DISEASES OF THE NERVOUS SYSTEM AND HOW THEY AFFECT THE BLADDER

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I. INTRODUCTION

Transverse Myelitis is a rare cause of bladder dysfunction compared to Spinal Cord Injury or Multiple Sclerosis. In its most severe form the initial presentation and natural history of the bladder and sphincter dysfunction is very similar to that of Spinal Cord Injury. Long term major dysfunction may occur in 20% of patients and it is to this group that most of my remarks are addressed.

In this presentation, I will:

1) briefly review the essential neuroanatomy of the lower urinary tract,

2) describe the methods for evaluating the neurogenic bladder,

3) discuss the detailed management of the neurogenic bladder secondary to Transverse Myelitis from the time of onset until a stable state has been reached.

II. NEUROANATOMY OF THE LOWER URINARY TRACT.

There are four reflex pathways (Bradley's Loops) crucial to the innervation of the lower urinary tract:

1) Relays between the frontal cortex and pontine detrusor nucleus constitute the first loop and represent the mechanism underlying voluntary control of bladder function.

2) A reflex pathway consisting of long-routed sensory axons extend from bladder afferents and ascend in the spinal cord to synapse in the pontine detrusor nucleus. From this nucleus axons descend in the spinal cord to synapse with the antero-lateral horn cells of S2,3 and 4 and thus, the pelvic nerves to the bladder.

3) This loop consists of afferent sensory axons originating in the bladder wall and passing into the conus to synapse with the nucleus of the pudendal nerves.

4a) This loop represents the supraspinal innervation of the external urinary sphincter with afferents in the perineal area and pelvic floor. Efferents originate in the motor cortex, descending in the corticospinal tracts to synapse with the pudendal motor nucleus.

4b) This loop serves the segmental innervation of the external sphincter with afferents in the urethra, sphincter and pelvic floor and efferents in the pudendal nerve.

The essential event in the initiation of normal voiding is a relaxation of the pelvic floor associated with a coordinated detrusor contraction with a smooth and sustained rise in intravesical pressure. The long-routed detrusor reflex (loop II) allows the detrusor contraction to be sustained throughout voiding until the bladder is empty.

III. METHODS FOR EVALUATING THE NEUROGENIC BLADDER.

1) Neurological Diagnosis.

The diagnosis of lower urinary tract neuropathy is established by integrating the neuroanatomic findings derived from the history, neurological examination and imaging studies with the results of the bladder and sphincter function tests. The latter are relatively non-specific and give information on the type of bladder and urethral dysfunction but do not always indicate the precise level of the lesion. For deciding on management strategies a functional classification (Table 1) is often better than an anatomical one.

2) Studies of the Lower Urinary Tract

a) Cystometrogram (CMG) and Sphincter Electromyogram (EMG).
This is a study recording pressure and volume at various filling rates using fluid or carbon dioxide as the medium. The author's preference is to use fluid at 50 ml per minute filling rate. The CMG gives information on bladder sensation, compliance and the presence or absence of a detrusor contraction. Individuals with normal bladder innervation will usually suppress the detrusor contraction with filling and the absence of a contraction with this test does not necessarily indicate an areflexic state. To determine that detrusor contractions are truly absent, multichannel urodynamics or ambulatory (long-term) monitoring may be required at which time a patient has a better opportunity for more "natural" voiding.

Integrated electromyography (EMG) of the pelvic floor can be performed during the CMG but again, this is only a filling study and the most important information is the response of the pelvic floor to voiding. Integrated EMG of the pelvic floor is therefore better performed with multichannel urodynamics where the voiding phase can be observed. A standard EMG with the recording of individual motor units and other electrodiagnostic tests are described below.

b) Multichannel Urodynamics with Fluoroscopy.
Bladder, intra-abdominal and subtracted (detrusor) pressure are recorded simultaneously with integrated pelvic floor EMG. Fluoroscopy of the bladder and urethra and, if appropriate, urinary flow rate are also recorded. The patient is filled at 50 ml per minute and allowed to void when capacity is reached. This examination is essential in patients with incomplete lesions who are still voiding but have symptoms of incomplete emptying. It is particularly helpful if there is a possibility of mechanical obstruction from prostate enlargement or stricture. Candidates for sphincterotomy, patients not responding to anticholinergics, and those with conal or cauda equinal lesions with reduced sphincter resistance will also need to be studied for a more precise diagnosis. Urodynamic definitions are listed in Table 2.

c) Electrodiagnostic tests.
Pelvic floor EMG of individual motor units, sacral response times from visceral or somatic afferents to somatic efferents, and somatosensory evoked potentials are all helpful with conal, cauda equinal or peripheral lesions.

d) Ambulatory (long-term) monitoring.
This is a new investigative procedure that allows continuous monitoring of bladder, intra-abdominal and even EMG activity over several hours with natural bladder filling and with the patient undertaking their normal daily activities. Studies so far on patients with neurogenic bladders have revealed that, compared to standard CMG or urodynamics, compliance, phasic activity and voiding pressures are all higher with ambulatory monitoring.

3) Studies of the Upper Urinary Tract

If bladder dysfunction persists after Transverse Myelitis some upper tract study should be performed. Ultrasound is usually adequate as a screening test.

IV. MANAGEMENT OF THE NEUROGENIC BLADDER

A. GOALS

In general, the goals of management are to allow storage of adequate volumes of urine (500-600 ml) at low pressure (compliance > 10 ml per cm of water) with emptying at pressures within normal limits (< 60 cm of water in men and < 30 cm of water in women) to residuals that are reasonably low (50-100 ml). Continence of urine between emptying is the ideal. In infrasacral lesions incontinence may be due to sphincter weakness. Hyperreflexic contractions or overflow are the mechanisms responsible for incontinence in suprasacral lesions.

B. FACTORS AFFECTING MANAGEMENT

1) Upper Tract Status

Significant upper tract decompensation will drive the bladder management in some late cases, whereas the early management depends on the other factors that are discussed below.

2) Motivation and Lifestyle

These are perhaps the most important and also the most intangible factors to consider. A lot can be achieved by an intelligent, motivated, and careful patient that may be impossible in another who wants convenience and simplicity at the expense of increased risks. For example, there are large number of patients at the Veteran's Spinal Cord Injury center with indwelling catheters who have resisted recommendations to change to other forms of management for the sake of convenience with the increased risks of urinary infection, urethral damage and possibly bladder cancer.

3) Gender, level of lesion, and spasticity of lower limb

Men can much more readily do clean intermittent self-catheterization, even at levels of injury at C-6 or C-7. Women may have difficulty with urethral catheterization even at lower spinal levels due to leg spasms and difficulty with upper body balance. Women also need to transfer to a toilet for self-catheterization whereas men can do this in their wheel chairs.

4) Body habitus

Obesity may also be a limiting factor in the ability of patients of both sexes to do self catheterization.

C. INITIAL MANAGEMENT

Immediately after the onset of paraplegia and retention a Foley catheter is maintained until the patient is stable and the intake of fluid can be restricted so that a urine output of 1,500 to 2,000 ml. a day is achievable. Intermittent sterile catheterization is then started, if possible, by a dedicated catheterization team and many patients can themselves learn sterile catheterization while in hospital. Bladder volumes of 500 - 600 ml should be the maximum allowed and if larger volumes are produced after the patient becomes recumbent in the evenings, an extra catheterization should be ordered to maintain this upper limit. If and when the "spinal shock" phase is over and reflex detrusor contractions return, the patient may begin to have episodes of incontinence. At this time anticholinergic medication may be indicated.

D. INITIAL URINARY TRACT COMPLICATIONS

1) Bacteriuria

Urinary tract infection often combined with increased pressure and obstruction is the final common path way to renal damage in neurogenic bladder disease. It is as important to treat the underlying obstruction, stones, ureteral reflux, and high bladder pressures as it is to give antibiotics.

The management of asymptomatic bacteriuria is more controversial:

a) Patients with Foley catheters should not be given prophylactic antibiotics as resistant organisms are inevitable. High fluid intake and excellent catheter care and hygiene are essential. Symptomatic bacteriuria will have to be treated, but with short term courses, unless severe pyelonephritis is present.

b) In patients on clean intermittent catheterization, many studies have shown no overall benefit from suppressive antibiotics. Treatment for symptoms, which include increased spasms as well as the more obvious ones of fever, cloudy urine, odor, frequency and incontinence, etc. gives patients and their physicians a certain amount of latitude in managing this common problem.

c) In patients on condom catheters or no collecting devices, there may be some justification for expecting suppressive antibiotics to work. However, patients with badly managed condom catheters are at considerably increased risk for recurrent urinary tract infection and the bacteria will probably become multi-resistant.

2) Catheterization problems.

These are surprisingly rare considering the large number of catheterizations performed. The three common problems are trauma to the urethra with a creation of a false passage, external sphincter spasms and pain in patients with high incomplete lesions. Combinations of extra lubricant, different catheters and 2% xylocaine will resolve most problems. Occasionally, urethro-cystoscopy and surgical correction of a false passage will be indicated.

3) Autonomic dysreflexia

This occurs in many patients with lesions above T6. It is more often seen in higher and more complete lesions.

V. LONG-TERM MANAGEMENT OF SUPRASACRAL BLADDER NEUROPATHY

Bladder management options are listed in Table 3. However it is easier to discuss the various strategies that might be applied to a patient after the spinal shock phase as his or her recovery evolves.

A. PATIENTS WILLING AND ABLE TO DO SELF-CATHETERIZATION

1) Anticholinergic/Musculotropic drugs.

Clean, intermittent self-catheterization is the mainstay of bladder management in motivated patients who have sufficient hand function. When reflex bladder activity returns, as it does in the majority of patients, the various anticholinergic and musculotropic drugs are then used to convert the bladder back to a passive reservoir as it was during the spinal shock phase. There has been recent interest in giving Oxybutynin intravesically as this has been associated with a better therapeutic response and fewer side effects. As yet there is no approved preparation but the non-sterile 5 mg tablet can be dissolved in 10 ml of sterile water and instilled into the bladder at the end of a catheterization procedure.

2) Bladder Augmentation and Continent Diversion.

In a number of patients, these drugs do not work satisfactorily and these individuals are now candidates for bladder augmentation or perhaps continent diversion which are, at the present time, the most acceptable method of restoring the reservoir function of the bladder so that intermittent self-catheterization can be continued.

The principles of the surgery are to bivalve the bladder and sew in a large patch of bowel, being reconstructed in such a way that its tubular configuration and peristaltic functions have been destroyed. Almost any segment of the gastro-intestinal tract can be used, but, at the present time, small bowel is preferred over large bowel segments, and stomach has been tried because its low pH and reduced mucous production may lessen the incidence of bacteriuria. Patients considering augmentation must be committed to performing the self-catheterization program indefinitely and must be prepared to undergo major surgery with a small risk of immediate bowel complications such as obstruction or anastomotic leak with peritonitis or fistula. Long-term alteration in bowel function, usually less constipation, may occur but diarrhea is rarely a long-term problem. This procedure produces an excellent low pressure reservoir with a capacity of up to 600 ml or more. Bacteriuria and symptomatic urinary tract infection can still occur, and mucous is often a problem, especially with bladder infections. If an adequate amount of small bowel is used, there is rarely any need for anticholinergic or musculotrophic drugs; however, large bowel and stomach augmentations have more activity, at least initially, and may require the use of these agents. A greater than 10 year follow-up is not available yet, but, because the risk of carcinoma developing in these augmented bladders is unknown, all patients should have yearly cystoscopy beginning 10 or 15 years following an augmentation.

In a continent diversion, the urethra and sphincter mechanisms are abandoned and an internal reservoir, constructed of bowel only or the augmented bladder, is connected to the abdominal wall by a continent segment of bowel. The patients then catheterize this segment in the same way as they would the orthotopic urethra. A continent diversion is generally a much better system for women who can now catheterize in their wheelchairs without the problems of leg spasms and having to transfer each time. It is also suitable for males who have diseases such as stricture, fistula or diverticula information in the urethra which makes the latter unusable.

3. Neurostimulation.

This is available at various centers in the United States and in Europe. It requires a complete dorsal rhizotomy at the S-2,3,4 level bilaterally. Electrodes are implanted on the anterior roots of some of the sacral nerves. Stimulation is intermittent to produce intermittent post-stimulus voiding, which is said to allow emptying at acceptable pressures. Reflex erections are abolished in all men but usable electroerections occur in less than 30%. Many patients find that bowel evacuation is easier with stimulation.

4) Other (experimental) methods of management of hyperreflexia.

a) Sacral rhizotomy. This, if complete at S2, 3 and 4 bilaterally, can abolish hyperreflexia but leads to loss of reflex erections in men.

b) Bladder over-distention in the spinal shock phase. One investigator intentionally over-distended the bladder in complete paraplegics in the acute phase and achieved an areflexic bladder in 63% in contrast to the usual prevalence of areflexia of 15% one year from injury.

c) Intrathecal Baclofen. As a side effect, this therapy has been shown to depress both the detrusor and pelvic floor reflexes and would be of benefit for patients on clean intermittent self-catheterization who had hyperreflexia and incontinence. This has not been used as yet for hyperreflexia alone.

5) Other (experimental) methods of management of bladder emptying.

a) Sphincter stretch. This method has been around for some time but has not become popular. The patient has to be well motivated, able and willing to transfer frequently for voiding, have adequate Valsalva pressures for voiding (with or without an abdominal binder) and have a sensory complete lesion. It is based on the principle of striated muscle relaxation when the muscle is gently stretched. The driving force for evacuation is a Valsalva, not detrusor contractions. Its failure to become popular is probably related to the inconvenience of transferring for bladder emptying compared to doing intermittent catheterization in a wheelchair.

B. PATIENTS UNWILLING & UNABLE TO DO SELF-CATHETERIZATION

1) Clean intermittent catheterization by others

Male quadriplegics who are unable to do self-catheterization may sometimes have enough support from family and attendants to continue intermittent catheterization after leaving the hospital. However, many find that this restricts their ability to go to school or work and the program often breaks down. In fact, these patients have a higher incidence of bacteriuria with fever than any other group, including those with indwelling Foley catheters.

2) Balanced Bladder

A few patients achieve a "balanced" bladder in which there are adequate detrusor contractions associated with reflex relaxation of the pelvic floor. However, the attainment of a "balanced" bladder is rare.

3) Sphincterotomy

Until there are established alternatives for bladder emptying, possibly sacral root stimulation, many of these men will want to consider sphincterotomy. This operation has a relatively high perioperative morbidity (bleeding, clot retention, infection and dysreflexia) and long-term failure due to stricturing at the sphincterotomy site. There is also a low incidence of impotency as a result of the surgery (about 1-2%). A cylindrical stent made of stainless steel mesh (Wallstent) is now available for implantation into the urethra. In addition to sphincterotomy, it has also been used extensively for anterior urethral strictures and benign prostatic hyperplasia. The stent is a permanent implant that becomes incorporated into the urethral wall as the epithelium grows through the spaces in the mesh and actually covers the stainless steel wires. This process takes approximately 3-6 months. The advantages of this over the standard sphincterotomy are that there is no incision and therefore no bleeding or risk of impotency. Also, the stent will prevent restricturing and the need for further sphincterotomies. The results worldwide appear to be excellent in suitable candidates with few complications reported in the 3 year follow-up to date.

4) Indwelling catheters and standard supravesical diversions.

Other methods of bladder management, including a Foley catheter, suprapubic catheter and a more proximal diversion with an ostomy bag, are still in use although not recommended very often. In patients who have an indwelling catheter for more than ten years, it is recommended that they have a yearly cystoscopy with cytology or biopsy as the occurrence of bladder cancer may be higher because of the indwelling catheter.

VI. LONG-TERM MANAGEMENT OF INFRASACRAL LESIONS

The bladder is insensate, hypo- or noncontractile, and the pelvic floor flaccid. Some patients, especially those with complete lesions, develop poor compliance. Patients may void by Valsalva; however, men may need relaxation of the bladder neck with alpha-adrenergic blockade or surgical resection. Women, having lower outflow resistance than men, void more easily but tend to develop stress incontinence. In the latter, a bladder neck sling with clean intermittent catheterization is indicated or occasionally an artificial urinary sphincter with continuation of Valsalva voiding. Men with poor compliance may respond both to anticholingerics and alpha-adrenergic blockade, but the responses are not impressive and they are then candidates for either augmentation with continued clean intermittent catheterization, or sphincterotomy and a condom catheter.

VII. MANAGEMENT OF UPPER TRACT COMPLICATIONS

1) Ureteral reflux

The first goal is to lower the bladder pressure with the use of medications and clean intermittent catheterization. If this fails, reimplantation, combined with augmentation, is the next logical step for those with the will and ability to do intermittent self-catheterization. The alternative is to do a sphincterotomy and possibly treat the reflux by endoscopic injections.

2) Stones

Extracorporeal shock wave lithotripsy (ESWL) is appropriate for those with a combined diameter of less than 3 cm. For larger stones and in patients with deformed collecting systems, a percutaneous approach is preferable. As the majority of stones are infective in origin, patients should be pretreated with antibiotics. Although struvite (infection) stones break well with ESWL, clearance of the fragments is often impaired in immobile patients and unless the stones or infections are cleared from the kidney, recurrence is inevitable. Ureteral stones can be treated by the usual techniques but urgent drainage procedures are often required as obstruction, combined with infection, are common in this population and may be present silently with fever only.

VIII. ROUTINE SURVEILLANCE

The following schedule is currently followed at the University of Washington Affiliated Hospitals for routine surveillance after Spinal Cord Injury:

1. Initial Rehabilitation Admission

- Urine analysis, initial and as needed
- Urine C&S weekly
- Renal ultrasound (a baseline test)
- Post-void residuals (PVR)
- CMG and/or Urodynamics
- 24° Urine for CrCl

2. Annual Evaluations

- Renal Ultrasound and KUB at each annual evaluation (IVP, CTKUB, or Renogram as indicated)
- 24-hour urine for CrCl annually
- Urine analysis and C&S annually
- PVR (by portable ultrasound or by catheter) annually unless indwelling catheter
- Urodynamics as indicated

3. Cystoscopy

Generally performed in patients after 10 years of chronic, continuous indwelling catheterization (urethral or suprapubic) or sooner (at 5 years) if high risk (heavy smoker, age greater than 40, or history of complicated UTI's) or in any patient with symptoms that warrant such a procedure.

IX. SUMMARY

The management of the neurogenic bladder in spinal cord neuropathy has moved from the old concepts using condom catheters with "balanced" bladders or sphincterotomy, indwelling catheters or standard diversion, to intermittent self-catheterization for those able to do this. In order to keep the bladder at low pressure for the catheterization program, medications and then augmentation are the standard of care for those patients sufficiently motivated. Continent diversions will have a place in women wishing to do clean intermittent catheterization and some men in whom the urethra has become diseased and unusable. In men with quadriplegia, sphincterotomy with a stent will probably become the procedure of choice. Sacral root stimulation, and intrathecal Baclofen may play an increasing role in the future.

BIBLIOGRAPHY

1. Anderson RU, Hsieh-Ma ST: Association of bacteriuria and pyuria during intermittent catheterization after spinal cord injury. J Urol 130:299-301, 1983.

2. Berger Y, Blaivas JG, Oliver L: Urinary Dysfunction in Transverse Myelitis. J Urol 144:103-105, 1990.

3. Bickel A, Culkin DJ, Wheeler JS Jr: Bladder cancer in spinal cord injury patients. J Urol 146:1240-1242, 1991.

4. Bradley WE, Sundin T: The physiology and pharmacology of urinary tract dysfunction. Clin Neuropharmacol 5:131-158, 1982.

5. Brindley GS, Rushton DN: Long-term follow-up of patients with sacral anterior root stimulator implants. Paraplegia 28:469-475, 1990.

6. Burr RG, Nuseibeh I: Biochemical studies in paraplegic renal stone patients: I. Plasma biochemistry and urinary calcium and saturation. Br J Urol 57:269-274, 1985.

7. Burr RG, Nuseibeh I, Abiaka CD: Biochemical studies in paraplegic renal stone patients. II. Urinary excretion of citrate, inorganic pyrophosphate, silicate and urate. Br J Urol 57:275-278, 1985.

8. Cardenas DD, Kelly E. Mayo ME: Manual stimulation of reflex voiding after spinal cord injury. Arch Phys Med Rehabil 66:459-462, 1985.

9. Cardenas DD, Mayo ME: Bacteriuria with fever after spinal cord injury. JArch Phys Med Rehabil 68: 291-293, 1987.

10. Cardenas DD, Mayo ME, Turner LR: Lower urinary changes over time in suprasacral spinal cord injury. Paraplegia 33:326-329, 1995.

11. Cartwright PC, Snow BW: Bladder autoaugmentation: Early clinical experience. J Urol 142:505-508, 1989.

12. Chao R, Mayo ME, Bejany DE, et al: Bladder neck closure with continent augmentation of suprapubic catheter in patients with neurogenic bladders. J Am Paraplegia Soc 16:18-22, 1992.

13. DeVivo MJ, Fine PR, Cutter GR, et al: The risk of renal calculi in spinal cord injury patients. J Urol 131:857-860, 1984.

14. Erickson RP, Merritt JL, Opitz JL, et al: Bacteriuria during follow-up in patients with spinal cord injury: I. Rates of bacteriuria in various bladder-emptying methods. Arch Phys Med Rehabil 63:409-412, 1982.

15. Frost F, Nanninga J, Penn R, et al: Intrathecal baclofen infusion: Effect on bladder management programs in patients with myelopathy. Am J Phys Med Rehabil 142:112-115, 1989.

16. Gasparini ME, Schmidt RA, Tanagho EA: Selective sacral rhizotomy in the management of the reflex neuropathic bladder: A report on 17 patients with long-term follow-up. J Urol 148:1207-1210, 1992.

17. Gerridzen RG, Thijssen AM, Dehoux E: Risk factors for upper tract deterioration in chronic spinal cord injury patients. J Urol 147:416-418, 1992.

18. Golji H: Complications of external condom drainage. Paraplegia 19:189-197, 1987.

19. Griffiths CJ, Assi MS, Styles RA, et al: Ambulatory monitoring of bladder and detrusor pressure during natural filling. J Urol 142:780-784, 1989.

20. Hackler RH, Hall MK, Zampieri TA: Bladder hypo-compliance in the spinal cord injury population. J Urol 141:1390-1393, 1989.

21. Haldeman S, Bradley WE, Bhatia NN: Evoked responses from pudendal nerve. J Urol 128:974, 1982.

22. Hoffberg HJ, Cardenas DD: Bladder trabeculation in spinal cord injury. Arch Phys Med Rehabil 67:750-753, 1986.

23. Iwatsubo E, Komine S, Yamashita H, jet al: Overdistension therapy of the bladder in paraplegic patients using self-catheterization: A preliminary study. Paraplegia 22:210-215, 1984.

24. Kaufman JM, Fam B, Jacobs SC, et al: Bladder cancer and squamous metaplasia in spinal cord injury patients. J Urol 118:967, 1977.

25. Kiviat MD: Transurethral sphincterotomy: Relationship of site of incision to postoperative potency and delayed hemorrhage. J Urol 114:399-401, 1975.

26. Kiviat MD, Zimmerman TA, Donovan WH: Sphincter stretch: A new technique resulting in continence and complete voiding in paraplegics. J Urol 114:895-897, 1975.

27. Leroy-Malherbe V, Sebire G, Hollenberg H, Tardieu M, Landrieu P: Neurogenic bladder in children with acute transverse myelopathy. Arch Pediatr 5(5) 497-501, 1998

28. Lockhart JL, Walker JD, Vorstman B, et al: Augmentation cystoplasty in the management of neurogenic bladder disease and urinary incontinence. J Urol 135:969, 1986.

29. Madersbacher H, Jilg G: Control of detrusor hyperreflexia by the intravesical instillation of oxybutynine hydrochloride. Paraplegia 29:84-90, 1991.

30. McInerney PD, Vanner TF, Harris SAB, et al: Permanent urethral stents for detrusor sphincter dyssynergia. Br J Urol 61:291-294, 1991.

31. Newman E, Price M: External catheters: Hazards and benefits of their use by men with spinal cord lesions. Arch Phys Med Rehabil 66:310-313, 1985.

32. Niefrach WL, Davis RS, Tometi FW, et al: Extracorporeal shock-wave lithotripsy in patients with spinal cord dysfunction. Urology 38:152-156, 1991.

33. Ross JC, Gibbon NOK, Sham Sunder G: Division of the external urethral sphincter in the neuropathic bladder: A 20 year's review. Br J Urol 48:649-656, 1976.

34. Sidi AA, Becher EF, Reddy PK, et al: Augmentation enterocystoplasty for the management of voiding dysfunction in spinal cord injury patients. J Urol 143: 83-85, 1990.

35. Sires Trop C, Bennett CJ: Automatic dysreflexia and its urological implications: A review. J Urol 146:1461-1469, 1991.

36. Sislow JG, Mayo ME: Reduction in human bladder wall compliance following decentralization. J Urol 144:945-947, 1990.

37. Staskin DR: Hydronephrosis after spinal cord injury: Effects of lower urinary tract dysfunction on upper tract anatomy. Urol Clin North Am 18:309-316, 1991.

38. Stickler DJ, Chawla JC: An appraisal of antibiotic policies for urinary tract infections in patients with spinal cord injuries undergoing long-term intermittent catheterization. Paraplegia 26:215-225, 1988.

39. Tanagho EA, Schmidt RA, Orvis BR: Neural stimulation for control of voiding dysfunction: A preliminary report in 22 patients with serious neuropathic voiding disorders. J Urol 142:340-345, 1989.

40. Webb RJ, Styles RA, Griffiths CJ, et al: Ambulatory monitoring of bladder pressure in low compliance neurogenic bladder pressure dysfunction. J Urol 148:1477-1488, 1992.

41. Wein AJ, Malloy TR, Shofer F, et al: The effects of bethanechol chloride on urodynamic parameters in normal women with women with significant residual urine volumes. J Urol 124:397-399, 1980.

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TABLE 1 Functional Classification of the Neurogenic Bladder

	Bladder Factors	Outlet Factors
Failure to store	Hyperreflexia	Denervated pelvic floor
	Decreased compliance	Bladder neck descent
		Intrinsic bladder neck sphincter failure
Failure to empty	Areflexia	Detrusor-sphincter dyssynergia (striated sphincter and bladder neck)
	Hypocontractility	Nonrelaxing voluntary sphincter
		Mechanical obstruction (benign prostatic hypertrophy or stricture)

TABLE 2 Urodynamic Definitions

BLADDER	
Hyperreflexia	Uninhibited contractions of the detrusor during filling due to neurological disease
Hypocontractility	Unsustained contractions causing failure to empty
Areflexia	Absent contractions with attempt to void
Compliance	Change in volume divided by change in baseline pressure with filling (<10 mL/cm H_2O abnormal; 10–20 mL/cm H_2O borderline if capacity reduced)
OUTLET	
Detrusor-sphincter dyssynergia	
1. At bladder neck	Usually in high quadriplegic patients with autonomic hyperactivity
2. At striated sphincter	Uncoordinated pelvic floor and striated sphincter contraction with detrusor contraction during attempts to void
Nonrelaxing sphincter	Poor voluntary relaxation of voluntary sphincter in patients with areflexia attempting to void by Valsalva's maneuver
Decreased outlet resistance	Incontinence due to damage to the bladder neck or striated sphincter, pelvic floor descensus, or denervation

TABLE 3 Bladder Management Options

Failure to store	
Bladder factors	
Behavioral	Timed voids
Collecting devices	Diaper, condom catheter, indwelling catheter
CIC	With drugs to lower bladder pressure
Drugs	Anticholinergics, musculotropics, intrathecal baclofen,* calcium channel blockers*
Surgery	Augmentation, continent diversion, denervation procedures*
Outlet factors	
Behavioral	Timed voids, pelvic floor exercises
Collecting devices	Diaper, condom catheter, indwelling catheter
Drugs	α-Agonists, imipramine, estrogens
Surgery	Collagen injection, fascial sling, artificial sphincter, Teflon injection*
Failure to empty	
Bladder factors	
Behavioral	Timed voids, bladder stimulation, Valsalva's and Credé's maneuvers
Collecting devices	Indwelling catheter
CIC	
Drugs	Bethanechol
Surgery	Neurostimulation*
Outlet factors	
Behavioral	Anal stretch void
Collecting devices	Indwelling catheters
CIC	
Drugs	α-Blockers, oral striated muscle relaxant, intrathecal baclofen*
Surgery	Sphincterotomy incision, bladder neck incision, prostate resection, pudendal neurectomy,* stent sphincterotomy*
Failure of storage and emptying with nonusable urethra	
Surgery	Suprapubic catheter ± bladder neck closure, ileal conduit

*Experimental or nonstandard management.
Abbreviation: CIC, clean intermittent catheterization.