NEUROUROLOGY

BACKGROUND

Lower urinary tract dysfunction is common among patients with underlying neurologic conditions. Also known as "neurogenic bladder", this occurs as a result of the disruption of the neurologic control centers (O'Leary). Patients often present with a known neurologic disorder and an associated urinary dysfunction. However, others initially complain of urinary symptoms which can be the first sign of an undiagnosed neurologic disease (Nitti). The urinary symptoms that result in the setting of neurologic disorders are often bothersome and debilitating for patients and can sometimes lead to chronic bladder and kidney damage. For this reason, it is important to understand the basic anatomy and physiology underlying the neurogenic bladder as well as the steps required for its proper evaluation and management.

NEURO-ANATOMY & PHYSIOLOGY

The bladder and the urethra constitute the lower urinary tract system. The bladder base refers to the trigone while the bladder neck and body refers to the supratrigonal region (Clemens). The bladder is composed of three different muscular layers which converge at the level of the bladder neck, forming the internal urethral sphincter (LeBrun). The urethra is composed of the proximal internal sphincter made of involuntary smooth muscle fibers which is under sympathetic control. The striated urethral sphincter begins at the midurethra and is composed of slow-twitch muscle fibers that sustain intrinsic tone, as well as fast-twitch muscle fibers that are under voluntary control and can increase pressure as needed to maintain continence (LeBrun).

The lower urinary tract system has two functions which are under voluntary neural control: storage and elimination. Because the bladder is responsible for this dual function, most of the neural circuits responsible have a switch-like pattern of activity which makes the bladder a unique organ (Chai). These processes involve the coordination of neural events in both the central and peripheral nervous systems. The central nervous system is composed of the brain and spinal cord (Clemens) while the peripheral nervous system is composed of afferent (sensory) and efferent (motor) neurons. These two types of neurons can be further subdivided into two, namely the autonomic (visceral) and somatic systems. In the urinary tract, the autonomic nervous system is mediated by the sympathetic and parasympathetic nerves while the somatic system is mediated by the pudendal nerve (Fowler). Parasympathetic nerve fibers emerge from the cranial and sacral portions of the spinal cord while the sympathetic nerves emerge from the thoracic and lumbar portions of the spinal cord (Clemens).

The autonomic nervous system involves a sequential two-neuron efferent pathway. A preganglionic neuron synapses onto a postganglionic neuron before innervating the target organ. The sympathetic division arises from the thoracolumbar spinal cord (T12-L2) (Fowler) and consists of cell bodies in the lateral horn of the spinal cord called the intermediolateral cell columns (IMLC) (Chai). These cell bodies are general visceral efferent neurons, and serve as preganglionic neurons that synapse on their respective postganglionic neurons, the paravertebral ganglia of the sympathetic chain found on either side of the vertebral bodies or the prevertebral ganglia (also known as the pelvic plexus or the inferior hypogastric plexus), located bilaterally

on the walls of the rectum. The hypogastric nerve is the postganglionic nerve that travels inferiorly and descends into the pelvis to form the inferior hypogastric plexus. (Walters) It releases noradrenaline, hence activating the β-adrenergic inhibitory receptors in the bladder causing detrusor muscle relaxation and the α-adrenergic excitatory receptors in the urethra and bladder neck resulting in the contraction of these muscles (Andersson).

The parasympathetic division arises from cell bodies in the ventral rami of the sacral spinal cord (S2-S4) (Fowler). These cell bodies are the cholineric preganglionic neurons that exit the spinal cord in the ventral spinal nerves forming the pelvic nerve (Chai). They then synapse with the postganglionic neurons in either the pelvic plexus or the intramural ganglia found within the bladder (Chai). The pelvic plexus is a paired structure, containing both sympathetic and parasympathetic fibers, with each pair situated on the side of the rectum and the vagina. The postganglionic nerves release acetylcholine which activates the excitatory muscarinic (M3) receptors of the bladder, resulting in detrusor muscle contraction and urine flow (Fowler). Other postganglionic nerves release nitric oxide which acts on the smooth muscle of the urethra, causing relaxation and facilitating voiding (Andersson).

The pudendal nerve arises from the ventral rami of the sacral nerves (S2-S4). It passes between the piriformis and coccygeus muscles and leaves the pelvis through the lower part of the greater sciatic foramen. It crosses the spine of the ischium, and reenters the pelvis through the lesser sciatic foramen. It accompanies the internal pudendal vessels upward and forward along the lateral wall of the ischiorectal fossa, being contained in a sheath of the obturator fascia termed the pudendal canal (Alcock's canal) (Walters). The pudendal nerve is a somatic cholinergic motor nerve that activates the striated external urethral sphincter muscle as well as the muscles of the pelvic floor (Fowler). It gives off the inferior rectal nerves and divides into two terminal branches: the perineal nerve and the dorsal nerve of the clitoris. (Walters)

Sensation of bladder fullness is conveyed to the spine via the pelvic and hypogastric nerves, while sensory input from the bladder neck and the urethra is carried by the pudendal and hypogastric nerves (Fowler, Janig). There are two main types of fibers: A-δ fibers which contain myelinated axons and transmit low threshold signals such as bladder filling; and C fibers which are unmyelinated and transmit noxious stimuli such as irritation or coldness (Janig, Chai, Clemens). The cell bodies of both fibers are found in the dorsal root ganglia of the spine at T11-L2 and S2-4. These cell bodies synapse with neurons that transmit information to the brain involving regulation of bladder function (Fowler).

The regulation of micturition is a complex interaction between the autonomic and somatic nervous systems and the brain while the spinal cord acts as an information transmitter (Chai). Afferent nerves from the bladder and the urethra transmit signals to respective preganglionic neurons located in the lateral dorsal horns of the spine (Fowler). Interneurons project from this area to different regulatory centers in the gray matter of the brain including the Barrington's nucleus in the pons --often referred to as the pontine micturition center -- and the periaqueductal gray cell bodies of the hypothalamus (Fowler, Blok).

When the bladder fills, detrusor muscle activity is thwarted via inhibition of the parasympathetic nervous system, while both the smooth and striated muscles of the urethra are

activated. This controls filling and prevents involuntary emptying and is mainly controlled by spinal reflexes in the spinal cord that are triggered by the afferent pelvic nerves coming from the bladder (Fowler). The lateral region of the pons is also involved and it helps facilitate the activation of these spinal reflexes (Griffiths). Interneurons in the spinal cord transmit bladder filling sensory signals to the periaqueductal gray cell bodies of the hypothalamus, which in turn, signal the pontine micturition center together with the prefrontal cortex (Holstege). Activation of the cerebral cortex facilitates awareness of bladder filling and allows for suppressive signals to be sent to the pons in order to prevent activation of the micturition center which is responsible for voluntary voiding (Holstege2). Excitation of the pontine micturition center through voluntary signals from the cerebral cortex (Clemens), activates descending spinal pathways leading to urethral relaxation and detrusor muscle contractility. This results to urine flow and emptying (Fowler). The descending signals activate the parasympathetic sacral nerves leading to the release of acetylcholine at the muscarinic receptors of the bladder. At the same time there is a release of nitric oxide and removal of adrenergic signals at the level of the urethra, allowing both smooth and striated muscle to relax (Fowler).

VESICOURETHRAL DYSFUNCTION: "THE NEUROGENIC BLADDER"

Disruption of the neural pathways described above can lead to voiding dysfunction. However, the manifestation depends on the level of injury and severity of disruption. Lesions above the brainstem can cause disruption of the brain's ability to inhibit the micturition reflex at the level of the spinal cord (LeBrun). This leads to detrusor overactivity which presents as urinary urgency, frequency and nocturia (Abrams). Patients may also present with associated urge incontinence and even sensation of incomplete bladder emptying (LeBrun). The International Continence Society classifies detrusor overactivity in the setting of neurologic disease as 'neurogenic detrusor overactivity' (Abrams). Overall, these patients have preserved sensation and compliance of the bladder as well as normal urethral closure pressure and relaxation in order to facilitate voiding (Wein).It is important to note that when lesions in the brain occur, the earliest manifestation of voiding dysfunction is usually bladder areflexia. Also known as 'spinal shock', this refers to the initial acute event that leads to cessation of cerebral regulation of micturition and loss of neural inputs to the bladder (Wein).

When urinary incontinence occurs in patients with neurologic disease, it can be attributed to one of three dysfunctions: detrusor overactivity, poor bladder compliance and inability to fill properly or urethral sphincter incompetence (Nitti). As mentioned above, patients with detrusor overactivity almost always have lesions above the spinal cord (e.g.: cerebral cortex). If the lesion is above the level of the pons, there is no disruption of the pathway that allows for simultaneous detrusor muscle contraction and urethral sphincter relaxation -- the key to maintaining continence and controlling voiding (Blaivas, Wein). On the other hand, when the lesion is below the level of the pons, the pathway is interrupted and coordination maintained between detrusor muscle contraction/relaxation and external urethral sphincter contraction/relaxation is lost. This interruption causes a phenomenon called detrusor sphincter dyssynergia (DDS) and is most often found in patients with abnormalities in the pathway between the sacral spinal cord and the pons (Wein, Chancellor).

Improper bladder emptying leads to urinary retention and elevation of the bladder residual volume. This is usually caused by decreased bladder contractility or outlet obstruction.

Neurologic disorders that affect the voiding reflex and decrease the sensory inputs to the brain regarding bladder filling can also contribute to this dysfunction by causing chronic overdistension of the bladder. This results to eventual impairment in bladder contractility (McCrery). In addition, if awareness of bladder filling, which is regulated by the frontal cortex of the brain, is affected, urinary retention ensues. This, again, can cause contractility dysfunction (Wein). Detrusor sphincter dyssynergia can also give way to functional outlet obstruction since failure of the external urethral sphincter to relax at the time of detrusor contractility can lead to changes in urine stream, incomplete emptying and retention (LeBrun, Wein).

EXAMPLES OF LESIONS ABOVE THE SPINAL CORD

Cerebrovascular Accident (CVA) can result from thrombosis, embolic occlusion or hemorrhage and occurs in approximately 1:200 individuals (Wyndalele). It is the third leading cause of death in the United States (Marinkovic). However, approximately 75% of affected patients survive (Blaivas) the event and suffer some degree of impairment, while only 10% of those who survive have no impairment (Arunable). After the initial event, urinary retention may occur from detrusor areflexia; the underlying cause of this change in function is not clear (Wein). A chronic deficit then eventually appears; the most common type of change is phasic detrusor overactivity (Wyndaele, Fowler) with associated urgency and frequency (Wein). Incontinence may also develop with these symptoms depending upon the location of the lesion. Patients with lesions in the basal ganglia or thalamus usually have normal urethral striated sphincter function whereas patients with lesions in the cerebral cortex or internal capsule are less able to contract their striated sphincter (Khan) and are more likely to experience incontinence. In addition, patients with lesions located in the cerebral cortex may also have decreased sensation of bladder filling and less ability to contract the detrusor muscle, which can lead to involuntary voiding and incontinence (Griffiths). Patient with CVA usually have normal urethral smooth sphincter function (Wein).

Dementia occurs as a result of atrophy and loss of gray and white matter of the brain. Often, an associated cortical cholinergic loss is present, as well. This leads to impairment in memory and cognition (Wein). Alzheimer's is the most commonly diagnosed cause of dementia (Wyndaele). Patients with dementia often have voiding dysfunction with incontinence as its most common complaint. The underlying mechanism is similar to that of CVA patients whose lesions are located in the cerebral cortex (Wein). Although urethral sphincter control can remain voluntary in these patients, they often have decreased sensation of bladder filling as well as changes in the frontal cortex of the brain which affects their awareness of filling and need to void which can lead to incontinence (Wein).

Traumatic Brain Injury occurs in patients of all ages. Patients initially experience detrusor areflexia leading to urinary retention, similar to CVA patients. If the traumatic lesion is located above the pons where the pontine micturition center is located, patients usually have involuntary detrusor contractions with coordinated urethral sphincter activity. They often experience urgency and frequency symptoms. On the other hand, if the lesion is located below the pons, they manifest with detrusor sphincter dyssynergia which can lead to urinary retention, as well (Wein).

Brain Tumors also contribute to voiding dysfunction. The type of dysfunction is directly related to the location of the mass, and not the type of tumor (Wein). Tumors most often affect the frontal lobes of the cerebral cortex with resultant detrusor overactivity as well as decreased awareness of bladder filling. As a consequence, patients are unable to suppress their micturition reflex which can lead to incontinence in the setting of urge symptoms. Urodynamics in these patients often shows that the smooth and striated sphincter activity remains synergistic (Fowler).

Cerebellar Ataxia is characterized by the degeneration of the central nervous system, mostly affecting the cerebellum. Patients usually present with poor coordination, depressed deep tendon reflexes, dysarthria, dysmetria and choreiform movements (Ferrarin). Their voiding complaints are usually that of incontinence with associated detrusor overactivity and sphincter synergia. If there is spinal cord involvement, which is not uncommon in these patients, sphincter dyssynergia is present which can lead to poor bladder emptying and urinary retention (Wein).

Normal Pressure Hydrocephalus is diagnosed in patients with normal cerebrospinal fluid volumes but markedly enlarged cerebral ventricles (Adams). Patients present with progressive dementia and ataxia and also complain of voiding dysfunction (Adams). Detrusor overactivity and sphincter synergia is most commonly found in these patients (Wein).

Parkinson's Disease is a neurodegenerative disorder affecting the dopaminergic neurons of the substantia nigra (Long). Dopamine deficiency results in typical motor dysfunction which includes tremor, skeletal rigidity and bradykinesia (Wein).Voiding dysfunction is very common among these patients (Wyndaele) as there is a progressive loss of the inhibitory effect of the basal ganglia on the micturition reflex (Fowler). The majority (50-75%) of the patients (50-75%) have detrusor overactivity leading to urgency, frequency, nocturia and associated incontinence (Wein); the remainder of patients have obstructive symptoms. There is usually sphincter synergia but pseudodyssynergia may occur in advanced disease as there can be a delay in smooth sphincter relaxation (Wein).

Multiple System Atrophy is also a neurodegenerative disorder caused by gliosis and cell loss in widespread areas of the brain (Bensimon). The diagnosis is often confused with Parkinson's Disease as patients experience similar motor dysfunction. However, it can be differentiated from Parkinson's when patients also show a predominance of cerebellar, autonomic and pyramidal cortical dysfunction (Gilman). In contrast to Parkinson's, voiding symptoms occur earlier and are often more severe (Chandiramani). The most common of which includes urgency, frequency, and associated incontinence. In cases of distal spinal cord lesions, the autonomic neurons are also affected leading to decreased bladder compliance. With progression of the disease, the pons or the sacral spinal cord may also be affected with resultant dysfunction in initiation or maintenance of urination (Wein).

EXAMPLES OF LESIONS AT THE LEVEL OF THE SPINAL CORD

Spinal Cord Injury (SCI) is commonly associated with lower urinary tract dysfunction (Wein). In the United States, it occurs with an incidence of approximately 12,000 per year (Rabchevsky). After the initial injury, a process referred to as "spinal shock" commonly occurs, resulting in suppression of autonomic and somatic activity causing areflexia and acontractility of

the bladder leading to poor bladder emptying and severe urinary retention (Wein). Complete spinal cord injuries above the sacral spinal cord and below T8 results to loss of sensation below the level of the lesion, spasticity of all skeletal muscles distal to the lesion and hyperreflexic deep tendon reflexes. There is usually detrusor overactivity, smooth sphincter synergia and striated sphincter dyssynergia (Wein). Lesions at or above T8 are similar to those below this level, but are characterized by smooth sphincter dyssynergia. (Thomas, Chancellor). With striated sphincter dyssynergia, functional obstruction can occur, leading to urinary retention and increased pressures inside of the bladder. Autonomic hyperreflexia can occur in patients with lesions above T6-T8. This type of response is activated by stimulus such as bladder distension, and is characterized by extreme sympathetic activity (Wein). The bulbospinal inhibitory response that is usually present above the lesion cannot control the sympathetic preganglionic neurons that are activated by afferent impulses triggered by the stimulus (Vaidyanathan). Lesions located at or below the sacral spinal cord present very differently than lesions above this region. Patients present with skeletal paralysis rather than spasticity, depressed deep tendon reflexes, and decreased sensation below the lesion (Wein). Voiding dysfunction is initially characterized by detrusor areflexia with high to normal compliance, with the eventual development of decreased compliance (Blaivas). Sphincter tone is also affected by this type of lesion -- the smooth sphincter looses the ability to relax and the striated sphincter loses all voluntary control (Wein).

Transverse Myelitis is a neurologic disorder that is caused by an inflammatory process of the spinal cord leading to axonal demyelination caused by a preceding viral infection and is often self-limiting (Pandit). Patients present similarly as SCI patients depending upon the location of the lesion.

Vertebral disc disease can also affect voiding function. Most disc disease is found at the L4-L5 and L5-S1 level of the spinal column. This portion of the column contains the sacral segments of the actual spinal cord (Wein). Disc protrusions at these levels compress the spinal nerve roots which can cause radiculopathy, sensory loss in either the S1-S2 or S2-S4 dermatomes and sometimes, voiding dysfunction (Goldman). Incomplete emptying due to bladder areflexia and subsequent urinary retention is the most common type of dysfunction seen among patients (Bartolin). Patients with ***Cauda Equina Syndrome***, on the other hand, present with perineal sensory loss, loss of voluntary control of both the anal and urethral sphincters and an acontractile detrusor muscle. It usually occurs because of severe central posterior disc protrusion (Wein) at the level of the conus medullaris, the termination point of the spinal cord (Wallid). Cauda equina syndrome is a surgical emergency. ***Spinal stenosis*** can cause symptoms similar to disc disease and can even cause cauda equina syndrome depending upon the level of the spinal cord affected. Symptoms vary in severity depending upon the amount of spinal cord or nerve root involved (Wein).

Multiple Sclerosis (MS) is an immune-mediated disorder characterized by neural demyelination in the brain and spinal cord and is more common in young and middle aged women (Coles). Neurologic abnormalities occur as a result of decreased conduction in the axonal pathways. The lateral corticospinal and reticulospinal columns are commonly involved (Compston). Voiding dysfunction is very common, affecting up to 72% of patients with MS. (Wyndaele). Detrusor overactivity is the most common type of abnormality seen (Litwiller). Dysfunction, however, varies among patients and is usually characterized by one of the

following: detrusor overactivity with striated sphincter synergia, detrusor overactivity with striated sphincter dyssynergia, and detrusor areflexia. Sensation remains intact (Wein).

Diabetes Mellitus is one of the most common causes of peripheral and autonomic neuropathy in developed countries which often leads to sensory dysfunction. Over 8% of the American population has been diagnosed with diabetes mellitus and about 1.9 million new cases were diagnosed in 2010 (CDC). With persistent hyperglycemia, there is a resultant leads loss of myelinated and demyelinated nerve fibers (Clark). Afferent sensory pathways are thus affected reducing bladder sensation, hence, urinary retention and eventual detrusor overdistension and severe emptying dysfunction (Wein). In a similar fashion, ***Guillan-Barré Syndrome*** also affects the autonomic nervous system. It is an inflammatory demyelinating disorder of both the peripheral and autonomic nervous systems that causes limb weakness, decreased deep tendon reflexes, decreased peripheral sensation and sometimes loss of bladder sensation, resulting to urinary retention (Zochodone).

EVALUATION OF THE NEUROGENIC BLADDER

A careful patient history and physical exam can provide important information about a patient's functional status as well as help diagnose underlying neurologic disease. A complete gynecologic, urologic and neurologic exam should be performed. The neurologic evaluation includes assessment of mental status, motor strength, sensory reflexes, and evaluation of gait and stability (LeBrun). The bulbocavernosus and perianal reflexes, as well as anal sphincter tone, should especially be evaluated, to assess for the presence of polysynaptic reflexes that are mediated in the S2-S4 spinal cord.

Urodynamic testing is an integral part in the evaluation of a patient with lower urinary tract dysfunction. It can be considered as an extension of the patient's history and physical examination. Its primary goal is to provoke the behavior of the lower urinary tract by simulating bladder storage and emptying while provoking the patient's symptoms (Heesakkers). A complete urodynamic evaluation includes cystometry and urethral function tests. Cystometry measures the pressure and volume relationship of the bladder and can assess detrusor function, sensation, capacity and compliance (Abrams). These functions are assessed in two phases: a filling (storage) phase and an emptying (voiding) phase (Walters, Peterson). Urethral pressure profiles are measured as well during various portions of the study which allows for evaluation of the function of the urethra as it relates to bladder function. The mean urethral closure pressure or the abdominal leak point pressure is recorded (Peterson). Flow studies are performed after completion of filling to assess voiding function (Abrams) and once the patient has voided completely, postvoid residual (PVR) urine volumes are also recorded (Walters). Patients with areflexia of the bladder will have urinary retention and elevated PVRs. Patients with detrusor muscle instability will have demonstrate increased detrusor pressures and involuntary detrusor contractions at the time of bladder filling while patients with sensory impairment will have increased bladder compliance with decreased sensation to void at high filling volumes (LeBrun). Patients with DSD will demonstrate voiding dysfunction and abnormalities in their flow profiles and will have incomplete bladder emptying and elevated PVRs (Wein).

Another modality that can be used to evaluate patients is Neurophysiologic Testing. Common tests used to evaluate peripheral neurologic disease include electromyography (EMG),

nerve conduction studies and spinal reflex testing (Vodusek). Because the spinal reflexes involved in the control of the micturition center involve both sensory and motor neuron activity, they cannot be evaluated directly. However, EMG can be used to evaluate the function of the striated urethral sphincter and can sometimes help distinguish between various neurologic conditions that cause denervation or spasticity of the lower urinary tract (LeBrun). This type of testing is highly specialized and is conducted by experts familiar with the routine evaluation of neuropathic and myopathic disorders.

Imaging can play an important role in the evaluation of patients who present with neurogenic dysfunction of the lower urinary tract. Bedside transabdominal ultrasound should always be performed to measure the postvoid residual in patients to make sure that they are not experiencing chronic retention. In addition, renal ultrasound can be obtained to evaluate for chronic renal damage from worsening urinary tract dysfunction (Fowler 1996). If further evaluation of renal function is necessary, IV urography and radionucleotide scanning can be performed (LeBrun). If renal stones are suspected, plan film Xray or computed tomography of the upper urinary tract should be obtained (Nitti).

TREATMENT OF THE NEUROGENIC BLADDER

In the management of lower urinary tract dysfunction, the primary goal is improvement of patient's quality of life. Second to this is the prevention of chronic damage to the bladder and kidneys which can lead to worsening impairment and symptoms. Treatment is often multifactorial, including behavioral modifications, bladder training programs and pharmacotherapy. In this section, we address the pharmacologic agents that can be used to treat lower urinary tract disorders. These agents can be grouped into two different categories: those that help with bladder emptying and those that assist with the storage function of the bladder (Walters).

The goals of facilitating bladder emptying are to improve bladder contractility and decrease outlet resistance. Acetylcholine is the primary neurotransmitter involved in the mechanism that facilitates bladder contraction. As previously described, the postganglionic nerves release acetylcholine which activates the excitatory muscarinic (M3) receptors of the bladder, resulting in detrusor muscle contraction and urine flow (Fowler). Dopamine antagonists such as metoclopramide inhibit plasma acetylcholinesterase and increase the levels of acetylcholine available (Kambam) to bind to the receptors of the detrusor muscle, thereby facilitating bladder contraction. α-adrenergic antagonists such as tamsulosin are also used as they block the inhibitory effect of the sympathetic neurons on the parasympathetic pathway (Walters).

Storage disorders are usually caused by detrusor overactivity with or without urethral sphincter dysfunction. Pharmacologic agents that inhibit bladder contractility act on the detrusor muscle causing an increase in bladder compliance. These agents include anticholinergics which act directly on the muscarinic receptors (M3) of the detrusor muscle (Wein 1995) via the neurotransmitter acetylcholine. Anticholinergic agents that have been used in the treatment of overactive bladder symptoms include oxybutynin, tolterodine, propiverine, trospium chloride, solifenacin, and darifenacin (Walters). These drugs pass through the blood-brain barrier, activate the various muscarinic receptors that are present in the brain, and have side effects such as

fatigue, changes in memory and attention, drowsiness as well as delirium (Todorva). It is important to counsel patients about these side effects and to titrate medications accordingly. Tricyclic antidepressants such as imipramine hydrochloride are also used in the treatment of storage dysfunction. These agents have anticholinergic and antimuscarinic effects that lead to relaxation of the detrusor muscle as well as increased bladder outlet resistance (Woodman). Botulinum-A toxin is an agent that requires injection into the detrusor muscle itself, leading to decreased contractility of the muscle (Leippold). While long-term data on this therapeutic modality is lacking, preliminary data shows good results and patient satisfaction. Intravesical treatments also exist for the management of overactive bladder. These include vallinoid, also known as capsaicin, which is derived from hot peppers, and acts on the sensory neurons of the spinal reflex through vallinoid receptors (Tominaga). Resiniferatoxin is derived from the cactus plant and reduces sensory input at the level of the vallinoid receptor (Walters). Local anesthetics can also be used and act similarly on the afferent reflex arc, thereby decreasing involuntary bladder emptying. Intravesical treatments such as oxybutynin and botulinum toxin can be used to interrupt the efferent cholinergic transmission to the detrusor muscle (Wein-1995).

Increasing outlet resistance is another way to improve storage dysfunction. α-adrenergic agonist agents are often used to facilitate this mechanism as there are many α-adrenergic receptors at the level of the bladder neck and proximal urethra. These agents increase urethral pressures by facilitating smooth muscle contraction (Walters, Wein-1995). Serotonin (5-HT)-norepinephrine reuptake inhibitors (SNRI) can also be used to increase urethral pressures. Increased levels of serotonin and norepineprhine stimulate the pudendal nerve which leads to increased contractility and resistance at the level of the urethra (Walters).

CONCLUSIONS

The two major functions of the lower urinary tract are storage and emptying of urine. These processes are controlled by complex neurophysiologic mechanisms and are subject to injury and disease. Hence, an understanding of the basic mechanisms can guide providers in their evaluation and treatment of patients who present with lower urinary tract disorders. As neurologic diseases progress, voiding function often changes or worsens, necessitating a good understanding of the underlying physiology in question.

QUESTIONS

1. The pudendal nerve may be stretched or damaged during vaginal delivery. How would a patient with this type of injury present? Circle all of the correct answers.
   (a) Urinary Retention
   (b) Urinary Incontinence
   (c) Urethral dysyenergia on urodynamic studies
   (d) Abnormal EMG of the pelvic floor muscles
   (e) None of the above

Answers: b,c,d

Damage to the pudendal nerve may cause weakness in the pelvic floor and the external urethral sphincter. This will result to incontinence and pelvic organ prolapse. Furthermore, relaxation of the pelvic floor muscles prevents compensatory compression of the urethra during increased abdominal pressure. Assessment involves sensation over the clitoris and levator muscle tone.

2. A patient complains of daytime and night time wetting as well as urinary retention. On urodynamic testing you note an increase in detrusor pressure and simultaneous increase in the urethral pressure. What might this represent?
(a) Autonomic Hyperreflexia
(b) Bladder Areflexia
(c) Detrusor Sphincter Dyssynergia
(d) Cauda Equina Syndrome
(e) None of the above

Answer: c
This may be indicative of detrusor sphincter dyssynergia (DSD) caused by either MS, spinal lesion or trauma above the lumbar spine. This leads to the disruption of the trans-spinal pathways that connect the pontine micturition center and the sacral cord, which is responsible for synchronizing bladder and outlet activities.

3. A patient demonstrates detrusor overactivity on urodynamic testing and was diagnosed with overactive bladder syndrome. You choose to treat with focus on the afferent pathway of the neural system. What type of treatment would you choose?
(a) metoclopramide
(b) oxybutynin
(c) tamsulosin
(d) botulinum-A toxin
(e) imipramine hydrochloride

Answer: d
Botulinum-A toxin is a treatment modality that aims at decreasing sensory input at the time of bladder filling.

4. Patients with dementia differ from patients who have suffered CVA or traumatic brain injury as they are more likely than the others to have the following finding:
(a) Detrusor overactivity
(b) Decreased bladder compliance
(c) Decreased bladder sensation
(d) Urethral sphincter dyssynergia
(e) All of the above

Answer: c
Although urethral sphincter control can remain voluntary in dementia patients, they often have decreased sensation of bladder filling as well as changes in the frontal cortex of the brain which affects their awareness of filling and need to void which can lead to incontinence.

5. A patient presents with perineal sensory loss, loss of voluntary control of both the anal and urethral sphincters and an acontractile detrusor muscle. What is the diagnosis?
(a) Transverse Myelitis

(b) Cauda Equina Syndrome
(c) Cerebellar Ataxia
(d) Multiple System Atrophy
(e) Multiple Sclerosis

Answer: b
Patients with cauda equina syndrome present with perineal sensory loss, loss of voluntary control of both the anal and urethral sphincters and an acontractile detrusor muscle. The most common type of lower urinary tract dysfunction is incomplete emptying due to bladder areflexia and subsequent urinary retention. It usually occurs because of severe central posterior disc protrusion (Wein) at the level of the conus medullaris, the termination point of the spinal cord (Wallid). It is a surgical emergency.