Renal Physiology: Filling of the Urinary Bladder, Micturition, Physiologic Basis of some Renal Function Tests

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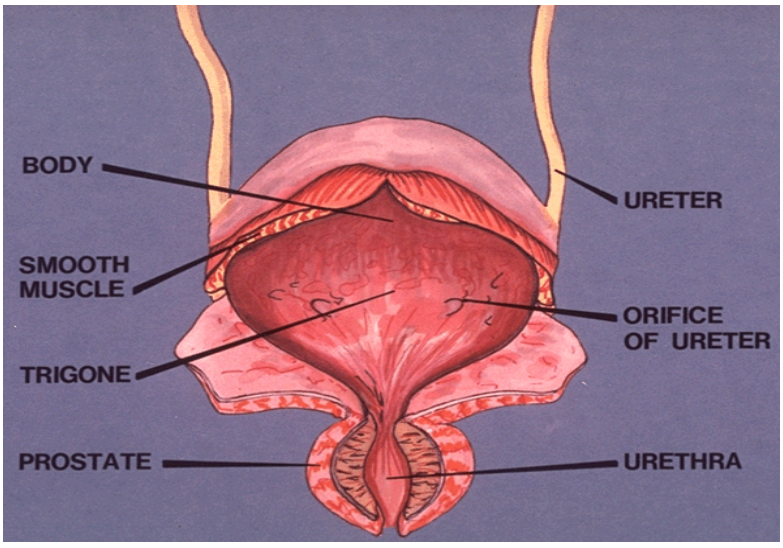

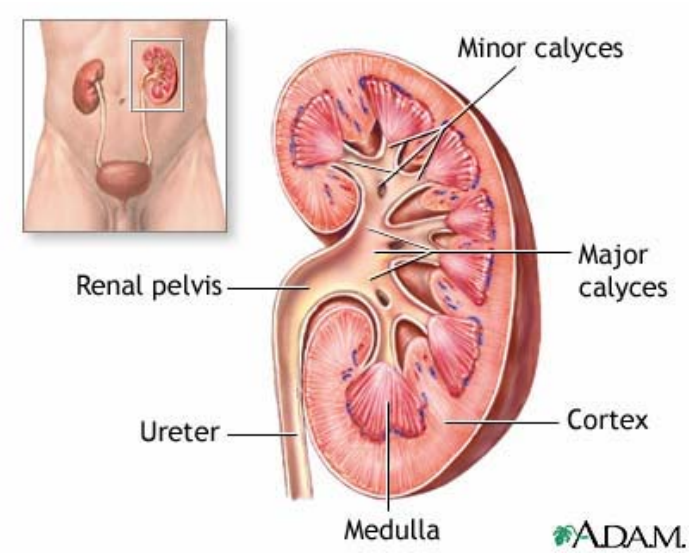

Functions of the Urinary Bladder

- 1. storage of urine
  - 150 cc 1st urge to void
- 2. voiding of urine
  - 300 – 400 cc marked sense of fullness

- Passive diffusion of water and solute can occur in the ureters and UB. Therefore, urine can be modified after it leaves the kidneys

Filling of the Bladder

- Urine collected in the pelvis of the kidney passes to the ureters to the bladder by
  - 1. the forces of gravity in erect position
  - 2. contractions of muscle layers of the ureter
    - Necessary in order to develop sufficient pressure to overcome the gradually increasing tension in UB as urine accumulates
    - Regular peristaltic contractions 1.5x/min
    - Urine enters the bladder in spurts synchronous with each peristaltic wave
    - Enhanced by parasympathetic stimulation, inhibited by sympathetic

Ureteral Reflux

- Ureteral sphincters are not present
- Prevented by:
  - Mucosal flap formed by ureters passing obliquely through the bladder wall
  - Ureters pass under the lining of the bladder for a few centimeters before entering, so full bladder compresses the ureters

Transport of urine from the kidney through the ureters and into the bladder

- No significant changes in composition as urine flows through renal calices, ureters to the bladder
- Urine flowing from the CD into the renal calices stretches the renal calices and increases their inherent pacemaker activity → peristaltic contractions that spread to the renal pelvis and then downward along the length of the ureter, forcing urine from the renal pelvis toward the bladder

Ureter

- Wall: smooth muscle
- Innervation:
  - Sympathetic
  - Parasympathetic
  - Intramural plexus of neurons and nerve fibers that extends along the entire length of the ureters
- Enter the bladder through detrusor muscle in the trigone
- Course obliquely for several cms
- Compressed by normal tone of detrusor in the bladder wall

Vesicoureteral reflux

- The distance that the ureter courses through the bladder wall is less than normal
- Contraction of the bladder during micturition does not always lead to complete occlusion of the ureter
- Some of the urine is propelled backward into the ureter
- Can lead to enlargement of the ureters
- Can increase the pressure in the renal calices and structures of the renal medulla causing damage

Ureterorenal reflex

- Ureters are well supplied with pain nerve fibers
- Blockage causes intense reflex constriction associated with severe pain
- Pain impulses cause a sympathetic reflex back to the kidney to constrict the renal arterioles, decreasing urine output from the kidney
- Important for preventing excessive flow of fluid into the pelvis of the kidney with blocked ureter

Emptying the Bladder

- Anatomic considerations
  - Urinary bladder
    - Body – major part, where urine collects
    - Neck/posterior urethra – funnel shape, connects with urethra
  - Detrusor muscle –
    - Where ureters enter the bladder
    - In the trigone layer of the bladder
    - Smooth muscle, fibers run in all direction
    - Thick, 3 layers
    - Can increase pressure in bladder 40-60 mmHg which major step for emptying

Anatomic considerations

- Internal urethral sphincter
  - extension of detrusor muscle passing on either side of the urethra
  - Natural tone normally keeps the bladder neck and posterior urethra empty of urine
  - Prevents emptying of the bladder until the pressure in the main part of the bladder rises above a critical threshold

External urethral sphincter

- Area of urogenital diaphragm
- Voluntary skeletal muscle
- Under voluntary control of the nervous system
- Can be used to consciously prevent urination even when involuntary controls are attempting to empty the bladder

Innervation of the Bladder

- Pelvic nerves – principal nerve supply
- Sensory nerve fibers – detect the degree of stretch in the bladder wall
  - Stretch signals from the posterior urethra are strong and are mainly responsible for initiating the reflexes that cause bladder emptying
- Motor nerves – parasympathetic fibers
- Somatic nerve fibers – control the voluntary skeletal muscle of the sphincter
- Sympathetic fibers through the hypogastric nerves

Micturition

- The process by which the UB empties when it becomes filled
- 2 main steps:
  - Bladder fills progressively until the tension in its walls rises above a threshold level
  - Micturition reflex – a nervous reflex that empties the bladder
    - If it fails, at least causes a conscious desire to urinate
    - Autonomic spinal cord reflex; can be inhibited or facilitated by centers in the cerebral cortex or brain stem

Reflex control of micturition

- Stimulus
  - Vesicular pressure at about 18 cmH2O
  - Urine volume of about 300-400 cc (150 cc first urge to void is felt; 400 cc marked sense of fullness)
- Receptors – stretch and tension receptors in the bladder wall
  - Excited by threshold stimulus
  - Afferent impulses from receptors are responsible for the sensations of distention and the desire to urinate; can also cause the act of micturition when spinal reflexes are released from cerebral control
- Afferent limb – fibers in pelvic nerves
- Center – sacral cord
- Efferent limb – pelvic nerves

Micturition reflex

- As the bladder fills, many superimposed micturition contractions begin to appear
  - Initiated by sensory stretch receptors in the bladder wall
  - Sensory signals → sacral segments of the cord through the pelvic nerves → back to bladder through the parasympathetic nerve fibers by way these same nerves

Micturition reflex

- Bladder is only partially filled
  - MC usually relax spontaneously after a fraction of a minute
  - Detrusor muscle stop contracting
  - Pressure falls back to the baseline
- As bladder continues to fill
  - Micturition reflexes become more frequent, greater contractions of detrusor muscle
- Once it begins, it is self-regenerative

MR is a single complete cycle of:

- 1. progressive and rapid increase of pressure
- 2. a period of sustained pressure
- 3. return of the pressure to the basal tone of the bladder

Higher control of micturition

- It is normally a voluntary act
  - Voluntary control can be exerted until the vesicular pressure increases to about 100 cmH2O at which point involuntary micturition begins
- Afferent nerves: pelvic nerves, hypogastric and pudendal nerves
  - Enter the SC at sacral levels III and IV → hypothalamus and cortex where voluntary control resides

Higher control

- Facilitory areas
  - Pontine region
  - Posterior hypothalamus
  - Cerebral cortex
- Inhibitory areas
  - Midbrain
  - Cerebral cortex

- The micturition reflex is the basic cause of micturition, but the higher centers normally exert final control as follows:
  - The higher centers keep the MR partially inhibited except when micturition is desired
  - The higher centers can prevent micturition, even if the MR does occur, by continual tonic contraction of the external bladder sphincter until a convenient time presents itself
  - When it is time to urinate, the cortical centers can facilitate the sacral micturition centers to help initiate a MR and at the same time inhibit the external urinary sphincter so that urination can occur

Voluntary urination

- A person voluntarily contracts his abdominal muscles, which increases the pressure in the bladder and allows extra urine to enter the bladder neck and posterior urethra under pressure, stretching their walls
- Stimulates the stretch receptors
- Excites the MR
- Inhibits the external urethral sphincter
- 5-10 ml left in the bladder

Abnormalities of Micturition

- Three major types of bladder dysfunction due to neural lesions
  - Types due to interruption of the afferent nerves from the bladder
    - The atonic bladder caused by destruction of sensory nerve fibers
      - MR contraction cannot occur
      - Lose of bladder control despite intact efferent fibers from the cord and intact neurogenic connections from the brain
      - Bladder fills to capacity and overflows a few drops at a time (overflow incontinence)
      - Cause: crush injury to the sacral segment; certain diseases like syphillis

- Types due to interruption of both afferent nerves and efferent nerves
  - Automatic bladder caused by SC damage above the sacral region
    - Sacral cord segments still intact, MR can still occur but no longer controlled by the brain
    - 1st few days to several weeks after damage, MR are suppressed because of state of spinal shock caused by sudden loss of facilitory impulses
    - If bladder is emptied periodically by catheterization to prevent bladder injury, MR gradually increases

- Types due to interruption of facilitory and inhibitory pathways descending from the brain
  - The uninhibited bladder caused by lack of inhibitory signals from the brain
    - Frequent and uncontrolled micturition
    - Partial damage in SC or brain stem that interrupts most of the inhibitory signals
    - Facilitory impulses passing continually down the cord keep the sacral centers so excitable that even a small quantity of urine will elicit an uncontrollable MR, and thereby promote frequent urination

Abnormal Renal Function

- Effects of Disordered Renal Function
  - If the kidneys do not function normally, the constancy of the ECF is not maintained
  - Generalized edema resulting from water retention
  - Acidosis resulting from failure of the kidneys to get rid of normal acidic products
  - High potassium concentration resulting from failure of potassium excretion
    - Uremia

- Uremia – results from high concentrations of normal urinary excretory products that collect in the body fluids
- Uremic coma – after a week or more of renal shutdown, patient's sensorium becomes clouded → progresses into coma →respiratory attempt to compensate for metabolic acidosis
  - Last day before death, ABP falls progressively, then rapidly. Death when ph falls about 7

- High concentrations of NPN (urea) resulting from failure of the body to excrete the metabolic end products

Renal Function Tests

- Renal function can be appraised in various ways
  - Chemical and Physical analysis of urine
    - Urinalysis (leucocytes, protein, casts, etc.)
    - Urine specific gravity
      - Normal: hypertonic
      - If water is withheld urine becomes even more concentrated
      - Kidney diseases, loss of concentrating and diluting ability

  - Measurement of substances in the blood that are normally excreted by the kidneys
    - BUN, Creatinine – increases in renal insufficiency
      - Easy to perform, can tell how seriously the internal environment has been impaired
      - Normal 26 mg/100 cc urea, can rise to as much as 200 mg%
      - Normal Crea 1.3 mg%, can rise to as much as ten-fold
    - Bicarbonate ion content – used to determine the degree of net acidosis resulting from renal dysfunction

- Determination of renal clearance
  - IV Pyelography
    - Several substances containing large quantities of iodine in their molecules are excreted into the urine either by glomerular filtration or by active tubular secretion
    - The concentration in the urine becomes very high within a few minutes after IV injection
    - Iodine in the compounds makes renal pelvis, ureters , UB relatively opaque
    - A sufficient quantity is excreted within 5 minutes after injection to give good shadows of the kidney pelvis. Failure indicates hypofunction

Volume of urine

- Acute renal shutdown – urine volume can fail to zero
- Severe renal insufficiency – urine volume diminished
- Moderate renal insufficiency – urine volume actually increase output because of overfunction of the remaining nephrons when the majority has been destroyed