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 1\textsuperscript{st} 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
  - connect with cord segments S-2 and S-3
  - sensory fibers detect the degree of stretch in the bladder wall
  - motor nerves – parasympathetic fibers
- Pudendal nerves – external bladder sphincter
  - somatic nerve fibers
- Hypogastric nerves – sympathetic innervation
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 (parasympathetic fibers)
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
• 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 syphilis (tabes dorsalis)
        - Distended, thin-walled, hypotonic
– Types due to interruption of both afferent nerves and efferent nerves
  • Bladder is flaccid and distended for a while
  • Gradually the muscle becomes active
  • Many contraction waves that expel dribbles of urine out of the urethra
    → bladder shrunken, wall hypertrophied
- 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
– 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

• Spinal cord transection
  – No voluntary control
  – No facilitation or inhibition from higher centers
  – Voiding reflex may return
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
Post test

1. In the adult, the volume of urine in the bladder that normally initiates a reflex contraction is about how many ml?
   A) 200-250
   B) 300-400
   C) 350-450
   D) 250-350
   E) 400-500

2. True about the urinary bladder
   A) also called trigone
   B) triangular in shape
   C) capacity averages 500 ml
   D) A and B
   E) all of the above
   F) none of the above
3. Micturition reflex causes
   A) contraction of the internal urethral sphincter
   B) relaxation of detrusor muscle
   C) contraction of external urethral sphincter
   D) all of the above
   E) none of the above

4. True about ureteral contractions
   A) necessary for filling of the bladder
   B) occur once per second
   C) enhanced by sympathetic stimulation
   D) A and B
   E) all of the above
5. True about the ureter
   A) enters the bladder through the detrusor muscle
   B) ureteral sphincter prevents reflex
   C) wall is made up of smooth and skeletal muscles
   D) endowed with internal sphincter
   E) all of the above
   F) A and B