**Module 1: Normal Urinary Tract Anatomy and Physiology: Bladder Filling, Storage and Emptying**

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The anatomy and physiology of bladder filling, storage and emptying is complex. The bladder is composed of three layers. The bladder lining or urothelium maintains an impermeable barrier to urine, it's components, and toxic substances. Local factors such as mechanical or chemical injury or infections can compromise the integrity of the urothelium, causing urgency, frequency and pain during bladder filling and voiding. The urothelium also contains important afferent neurologic systems involved in bladder function.

The detrusor muscle, made up of smooth muscle arranged in an interlacing mesh work of muscle fibers allows the bladder to collapse in all dimensions when it contracts and an outer serosal layer.

The bladder can also be divided into two functional units - the bladder body and bladder base. The bladder base can be further divided into the trigone and bladder neck. The trigone is a unique part of the bladder located between the bladder neck and ureteric orifices on each side. It has a triangular shape and an endodermal embryologic origin. The bladder neck is closed during filling of the detrusor but opens as a funnel during voiding while the detrusor contracts. This coordination is dependent on complex neurologic pathways which will be discussed shortly.

In a woman, the urethra is short with an average length of about 3 cm compared to an average length of 20 cm in a man. It is built with several layers: mucosa, spongy tissue around the lumen, and muscular layers around (both longitudinal and circumferential). The sphincteric region is in the mid-urethra. This is an intrinsic or involuntary system responsible for continuous tonic activity necessary for urine storage between micturition. There is also an extrinsic or voluntary system, part of the urogenital diaphragm and pelvic musculature.

The sphincter mechanism is effectively an intra-abdominal structure. This anatomic relationship is important, so that during episodes of increased intra abdominal pressure continence is maintained. For example, during a cough you can see the resting urethral pressure in the sphincter remains greater than pressure within the bladder, preventing urine loss.

In a man, the bladder neck blends into the prostatic urethra. The membranous urethra is the location of the sphincteric unit. It also has an intrinsic (involuntary) and an extrinsic (voluntary) mechanism.

The peripheral nervous system innervations of the urinary tract involve complex connections and reflexes of autonomic and somatic efferent-nerve pathways.

During this animation, nerves will be represented in color. Sympathetic nerves will be red, parasympathetic nerves will be blue, and somatic nerves will be green.

Sympathetic nerves arising from T11 to L2 spinal segments are transmitted through the hypogastric nerve to supply the bladder and proximal urethra. Their activation results in release of norepinephrine which activates a dense plexus of alpha 1 adrenergic excitatory receptors resulting in contraction of smooth muscle at the bladder base and intrinsic urethral sphincter. Also, impulses from the hypogastric nerve to the bladder body causes stimulation of beta 2 adrenergic receptors and relaxation of the detrusor.

The somatic nervous system mediated by the pudendal nerve, stimulates closure of the striated extrinsic urethral sphincter and innervates all striated muscles of the pelvic floor. The pudendal nerve originates from Onuf's nucleus located the ventral horn of sacral roots S2-S4. Stimulation of pudendal nerve causes release of acetylcholine and stimulates nicotinic cholinergic receptors resulting in contraction of the extrinsic sphincter. (Modulation of the intrinsic sphincter also occurs by the central influence of the pontine micturition center.)

During bladder filling the parasympathetic innervation of the detrusor is inhibited while the sympathetic input to intrinsic and extrinsic urethral sphincters are stimulated. The coordinated inhibition of detrusor contraction and detrusor relaxation while tightening of the sphincter facilitates bladder storage of urine and is mediated by interneuronal pathways in the spinal cord and prevents involuntary emptying.

Bladder emptying is dependent on parasympathetic innervation via cholinergic receptors causing detrusor contraction. Parasympathetic preganglionic fibers originate in sacral segments S2-S4 and travel in pelvic nerves to ganglia in the pelvic plexus, from there the postganglionic parasympathetic nerves innervate the muscle fibers of the detrusor by release of acetylcholine stimulating a dense network of M3 muscarinic receptors, resulting in detrusor contraction.

During detrusor contraction and bladder emptying, there is a coordinated relaxation of intrinsic and extrinsic sphincters. This coordinated switching mechanism is due to spinal interneuron reflexes and central nervous system influences.

The feeling of bladder fullness is communicated to the spinal cord by the pelvic and hypogastric nerves. The sensory input from the bladder neck and the urethra is via the pudendal and hypogastric nerves. These nerves ultimately synapse with interneurons that are involved in spinal reflexes with spinal cord neurons that project to brain centers that mediate bladder function.

The CNS plays a critical role in the control and coordination of bladder storage and emptying.

Micturition centers located in the brain mediate afferent sensory input from the cord and efferent motor activity down the cord to the lower urinary tract.

The brain stem, specifically in the rostral pons or pontine micturition center, is the center for the coordination and integration of bladder and sphincter activity. The pontine micturition center functions as a sort of control tower integrating the various signals from the afferent fibers from the spinal cord and from a number of cortical and subcortical brain structures.

Information from a number of cortical areas, including the frontal lobes (which have predominantly inhibitory input) the periaqueductal gray, basal ganglia, cerebellum, thalamus, hypothalamus, and limbic regions of the brain (the latter participating in the emotional control of micturition) all play a role in modulating sensory input and motor output regulating micturition and can delay voiding until an appropriate time.

Once the voluntary decision to void is processed, a release of central inhibitory processes occur and descending tracts transmit impulses to the sympathetic and parasympathetic neurons, allowing the coordinated relaxation of the urinary sphincters a few milliseconds before the onset of detrusor muscle contraction.

In summary, urine storage and emptying is controlled by complex connections and reflexes between the central and peripheral nervous systems.

Bladder filling and urine storage is controlled by sympathetic and somatic nerves. The predominant sphincter mechanism is innervated by sympathetic nerves that arise from T11-L2 to form the hypogastric nerve. Activation of sympathetic nerves results in the release of norepinephrine which activates alpha 1 adrenergic receptors that result in contraction of smooth muscle at the bladder base and intrinsic sphincter. Beta 2 adrenergic receptors are also activated resulting in relaxation of the detrusor muscle. The extrinsic or voluntary sphincter is innervated by the pudendal nerve. Stimulation of the pudendal nerve causes release of acetylcholine and stimulates nicotinic cholinergic receptors resulting in voluntary contraction of the extrinsic sphincter. During bladder filling, the sensation of bladder fullness is mediated by afferent signals traveling from the bladder up the spinal cord to various areas of the brain.

Bladder emptying is dependant on the activation of the parasympathetic nervous system and the inhibition of the sympathetic and somatic nervous systems. Parasympathetic preganglionic fibers originate in S2-S4 forming the pelvic nerve. Once a voluntary decision to void is processed by the CNS, nerve impulses sent down the spinal cord activate parasympathetic nerves. Pelvic nerves release acetylcholine stimulating M3 muscarinic receptors in the detrusor body resulting in detrusor contraction. Almost simultaneously the sympathetic and somatic systems are inhibited, causing relaxation of the intrinsic and extrinsic urethral sphincters allowing flow of urine.