorders
    • Striated muscle: dermatomyositis, pelvic floor damage, etc.
  – Neurogenic:
    • Intrinsic innervation
      – Damage to enteric nervous system (plexus myentericus): chronic constipation, aganglionic colon (Hirschsprung).
    • Extrinsic innervation
      – Afferent: neuropathy (diabetes), multiple sclerosis, trauma to n. erigentes (x-ray, iatrogenic, fractures, etc.), receptor adaptation, spinal lesions, etc.
      – Efferent: trauma to n. erigentes (plexus pelvicus; x-ray, iatrogenic, fractures, etc.).
      – Integrative: Chronic suppression of urge, Parkinson’s disease, cerebrovascular insults, etc.
  – Idiopathic: unknown cause.
Take-Home Messages

• Role of colon is to compact/portion chyme for defecation.
• Defecation is initiated by rectal distension.
• THE major element for continence is the internal sphincter, which is under unconscious control.
• All three nervous systems (ENS, ANS and CNS) are involved in the control of defecation.
• Spinal injury patients are typically constipated; amplification of afferent stimuli can help to initiate “unconscious” defecation.
• Suppression of urge to defecate can lead to constipation.
• Constipation is the most highly ranked patient complaint.
Which of the following sequences correctly represents the top-down hierarchy (from highest to lowest control levels) involved in establishing continence?

A. autonomic nervous system → parasympathetic fibres → enteric nervous system → brain centres → smooth muscle/mucosa/vasculature.

B. parasympathetic fibres → brain centres → autonomic nervous system → enteric nervous system → smooth muscle/mucosa/vasculature.

C. brain centres → parasympathetic fibres → autonomic nervous system → enteric nervous system → smooth muscle/mucosa/vasculature.

D. autonomic nervous system → brain centres → parasympathetic fibres → enteric nervous system → smooth muscle/mucosa/vasculature.

E. brain centres → autonomic nervous system → parasympathetic fibres → enteric nervous system → smooth muscle/mucosa/vasculature.