BLADDER PHYSIOLOGY & MICTURITION

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TOPICS OF INTEREST

- Anatomy of the Bladder
- Biomechanical Basics of the Urinary Bladder
- Neural Control of the Bladder
ANATOMY OF THE BLADDER
Anatomy of the Bladder

- The urinary bladder is a smooth muscle chamber composed of **TWO** main parts:
  - **body**: major part that collects urine
  - **neck**: a funnel-shaped extension of the body, passing inferiorly and anteriorly into the urogenital triangle and connecting with the urethra
Anatomy of the Bladder

- The lower part of the bladder neck is also called the **posterior urethra** because of its relation to the urethra.
- The smooth muscle of the bladder is called the **detrusor muscle**.
Anatomy of the Bladder

- On the posterior wall of the bladder; lying immediately above the bladder neck, is a small triangular area called **trigone**

- The trigone can be identified by the fact that its **mucosa** is **smooth**, in contrast to the remaining bladder mucosa, which is folded to form **rugae**
Anatomy of the Bladder

- At the lower most apex of the trigone, the bladder neck opens into the posterior urethra, and the two ureteres enter the bladder at the uppermost angles of the trigone.
- Each ureter; as it enters the bladder, courses obliquely through the detrusor muscle and then passes another 1 to 2cm beneath the bladder mucosa before emptying into the bladder.
Anatomy of the Bladder

- The **bladder neck** (posterior urethra) is a 2 to 3 cm long, and its wall is composed of **detrusor** muscle interlaced with a large amount of elastic tissue.
- The muscle in this area is called the **internal sphincter**.
Anatomy of the Bladder

- Natural tone of the bladder normally keeps the bladder neck and posterior urethra empty of urine
- Therefore, prevents emptying of the bladder until the pressure in the main part of the bladder rises above critical threshold
Anatomy of the Bladder

- Beyond the posterior urethra, the urethra passes through the urogenital diaphragm, which contain a layer of muscle called the external sphincter of the bladder.
Anatomy of the Bladder

- The external sphincter of the bladder is a voluntary skeletal muscle, in contrast to the muscle of the bladder body and bladder neck, which is entirely smooth muscle (involuntary).
- The external sphincter muscle is under voluntary control of the nervous system and can be used to consciously prevent urination even when involuntary controls are attempting to empty the bladder.
Innervation of the Bladder

1. Autonomic
   - Parasympathetic (S2 to S4)
     - motor to detrusor
     - inhibitory to internal urethral sphincter
   - Sympathetic (T10 to L2)
     - motor to sphincter
     - inhibitory to detrusor

2. Somatic nerve (S2, S3, S4)
   - Pudendal nerves
Innervation of the Bladder

- Origin of fibres in spinal cord to urinary bladder
  - **Parasympathetic**: intermediolateral grey horn
  - **Sympathetic**: intermediolateral grey horn
  - **Somatic/Pudendal**: nucleus of ONUF / sacral pudendal nucleus in ventral horn
**Innervation of the Bladder**

- **Parasympathetic** nerve supply
  - Stretch receptors present on the wall of the urinary bladder $\rightarrow$ sensory fibers in the pelvic nerve $\rightarrow$ intermediolateral column of spinal cord $\rightarrow$ emptying of urinary bladder
  - If parasympathetic fibres are destroyed, normal micturition is NOT possible
Innervation of the Bladder

- **Sympathetic** nerve supply & Internal urethral sphincter
  - no significant role in micturition
  - sympathetic fibres are chiefly vasomotor
  - Increased sympathetic discharge to bladder occurs during ejaculation
  - helps to prevent the reflux of sperms from the prostatic urethra into the bladder
Innervation of the Bladder

- **Somatic** nerve supply
  - This maintains the tonic contractions of the skeletal muscle fibers of the external sphincter
  - Therefore the external sphincter is contracted always
  - During micturition this nerve is inhibited, causing relaxation of the external sphincter and voiding of urine
Innervation of the Bladder

- Voluntary control of micturition is attained by age of 2 – 3 yrs

- Nocturnal micturition (Bed wetting)
  - Considered normal upto age < 3 yrs
  - It occurs due to incomplete myelination of motor nerve fibers of the bladder resulting loss of voluntary control of micturition
Innervation of the Bladder

- T10, T11, T12, L1, L2: Sympathetic input
- S2, S3, S4: Parasympathetic input
- Hypogastric ganglion
- Hypogastric nerve
- Pelvic ganglion (NERVI ERIGENTES)
- Pelvic nerve
- Detrusor muscle
- Somatic control (Pudendal nerve)
- Internal urethral sphincter
- External urethral sphincter (voluntary)
Blood supply

- The bladder is supplied by the **superior and inferior vesical arteries** which are branches of anterior trunk of internal iliac artery

- The veins that drain the bladder form a plexus on the infero-lateral surface before ending in the **internal iliac vein**

- Most of the lymph from the urinary bladder ends in the **external iliac nodes**
BIOMECHANICAL BASICS OF THE URINARY BLADDER

Bladder Physiology and Micturition
The wall tension of a spherical body (bladder) is dependent on its:
- internal pressure ($P_{ves}$)
- radius of the bladder ($r$)
- bladder wall thickness ($d$)

**wall tension** = \( \frac{(P_{ves} \times r)}{2d} \)
Laplace's Law

Wall tension = \( \frac{P_{\text{ves}} \times r}{2d} \)

- The wall tension increases during urinary retention, although the bladder pressure remains relatively constant.
- The wall tension increases because of the:
  - enlarged radius \( r \) AND
  - decrease in wall thickness \( d \)
- This leads sometimes to an enormously dilated bladder.
Compliance of the bladder

- The compliance (elasticity) of the bladder depends on both:
  - neuromuscular factors
  - quantity of connective tissue in the bladder wall
- The bladder compliance is calculated by the increase in bladder volume as a function of intravesical pressure (normal 20–60 ml/cm H₂O):

\[
\text{bladder compliance} = \frac{\text{(change in volume)}}{\text{(change in bladder pressure)}}
\]
Detrusor Pressure

- The detrusor pressure can be calculated by the difference of the intravesical pressure and intra-abdominal pressure.
- Both pressures can be easily measured with the help of catheter in bladder and rectum:

\[
\text{Detrusor pressure} = (\text{intravesical pressure}) - (\text{intra-abdominal pressure})
\]
The urethral resistance can be calculated using:

- maximum urinary flow ($Q_{\text{max}}$)
- detrusor pressure at maximum urine flow ($P_{\text{det at } Q_{\text{max}}}$)

Urethral resistance = \frac{P_{\text{det at } Q_{\text{max}}}}{(Q_{\text{max}})^2}
Urethral Resistance

- Normal values for the urethral resistance using the formula above:
  - men <0.6
  - women <0.2

- The formula should only be used with voiding volumes between 200–400 ml

- The low urethral resistance explains the very low and sometimes not measurable detrusor pressures in women during normal micturition
NEURAL CONTROL
OF THE
BLADDER
Neural Control of the Bladder

- Two functional states of the urinary bladder must be distinguished:
  - storage phase
  - emptying phase (micturition, voiding)
Storage Phase of the Bladder

- The filling of the bladder (storage) is enabled by:
  - contraction of the striated sphincter (somatic innervation)
  - contraction of smooth muscle sphincter (sympathetic innervation)
  - inhibition of detrusor activity (sympathetic innervation)
Emptying Phase of the Bladder

- Voiding (micturition) is enabled by:
  - relaxation of the striated sphincter (somatic innervation)
  - relaxation of the smooth muscle sphincter and opening of the bladder neck (sympathetic innervation)
  - detrusor contraction (parasympathetic innervation)
Neural Reflex Arcs to Control the Bladder Function

- The afferent signals from stretch and volume receptors transmit information about bladder filling to centers of the spinal cord and CNS.

- Depending on the storage phase, several reflex arcs are activated:
  - spinal pathways
  - pontine micturition center
  - central pathways
  - urethra to bladder reflexes
Spinal reflexes:

- inhibit micturition during the filling phase, activate the striated sphincter (pudendal nerve)
- inhibit the detrusor muscle, activate the smooth muscle sphincter via activation of the sympathetic nervous system
Spinal pathways

- Afferent signals for the activation of the spinal pathway derive from:
  - bladder (increasing bladder filling)
  - pelvic floor muscles
  - penis,
  - vagina
  - Rectum

- These mechanisms explain the risk of urinary retention after operations in the regions mentioned above

- The spinal reflexes are also the basis for the sacral neurostimulation in therapy of the overactive bladder
An increasing bladder filling increases the afferent neuronal activity of the bladder

- this activates the pontine micturition center in the brainstem (pons)

The pontine micturition center (Barrington's nucleus) inhibits the spinal reflexes

- this causes the activation of the detrusor muscle and inhibition the urinary sphincter
Central pathways

- Central pathways inhibit the micturition reflex
- At a certain bladder filling, the filling is consciously perceived and afferent signals thus passed on cortical centers
- The initiation of micturition is voluntary controlled, the central pathways can inhibit the pontine micturition center over a certain range of the bladder filling
Central pathways

- Lesions of the cortical micturition center leads to the elimination of the inhibitory pathways and to an overactive bladder.
- Like any striated muscle the external sphincter of the urinary bladder is voluntarily controlled via the pyramidal tract and the extrapyramidal system.
Urethra to bladder reflexes

- Urine flow or mechanical stretching of the urethra cause a stimulation of bladder contractions
- This reflex has an important function in complete bladder emptying
- The reflex serves as an explanation for the combined urge and stress incontinence in women: stress-induced urine leakage into the urethra leads to a detrusor contraction
HOSPITAL

FOR RADIOLOGY FOLLOW THE YELLOW LINE

FOR UROLOGY FOLLOW THE YELLOW PUDDLES
- HOSPITAL -
FOR RADIOLOGY FOLLOW THE YELLOW LINE →
FOR UROLOGY FOLLOW THE YELLOW PUDDLES →
Innervation of the Bladder

- The principal nerve supply of the bladder is by way of the pelvic nerves, which connect with the spinal cord through the sacral plexus, mainly connecting with cord segments S2 S3 S4.
- Coursing through the pelvic nerves are both sensory nerve fibers and motor nerve fibers.
- The sensory fibers detect the degree of stretch in the bladder wall.
- Stretch signals from the posterior urethra are especially strong and are mainly responsible for initiating the reflexes that cause bladder emptying.
The motor nerves transmitted in the pelvic nerves are parasymphatetic fibers. These terminate on ganglion cells located in the wall of the bladder. Short postganglionic nerves then innervate the detrusor muscle.
Innervation of the Bladder

- In addition to the pelvic nerves, there are another two types of innervations which are important in bladder function.

- Most important are the **skeletal motor fibers** transmitted through the **pudendal nerve** to the **external urethral sphincter**.

- These are **somatic** nerve fibres that innervate and control the **voluntary** skeletal muscle of the sphincter.
Innervation of the Bladder

- Also, the bladder receives sympathetic innervations from the sympathetic chain through the hypogastric nerves, connecting mainly with the L2 segment of the spinal cord.
- These sympathetic fibers stimulate mainly the blood vessels and have little to do with bladder contraction.
- Some sensory nerve fibers also pass by way of the sympathetic nerves and may be important in the sensation of fullness and in some instances, pain.