Bladder and Voiding

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1. Introduction to Normal Voiding Physiology

Bladder and sphincter mechanism has to fulfill storage and emptying functions in order to accommodate normal voiding at socially acceptable times.

Storage of urine occurs at low pressure, which implies that the bladder relaxes during the filling phase. Emptying requires a coordinated contraction of the bladder and relaxation of the urethra and striated sphincter. [1] Voiding and Storage reflexes will be discussed in this chapter in the context of normal voiding physiology. Several important CNS structures govern voiding and storage functions:

Key CNS Structures

- **Periaqueductal grey (PAG),** a midbrain area known for its role in nociception and emotional responses
- **Pontine micturition center (PMC)** also called Barrington's nucleus is located in dorsomedial pontine tegmentum
- **Onuf's nucleus**(Onufrowicz's nucleus) small motor neuron group in ventral horn of the sacral spinal cord (levels S2–S4)

1.1 Normal Voiding Mechanism

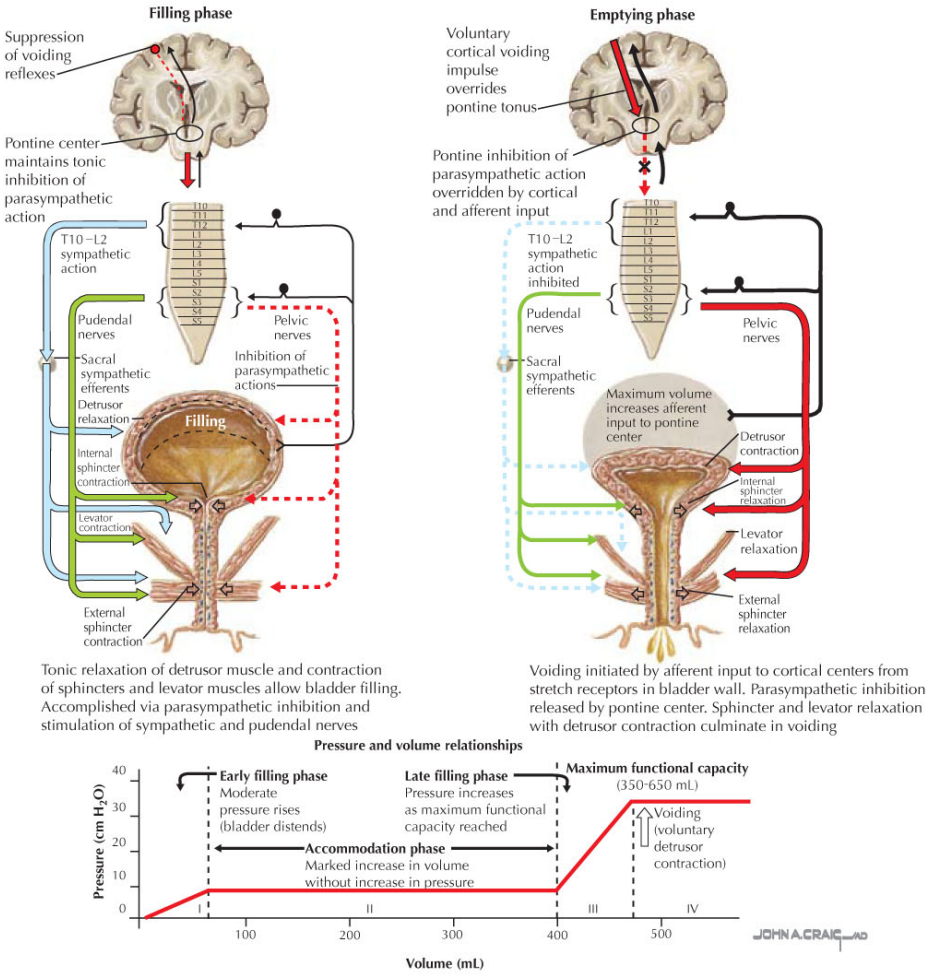

Figure 1: Filling Emptying Phase

In order to achieve successful micturition striated sphincter has to relax (somatic nervous system) and detrusor muscle must mount adequate contraction (parasympathetic). Such a complex motor action needs precise coordination by neurons in the central nervous system that have access to the motor neurons that innervate these muscles. [2]

1.2 Voiding Reflexes

At the initiation of micturition, intense vesical afferent activity activates the brainstem micturition center, which inhibits the spinal guarding reflexes (sympathetic and pudendal outflow to the urethra). The pontine micturition center also stimulates the parasympathetic outflow to the bladder and internal sphincter smooth muscle. Maintenance of the voiding reflex is through ascending afferent input from the spinal cord, which may pass through the periaqueductal gray matter (PAG) before reaching the pontine micturition center. [3]

Supraspinal vesicovesical (vesico-bulbo-vesical) reflex *(Aδ-fibers bladder afferent to bladder efferent reflex).*

Bladder filling activates stretch (tension) receptors within the bladder wall increasing activity in myelinated Aδ-fibers reaching spinal cord via pelvic nerve. The central branch of these fibers contacts second order neurons in the dorsal horn of the sacral spinal cord, that in turn project to the periaqueductal grey (PAG), a midbrain area known for its role in nociception and emotional responses. When the bladder is filled to such a degree that voiding is appropriate, the PAG, activates an area in the dorsomedial pontine tegmentum, referred to as the **pontine micturition center (PMC)**. Neurons in the PMC project directly to the bladder preganglionic neurons in sacral parasympathetic nucleus which produces complete (synergic) micturition via long descending pathways to the parasympathetic bladder neurons in the sacral spinal cord.[4]

Sacral parasympathetic preganglionic neuron axons traverse the pelvic nerve to activate pelvic parasympathetic postganglionic neurons in the pelvic plexus, which causes them to release acetylcholine and a subsequent bladder contraction mediated by stimulation of M2 and M3 receptors. [5]

Sympathetic and somatic nerve activity becomes inactive as voluntary relaxation of the external sphincter initiates the micturition reflex in the absence of anatomical obstruction.

Thus, PMC can be seen as a switch in the micturition reflex, inhibiting parasympathetic activity in the descending pathways when there is low activity in the afferent fibers and activating the parasympathetic pathways when the afferent activity reaches a certain threshold.[6]

Vesico-Spinal-Vesical Reflex (*C-fiber bladder afferent to bladder efferent reflex).*

Spinal lesions rostral to the lumbosacral level interrupt the vesico-bulbo-vesical pathway and abolish the supraspinal and voluntary control of micturition.[7] The parasympathetic efferent pathways of this reflex appear to be the same as those of the supraspinal reflex.

This results initially in an areflexic bladder accompanied by urinary retention. An automatic vesico-spinal-vesical micturition reflex develops slowly, although voiding is generally insufficient due to bladder-sphincter dyssynergia, that is, simultaneous contraction of bladder and urethra. It has been demonstrated in chronic spinal cats that the afferent limb of this reflex is conveyed through unmyelinated C-fibers, which usually do not respond to bladder distension, suggesting changed properties of the afferent receptors in the bladder. This reflex does not depend on bladder fullness, as does the supraspinal reflex mediated by A-fibers. [5,8]

1.3 Summary

The pelvic nerve conveys information about the degree of bladder filling to neurons in the lumbosacral cord, which, in turn, project to the **periaqueductal grey** (PAG). When the bladder is filled to such a degree that voiding is appropriate, the PAG, activates **pontine micturition center (PMC)** which produces complete (synergic) micturition via long descending pathways to the parasympathetic bladder neurons in the sacral spinal cord.[4]

Sympathetic and somatic nerve activity becomes inactive as voluntary relaxation of the external sphincter initiates the micturition reflex.

Parasympathetic activity: gives rise to the smooth muscle contraction and inhibits sympathetic reflex

Sympathetic and somatic nerve activity: becomes inactive as voluntary relaxation of the external sphincter initiates the micturition reflex

The Pons/CNS coordinates the bladder and outlet activity.

Bladder outlet opens via lowering of resistance at the outlet in the absence of anatomic obstruction.[7]

2. Storage Physiology

2.1 Filling/Storage Mechanism

During the storage of urine, distention of the bladder produces low-level bladder afferent firing. Afferent firing, in turn, stimulates the sympathetic outflow to the bladder outlet (base and urethra) and pudendal outflow to the external urethral sphincter. These responses occur by spinal reflex pathways and represent “guarding reflexes,” which promote continence. Sympathetic firing also inhibits detrusor muscle and transmission in bladder ganglia.

2.2 Storage reflexes

Sympathetic storage reflex (pelvic-to-hypogastric reflex) is initiated as the bladder distends. Stretch receptors in the detrusor, for which cell bodies are located in the sacral DRG, send afferent signals along myelinated Aδ -fibers in the pelvic nerve to the spinal cord.[5] Within the spinal cord, sympathetic firing from the lumbar region (L1–L3) is initiated, which, by effects at the ganglionic level, decreases excitatory parasympathetic inputs to the bladder. Postganglionic neurons release noradrenaline, which facilitates urine storage by stimulating β_3-adrenoceptors (ARs) in the detrusor smooth muscle During micturition, this sympathetic reflex pathway is markedly inhibited via supraspinal mechanisms to allow the bladder to contract and the urethra to relax.[8]

Somatic storage reflex (pelvic-to-pudendal reflex), also called the *guarding reflex* is initiated during sudden increase in valsalva or intra-abdominal pressure—during coughing, straining or sneezing.

During normal urine storage this pathway is tonically active, while during (and in anticipation of) sudden abdominal pressure increases, it becomes dynamically active to contract the rhabdosphincter, thereby, guarding against urine release during a sudden increase in bladder pressure.[5] Afferent activity travels along myelinated Aδ nerve fibers in the pelvic nerve to the sacral spinal cord activating efferent somatic urethral motor neurons in the Onuf’s nucleus. Afferent information is also conveyed to the PAG and from there to the PMC (the L region). From this center, impulses are conveyed to the motor neurons in the nucleus of Onuf. Axons from these neurons travel in the pudendal nerve and release acetylcholine, which activates nicotinic cholinergic receptors on the rhabdosphincter, which contracts.

During micturition, this reflex is strongly inhibited via spinal and supraspinal mechanisms to allow the

rhabdosphincter to relax and permit urine passage through the urethra. In addition to this spinal somatic storage reflex, there is also supraspinal input from the pons, which projects directly to the nucleus of Onuf and is of importance for voluntary control of the rhabdosphincter. [8,9,10]

2.3 Summary

Three processes activate during filling/storage phase:

1. Accommodation of increasing volumes of urine at low pressures with appropriate sensations through 3 activities:

- The afferent activity sending sensations to the CNS
- The tonic inhibition from the brain inhibits parasympathetic activity
- The inhibition of the parasympathetic system also provided by sympathetic and somatic reflex activity

1. The prevention of involuntary detrusor contractions
2. The prevention of parasympathetic activity

Bladder outlet must remain closed during filling phase by spinal reflex activity that activates sympathetic and somatic nerve pathways (the guarding reflex).[7]

References

1 Andersson KE, Arner A. Urinary bladder contraction and relaxation: physiology and pathophysiology. Physiological reviews 2004;84:935-86.

2 Holstege G. The emotional motor system and micturition control. Neurourol Urodyn 2010;29:42-8.

3 Yoshimura N, Chancellor, MB. Physiology and Pharmacology of the Bladder and Urethra. In: Campbell-Walsh Urology. 10 edition. clinicalkey-com.archer.luhs.org: Saunders, an imprint of Elsevier Inc; 2012:1786-833.

4 Bertil F. M. Blok ATMWaGH. A PET study on brain control of micturition in humans. Brain 1997:111-21.

5 ☆ Thor KB, Donatucci C. Central nervous system control of the lower urinary tract: new pharmacological approaches to stress urinary incontinence in women. The Journal of urology 2004;172:27-33.

6 Andersson KE, Wein AJ. Pharmacology of the lower urinary tract: basis for current and future treatments of urinary incontinence. Pharmacological reviews 2004;56:581-631.

7 Rackley RR. Neuropathic bladder: voiding dysfunctions associated with neurological disease. In: Daniel A. Shoskes AFM, ed. Educational Review Manual in Urology. second ed: Castle Connolly Graduate Medical Publishing, Ltd; 2010:299-318.

8 Andersson KE. Neurophysiology & Pharmacology of the Lower Urinary Tract. In: McAninch JW, Lue TF, ed. Smith and Tanagho's General Urology. 18 ed. New York, NY: McGraw-Hill; 2013.

† Thor KB, de Groat WC. Neural control of the female urethral and anal rhabdosphincters and pelvic floor muscles. American journal of physiology Regulatory, integrative and comparative physiology 2010;299:R416-38.

9 Comprehensive review of CNS control of internal and external sphincter, micturition and storage reflexes, and the association of serotonergic and noradrenergic systems with these reflexes are discussed. Pharmacological approaches to stress incontinence are also addressed.

† Holstege G. Micturition and the soul. The Journal of comparative neurology 2005;493:15-20.

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