Neurogenic Bladder

Editor:
Bernard Fallon, MD
Professor of Urology
University of Iowa Hospitals and Clinics
Iowa City, IA

Contributor:
Robert C. McDonough, III, MD
Fellow Associate, Urodynamic and Female/Reconstructive Urology
Department of Urology
University of Iowa Hospitals and Clinics
Iowa City, IA

Table of Contents

Introduction ............................. 2
Failure to Empty .......................... 2
Failure to Store ........................... 5
Reflex Neurogenic Bladder ............... 7
Autonomous Neurogenic Bladder ......... 10
Conclusion ............................... 10
References .............................. 11

Cover Illustration by Kathryn K. Johnson
INTRODUCTION

At first glance, the bladder is a simple organ with only 2 functions: the storage and emptying of urine produced by the kidneys. All bladder dysfunction can be classified as a failure of one of these mechanisms. However, neural control of these functions is fairly complex, involving several neurologic components, such as the cortex, brainstem, spinal cord, and peripheral nerves leading to and from the bladder. Neurogenic bladder is most easily defined as a failure of the bladder to function normally as a result of neurologic insult to any component of this control mechanism. Unfortunately, the term “neurogenic bladder” is very nonspecific, and although easily applied as a diagnosis, it does not provide any information as to the actual type of neurogenic dysfunction.

Several classification systems have been proposed to better distinguish types of neurogenic dysfunction. Described in 1982, the Bradley loop classification is a fairly cumbersome system that organizes the types of neurogenic bladder by level of injury to different “loops” in the neurologic control mechanism. A simpler and more commonly used classification system described by Lapides organizes neurogenic bladder dysfunction into the following categories: sensory, motor paralytic, autonomous, uninhibited, and reflex. Each category is descriptive of the specific type of bladder dysfunction and easily understood by the urologist (Table).

Patients with neurogenic bladder may present with a variety of problems, including incontinence, urinary tract infections, urgency/frequency, urolithiasis, urinary retention, and irreversible damage to the kidneys. The urologist must be prepared to properly identify and treat specific types of bladder dysfunction so that these problems are minimized or eliminated.

NORMAL BLADDER PHYSIOLOGY

Normal bladder physiology is presented in Figure 1. The filling phase of the bladder is maintained by sympathetic control. Sympathetic nerve input to the bladder allows for large urinary volumes to be stored at a low pressure, with the bladder outlet remaining closed at rest. The bladder outlet consists of the internal involuntary smooth muscle sphincter and the external striated muscle sphincter (which is primarily under somatic control). Under normal circumstances, there are no unstable or involuntary contractions of the bladder. The emptying phase of the bladder is controlled by the parasympathetic nervous system via cholinergic stimulation. This contraction, coordinated with relaxation of both the internal and external sphincters, should empty the bladder almost completely.

Bladder filling and contraction are controlled by a reflex loop consisting of afferent and efferent nerves that arise at the S2 to S4 level of the spinal cord. When the bladder meets a certain volume threshold, a reflex contraction is initiated; however, this reflex can be poorly coordinated. To compensate for this, afferent signals are sent up the spinothalamic tracts to the pontine micturition center in the brainstem. Efferent signals from the micturition center are then sent back down the spinal cord to allow for a coordinated contraction of the bladder and appropriate relaxation of the sphincteric mechanism. The cortex provides overreaching control of the entire reflex mechanism. If a reflex bladder contraction is signaled by the bladder but voiding is not socially appropriate, the reflex is suppressed by input from the cortex to the pontine micturition center (often referred to as the guarding reflex). If the bladder attempts to contract at a socially inappropriate time, the external sphincter contracts and intravesical pressure is briefly increased, which leads to an abrupt cessation of contractile activity. As the bladder begins to fill, external sphincter activity also involuntarily increases so that the external sphincter remains closed even when the patient is unable to feel the volume in the bladder.

FAILURE TO EMPTY

CASE EXAMPLES

Case 1

A 45-year-old woman with insulin-dependent diabetes since childhood is referred to the urologist for a documented history of recurrent bladder infections. The patient’s diabetes is poorly controlled, and she
Neurogenic Bladder

CASE 1

A 43-year-old woman presents to the emergency department with complaints of pelvic pain and urinary retention. She has a history of multiple sexually transmitted diseases, including herpes simplex, gonorrhea, and chlamydia. She denies a history of urinary retention but states that she has had dribbling urinary incontinence that is not associated with an urge to void. Urinalysis reveals no abnormalities. A postvoid residual volume obtained by noninvasive bladder ultrasonography reveals 1500 mL of urine in the patient’s bladder. The patient states that she had no urge to void at that time. Video urodynamics demonstrate that the patient has a large capacity, poorly sensitive bladder and impaired bladder contractility.

• How would you classify the type of neurogenic bladder in each of these patients?

SENSORY NEUROGENIC BLADDER

The patient in case 1 demonstrates lack of bladder sensation that has led to overfilling of the bladder. Sensory neurogenic bladder is characterized by poor bladder sensation as a result of injury or insult to the afferent nerves in the reflex arc leading to the spinal cord. Loss of sensation allows for the bladder to distend without triggering a reflex bladder contraction. In addition, because the sensation of bladder contraction is carried along the afferent neural pathway, the patient is unaware that the bladder is distended. Over time, gradual stretching of the detrusor muscle leads to detrusor failure and urinary incontinence.

Figure 1. Components of the nervous system and neural pathways governing function of the bladder. (Adapted with permission from Nygaard IE, Kreder KJ. Urological management in patients with spinal cord injuries. Spine 1996;21:128–32.)

<table>
<thead>
<tr>
<th>Type</th>
<th>Pathogenesis</th>
<th>Possible Etiology</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory</td>
<td>Damage to sensory fibers from bladder to spinal cord</td>
<td>Diabetes mellitus, pernicious anemia, advanced syphilis</td>
<td>No bladder sensation, eventual loss of motor function</td>
</tr>
<tr>
<td>Motor</td>
<td>Damage to motor fibers from spinal cord to bladder</td>
<td>Herpes zoster infection, pelvic trauma, surgery</td>
<td>Normal sensation, failure of motor function</td>
</tr>
<tr>
<td>Autonomous</td>
<td>Damage to both motor and spinal fibers between bladder and spinal cord</td>
<td>Pelvic trauma, low myelomeningocele, surgery</td>
<td>Failure to generate bladder contraction, loss of bladder sensation</td>
</tr>
<tr>
<td>Uninhibited</td>
<td>Injury to cortical regulation of bladder reflex</td>
<td>Stroke, brain tumor, cortical trauma</td>
<td>Normal sensation and motor function, urge incontinence, urinary frequency</td>
</tr>
<tr>
<td>Reflex</td>
<td>Damage to spinal cord between sacrum and brainstem</td>
<td>Spinal cord injury, myelomeningocele, transverse myelitis</td>
<td>Poorly coordinated bladder function, loss of sensation, incontinence</td>
</tr>
</tbody>
</table>

Table. Lapides Classification of Neurogenic Bladder

www.turner-white.com
retention. Possible etiologies for loss of afferent nerve function include diabetes, pernicious anemia, and advanced syphilis. In case patient 1, the afferent nerves are affected by autonomic neuropathy similar to that which causes gastroparesis in patients with poorly controlled diabetes. Complications of urinary retention include overflow incontinence and an increased risk of urinary tract infections due to stasis of urine.

**MOTOR NEUROGENIC BLADDER**

The patient in case 2 has normal sensation of bladder filling but is unable to generate detrusor pressure sufficient to empty the bladder. This is the hallmark of the motor neurogenic bladder, a result of insult or injury to the efferent nerve supply to the detrusor muscle. Because the patient’s sensation remains intact, this is solely a motor deficit. Unlike patients with sensory neurogenic bladder, patients with motor neurogenic bladder can be very uncomfortable, as they are able to feel the bladder becoming overly distended but are unable to do anything about it. Possible etiologies of injury to the efferent nerves to the bladder include herpetic infection, trauma, and iatrogenic injury due to pelvic surgery. The end result of motor neurogenic bladder is urinary retention, just as in sensory neurogenic bladder.

- **How should these patients be managed?**

**TREATMENT OF FAILURE TO EMPTY**

Therapy for any type of neurogenic bladder should be directed at the final pathophysiologic result rather than the underlying etiology. The mainstay of therapy for failure to empty is catheter drainage. This can be accomplished by using an indwelling urethral catheter, placement of a suprapubic catheter, or clean intermittent catheterization. However, indwelling catheters (either urethral or suprapubic) are not ideal due to the necessity of frequent catheter changes as well as the risks of encrustation and infection. In addition, in patients with spinal cord injury, chronic indwelling catheters are an independent risk factor for squamous cell carcinoma, with an incidence of up to 10% in this patient population. As such, use of chronic indwelling catheters eventually requires surveillance cystoscopy and possibly bladder biopsy to ensure that the patient does not develop squamous cell carcinoma.

The concept of clean intermittent catheterization was introduced by Lapides and colleagues in the early 1970s and dramatically changed the management of patients with neurogenic urinary retention. With this strategy, patients (or their caregivers) catheterize the bladder using clean technique based on an individually determined catheterization schedule. This method of treatment eliminates the risk of developing squamous cell carcinoma of the bladder and reduces the risk of infection. Overall, this is a safe technique with minimal risk. Possible complications of clean intermittent catheterization include hematuria, urethral injury, stricture disease, and epididymitis.

Bethanechol is a cholinergic agonist that has been approved by the U.S. Food and Drug Administration for use in patients with atonic bladders. However, bethanechol has not been conclusively proven effective in patients with neurogenic bladder, with studies demonstrating conflicting results. Use of this drug for treatment of failure to empty has largely been abandoned in favor of catheterization.

Bladder muscle augmentation using latissimus dorsi transposition has been successful in a small group of patients. However, this is a highly complex surgery, and few urologists perform this procedure.

Sacral nerve root neuromodulation is a relatively new treatment for patients with nonobstructive urinary retention and is an alternative to catheterization. The sacral nerve roots (S2–S4) provide both somatic and autonomic innervation to the lower urinary tract, with S3 providing the majority of innervation to the bladder. Selective microstimulation of autonomic nerve fibers has been shown to induce bladder contraction. Implantable neurostimulators are now available in the United States, marketed as Interstim therapy (Medtronic, Inc., Minneapolis, MN). Early studies demonstrated improvement in urinary flow from virtually no flow to a mean maximal flow rate of 13.9 mL/sec. In addition, postvoid residual volumes improved from 78% of total voided volume to 5% to 10% of total voided volume. In a large population of patients with idiopathic urinary retention who were treated with sacral neuromodulation, Jonas et al found that, of patients who responded to initial test stimulation, 83% had improvement in urinary function as opposed to only 9% of control patients.

Implantation of a sacral neurostimulator is not successful in all patients, and patients with urinary retention are often poor responders to test stimulation and do not progress to placement of a permanent generator. For example, in the study by Jonas et al, only 38% of patients in the overall patient population responded to test stimulation. In patients who respond to the test phase, sacral neurostimulation is an excellent alternative to catheterization. However, at this time, it is not possible to predict which patients will respond to testing. Early data from our institution indicate that patients who are able to generate higher detrusor pressures (> 30 cm H2O) are more prone to failure compared with patients.
who generate lower pressures, suggesting that even small amounts of outflow resistance may be problematic with sacral neurostimulation. However, the clinical applicability of these data is yet to be determined.

FAILURE TO STORE

CASE EXAMPLE

A 70-year-old woman is admitted to the neurology service after a left-sided ischemic stroke. In addition to right-sided motor deficits, the patient is unable to void. A catheter is placed for bladder drainage. The patient recovers some motor function, and her bladder eventually regains the ability to empty; however, the patient now complains of severe urgency and frequency as well as new-onset urge incontinence. She is referred to a urologist. Cystoscopy reveals no bladder or urethral lesions. Urodynamic testing demonstrates normal bladder sensation and filling parameters; however, multiple unstable contractions are noted during the filling phase. The patient is able to generate normal bladder pressures and empties the bladder to completion. Although she contracts the external sphincter in an attempt to prevent leakage associated with the unstable contractions, she is able to relax the sphincter voluntarily to allow a normal voiding contraction.

- How would you classify the type of neurogenic bladder in this patient?
- How should this patient be managed?

UNINHIBITED NEUROGENIC BLADDER

This patient demonstrates normal and coordinated reflex bladder function, but she is unable to effectively stop contractions through use of her guarding reflex. This type of bladder dysfunction is typical with cortical lesions, such as intracranial bleed, ischemic stroke, or brain tumor. Patients with uninhibited neurogenic bladder are able to fill and empty appropriately but are often incontinent because they are unable to suppress bladder contraction and therefore cannot store urine appropriately. This patient also initially demonstrates a sort of “spinal shock” syndrome with complete failure of bladder function. This is not uncommon with initial injury to the central nervous system, although typically the bladder function will evolve into a more complex and abnormal pattern of activity.

TREATMENT OF FAILURE TO STORE

Failure to store urine is often marked by unstable bladder contractions, specifically, bladder contractions that are triggered before the bladder has an opportunity to fill to an appropriate volume (Figure 2). Unstable bladder contractions are associated with urgency, and if the bladder contractions cannot be halted, the patient may experience an urge incontinent episode. The terminology describing unstable bladder contractions can be confusing. Formerly, unstable contractions that were associated with an underlying neurologic cause were called detrusor hyperreflexia, while those with no known etiology were termed detrusor instability. These terms have largely been abandoned in favor of the broader term detrusor overactivity, but it is not uncommon to encounter the more historical terminology in the literature.
Medical Therapy

Detrusor instability is treated with medical therapy designed to block parasympathetic activation of bladder contraction. Postganglionic parasympathetic nerves release acetylcholine at the end organ (the bladder) and stimulate bladder smooth muscle contraction. Acetylcholine receptors are either muscarinic or nicotinic; muscarinic receptors are largely responsible for smooth muscle contraction. Five subtypes of muscarinic receptors have been identified (M1–M5), with several subtypes of receptors located in most organs. Some subtypes tend to predominate in certain sites, such as M4 predominance in the cerebral cortex and lung and M5 predominance in the eye. M3 receptors mediate salivary secretion and bowel motility. M2 receptors, the most common subtype, make up 80% of receptors in the body and comprise the majority of muscarinic receptors in the heart, salivary glands, and detrusor muscle. The detrusor muscle is primarily regulated by both M2 and M3 receptors in a 3:1 ratio, respectively.16

Other neural regulatory mechanisms, including purinergic (adenosine triphosphate–mediated) inputs and substance P and vanilloid receptors (which activate small C-fiber afferent nerves), are present in the bladder. However, these neural regulatory mechanisms contribute much less to overall bladder function when compared with cholinergic input.16

The majority of medical therapy for failure to store is based on blockade of the muscarinic receptors by drugs similar to atropine. Several oral agents exist for this purpose, including oxybutynin, tolterodine, trospium, darifenacin, and solifenacin. Each of these medications provides varying spectrums of affinity for both the M2 and M3 receptors, although there is some crossover into all 5 subtypes. In general, these medications are largely equivalent in efficacy, but long-acting formulations (versus immediate-release agents) seem to provide better symptom control with fewer side effects.17,18 Side effects are mediated by anticholinergic effects on other organs, with dry mouth (from salivary gland inhibition) and constipation (from decreased gut motility) being the primary complaints. Less frequent side effects include tachycardia, arrhythmia, blurry vision, hallucinations, and dry eyes.19

An alternative to oral therapy is intravesicular delivery of drugs. Vanilloid stimulators, such as capsaicin and resiniferatoxin (RTX), have been investigated with promising results. Capsaicin, a compound isolated from capsicum peppers, interacts with vanilloid receptors and initially causes irritation and discomfort, but eventually leads to desensitization with repeated exposure. RTX is derived from the cactus relative Euphorbia resinifera and works in the same way as capsaicin, but with significantly higher potency.

Capsaicin has been used for detrusor hyperreflexia in patients with spinal cord injury and multiple sclerosis. Decreased bladder activity and increased bladder capacity have been demonstrated for up to 9 months after instillation of capsaicin, and chronic therapy has reduced hyperreflexia for up to 5 years. Improvement in incontinent episodes has been reported in 60% to 80% of patients.20–22

In urodynamic studies of spinal cord injury patients with detrusor overactivity, intravesical instillation of RTX increased the amount of bladder filling necessary to trigger an unstable bladder contraction as well as increased overall bladder capacity when compared with placebo.23 In a study by Kuo et al,24 RTX administration subjectively improved incontinence grade in 62% of patients with anticholinergic refractory detrusor overactivity as compared with 21% of patients in the placebo group. However, this benefit was sustained in only 50% of patients over a 6-month period.24

Surgical Therapy

Although data are sparse with regard to use of sacral neuromodulation in patients with neurogenic bladder, this treatment modality has proven effective for patients with urinary retention (see Treatment of Failure to Empty), medication-refractory urgency/frequency, and urge incontinence. In patients with refractory urinary urgency/frequency, sacral nerve neuromodulation decreased the number of daily voids, increased void volumes, and decreased the degree of urgency over a 6-month period when compared with controls.25 Sacral nerve neuromodulation also significantly decreased urge incontinent episodes from 8.8 to 2.3 episodes per day as well as reduced pad usage from a mean of 4.7 to 0.82 pads daily in patients with urge incontinence refractory to conservative therapy.26 Improvements in urinary urge incontinence, urgency/frequency, or retention were sustained over time, with 59% of patients reporting more than a 50% reduction in pad usage 3 years after initial implantation.27

In patients with neurogenic bladder, only a single study evaluating sacral neuromodulation has been reported.28 In 27 patients who had varying etiologies of neurogenic bladder, 12 had successful test stimulation and proceeded to permanent implantation. Sixty-six percent of patients showed more than 50% improvement in symptoms of lower urinary tract dysfunction, although the effect was not permanent. By 54 months, all but 1 of the implants were considered ineffective. The cause for the reduction in efficacy is unclear, although
the authors propose nutritional impairment, fibrosis, electrode dislocation, and the plasticity of the nervous system as possible etiologies.  

In contrast, Hansen et al. reported successful use of a different method of neuromodulation in patients with spinal cord injury. Under urodynamic surveillance, neurogenic bladder patients underwent event-driven electrical stimulation of the dorsal penile/clitoral nerve, and increases in detrusor pressure during filling were observed. Using this methodology, detrusor pressure below 55 cm H2O was maintained and average bladder capacity was increased by 53%. Although this method is not feasible for outpatient or long-term treatment, this study demonstrates that neuromodulation has a positive effect in neurogenic bladder patients. Further studies are needed to determine the role of this modality in the treatment of neurogenic bladder.

Botulinum toxin (BTX) is emerging as another alternative for treatment of detrusor overactivity in neurogenic bladder patients. BTX is a product of Clostridium botulinum and a potent neurotoxin that induces paralysis. After binding to a nerve terminal receptor, the toxin is internalized and prevents the release of neurotransmitter, effectively disabling any propagation of neural stimulation. Two subtypes of BTX are produced commercially (A and B) and have been approved by the U.S. Food and Drug Administration for the treatment of strabismus, benign essential blepharospasm, seventh cranial nerve disorders, and cervical dystonia; BTX also is approved for use in improving the appearance of moderate to severe frown lines. Although currently an off-label indication, BTX-A has been used in the treatment of neurogenic urinary incontinence. In a randomized controlled trial of 59 patients with urinary incontinence caused by neurogenic detrusor overactivity, multiple detrusor injections (200 U or 300 U) were performed cystoscopically, resulting in a significant improvement in incontinent episodes when compared with placebo and a durable response lasting up to the end of the 24-week study.

The largest concern with the use of BTX is the risk of systemic side effects, specifically systemic weakness or paralysis. In humans, the lethal dose of BTX is 2000 to 3000 U, and current urologic applications use tenfold less than this threshold. Other possible side effects include detrusor areflexia, urinary retention, increased residual urinary volume, and erectile dysfunction. Clinical resistance via antibody formation can also occur, which reduces the effectiveness of BTX. Higher doses and shorter intervals between injections may enhance antibody formation. Currently, investigators recommend that BTX injection be performed no sooner than every 3 months, with the smallest possible dose.

Sacral rhizotomy is an alternative approach to increase bladder capacity and to improve continence. Although used for more than a century for the treatment of spasticity, sacral rhizotomy was first proposed for improving bladder function in 1950. However, many complications such as bladder atony, urethral and rectal sphincteric dysfunction, and impotence severely limited this procedure. The procedure was later refined to selective sacral rhizotomy with the addition of electrical stimulation to identify appropriate nerve roots for denervation. Since that time, multiple studies have shown that this procedure is effective, both with and without the addition of an anterior sacral root nerve stimulator. Patients with cerebral palsy have demonstrated improvement in total bladder capacity and pressure-specific volumes on urodynamic studies. In patients with spina bifida, selective sacral rhizotomy has shown durable responses in maintaining low-pressure bladders of appropriate volume as well as significantly improved uninhibited contractions for longer than 49 months. In spinal cord injury patients with spastic bladder, sacral rhizotomy with anterior sacral root stimulation completely resolved incontinence and led to significant improvements in postvoid residual volumes and overall bladder capacity. Unfortunately, this procedure is technically challenging and is performed by few urologists.

**REFLEX NEUROGENIC BLADDER**

**CASE EXAMPLE**

A 35-year-old man with a history of a complete T2 spinal cord injury is referred to a urologist for evaluation of his urinary tract. He does not use a catheter and voids into a diaper. The patient’s serum creatinine level is 2.5 mg/dL. Renal ultrasonography shows bilateral hydronephrosis with some bilateral renal cortical thinning. Urodynamic testing reveals a poorly compliant bladder with baseline storage pressures rising above 40 cm H2O after only 100 mL of fluid is instilled. The urodynamic study also demonstrates unstable contractions against a closed bladder outlet. The procedure is stopped early because the patient complains of facial flushing, headache, and sweating. At this time, the patient’s blood pressure is 240/120 mm Hg and heart rate is 40 bpm.

- How does this patient’s spinal cord injury contribute to his clinical picture, and how should this patient be managed?
Neural injury between the sacral reflex center and the brainstem can result in loss of input from the pontine micturition center and therefore lead to lack of coordination of the normal reflex voiding activity of the bladder. Although the bladder is still capable of filling and emptying based primarily on reflexes channeled through the sacral spinal cord, the entire process is disorganized and may result in detrusor–external sphincter dyssynergia, autonomic dysreflexia, or high bladder storage pressure. Bladder hypertonicity can cause high storage pressures and place the upper urinary tract at risk for reflux and eventual loss of renal function. Detrusor–external sphincter dyssynergia leads to extremely high voiding pressures. Instability and reflex incontinence may also occur. Because sensory input to the cerebral cortex is lost, the patient is often unaware of any of these problems.

DETRUSOR–EXTERNAL SPHINCTER DYSSYNERGIA

Failure of the external sphincter to relax with a bladder contraction is often seen in patients with spinal cord injury between the sacral and pontine micturition centers (Figure 3). Possible causes of external sphincter failure include traumatic spinal cord injury, multiple sclerosis, or myelomeningocele. As the bladder contracts against a closed outlet, intravesicular pressure can reach dangerously high levels, leading to a number of possible complications (e.g., vesicoureteral reflux, hydroureter, and eventual reflux nephropathy). In addition, poor bladder emptying can cause recurrent bladder infections.

Therapy

Therapy for detrusor–external sphincter dysynergia is directed at reducing outlet resistance, primarily through surgical intervention. Medical therapy to reduce external urethral sphincter tone has been described but has not been effective and is often complicated by prohibitive side effects. While urinary incontinence is a possible side effect of medical therapy, eventual renal failure is a far worse consequence. Surgical sphincterotomy was the first surgical intervention described for treatment of detrusor–external sphincter dyssynergia. The external urinary sphincter is identified cystoscopically and incised with electrocautery. Eventual improvement of bladder emptying and stabilization of upper tract dysfunction can be expected in 70% to 90% of patients. However, reoperation for failed resection is common, with reoperation rates ranging from 15% to 50%. Bladder leak point pressure of more than 40 cm H₂O has been proposed as an indicator of failure of surgery and need for reoperation. Significant postoperative hemorrhage is a common complication of sphincterotomy and has been severe enough to warrant transfusion in 5% to 20% of cases. Erectile dysfunction has also been reported in 3% to 65% of cases.

An alternative to sphincterotomy is cystoscopic placement of an intravesical stent. Several stents are available for use in the United States. Intravesical stents have shown success rates equivalent to sphincterotomy. Possible complications of stent placement include obstructive granulation tissue overlying the stent, encrustation, infection, and migration. If complications occur, the stent must be removed, which can be technically challenging.

BTX has also been injected into the external sphincter to provide a “medical sphincterotomy.” In patients treated with BTX, the mean decrease in postvoid residual volumes was 156 mL, a significant difference when compared with controls. BTX therapy is not permanent and requires repeated administration to maintain the desired effect. Pudendal nerve destruction or neurectomy is an alternative approach to decreasing external urethral sphincter tone. In a study by Engel and Schirmer, surgical neurectomy decreased postvoid residual volumes to a mean of less than 50 mL, with a durable response of more than
2 years. Ko and Kim\textsuperscript{45} demonstrated that pudendal nerve destruction with injected phenol decreased mean post-void residual volumes from 255 mL to 57 mL.\textsuperscript{45} Despite excellent success rates, urologists have been reluctant to embrace either of these techniques.\textsuperscript{49}

**AUTONOMIC DYSREFLEXIA**

This case demonstrates a classic example of autonomic dysreflexia, an acute syndrome that occurs in patients with spinal cord injuries above the level of T6 (it has been reported as low as T8). Certain stimuli located below the level of spinal injury can trigger a massive reflex sympathetic discharge. This reflex is typically associated with an increase in blood pressure due to increased vascular tone and is often associated with compensatory brachycardia. Other symptoms include piloerection, headache, facial flushing, and sweating. Patients with spinal cord injury often have lower mean blood pressures; the sudden onset of severe malignant hypertension can lead to seizures, intracerebral hemorrhage, or even death.\textsuperscript{46}

In patients with high spinal cord injury, the most common stimulus for severe hypertension is bladder distention. The urologist can trigger this response with any intervention that fills or stimulates the bladder, such as urodynamic testing or cystoscopy. However, in otherwise asymptomatic patients, “normal” bladder filling has caused significant blood pressure elevation.\textsuperscript{46} Rectal distention is the second most common stimulus; other stimuli include cystitis, testicular torsion, epididymitis, acute abdominal conditions, and exposure to extremes in temperature.\textsuperscript{47}

Prompt identification of autonomic dysreflexia is important, as it can have devastating consequences to the patient. Initial management of autonomic dysreflexia is directed at identifying the noxious stimulus and removing it. This can be as simple as emptying a full bladder. Further, patients should be taught to recognize the symptoms of autonomic dysreflexia and take actions to prevent overdistention of the bladder or bowels. Medical therapy has also been recommended, with some success demonstrated with either sublingual nifedipine or \(\alpha\)-receptor blockade.\textsuperscript{1} Sacral posterior rhizotomy has been proposed as a possible surgical alternative, but studies have demonstrated that it does not significantly prevent autonomic dysreflexia.\textsuperscript{37,48}

**HIGH BLADDER STORAGE PRESSURE**

In patients with decreased bladder compliance and increased detrusor tonicity, it is not uncommon to reach high bladder storage pressures at relatively low bladder volumes. In a study by McGuire et al.,\textsuperscript{49} myelodysplastic patients with neurogenic bladder had a much greater likelihood of upper urinary tract deterioration with detrusor leak point pressures greater than 40 cm H\(_2\)O. Detrusor fibrosis is often found in bladders with high storage pressure as well. Some authors have advocated biopsy alone or in conjunction with urodynamic studies to stratify patients at risk for upper tract deterioration; however, this approach has not been embraced by the urologic community at large.\textsuperscript{50} Regardless, it is important to monitor renal function in patients with high bladder storage pressures by measuring serum creatinine levels and intermittent radiologic imaging of the upper urinary tract (typically with ultrasonography). The frequency of urodynamic assessment may be left to the discretion of the urologist.

**Therapy**

In patients with high bladder storage pressure, therapy is aimed at lowering the detrusor storage pressure. Urodynamic testing can be used to identify the volume at which the detrusor leak point pressure is reached, and intermittent catheterization can be used to empty the bladder before these volumes are reached through normal urine production. Medical therapy with anticholinergic agents allows for improved bladder compliance and permits higher volumes to be stored without reaching unsafe pressure levels. Urodynamic detrusor pressure does not typically change, however, as this is a measure of the bladder outlet. Use of anticholinergics can allow the patient to catheterize with decreased frequency, as larger volumes can be stored safely.

Even in the most compliant patients, nonoperative management is not always successful. In these cases, surgery is a therapeutic option. The bladder can be augmented or bypassed entirely using various urinary diversions. Several studies have demonstrated the efficacy of bowel augmentation of the bladder. One study reported an average increase in bladder capacity from 201 mL to 615 mL with a decrease in maximal detrusor pressure from 81 to 20 cm H\(_2\)O.\textsuperscript{34} These results were sustained over an 8-year period. Patients were also extremely satisfied with this management option; 25 of 26 patients would recommend this procedure to a friend, and average satisfaction with the procedure was rated at 8.7 on a 10-point scale. Of course, the risk of complications should always be considered. In a study involving 106 patients, 21% of patients developed bladder stones, 15% required operative revision of their augmentation, 13% had persistent incontinence, and 11% developed pyelonephritis.\textsuperscript{52} Despite these complications, 95% of patients were considered to have excellent or improved results.

As an alternative surgical approach to using the
bowel for bladder augmentation, “autoaugmentation” or detrusor myomectomy may be considered. The detrusor muscle is split down to the level of the bladder mucosa, which permits the bladder mucosa to essentially herniate through the muscle defect. This results in increased bladder volumes and decreased bladder pressures. Leng et al compared detrusor myomectomy to enterocystoplasty and found that complications were significantly lower in patients who underwent myomectomy (3% versus 22% in the enterocystoplasty group). However, 95% of patients in the bladder augmentation group reported symptomatic improvement compared with only 59% in the detrusor myomectomy group. In addition, urodynamic studies showed improvement in 68% of myomectomy patients versus 100% of the enterocystoplasty patients. Although detrusor myomectomy is technically easier to perform and has lower complication rates, there is an obvious trade-off in success rates compared with bladder augmentation.

Because urine often leaks from the ostomy at low pressures, ileovesicostomy may also be used to decrease bladder storage pressure. In a study by Gudziak et al involving 13 patients with neurogenic bladder who underwent ileovesicostomy, only 1 patient required revision in the observation period for stomal stenosis (mean follow-up, 23 mo). Urodynamic studies showed average bladder leak point pressures of 8 cm H₂O through the stoma.

The bladder may also be bypassed via complete urinary diversion, which can be accomplished through a number of methods. A full discussion of these techniques is beyond the scope of this review, but these methods generally lead to a significant decrease in storage pressures in the diversion. This surgical option is not without complications, however, as upper tract infection, reflux, and stenosis of the ureteroenteric anastomosis may occur. With regard to the fate of the native bladder after bypass, Fazili et al reported on the complication rate in patients who underwent urinary diversion for benign disease with the native bladder left in situ. Only one third of the patient population had neurogenic bladder. Fifty-four percent of patients had complications related to the native bladder (ie, infection, pain, bladder spasms, persistent sensation of incomplete emptying), 33% had frank pyocystis, and 25% eventually underwent cystectomy. Although not indicated in all patients undergoing urinary diversion, strong consideration should be given to concurrent cystectomy at the time of urinary diversion, especially when there is little to no chance that the patient will use his or her native bladder again.

**AUTONOMOUS NEUROGENIC BLADDER**

**CASE EXAMPLE**

A 45-year-old man is referred to a urologist for urinary retention after recently undergoing an abdominoperineal resection for rectal cancer. Prior to his surgery, he had no history of urinary complaints. He has no past history of urinary retention or infection, urethral stricture disease, or benign prostatic hypertrophy. A catheter was placed intraoperatively without difficulty, but the patient was unable to void after the catheter was removed. After 12 hours, the catheter was replaced, with return of 600 mL of urine. During that time, the patient was comfortable and had no sensation of needing to void. Cystoscopy reveals a normal urethra, prostatic fossa, and bladder. Urodynamic testing demonstrates a normal capacity, compliant bladder. The patient is unable to sense filling at any volume and is also unable to generate any voiding contraction.

**How should this patient be managed?**

**APPROACH TO MANAGEMENT**

This patient has impaired sensory as well as motor function, typical of autonomous neurogenic bladder. In this type of neurogenic bladder, both afferent and efferent neural connections to the bladder are lost. Autonomous neurogenic bladder is often caused by lower sacral trauma and can be iatrogenic due to pelvic surgery. Low myelomeningoceles can also result in this pattern of bladder function.

Therapy is individualized to the patient. Patients with autonomous neurogenic bladder generally do not have high bladder storage pressure and therefore the upper tract is typically not at risk. The urologist’s attention should be directed at achieving appropriate bladder drainage through clean intermittent catheterization, indwelling catheters, or sacral nerve root neuromodulation.

**CONCLUSION**

The patient with neurogenic bladder can present with a variety of urologic complaints and is at risk for complications. It is important to establish bladder
function with urodynamic testing early in the evaluation. Baseline renal function should also be assessed and ultrasonography should be performed to rule out hydronephrosis. Management of patients with neurogenic bladder should be individualized depending on results of urodynamic testing. In the event that the patient’s symptoms change (eg, worsening renal function, change in voiding symptoms, or infection), urodynamic testing should be repeated and new findings should be addressed. If properly monitored and treated, the patient with neurogenic bladder can maintain a good quality of life with minimal complications.

REFERENCES


