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**The Free Neurovascular Transfer of *Latissimus dorsi*
Muscle for Treatment of Bladder Detrusor Acontractility -
Retrospective Clinical Study and
Description of the Surgical Technique**

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1 Introduction and purpose of this study

1.1 Introduction

Bladder acontractility or permanent detrusor dysfunction is a debilitating disorder affecting relatively young people. The underlying abnormality may be due to damage to the detrusor muscle itself, its autonomic nerve supply, the spinal micturition center or the upper motor neuron system. Possible causes include congenital anomalies (meningomyelocele, myelodysplasia), acquired infectious or inflammatory diseases, autoimmune diseases and central or peripheral nerve injuries secondary to trauma or degenerative disease.

In the past the only treatment option available for bladder acontractility due to a lower motor neuron lesion was lifelong intermittent catheterization with its inherent risks of urethral laceration, bladder perforation, urinary tract infection and deteriorating renal function. Several experimental studies investigating restoration of detrusor function and voluntary bladder emptying by functional electrical stimulation, direct bladder surface stimulation and detrusor myoplasty have been published [Brindley 1990; Nashoid 1981].

Unfortunately, these approaches are not feasible in cases of dysfunction of the spinal micturition center, sacral motor root, pelvic or intramural nerve or neuromuscular end plate.

Initial attempts to use pedicled muscle flaps like rectus abdominis, gracilis or rectus femoris as a substitute for the acontractile detrusor have been hampered either by their size, muscle configuration or neurovascular supply [Chancellor 1994; Ebner 1992; Messing 1985; Zhang 1990]. Latissimus dorsi muscle transfer (LDDM), developed by Ninkovic and Stenzl, provides a suitable neurovascular pedicle, muscle size and configuration of muscle fibers [Stenzel and Ninkovic 1997; Manktelow 1989].

2.2 Purpose of the Study

Analysis of the Problem: Failure to evacuate urine

Under normal circumstances, the urinary bladder empties completely. Failure to evacuate urine results from reduced smooth muscle content, decreased smooth muscle contractility, loss of proper neural input, excessive bladder outlet resistance, or any combination of these conditions. Absolute or relative failure of the detrusor to contract may derive from a temporary or permanent alteration in the neuromuscular mechanisms necessary for initiating and maintaining a detrusor contraction. This includes not only loss of communication between a nerve terminal and muscle cell but also communication between muscle cells. Inhibition of the micturition reflex in a neurologically intact individual may occur by means of a reflex mechanism—for example, due to a painful stimulus, generated in the pelvis and perineum. Nonneurogenic causes include impairment of bladder smooth muscle contractility such as may occur following ischemia and metabolic disturbance, severe infection, or fibrosis. Increased outlet resistance can result from anatomic obstruction or failure of coordination of the smooth or striated sphincters during a bladder contraction. Treatment for failure to empty the bladder incorporates attempts to increase intravesical pressure, facilitate the micturition reflex, or decrease outlet resistance.

Within the appropriate social constraints and normal fluid intake and renal function, adult humans urinate up to nine times a day and once or never during 8 hours of sleep. However, as with most human behaviors there is a distribution of these values, and the definition of normal is difficult. The function of the bladder for greater than 99% of a 24-hour period is urine storage under low pressure (less than 10 cm H₂O).

Failure of the bladder to fill at low pressure and store urine may be related to the bladder, the outlet (bladder neck, urethra, and external urethral sphincter), or both.

2 Anatomical Considerations

The urinary bladder is an extraperitoneal organ that is abdominal in position in young (< 6 year old) patients and a pelvic organ after the pelvis has developed sufficiently. It is situated behind the symphysis pubis and depending upon the degree of distension may be palpated in the lower abdomen. While the body (fundus) of the bladder freely expands and contracts, the bladder neck is firmly fixed to the urethra and other ligaments in the deep pelvis.

The bladder is a hollow organ that has an inner epithelium lined with transitional epithelium. The muscular wall is composed of bundles that decussate longitudinally and circularly. The musculature of the trigone is superimposed on the bladder muscle and forms the thickest and most fixed portion of the bladder. The distance between the orifices in the trigone is 3 cm to 4 cm. The ureters enter the bladder posteriorly and inferiorly. At the point where the ureter meets the adventitia of the bladder, it is encased in Waldeyer's sheath which extends from the ureteral orifice to where it fuses with the musculature of the ureter. The ureteral path through the vesical wall is oblique to where it enters the bladder at the trigone. (Figures 1 and 2)

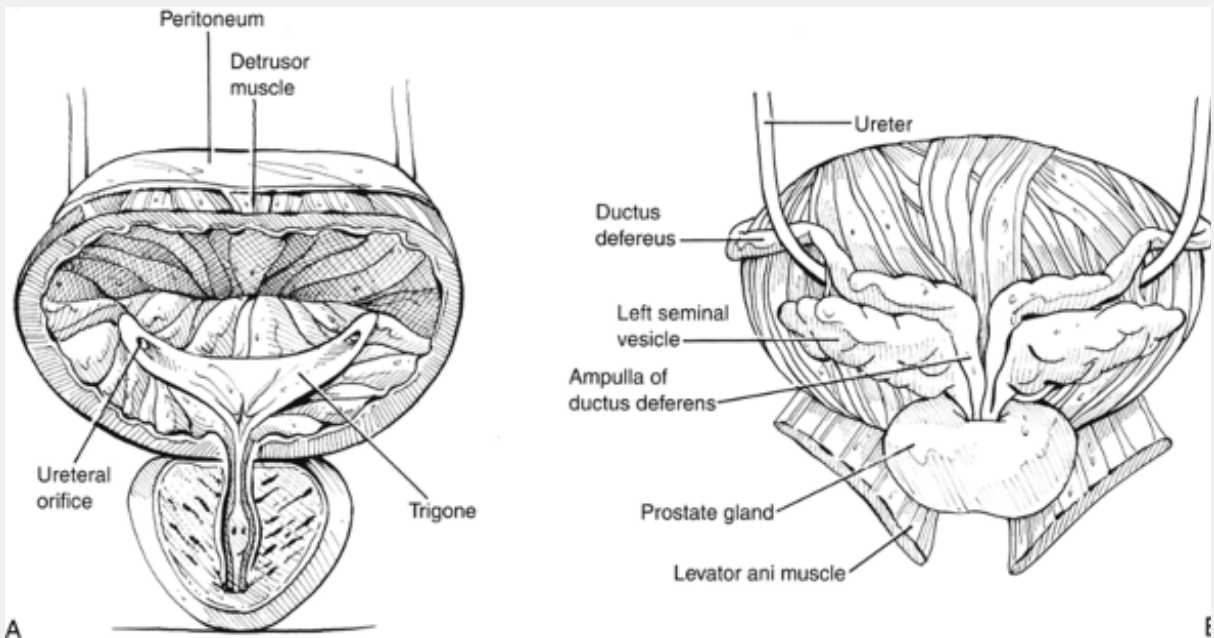


Fig. 1: (A) Anterior view of the bladder of a male opened and demonstrating intravesical anatomy. Note the trigone continues into the prostatic urethra. (B) Posterior view of the bladder of a male demonstrating the relationship of the seminal vesicles, vas deferens, and ureters.

From Graham SD, Keane TE, Glenn JF. Glenn's Urologic Surgery, 6th Edition Lippincott Williams & Wilkins

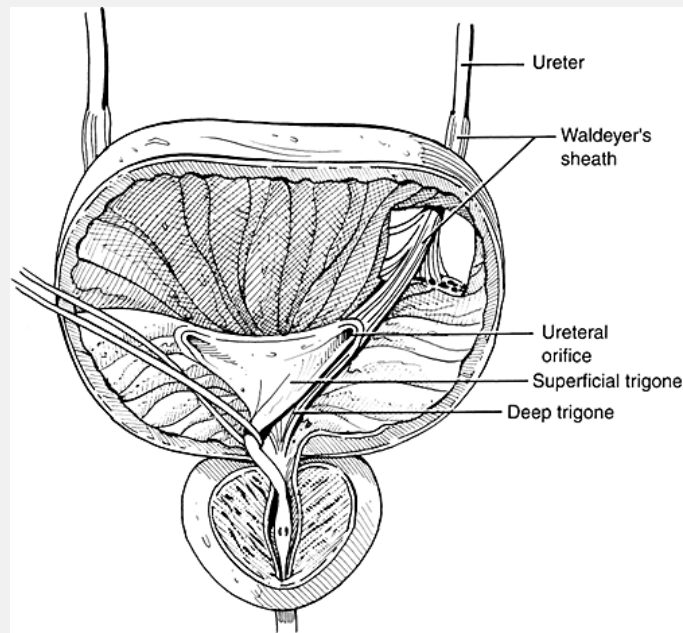


Fig. 2: Lateral view of ureter as it enters the bladder via the intramural tunnel. Note Waldeyer's sheath extends from the bladder to encase the distal ureter just proximal to the bladder and fuses to the ureteral musculature. Waldeyer's sheath is a continuation of the deep trigone and connects by a few fibers to the detrusor muscle at the ureteral hiatus.

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Superiorly and, to some extent, posteriorly the bladder is covered with peritoneum. The peritoneum forms the Pouch of Douglas at its most caudal extent behind the bladder. The two leaves of the peritoneum embryologically coalesce to form the anterior and posterior layers of Denonvillier's fascia (rectovesical fascia) (Figure 3).

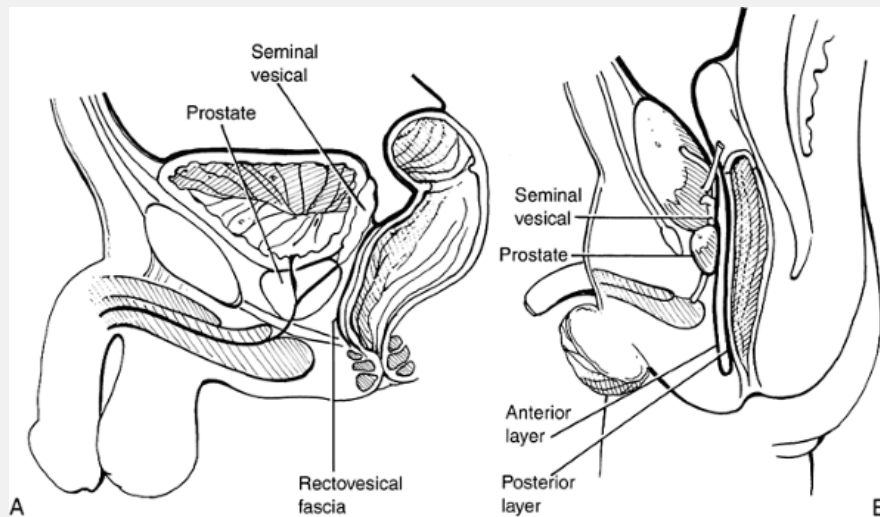


Fig. 3: Lateral view of the male pelvis showing (A) the peritoneal reflection and the pouch of Douglas and (B) the formation of Denonvillier's fascia in the fetus.

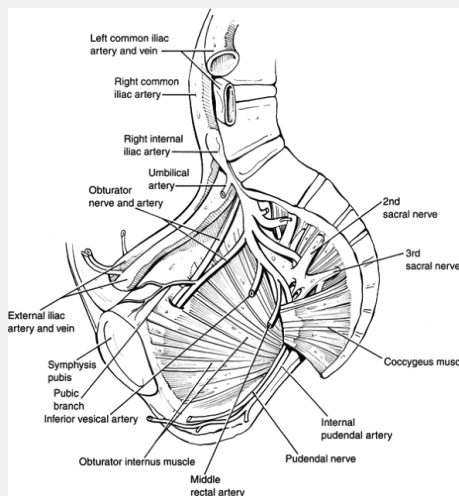


Fig. 4: Lateral pelvic side wall demonstrating the vasculature and innervation of the deep pelvis. The arterial supply of the bladder is from the superior lateral vesical artery and the inferior vesical artery enclosed in the posterior pedicle.

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The lateral vesical ligaments are a continuation of the pelvic fascia and contain the inferior and vesicodiferential arteries in the lateral extensions as well as the vasa

deferentia in males, and the pudendal plexuses of nerves and vessels. Inferiorly, this blends with the fascia lining the levator ani and laterally with the fascia of the obturator internus.

Aside from the fixation of the bladder to the lateral vesical ligaments or its base to the lateral pelvic side wall and levator ani, the bladder is also fixed to the symphysis pubis by the pubovesical ligaments in females and puboprostatic ligaments in the male. Between these paired ligaments passes the dorsal vein of the clitoris or penis, respectively. These ligaments form the anteromedial portion of the space of Retzius. The space of Retzius is bound anteriorly by the transversalis fascia, the puboprostatic (pubovesical) ligaments inferiorly, and infralaterally by the lateral ligaments of the bladder.

2.1 Relations of the Male Bladder to Adjacent Organs

The relations of the bladder to adjacent organs correlate closely with its relations to the pelvic connective tissue and peritoneum.

Peritoneal Covering of the Bladder

The bladder is attached to the peritoneum by loose connective tissue. This enables it to function as an expansile urinary reservoir that is mobile with respect to the peritoneum. Only a greatly distended bladder is fixed by its peritoneal covering (Fig. 5). The parietal peritoneum is continued from the anterior abdominal wall onto the bladder apex and covers the posterior surface of the bladder to the level of the tips of the seminal vesicles, sometimes extending to the level of the ureteral orifices. There the peritoneum is reflected onto the anterior wall of the rectum to form the rectovesical pouch, which is the lowest point of the peritoneal cavity. The entrance to the rectovesical pouch is bounded by the two sagittally oriented rectovesical folds.

These peritoneal folds are backed with connective tissue that provides posterior support for the bladder base.

The peritoneum is recessed between the bladder and anterior abdominal wall to form the supravescical fossae



Fig. 5: Midsagittal section through the pelvis.

from Mitchell, ME. Surgical Anatomy of the Genitourinary System: Pelvis Part 1 Adult & Pediatric Urology, 4th Edition

The right and left supravescical fossae are separated by the median umbilical fold. The supravescical fossa is bounded laterally by the medial umbilical fold. The peritoneal covering of the posterior bladder wall contains a reserve fold of peritoneum, the transverse vesical fold, which is progressively obliterated as the bladder distends.

Bladder and Pelvic Connective Tissue

The pelvic connective tissue consists of three main parts: the pelvic fascia (parietal and visceral), the neurovascular sheaths, and the loose connective tissue occupying the spaces of the pelvic viscera.

The visceral pelvic fascia is derived from the parietal pelvic fascia above the urogenital diaphragm at the site where the urethra pierces the diaphragm. The visceral fascia is reflected onto the prostate, and it invests the bladder as the vesical fascia.

The neurovascular sheaths are sheetlike condensations of intrapelvic connective tissue that invest and transmit nerves and blood vessels and that also perform retinacular functions. Portions distributed to the bladder and prostate assist in the fixation of the bladder base. The puboprostatic ligament (pubovesical ligament) extends from the symphysis and adjacent portions of the pubic bone to the prostate and continues onto the bladder neck. It binds the prostate and bladder to the anterior pelvic wall. The paracystic connective tissue (bladder retinaculum) passes to the bladder from the lateral pelvic wall. Between the paracystic connective tissue and pararectal connective tissue (rectal retinaculum) is the rectovesical septum, which represents the central portion of the lateral neurovascular sheath.

Loose connective tissue occupies the spaces between the condensations of the neurovascular sheaths and visceral fasciae. The prevesical space located between the anterior abdominal wall and bladder is bounded anteriorly by the transversalis fascia and posteriorly by the vesical fascia. The prevesical space is continuous inferiorly with the retropubic space. This space is bounded anteriorly by the posterior surface of the pubic symphysis, posteriorly by the prostatic fascia, and inferiorly by the urogenital diaphragm.

The rectovesical and retropubic spaces communicate laterally with the paravesical space. This mobile tissue plane is bounded posteriorly by the paracystic connective tissue, medially by the vesical fascia, and laterally and inferiorly by the parietal pelvic fascia.

Between the rectum and bladder is the rectovesical space. The rectovesical septum and the seminal vesicles subdivide this space into two separate compartments termed the vesicogenital space and the rectogenital space (Fig. 6).



Fig. 6: Paramedian section through the pelvis.

From: Mitchell, ME. Surgical Anatomy of the Genitourinary System: Pelvis Part 1 Adult & Pediatric Urology, 4th Edition

Vessels and Nerves of the Bladder

The arteries of the bladder may arise directly from the internal iliac artery or from one of its visceral branches.

The superior vesical artery is almost always multiple. Usually, there are two superior vesical arteries, their number ranging from one to four. The superior vesical arteries generally arise from the patent, unobliterated portion of the umbilical artery but occasionally are derived from the obturator artery (4.5%). They supply the base and body of the bladder and generally anastomose with the inferior vesical artery.

The inferior vesical artery is usually a direct branch of the internal iliac but may arise from a nearby vessel such as the internal pudendal artery (25%) or inferior gluteal artery (4%). It supplies the bladder base in addition to the prostate and seminal vesicles.

The veins of the bladder commence as intramural plexuses. The larger vessels emerging from the bladder wall form the vesical plexus, which communicates with the venous plexus of the prostate. Both plexuses drain into the internal iliac vein.

The lymph vessels of the bladder communicate with one another in the paravesical space and may end directly at the external iliac and interiliac lymph nodes or may reach them by way of smaller nodes (anterior, lateral, and posterior vesical nodes). Connections with the internal iliac lymph nodes are occasionally observed.

The nerves supplying the bladder are derived from the pelvic plexuses (Fig. 4). The parasympathetic fibers (pelvic splanchnic nerves) of these plexuses originate from the second to fourth sacral segments and supply the detrusor muscle. The sympathetic fibers reach the vesical plexus from the first two lumbar segments by way of the hypogastric plexus.

2.2 Relations of the Female Bladder to Adjacent Organs

The relations of the female bladder to the pelvic connective tissue are obviously gender specific. The parietal fascia of the pelvic floor is reflected onto the bladder at the bladder neck to form the vesical fascia.

The pubovesical ligaments in the female pelvis, derived from the intrapelvic neurovascular-retinacular sheaths, bind the bladder to the pubic symphysis.

The paracystic connective tissue passes from the lateral pelvic wall to the bladder. Tough connective-tissue fibers are distributed to this tissue from the cardinal ligament of the uterus.

The relation of the loose connective tissue to the female bladder is the same anteriorly (prevesical space) and laterally (paravesical space) as in the male. Posteriorly, between the body of the bladder and the cervix, loose connective tissue occupies the vesicouterine space. The vesicovaginal space is located more caudally between the bladder base and the front of the vagina.

The relation of the female bladder to the pelvic connective tissue accounts in large part for its relations to adjacent organs.

The female urethra has two clinical subdivisions: a superior part and an inferior part. The superior part, comprising the cranial one-fourth of the urethra, can move relative to the vagina because of the loose connective tissue in the urethrovaginal space. The inferior part lacks a true space, and in that area, the vagina and urethra are fused together by their visceral fasciae. The anterosuperior portion of the female urethra is fixed by the lowermost fibers of the pubovesical ligaments, known also as the pubourethral ligaments.

2.3 Anatomy of the *Latissimus dorsi* muscle:

The latissimus dorsi muscle is a large muscle of the back and shoulder, and its vascular supply for free transfer is based on the subscapular-thoracodorsal system.

The pedicle is lengthy (8 to 11 cm) and has a relatively large diameter proximally (up to 6 mm) [Bailey 1982; Jones 1983].

The advantages of this muscle are that it has a totally reliable vascular supply and innervation, adequate strength and range of excursion (configuration), suitable size and topography and minimal donor site morbidity.

It can be raised as a musculocutaneous flap or harvested with the entire subscapular axis to include up to two muscles (latissimus and a portion of the serratus anterior), a fasciocutaneous paddle, and vascularized bone; but for most indications in the upper extremity, the muscle only is taken and covered with a split-thickness skin graft. The donor site is easily closed, but seroma formation is a common sequelae. The functional morbidity from the loss of muscle is minimal in most patients.

The vertebral part of the latissimus dorsi muscle arises from the spinous processes of the fifth through twelfth thoracic vertebrae and its iliac part from the lumbodorsal fascia and the posterior iliac crest. The costal part of the latissimus dorsi muscle arises from the external surfaces of the tenth through twelfth ribs, and a variable scapular part originates from the inferior angle of the scapula. The fibers of the latissimus dorsi pass laterally upward with varying degrees of obliquity to the humerus, where they insert into the crest of the lesser tubercle.

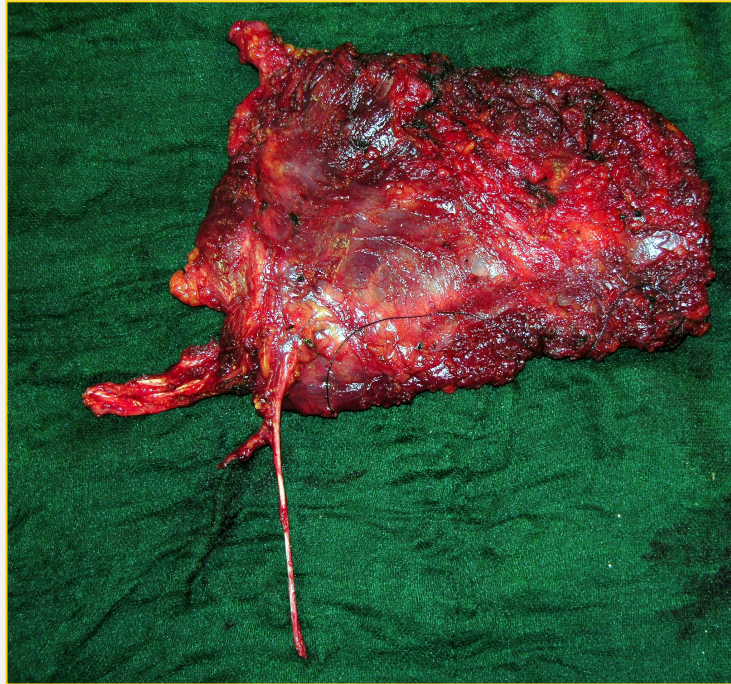


Fig. 8: Intraoperative view of *Latissimus dorsi* muscle with neurovascular pedicle after harvesting.

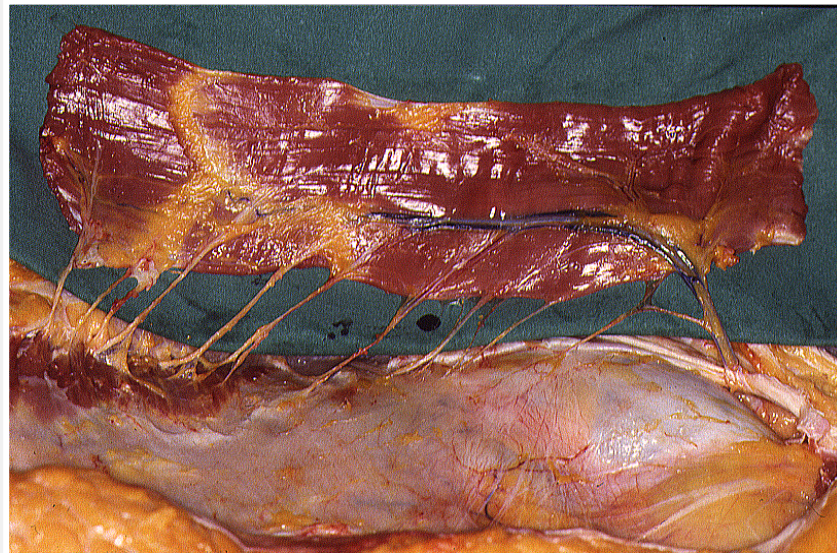


Fig. 9: Cadaver Dissection: View of the recipient nerves on the lateral border of rectus abdominis muscle (**lowermost intercostal nerves**) and recipient vessels: **deep inferior epigastric vessels**

3 Classification of Voiding Dysfunction

3.1 Lapedes Classification

Lapedes contributed substantially to the classification and care of patients with neuropathic voiding dysfunction and popularized a modification of a scheme originally proposed by McLellan in 1939. [Lapedes 1976]

The systems are virtually identical except that Lapedes further divided McLellan's category of autonomic bladder into motor neurogenic and sensory neurogenic bladder. The Lapedes classification is the scheme most familiar to urologists and describes the clinical and cystometric conditions in most types of neurogenic voiding dysfunction. In the uninhibited neurogenic bladder and reflex neurogenic bladder groups, the exact categorization further implies whether the striated sphincter is dyssynergic (reflex neurogenic bladder) or synergic (uninhibited neurogenic bladder) during bladder contraction. A sensory neurogenic bladder results from any disease that selectively interrupts the afferents between the bladder and spinal cord or the afferent tracts to the brain. Whether lightly myelinated (A δ) or unmyelinated fibers transmit sensation and pressure in humans is unclear. The distinction may become important as therapies are developed. Ice water tests and electrosensory threshold data indicate that more than one functional type of bladder afferent probably exists in humans. Classically, a sensory bladder is seen with long-standing diabetes mellitus, tabes dorsalis, and pernicious anemia. The first clinical changes consist only of impaired sensation of bladder distention. Unless voiding is initiated out of habit or on a timed basis, varying degrees of bladder overdistention are thought to lead to hypocontractility. With bladder decompensation, significant amounts of residual urine usually are found, and the cystometric curve many times demonstrates a large bladder capacity with a flat, low-pressure filling curve (high compliance). It was

thought that the bethanechol supersensitivity test was positive in the early stages, but later negative as decompensation of the bladder smooth muscle occurred. The neurobiologic basis for this scheme has been shown to be conceptually flawed. Sensory nerves—or, more appropriately, afferents—from the bladder contain neuropeptides, including substance P, calcitonin gene-related peptide (CGRP), and vasoactive intestinal polypeptide (VIP). If Canon's laws of denervation hold, loss of these peptides should not cause hypersensitivity to the cholinergic agent bethanechol.

A motor paralytic bladder results from disease processes that destroy the parasympathetic motor innervation of the bladder. Extensive pelvic surgery or trauma can produce a motor paralytic bladder. Interestingly, herpes viruses affect dorsal root ganglia (afferents), and their destruction may abolish afferent input necessary for reflex micturition. Theoretically, if myelinated (A δ) afferents mediating reflex micturition are destroyed, unmyelinated axons may still mediate sensation, but a distention-evoked reflex is abolished. This condition would appear to be a paralytic bladder; thus older schemes may list herpetic bladder disorders as motor paralytic. Consistent with this notion, early symptoms may vary from painful urinary retention to a relative inability to initiate and maintain normal micturition. In early stages, the filling limb of the cystometrogram is normal with normal sensation, but without a voluntary bladder contraction at bladder capacity. Later, chronic overdistention and bladder decompensation may occur, and a large-capacity bladder with a flat low-pressure filling limb and generally large residual urine volume will result. Again, the bethanechol test is reported to be positive despite, in some instances, a lack of anatomic and pharmacologic evidence for true afferent denervation.

The uninhibited neurogenic bladder is the most common manifestation of neurogenic pathology. A destructive lesion in many regions of the neuraxis can result in facilitation of the micturition reflex. Cerebrovascular accident, brain or spinal cord tumor, Parkinson's disease, and demyelinating disease are the most common causes of this type of lesion. These diseases generally result in a voiding dysfunction characterized clinically by frequency, urgency, and incontinence, and cystometrically by normal sensation with an involuntary detrusor contraction at low filling volumes. Nerve irritation or early degeneration, such as with neuropathies and herniated discs, can also elicit involuntary detrusor contraction. Residual urine is characteristically small or absent unless anatomic outlet obstruction or true involuntary smooth or striated sphincter dyssynergia occurs. The patient can initiate a bladder contraction voluntarily but is often unable to do so during cystometry because of insufficient urine storage before onset of detrusor hyperreflexia.

The term reflex neurogenic bladder describes the post-spinal shock condition after complete interruption of the sensory and motor pathways between the sacral spinal cord and the pontine micturition center. This develops in traumatic spinal cord injury and transverse myelitis and may occur with extensive demyelinating disease, tumor, or ischemia injury. Typically, the patient has absent bladder sensation and is unable to voluntarily initiate micturition. Incontinence ensues because of low-volume detrusor hyperreflexia, which coincides with striated-sphincter dyssynergia.

An autonomous neurogenic bladder denotes a complete motor and sensory separation of the bladder from the sacral spinal cord. Any disease process that destroys the sacral spinal cord or causes extensive damage to the sacral roots or pelvic nerves may result in this condition. The patient is unable to void voluntarily. Cystometry reveals detrusor areflexia and absent bladder sensation. This type of

bladder is equivalent to the complete lower motor neuron lesion in the Bors-Comarr system and represents parasympathetic decentralization. This is also the type of dysfunction seen in patients with spinal shock until a spinal reflex develops to initiate micturition weeks to months later. The characteristic cystometric pattern is initially similar to the late stages of the motor or sensory paralytic bladder, with a marked shift to the right of the filling curve and a large bladder capacity at low intravesical pressure. However, secondary changes in the filling limb may occur that cause an increase in slope (decreased compliance). This may be secondary to chronic inflammatory change or to the effects of the denervation, with secondary neuromorphologic and neuropharmacologic changes, especially in regulation of α -adrenergic receptors or reorganization of sympathetic pathways. Emptying in an autonomous neurogenic bladder may vary from none to a large percentage of bladder capacity, depending on the resistance offered by the bladder outlet.

3.2 Urodynamic Classification

Evolution of this type of classification system has paralleled urodynamic expertise and, in the United States, has been pioneered by Krane and Siroky.[Siroky 1979] When exact urodynamic classification is possible, this system provides a precise description of the particular voiding dysfunction. If a normal or hyperreflexic detrusor exists with coordinated smooth and striated sphincters and without anatomic obstruction, the bladder should empty completely. Striated-sphincter dyssynergia is most commonly seen in patients with a complete suprasacral spinal cord injury after the period of spinal shock has passed. Smooth-sphincter dyssynergia is seen most in autonomic dysreflexia when it is characteristically associated with detrusor hyperreflexia and striated-sphincter dyssynergia. Detrusor hyperreflexia can occur in

nearly all neurologic lesions above the sacral spinal cord, may be associated with inflammatory or infectious disease, or may be idiopathic. Detrusor areflexia may be secondary to bladder muscle decompensation or to various other conditions that produce inhibition at either the level of the brainstem micturition center, sacral spinal cord, bladder ganglia, or bladder smooth muscle. Areflexia also ensues if the sacral autonomic nucleus is destroyed. Patients with a voiding dysfunction that falls into this category often attempt bladder emptying by abdominal straining or a Credé manoeuvre. Their continence status and the efficiency of their emptying efforts are determined by the status of the smooth and striated sphincters of the outlet.

This classification system is best applied when detrusor hyperreflexia or normoreflexia exists, because urodynamic techniques exist to describe the activity of the smooth and striated sphincters during bladder contraction. Thus a typical T-10 paraplegic patient exhibits detrusor hyperreflexia, smooth-sphincter synergia, and striated-sphincter dyssynergia. When a voluntary or hyperreflexic bladder contraction cannot be elicited, this system is inadequate because it is not appropriate to speak of true dyssynergia in the absence of an opposing bladder contraction.

Rare and difficult to diagnose is smooth muscle or internal-sphincter dyssynergia. Although it often occurs with thoracic spinal cord lesions associated with detrusor hyperreflexia and external-sphincter dyssynergia, isolated pathology may exist. A young, anxious male with functional obstruction isolated to the bladder neck and proximal urethra may represent a spectrum of this disorder. A high urethral pressure at the bladder neck, and a fall in pressure over this region during voiding or fluoroscopic lack of opening during bladder contraction, help diagnose the pathology. Smooth muscle dyssynergia or nonrelaxation of the bladder neck probably results from overactivity of adrenergic nerves. Therefore lesions of the thoracolumbar spinal

cord, where sympathetic outflow originates, have also been reported to cause this disorder.

Functional System

Classification of voiding dysfunction can also be formulated on a functional basis, describing the dysfunction simply in terms of whether the deficit produced is primarily one of the filling or storage phase of micturition or of the emptying phase (Table 1). This type of classification system is an excellent alternative when a particular dysfunction does not lend itself to an agreed-on classification in one of the other systems. This system has been promoted primarily because of dissatisfaction with attempts to exactly classify voiding dysfunction based solely on urodynamics or neurological lesions.

This simple scheme is based on an agreement of the principles governing micturition. Bladder filling and urine storage require accommodation of increasing volumes of urine at a low intravesical pressure and with normal and appropriate sensation; absence of involuntary bladder contractions; and a bladder outlet that is closed at rest and remains so with stress. Storage failure can then result because of problems related to bladder hyperreflexia or low compliance and because of a permanent or intermittent decrease in outlet resistance. Bladder emptying requires a coordinated bladder contraction of adequate magnitude and lack of anatomic obstruction and concomitant lowering of resistance at the level of the smooth and striated sphincter. Failure to empty can then result from inadequate bladder contractility or increased outlet resistance. Failure in either category generally is not absolute but is more often relative.

Failure to Store*Because of the Bladder*

Detrusor hyperactivity

Involuntary contractions

Suprasacral neurologic disease

Bladder outlet obstruction

Idiopathic

Decreased compliance

Fibrosis

Idiopathic

Sensory Urgency

Inflammatory

Infectious

Neurologic

Psychologic

Idiopathic

Because of the Outlet

Stress Incontinence

Nonfunctional bladder neck/proximal urethra

Failure to Empty*Because of the Bladder*

Neurologic

Myogenic

Psychogenic

Idiopathic

Because of the Outlet

Anatomic

Prostatic Obstruction

Bladder neck contracture obstruction

Urethral structure

Functional

Smooth-sphincter dyssynergia

Striated-sphincter dyssynergia

TABLE 1: Expanded Functional Classification of Voiding Dysfunction

3.3 Investigational Procedures

Urodynamics

Urodynamics is an operator-dependent and interactive study best performed with physician participation. Basic urodynamic modalities include cystometry with residual volume determination, uroflowmetry (voiding flow rate), leak-pressure evaluation (abdominal and detrusor), urethral pressure profilometry (static and dynamic), and combined studies (with or without fluoroscopy). The type of these tests and sequence in which they are administered is dependent on the presenting symptoms, associated findings, and presumptive diagnosis based on other neurourologic tests.

Cystometry

Cystometry measures changes in intravesical pressure with progressive increases in bladder volume. A cystometrogram (CMG) evaluates the filling or storage phases of detrusor function. The presence or absence of a detrusor contraction, although an important observation, is not the only important information from this test.

Schematically, a normal CMG may be divided into four phases. There is an initial rise in pressure to achieve resting bladder pressure (phase I). The second phase—the tonus limb—is thought to reflect the viscoelastic properties of the smooth muscle, collagen, elastin, and mucopolysaccharides of the bladder wall. Distention may also release autocrinelike factors that influence contractility [e.g., parathyroid hormone–related protein, prostaglandin, peptides, and nitric oxide (NO)]. During the filling or storage phase, bladder pressure should rise very little because the normal bladder is designed to accommodate increasing urine volumes at low pressure. Normal adult bladder capacity averages 400 to 750 mL. Within this capacity, bladder pressure should not exceed 15 cm H₂O; the mean rise in normal bladders is 6 cm H₂O. Rapid filling may generate a steeper tonus limb (phase II). Bladder wall fibrosis due to

infection, radiation, and detrusor hypertrophy may also reduce accommodation and produce a steeper tonus limb. At peak capacity, the detrusor muscle and other elastic tissues achieve maximal elongation, and any additional increase in volume will be accompanied by a rise in intravesical pressure. During this third stage (phase III), the patient should still be able to suppress involuntary voiding contractions. Ruch and Tang believed that the characteristic shape of the cystometry curve is independent of neural control and is an inherent property of the structural elements of the bladder wall. More recent data with lesioning in animals or after intrathecal drugs in humans contradicts this notion, because acute changes in the tonus limb can occur with alterations in neural input.

The fourth phase of the normal CMG is the generation of a voluntary voiding that is dependent on smooth muscle and intact neural pathways to the micturition center located in the brainstem. A normal patient should be able to suppress voiding even at capacity. In at least 20% of CMG studies, the patient is unable to generate a micturition reflex on command. This has been attributed to psychologic supraspinal inhibition resulting from the unnatural circumstances of the study. Performance of this phase of the cystometrogram with the male patient in an erect posture and the female patient seated on a commode may facilitate a micturition reflex. Some patients with spinal cord injuries report that reflex voiding occurs only in certain positions. Formerly, urologists thought that compression of the urethra caused such difficulty. It is more likely that stimulation of sacral dermatomes reflexly inhibits micturition. Thus patients can void in the decubitus position but not in the seated position.

In the absence of detrusor contraction, diagnoses such as obstruction cannot be made urodynamically. This accounts for the observation that patients in retention,

who are not shown to be obstructed because of the lack of a possible detrusor contraction, may still benefit from surgical intervention.

The cystometric variables that may be observed during a study are those of compliance, contractility, sensation, and capacity. A stable bladder should remain so even at an unphysiologic rate of filling of 100 mL per minute or with changes in temperatures of filling. Certain patients require a slower rate of bladder filling, including patients with a known neurologic condition, those suspected of having a hyperreflexic bladder, those with bladders with decreased compliance, and children. In adults, slow filling (physiologic filling) is up to 10 mL per minute. Medium filling is defined as 10 to 100 mL per minute. Rapid filling is any value exceeding 100 mL per minute. In small-capacity or poorly compliant bladders, rates of 25 to 50 mL per minute are used. During filling, the bladder volumes are recorded at (a) first sensation of filling, (b) sensation of urgency to void, and (c) sensation of maximum capacity. During the filling, provocative measures such as coughing and the Valsalva maneuver should be used to uncover involuntary contractions. The total pressure (P_{ves}) measured within the bladder is intravesical pressure, which is the sum of the pressure induced by the detrusor (P_{det}) and by intraabdominal pressure (P_{abd}). Therefore a rise in intravesical pressure recorded on a simple cystometrogram may at least partially reflect intraabdominal pressure. To eliminate such artifacts, it may be necessary to measure intraabdominal pressure simultaneously by means of a rectal catheter. Cystometers are readily available that electronically subtract the rectal pressure from the total bladder pressure, thus giving the subtracted bladder pressure, which is detrusor pressure. This measurement is crucial for provocative cystometry and for voiding studies to determine the efficiency of the voiding contraction. Subtracted pressures are the standard for measuring intravesical pressures. In this

regard, care must be taken to accurately zero the pressures at the beginning of a study. The use of microtip transducers has led to misinterpretation because these devices are difficult to accurately zero. If not properly calibrated and zeroed, cystometry combined with flow rates will provide inaccurate information concerning obstruction, detrusor compliance, and detrusor leak pressures. In essence, the test results are only as valuable as the operator.

Abnormal Cystometric Patterns

Abnormalities of bladder function that may be detected by cystometry include altered sensation, changes in detrusor compliance, disorders of detrusor contractility, and presence of involuntary detrusor contraction or detrusor areflexia.

Bladder compliance refers to the ratio of the change in bladder volume to pressure that occurs during filling. Normally, filling pressures average 6 cm H₂O and should not exceed 15 cm H₂O. A bladder with decreased compliance is one in which the pressure rises steeply with filling. Technical variables affecting the absolute value for compliance include method of calculation and rate of filling.. Reduced compliance may result from detrusor hypertrophy, fibrotic changes in the bladder wall, bladder wall inflammation, and possibly neurologic lesions.

Involuntary detrusor contraction refers to a phasic rise in bladder pressure. This may occur in response to provocation such as a cough, stress, or postural change, or it may occur spontaneously. States of increased detrusor contractility have been referred to as detrusor instability or detrusor hyperreflexia. In general, detrusor hyperreflexia refers to an involuntary bladder contraction that is a direct result of associated neurologic disease, whereas detrusor instability is seen in the absence of neurologic disease. Detrusor hyperreflexia commonly occurs as a result of suprapontine cerebral disorders, such as cerebrovascular accidents or

Parkinsonism. This may also occur in patients with suprasacral spinal cord disease processes, such as multiple sclerosis, or trauma with or without concomitant detrusor-sphincter dyssynergia.

With marked detrusor instability (or hyperreflexia), the compliance may also be reduced, probably secondary to detrusor muscle hypertrophy, and alterations in extracellular matrix such as collagen subtype.

At the most severe end of the spectrum is the noncompliant bladder with reduced capacity. Steepness of the curve can be the result of muscle contraction and reduced compliance or severe fibrosis. This may be from a neurogenic cause, although it may be seen in patients with severe outlet obstruction or inflammation. An involuntary contraction can also be masked within the rising slope of the filling curve.

A capacious bladder of normal or increased compliance may result from chronic overdistention caused by decreased sensation. This sensory abnormality can occur in the diabetic patient or from chronic outlet obstruction. It may also be a behavioral phenomenon in patients who voluntarily inhibit micturition for long periods.

Reduced or low bladder compliance ($\Delta V/\Delta P$) is 20 mL/cm H₂O (548). Compliance is determined from the reference value of pressure when the bladder is empty until maximum cystometric capacity or the initiation of a detrusor contraction. A minimal ΔP of 1 cm H₂O is used. Therefore the maximal potential value for compliance equals the volume range over which it is calculated.

Uroflowmetry

The use of urine flow rates alone has diminished in recent years. Problems with reproducibility and specificity have caused this test to fall out of favor, especially in the evaluation of BPH. However, for following patients sequentially after therapy (e.g., urethroplasty) this test remains valuable. Flow rate is the volume of fluid expelled

from the urethra per unit time. It is expressed in milliliters per second. Flowmeters record overall rate and flow pattern. Both parameters provide useful information regarding lower urinary tract function. Urine flow rate is an expression of the combined activity of the detrusor and urethra. A normal flow rate will usually indicate a good function of both organs. Conversely, a low flow rate can result from poor detrusor contractility or outlet obstruction. Thus specificity is limited. Moreover, straining can result in artificial elevations in flow rates.

Obstruction of the urethra (due to benign prostatic hyperplasia or urethral stricture) may be overcome by a more forceful detrusor contraction. Higher bladder pressures during micturition may result in a normal peak flow rate during the early stages of the obstruction, but a reduced average flow (high pressure, normal flow obstruction). Initially, the detrusor may be able to overcome increased outlet resistance, resulting in a normal flow rate. This scenario may be particularly operative in young women and men. This situation demonstrates that a normal flow rate fails to rule out obstruction. For a full definition of lower tract function, simultaneous pressure (cystometry) and flow studies during voiding are usually indicated. However, a urine flow study even by itself has some value as a screening test for other types of lower urinary tract dysfunction, such as dyssynergia; for preoperative and postoperative assessment of lower urinary tract surgery; and to study the effects of pharmacologic agents on urethral resistance and voiding efficiency.

Most data in the literature relate to measurements of flow in men younger than 55 years of age and cite norms of 15 and 25 mL per second for mean and maximum rates. Flow rates in women may also be influenced by hormones. A recent study showed that instrumentation lowered flow rates and progesterone levels influenced micturition times.

Residual Urine Volume

Residual urine volume also reflects the activity of the bladder and outlet during the emptying phase of micturition. A consistently increased residual urine volume indicates increased outlet resistance, decreased bladder contractility, or both.

Although the bladder should empty completely, residual urine consistently greater than 150 mL is often deemed clinically significant. A postvoid residual is usually measured using ultrasonography or catheterization. More recently, portable bladder scans have been used by health care professionals and patients to detect bladder capacity and retained urine after voiding or instrumentation.

The greater the residual urine, the more likely that detrusor hypocontractility exists. Absent residual urine is compatible with normal lower urinary tract function during emptying, but it does not exclude significant disorders of filling or storage (incontinence) and problems with emptying in which the intravesical pressure is still sufficient to overcome increases in outlet resistance. Typical of this latter situation is the patient with outlet obstruction as a result of benign prostatic obstruction. Initially, despite significant obstruction, the detrusor empties the bladder by contracting with a greater force, manifested as hypertrophy and increased intravesical pressure. Yet with time, the detrusor will decompensate, leading to elevated residual volumes and reduced intravesical pressures produced during voiding.

Electromyography

Electromyography (EMG) is the measurement of bioelectric potentials generated by depolarization of muscle. Smooth muscle potentials are notoriously difficult to measure. Results of bladder or urethral smooth muscle potential determinations using catheter electrodes are still experimental and often not validated. Even with

somatic muscle EMG, most of the activity detected using patch electrodes is noise rather than true neurogenic activity.

Striated muscle is innervated by motoneurons whose cell bodies lie in the anterior horn of the spinal cord. The anterior horn cell in the gray matter of the spinal cord, its axon, and all of the muscle fibers that it innervates is called a motor unit. An excitatory impulse from an anterior horn cell causes contraction of all the muscle fibers in that motor unit. The electrical discharge produced by contraction of the muscle fibers of the motor unit by their depolarization is called motor unit action potential. This may be detected by electrodes and displayed on an oscilloscope screen, computer monitor, or strip chart. Even more helpful, it may be converted to an audible sound. Individually recorded on an oscilloscope, the motor unit action potentials may exhibit biphasic, triphasic, or rarely, polyphasic configurations. In the relaxed state, the normal striated muscle is almost electrically quiescent, and only infrequent action potentials are recorded. However, with progressive muscle contraction, increasing numbers of motor units are recruited, and each motor unit fires at a more rapid rate. These firings can be individually recorded electromyographically, and the configuration of the action potentials aids diagnosis. At the point of maximum contraction, motor unit action potentials are so frequent that total overlap occurs and EMG separation cannot be achieved, resulting in an interference pattern. It takes considerable experience to interpret the various parameters recorded on an oscilloscope during sphincter EMG. During cystometric bladder filling, there should be incremental increase in EMG activity as more motor units are recruited. This has been referred to as the guarding reflex. This activity will reach a maximum near peak bladder capacity, and at the command to void, there should be sudden and persistent cessation of sphincter activity throughout voiding.

On completion of bladder emptying, resumption of baseline sphincter activity occurs. To assess external sphincter activity, the examiner should ask the patient to interrupt voiding in the middle of the stream, at which point there should be an abrupt increase in sphincter activity that should be sufficient to stop the flow. Resumption of voiding should subsequently occur. If the holding pattern is maintained, the detrusor reflex should ideally be lost in approximately 10 seconds. This inhibition of detrusor activity with external sphincter contraction is due to somatic afferent input to the spinal cord, which can inhibit autonomic outflow to the bladder.

Abnormal EMG patterns may be detected in a number of situations. Detrusor-sphincter dyssynergia describes sphincter activity that is inappropriate to the activity of the detrusor. Three varieties of such incoordination have been described. One pattern involves an appropriate increase in EMG activity with bladder filling, which is followed by inappropriate involuntary increase in activity at the onset of detrusor contraction. Thus the detrusor contracts against a closed sphincter.

A second type of incoordination involves failure to develop an adequate reflex detrusor contraction because of increased EMG activity during voiding, which inhibits the detrusor motor nucleus in the sacral spinal cord, with resultant loss of detrusor contraction. This type of incoordination may be seen in patients with suprasacral spinal cord injury.

The third type involves contraction and relaxation of the sphincter during bladder filling. This amounts to periods of uninhibited sphincter relaxation, which is associated with reflex detrusor contraction leading to urgency and urge incontinence.

Simultaneous EMG activity with an increase in intravesical pressure does not uniformly indicate sphincter dyssynergia. Detrusor striated-sphincter dyssynergia is the most difficult and overdiagnosed entity in the field of voiding dysfunction. Patients

suspected of having this diagnosis should always be further investigated with urodynamic or radiologic evaluation to study activity of the bladder and the outlet during the emptying phase of micturition and the spinal cord to exclude neurologic disease. True detrusor striated-sphincter dyssynergia should exist only in patients who have an abnormality in pathways between the sacral spinal cord and brain, usually due to neurologic disease or injury. Such a diagnosis in a patient without such pathology deserves exhaustive study to exclude a neural cause.

In general, dyssynergia cannot occur unless a lesion resides between the pons and sacral spinal cord.

Interpretation is clouded by a voluntary contraction of the pelvic floor that occurs with a Valsalva maneuver and by voluntary contraction of the striated urethral sphincter as a method to abort urgency, both examples of so-called pseudodyssynergia.

The bulbocavernosus reflex is a crossed response, and it is therefore possible to stimulate on one side and record from both sides the ipsilateral and contralateral bulbocavernosus muscles. This is useful in detecting subtle abnormalities that affect only a single afferent or efferent pathway. It is possible to evaluate the right and left afferent and efferent pathways individually. The normal bulbocavernosus reflex latency varies from approximately 30 to 40 ms, but the exact values vary slightly from one laboratory to another and with age, sex, and bodily habitus. Any neurologic process that interferes with the integrity of the reflex arc will result in a prolonged latency. Common disorders that result in prolonged latencies include diabetes mellitus, alcoholic neuropathy, and prolapsed discs.

Leak-point Pressure

Abdominal Leak-point Pressures

Leak pressure terminology is confusing. Detrusor leak pressures are not equivalent to Valsalva leak pressures. Valsalva leak pressures measure the same function as abdominal leak pressures. However, the absolute values may vary depending on whether a slow strain, rapid Valsalva, or cough is used to test the integrating of the continence mechanisms of the bladder outlet. The most commonly performed leak pressure is the abdominal or Valsalva leak-point pressure (ALPP). This is a direct measurement of the abdominal pressure required to overcome urethral resistance. This urethral resistance is known as the urethral opening pressure. The abdominal leak pressure indirectly measures closure forces on the urethra or bladder outlet during straining and represents a simple test to classify urinary incontinence. The abdominal leak-point pressure is used in women to estimate to what degree stress urinary incontinence is due to anatomic displacement of the pelvic floor and bladder or intrinsic sphincter dysfunction. The lower the abdominal leak pressure, the greater the degree of intrinsic sphincter deficiency.

4 Etiology of Bladder Acontractility / Hypomotility

Peripheral Nerve Lesions

Diabetes Mellitus

Peripheral and autonomic neuropathies are common in diabetes. Diabetic neuropathy has been attributed to segmental demyelination and impairment of nerve conduction. Neuropathy tends to develop in middle-aged and elderly patients with long-standing or poorly controlled diabetes. The exact incidence of diabetic neuropathy is uncertain, because unselected patients generally do not complain of bladder symptoms. If specifically questioned, 5% to 50% report symptoms of voiding dysfunction. The insidious onset of impaired bladder sensation can be the first manifestation of such involvement. Likewise, in early diabetic neuropathy, detrusor hyperreflexia can develop. A gradual increase in the time interval between voiding then develops, which may progress to a point at which the patient urinates only once or twice a day without ever sensing any urgency. Ultimately, bladder decompensation may occur due to impaired detrusor contractility, which necessitates abdominal straining to initiate and maintain the voided stream, the strength and force of which are impaired.

Typical urodynamic findings include *impaired bladder sensation, increased cystometric capacity, decreased bladder contractility, impaired uroflow, and residual urine.*

Interestingly, diabetic men tend not to undergo as many prostatectomies for BPH, possibly because of impaired sensation, and in turn, lack of irritative voiding symptoms. The main differential diagnosis is outlet obstruction, because both conditions can produce a low flow rate. The flow pattern in diabetics reflects abdominal straining. Pressure/flow studies are easily able to differentiate the two

conditions. The secondary manifestations of resultant bladder decompensation are seen and may be prevented by early awareness of the problem and the institution of strictly timed voiding.

Guillain-Barré Syndrome

Guillain-Barré syndrome is an immune-mediated peripheral neuropathy. It elicits voiding difficulties—both detrusor hyperreflexia and areflexia—in nearly one-fourth of patients. Bladder symptoms appear after the weakness is established.

Tabes Dorsalis (Neurosyphilis)

Luetic involvement of the posterior sacral roots and the dorsal columns of the spinal cord may result in the loss of bladder sensation and resultant voiding dysfunction. Although rare in the postpenicillin era, tertiary syphilis is classically associated with detrusor areflexia with decreased or absent bladder sensation. Pernicious anemia (vitamin B12 deficiency) may also result in a similar type of “sensory neurogenic bladder”.

Viral Infections

An assortment of viral disorders can trigger voiding dysfunction, including herpes simplex genitalia, herpes zoster, herpes varicella, Epstein-Barr virus, cytomegalovirus, human T-lymphotropic virus (HTLV-1), and HIV. Bladder symptoms appear days to weeks after the primary viral manifestations of flulike symptoms, arthralgia, fever, and cutaneous lesions. Herpes infections, when associated with cutaneous lesions in the sacral dermatomes, are most commonly found with urinary retention secondary to detrusor areflexia from involvement of sacral dorsal root ganglia. These viruses appear in the urine and can be taken up by nerves in the bladder wall and anterogradely transported to the sacral cord.

Endoscopic examination in a patient with herpes zoster may reveal a similar type of vesicles within the bladder mucosa. This condition is usually self-limited and resolves spontaneously within a month or two. Tropical spastic paraparesis (HTLV-1) represents a somewhat unique viral cause of neurogenic bladder in which most patients have detrusor-sphincter dyssynergia.

Disc Disease

Most disc protrusions compress the spinal roots in the L-4 to L-5 or L-5 to S-1 disc interspaces. Voiding dysfunction due to a prolapsed or herniated disc correlates with the usual clinical manifestations of low back pain radiating in a girdlelike fashion along the involved spinal root areas. The most consistent urodynamic finding is detrusor areflexia. However, a herniated disc may initially irritate nerve roots and cause detrusor hyperreflexia. The striated sphincter may be normal or show evidence of denervation. In patients with cervical myelopathy due to disc disease or spondylosis, detrusor-sphincter dyssynergia has been reported. Patients with voiding dysfunction from a disc typically have difficulty urinating, straining, or urinary retention. Laminectomy may not improve bladder function, and it may be difficult to separate causation as a result of the disc sequelae from changes secondary to the surgery.

Pelvic Surgery

Voiding dysfunction is relatively common after pelvic plexus injury. This often arises after abdominoperineal resection and radical hysterectomy. Neurologic dysfunction after these procedures is reported in 10% to 60% of patients, and voiding dysfunction is permanent in 15% to 20%. The type of voiding dysfunction that occurs is dependent on the specific nerves involved, degree of injury, and the pattern of reinnervation or altered innervation that results over time. Urinary retention, with

varying degrees of sensory preservation, is generally the initial manifestation of such voiding dysfunction. The permanent pattern is generally a failure of voluntary bladder contraction, or impaired bladder contractility, with obstruction by residual striated-sphincteric tone, which is not subject to voluntarily induced relaxation. Often, the smooth-sphincter area is open and nonfunctional, attributed to destruction of the terminal sympathetic nerve supply to this area. Alternatively, such an appearance in a patient whose bladder neck has not been operated on may result from increased intravesical pressure and obstruction at the level of the striated sphincter. Decreased compliance is common, and with the obstruction caused by fixed residual striated-sphincter tone is the paradoxical occurrence of both storage and emptying failure. These patients often leak across the distal sphincter area and, in addition, are unable to empty their bladder because, although they have increased intravesical pressure, they have nothing that approximates a true bladder contraction. Thus they represent a combined problem of filling or storage and emptying. They often have urinary incontinence with increases in intraabdominal pressure. This is usually most obvious in females, because the prostatic bulk in males often masks a deficit in urethral closure function. Alternatively, patients may have variable degrees of urinary retention. Urodynamic studies may show decreased compliance, poor proximal urethral closure function, loss of voluntary control of the striated sphincter, and a positive bethanechol supersensitivity test. Upper tract risk factors are related to the leak-point, and the therapeutic goal is low-pressure bladder storage with periodic emptying.

Other Neurologic Causes of Voiding Dysfunction

A wide array of central and peripheral neurologic disorders have been associated with failure to store or empty urine. Many supraspinal disorders, including normal pressure hydrocephalus and cerebellar ataxia, can cause detrusor hyperreflexia and urge incontinence. Similarly, urodynamic evaluations in other neurodegenerative disorders and para-autonomic failure have revealed detrusor hyperreflexia or, rarely, areflexia.

Inherited disorders such as familial spastic paraparesis and congenital type II neuropathy cause voiding dysfunction. The disorder is associated with inability to relax the external urethral sphincter and detrusor hyperreflexia. The latter is associated with loss of bladder sensation. Of interest, the receptor for nerve growth factor is abnormal, resulting in loss of sensory nerves.

Disorders causing vasculitis or inflammation of the bladder or its innervation can also disturb micturition. Lyme's disease, periarteritis nodosa, systemic lupus erythematosus, Rocky Mountain spotted fever, and porphyria have been linked with either hyperactive voiding (detrusor instability) or urinary retention (detrusor areflexia). In these instances, it is difficult to distinguish bladder symptoms resulting from vasculitis or neural involvement. The paucity of reports of voiding problems, and rather circumstantial evidence for autonomic involvement, suggest that these associations are probably rare.

Myotonic dystrophy does not affect the external sphincter. Yet detrusor hypocontractility is common, suggesting involvement of bladder smooth muscle or autonomic nerves.

5 Therapy to Facilitate Bladder Emptying

5.1 Increasing Intravesical Pressure or Bladder Contractility

Credé Maneuver

External compression and Valsalva manual compression of the bladder (Credé maneuver) can be effective in patients with decreased bladder tonicity who can generate a pressure greater than 50 cm H₂O with this maneuver, and whose outlet resistance is low. The technique of voiding by the open-hand Credé method involves placement of the thumb of each hand over the area of the left and right anterior superior iliac spine and of the digits over the suprapubic area, with slight overlap at the fingertips. The slightly overlapped digits are then pressed into the abdomen, and when they have gotten behind the symphysis, pressed downward to compress the fundus of the bladder. Both hands are then pressed as deeply as possible downward into the real pelvic cavity. At times, compression of the bladder can be accomplished more efficiently by using the fist of one hand (closed-hand method) or a rolled-up towel.

A similar increase in intravesical pressure may be achieved by abdominal straining. This method of voiding is particularly useful in patients with orthotopic neobladders. In both men and women, the technique of straining (Valsalva) involves sitting and resting the abdomen forward on the thighs. During straining in this position, hugging of the knees and legs may be advantageous to prevent bulging of the abdomen. To increase intravesical pressure in this manner requires voluntary control of the abdominal wall and diaphragmatic muscles, or in the case of the Credé maneuver, adequate hand control. Straining at the time the Credé maneuver is applied should be avoided, because this increases intraabdominal pressure and causes bulging of the abdominal wall, which then tends to lift the compressing hands off the fundus of

the bladder. The Credé maneuver is much easier in a patient with a lax, lean abdominal wall than with a taut or obese one, and it is more readily performed on the abdominal bladder of a child than on the pelvic bladder of an adult. This straining maneuver is not without complications. Pelvic prolapse in women and hemorrhoids in both sexes can occur.

Voiding by these maneuvers is unphysiologic and is resisted by the same forces that prevent stress urinary incontinence. Reflex funneling of the bladder neck and proximal urethra does not generally occur with external compression maneuvers. In contrast, in patients with intact pelvic floor striated muscle reflexes, outlet resistance may increase. If adequate emptying is not achieved, other therapies to decrease outlet resistance may be considered, but these may adversely affect continence. Vesicoureteral reflux is another relative contraindication to Credé or Valsalva maneuvers, especially in patients who are capable of generating a high intravesical pressure. The greatest likelihood of success with this therapy is in patients with an areflexic and hypotonic or atonic bladder and some outlet denervation (striated or smooth sphincter or both). Not uncommonly, the patient also exhibits stress incontinence. The continued use of external compression or the Valsalva maneuver implies that the intravesical pressure between attempted voidings is consistently below that necessary to cause upper tract deterioration. This may be an erroneous assumption, and close follow-up is necessary to avoid this complication in patients with normal outlet resistance. The most flagrant misuse of this form of management is in patients with a decentralized or denervated bladder in whom decreased compliance during filling has developed. Such patients may silently develop upper tract deterioration with minimum filling.

Increasing Intravesical Pressure/Bladder Contractility:

External Compression, Valsalva

Promotion or Initiation of Reflex Contractions

Trigger Zones or Manoeuvres

Bladder Training, tidal Drainage

Pharmacologic Therapy

Parasympathomimetic Agents

Prostaglandins

Blockers of Inhibition

Alfa-adrenergic Antagonists

Opioid Antagonists

Electrical Stimulation

Directly to the Bladder

to the Spinal cord or nerve Roots

Reduction Cystoplasty

Decreasing Outlet Resistance:

At a site of anatomical obstruction

Prostatectomy

Urethral stricture repair/dilatation

At the level of the smooth sphincter

Transurethral resection or incision of the bladder neck

Y-V plasty of the bladder neck

Pharmacologic Therapy

Alfa-adrenergic Antagonists

Beta-Adrenergic Agonists

At the level of the striated sphincter

External sphincterotomy

Urethral overdilatation

Pudendal nerve block or Interruption

Pharmacologic Therapy

Skeletal muscle relaxants

Centrally acting relaxants

Dantrolene

Baclofen

Alpha-adrenergic Antagonists

Biofeedback, psychotherapy

Circumventing the problem:

Intermittent catheterization

Continuous catheterization

Urinary diversion

Table 2: Therapy to Facilitate Bladder Emptying.

5.2 Promotion or Initiation of Reflex Contraction

In spinal cord injury or disease characterized by detrusor hyperreflexia, manual stimulation of areas within the sacral and lumbar dermatomes may sometimes provoke a reflex bladder contraction. Pulling the skin or hair of the pubis, scrotum, or thigh, squeezing the clitoris, and digital rectal stimulation are examples of the type of activity that sometimes induces “trigger voiding” in these patients. According to Glahn [Glahn 1970], the most effective method of inducing such a contraction is rhythmic suprapubic manual pressure (seven or eight pushes every 3 seconds). This is thought to produce a summation effect on the tension receptors in the bladder wall, resulting in an afferent neural discharge, which activates the bladder reflex arc. Recent experimental data show that following complete spinal cord transection, somatic (cutaneous and visceral; i.e., vaginal, rectal) afferents can activate a transient spinal micturition reflex. In neurologically intact individuals, these somatic afferents inhibit micturition through spinal mechanism. The same mechanisms are exploited for use with cutaneous electrical stimulation in the treatment of detrusor hyperactivity. Patients who are potentially able to induce bladder contractions by such a manoeuvre should be encouraged to find their own optimal “trigger points” and position for urination. Unfortunately, this type of patient often suffers from sphincter dyssynergia, and such maneuvers may have to be combined with measures to decrease outlet resistance at the level of the striated or smooth sphincter.

No objective data support the notion that a rhythmic pattern of bladder filling and emptying by maintaining a copious fluid intake, and by periodically clamping and unclamping an indwelling catheter or with intermittent catheterization, can “condition” or “train” the micturition reflex.

5.3 Pharmacologic Manipulation

Parasympathomimetic Agents

The final common pathway for a physiologic bladder contraction is stimulation of the muscarinic cholinergic receptors on bladder smooth muscle. Cholinergic nerves supplying the bladder release acetylcholine, which acts primarily on muscarinic receptors of the M3 subtype to evoke a detrusor contraction and voiding. In addition, activation of M2 receptors on smooth muscle inhibits bladder relaxation by blocking signal transduction pathways that raise cyclic adenosine monophosphate (cAMP). Following injury or denervation, an upregulation of M2 receptors occurs. Hence, direct activation of muscarinic receptors should enhance detrusor contractility. Agents that imitate the actions of acetylcholine might be expected to be useful in the management of patients who cannot empty because of inadequate bladder contractility. Many acetylcholine-like drugs exist. However, only bethanechol chloride exhibits a relatively selective action on the urinary bladder and gut, with minimal action at ganglia or on the cardiovascular system. It is cholinesterase resistant and causes a contraction in vitro of smooth muscle from all areas of the bladder.

Bethanechol has been recommended for the treatment of postoperative or postpartum urinary retention in a subcutaneous dose of 5 to 10 mg. For more than 40 years, it has been used in the treatment of the atonic or hypotonic bladder, and it has been reported to be effective in achieving “rehabilitation” of the chronically atonic or hypotonic detrusor. [Lapides 1964]. However, few clinicians would consider this regimen to make a major difference in emptying the bladder. In uncontrolled reports where this drug is effective, it cannot be excluded that retention was psychogenic or that reflex micturition would have returned spontaneously.

Bethanechol has also been used to stimulate or facilitate the development of reflex bladder contractions in patients with suprasacral spinal cord injury. However, in hyperreflexic patients with poor bladder compliance, bethanechol may cause upper tract deterioration by raising intravesical pressure.

Bethanechol is capable of eliciting an increase in tension in bladder smooth muscle such as would be expected from in vitro studies, but its ability to stimulate or facilitate a physiologic-like bladder contraction in patients with voiding dysfunction has been unimpressive. In fact, it is difficult to find reproducible urodynamic data that support recommendations for the usage of bethanechol in any patients. Moreover, some spinal cord-injured patients develop hydronephrosis on this drug, possibly due to elevated intravesical pressures. This is further evidence that bethanechol's use should be abandoned.

Acetylcholinesterase drugs such as physostigmine and neostigmine have been administered to humans. Because these agents prevent the breakdown of acetylcholine, they may facilitate emptying. Neostigmine increases intravesical pressures and elicits detrusor contractions; however, its utility in emptying the bladder is unproven, and its side effects are prohibitive.

Activation of certain receptors enhances release of acetylcholine from nerve terminals in the bladder. In this regard, activation of serotonergic (5-HT₃) receptors has been proposed, but trials demonstrating the clinical usefulness of this approach are lacking.

Prostaglandins

Prostaglandins have a relatively short half-life, and it is difficult to envision a durable response. Hypotension, tachycardia, cardiac arrhythmia, convulsions, hypocalcemia,

and diarrhea can occur. The absence of any recent reports on efficacy seems to indicate lack of support for or interest in this approach.

Blockers of Inhibition

Sympathetic reflexes promote urine storage by exerting an inhibitory effect on pelvic parasympathetic ganglionic transmission, increasing outlet resistance, and possibly relaxing the bladder body. Activation of α -adrenergic receptors inhibits ganglion transmission. Some have suggested on this basis that α -adrenergic blockade, in addition to decreasing outlet resistance, may facilitate transmission through these ganglia and thereby enhance bladder contractility. Methyldopa had been tried with this rationale with at least some good initial results [Raz 1977]

Recent understanding of the roles of neuropeptides has also provided new insights into lower urinary tract function and its pharmacologic alteration. Endogenous enkephalins, serotonin, and gamma-aminobutyric acid (GABA) are thought to exert a tonic inhibitory effect on the micturition reflex, and agents such as narcotic antagonists and serotonin or GABA antagonists offer new possibilities for enhancing reflex bladder activity. In spinal cord-injured animals and one human trial, the opiate antagonist naloxone facilitated bladder emptying.

Electrical Stimulation

Clinical trials of direct electrical stimulation to completely empty the bladder have met with partial success and periodic enthusiasm. Direct electrical stimulation has been attempted in patients with hypotonic and areflexic bladders. Initial success, defined as a low postvoid residual with sterile urine, was achieved in only 50% to 60% of patients, and secondary failure, usually related to equipment malfunction, often supervened. The spread of current to other pelvic structures whose stimulus thresholds were lower than that of the bladder often resulted in abdominal, pelvic,

and perineal pain; a desire to defecate; contraction of the pelvic and leg muscles; and erection and ejaculation in males. It was also noted that the increase in intravesical pressure generally was not coordinated with bladder neck opening or pelvic floor relaxation and that other measures to accomplish these ends might be necessary. Electrical stimulation was applied directly to the sacral spinal cord, attempting to take advantage of the remaining intact motor pathways to initiate micturition. Although some short-term success was noted, many of the side effects seen with direct bladder stimulation occurred because the stimulus, so applied, was also unphysiologic [Nashold 1977,1980].

Other techniques rely on surgical interruption of pudendal fibres, blockade of somatic transmission, fatiguing of the external urethral sphincter, and activation of small fibres. The latter methodology has been exploited by Rijkhoff and colleagues [Rijkhoff 1997]. Small fibre activation requires a tripolar electrode that activates both large-diameter (somatic to external sphincter) and small-diameter (autonomic to bladder and urethra) fibres. The lower current needed to activate large fibres allows a differential activation. Blockade distal to the stimulating cathode using an anode will selectively cancel out the action potential in the large but not small fibres. This is termed anode blockade. Although acute experiments in humans are encouraging, problems remain with chronic stimulation because small changes in current alter parameters. Too small a current is insufficient to activate the bladder, and too large a current blocks the small-diameter fibres to the bladder. Moreover, charge-balanced biphasic currents are needed to prevent nerve damage.

Loss of neural input, at least experimentally, alters detrusor contractility and may even lead to apoptosis and fibrosis in the long term. For the outcomes of

electrostimulation to surpass those of intermittent self-catheterization, minimal morbidity and nearly complete emptying must be achieved.

5.4 Reduction Cystoplasty

On the surface, a reduction cystoplasty seems to be an attractive alternative for patients with chronic urinary retention who have large decompensated bladders. Reduction cystoplasty has been advocated for patients with megacystis due to Prune-Belly syndrome.

With techniques of reduction cystoplasty involving either fundus invagination or detrusor duplication (but not simple excision of bladder tissue only), symptomatic successes with lower bladder capacity and lower residual urine volumes have been achieved. However, it is puzzling that despite such improvement, Roberts and colleagues reported absolutely no change in bladder or sphincter activity [Roberts 1995]. In patients with contractile bladders, flow rates seem to change only when outlet reduction is also performed.

5.5 Circumventing the Problem: Intermittent Catheterization

Intermittent catheterization is the most effective means of attaining a catheter-free state in patients with acute spinal cord lesions. It is also an extremely effective method of treating an adult or child whose bladder fails to empty, especially when efforts to increase intravesical pressure or decrease outlet resistance have been unsuccessful. In patients with inadequate urine storage because of involuntary bladder contractions, decreased compliance, or stress incontinence with adequate or inadequate emptying, it may also be used if the dysfunction can be converted solely or primarily to one of emptying by pharmacologic or surgical means. Lapidus and associates deserve enormous credit for first applying the concept of intermittent self-

catheterization to large groups of outpatients with voiding dysfunction. Subsequently, Lapides and co-workers and many others have demonstrated the long-term efficacy and safety of such a regimen [Lapides 1972]. Requirements for intermittent catheterization include a cooperative, well-motivated patient or family, adequate hand control (or a family member willing to catheterize), and sufficient urethral exposure. Teaching intermittent self-catheterization requires an approach that communicates acceptance of the procedure by the instructor. It is advantageous to have a special urologic nurse who instructs the patients or families in the regimen; provides them with understandable written instructions to refresh their memories regarding technique, precautions, and danger signals; and provides continuing support for patients who call with questions or problems about their regimen.

For adult male patients, 14- or 16-Fr stiff or flexible catheters are generally used. In some cases (e.g., in patients with impaired fine motor skills), stiffer plastic catheters may be easier for the patient to insert. These are also commercially available in a disposable form. A notable advantage to red rubber catheters is their longevity and overall low cost. However, for catheterizing Mitrofanoff stomas, they lack sufficient stiffness. They can be reused indefinitely and boiled for sterilization if desired. Shorter, disposable plastic female catheters, now manufactured by several companies, are recommended for female patients. They are inexpensive and convenient. This 14-Fr, 6-inch catheters are easy to handle. Female patients may catheterize themselves on the toilet without a mirror, making intermittent catheterization less confusing, cleaner, and quicker. Red rubber or Robinson catheters may also be used for female patients if desired. For the patient's convenience, liquid cleansing agents are usually easier to handle in the form of

cotton balls soaked in the agent. These can be easily carried in a small jar. Any water-soluble lubricant is suitable for lubricating the catheter before insertion.

Several studies examining urinary tract infections and upper tracts with management by clean intermittent catheterization deserve mention.

Perkash and Giroux [1993] followed the upper tracts and urine cultures in 50 spinal cord injured patients on intermittent catheterization and found that 86% of patients developed positive urine cultures (greater than 10⁴ cfu/mL) and 42% had genitourinary complications. However, upper tract deterioration did not occur if adequate bladder compliance and low intravesical pressures were maintained. These latter two goals, rather than self-catheterization per se, may be more important determinants in the preservation of renal function.

Continuous Catheterization

Indwelling urethral catheters are best for short-term bladder drainage, and careful use of a small-bore catheter fails to adversely affect the ultimate outcome. Occasionally, an indwelling catheter is a last resort for long-term bladder drainage. After 72 hours, virtually all patients with an indwelling urethral catheter have bacteriuria. A contracted, fibrotic bladder can result from chronic inflammation. Encrustations may form on the catheter or on the retention balloon. Urethral complications are relatively uncommon in females, but bladder spasm may occur, producing urinary incontinence. The temptation to use a large retention balloon should be resisted, because the continuous use of such a balloon combined with some pressure on the catheter may cause erosion of the bladder neck. A suprapubic trochar catheter may be initially more comfortable than a urethral catheter, and it obviates urethral fistulae and strictures in the male over longer periods. Bladder spasm with incontinence may, however, be more of a problem, and when blockage

occurs, nursing personnel are more reluctant to change this type of catheter without physician assistance.

Broecker and associates [1981] surveyed 81 consecutive spinal cord–injured patients with indwelling urinary catheters for more than 10 years, and although they did not find carcinoma, they discovered squamous metaplasia of the bladder in 11 patients and leukoplakia in one patient.

The long-term morbidity of chronic indwelling catheters is recognized, but often other reasonable alternatives are nonexistent.

Overall, indwelling catheters are to be avoided for long-term usage. In males, suprapubic tubes are preferred. In females, eventual dilation of the urethra limits their use. However, for short-term use proper positioning of a urethral catheter can reduce the likelihood of bulbar urethral erosion

6 Latissimus Dorsi Detrusor Myoplasty

The clinical application of muscle flaps started in the beginning of the seventies [Ger 1971, Orticochea 1972], initially for coverage of deep defects. Muscle flaps associated to a skin island, denominated myocutaneous flaps, widened the spectrum of application to coverage of skin defects [Baudet 1976]. The rectus femoralis muscle was applied for restoration of the bladder function, but the functional results and the donor site morbidity were disappointing [Messing 1985].

The rectus abdominis muscle was also used for the same purpose, with the advantage of having the same anatomical localization with lower donor site morbidity. However, its anatomical singularity with the tendinous intersections and segmental innervation gave an insufficient contractility. The Latissimus dorsi muscle was also used for improvement of the heart contractility in severe cardiomyopathies [Moreira and Stolf 2001].

Innervated Microsurgical Muscle Flaps

Microsurgical muscle or myocutaneous flaps have been used since the beginning of seventies [Tamai 1970, Harii 1976]. Initially, their main application was coverage of soft tissue defects with exposition of vessels, organs, tendons, bone and articulations. With technical improvement, free composite flaps including bone and articulations and functional reconstructions after trauma or oncological resections were started.

Free muscle flaps with nerve anastomosis opened a new field in the reconstructive surgery. The functional reconstruction with *gracilis*, *latissimus dorsi*, *pectoralis minor*, *rectus femoris* and *vastus lateralis* is a routine procedure in any advanced microsurgical center [Zuker 2007]. Patients with motor sequelae following facial

palsy, brachial plexus injuries and abdominal wall hernias were treated [Ninkovic 1998].

6.1 Patients and Method:

Thirty-four patients (mean age: 37 years; range: 9-68; 21 males, 13 females) underwent LDDM between May 1995 and June 2005.

Preoperative evaluation of the patients included urethrocytoscopy, intravenous pyelography and electromyography of the rectus abdominis muscle. Preoperative urodynamic assessment showed acontractile bladder in all patients requiring complete clean intermittent catheterization (CIC) 4-8 times per day. All the patients involved in the study had at least 2 years of symptoms (mean 95,02 months).

The causes of detrusor dysfunction were spinal cord injury in 19 patients, spina bifida in 7, idiopathic and other causes in 8 patients.

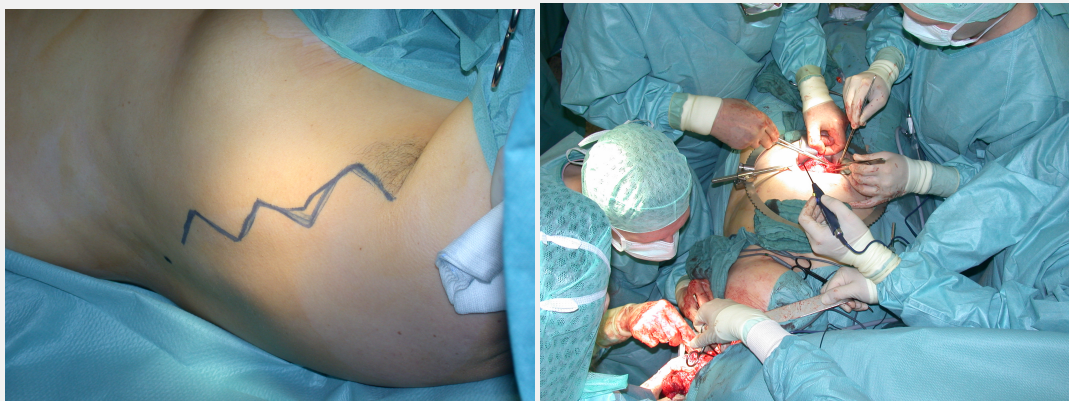
The technique was employed in small contracted bladders and also in dilated acontractile bladders (range 120-1200 ml of capacity, mean 641,47 ml) (Table 3).

Patient	Sex	Age	Etiology	Catheterization (months)	Preop. Bladder Capacity (ml)
1	m	24	spinal cord injury	60	700
2	m	28	spinal cord injury	24	400
3	m	68	Idiopathic	24	1000
4	f	60	Idiopathic	128	510
5	m	44	spinal cord injury	186	900
6	m	23	spinal cord injury	70	515
7	f	32	spinal cord injury	35	490
8	m	53	spinal cord injury	33	500
9	f	9	Congenital	118	120
10	m	60	Idiopathic	84	1200
11	f	26	Congenital	319	300
12	f	46	spinal cord injury	96	740
13	m	41	spinal cord injury	30	700
14	m	35	spinal cord injury	192	400
15	m	50	spinal cord injury	157	800
16	f	61	idiopathic	60	770
17	m	47	spinal cord injury	168	700
18	m	12	congenital	48	800
19	m	38	idiopathic	24	490
20	m	31	spinal cord injury	24	1000
21	m	20	spinal cord injury	28	619
22	f	17	spina bifida	204	500
23	m	40	Laminectomy wg neuroma	34	500
24	m	50	spinal cord injury	60	450
25	m	41	spinal cord injury	5	800
26	m	31	spinal cord injury	48	600
27	m	40	spinal cord injury	48	N
28	m	43	idiopatic acontractile detrusor	44	N
29	f	32	spina bifida	384	400
30	m	33	spinal cord injury	60	450
31	m	50	idiopatic acontractile detrusor	30	600
32	f	27	congenital spina bifida	324	500
33	m	39	parasympatic disfunction	46	800
34	f	38	iathrogenic (pelvic surgery)	36	600

TABLE 3. Pretreatment data

6.2 Operative technique.

At the same time that the latissimus dorsi muscle is harvested, the urological team freed the bladder down to the trigone via an extraperitoneal midline abdominal or Pfannenstiel incision. Posteriorly, the inner surfaces of both ischial bones and insertions of the sacrospinal ligaments were dissected.



Figs. 10-12: Patient positioning and preoperative planning for the simultaneous *Latissimus dorsi* harvesting and Bladder dissection.

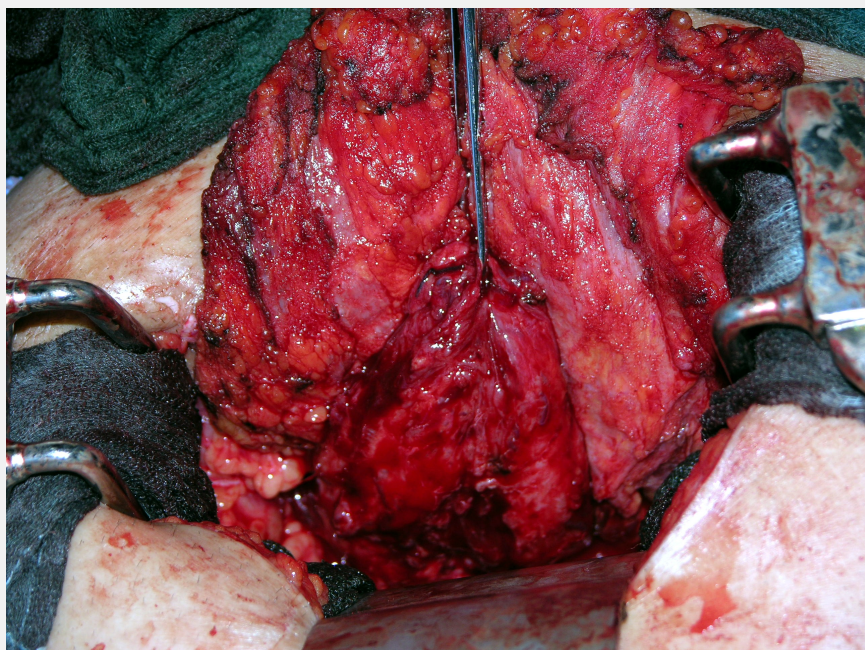
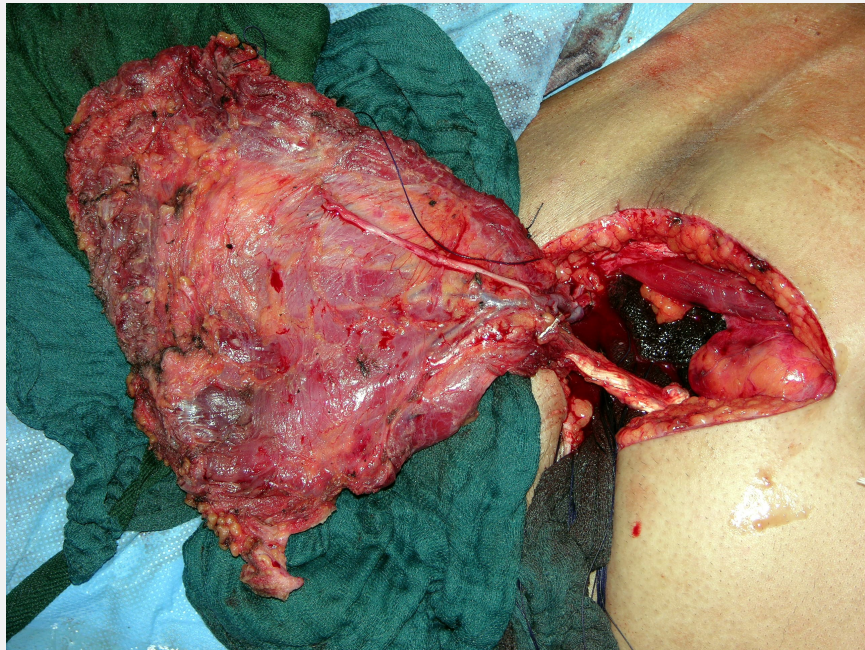
The *latissimus dorsi* muscle of the nondominant arm is harvested by the plastic surgery team via an axillary Z incision. Care was taken to document the resting muscle tension by placing 2 marking sutures at defined distances before dissection.

At the same time the urological team freed the bladder down to the trigone via an extraperitoneal midline abdominal or Pfannenstiel incision. The bladder was left intact in all but 2 patients in whom auto-augmentation was performed and one patient who had previously undergone gastroileal augmentation.

Posteriorly, the inner surfaces of both ischial bones and insertions of the sacrospinal ligaments were dissected free.

After identifying and severing the lowest motor branches of the intercostal nerve as well as the ipsilateral inferior epigastric artery and vein supplying the rectus abdominis muscle, the thoracodorsal vessels and nerve were divided, the *latissimus dorsi* muscle was transferred to the pelvis and a microsurgical vascular anastomosis was performed immediately. The muscle ischemia time was less than 60 minutes in all patients.

In the pelvis the transferred *latissimus dorsi* muscle was attached to the fascial and ligamentous structures. The original resting tension of the *latissimus dorsi* muscle was restored by bladder distention and by combining longitudinal tension with a slightly spiral configuration of the muscle fibers. Thus, most of the exposed portion of the bladder (approximately three-quarters of the entire bladder surface) was covered by *latissimus dorsi* muscle leaving only the area of the trigone with the ureteral orifices and the lateral vesical pedicles uncovered (figs. 13 and 14). In the final step microsurgical coaptation of the thoracodorsal nerve to the previously identified lowest branches of the intercostal nerve was performed using 9-zero monofilament nonabsorbable sutures.



Figs. 13 and 14: Tendon of the Latissimus dorsi muscle sutured to the pubic Symphysis. A cranial view of the Bladder partially covered with the LD muscle.

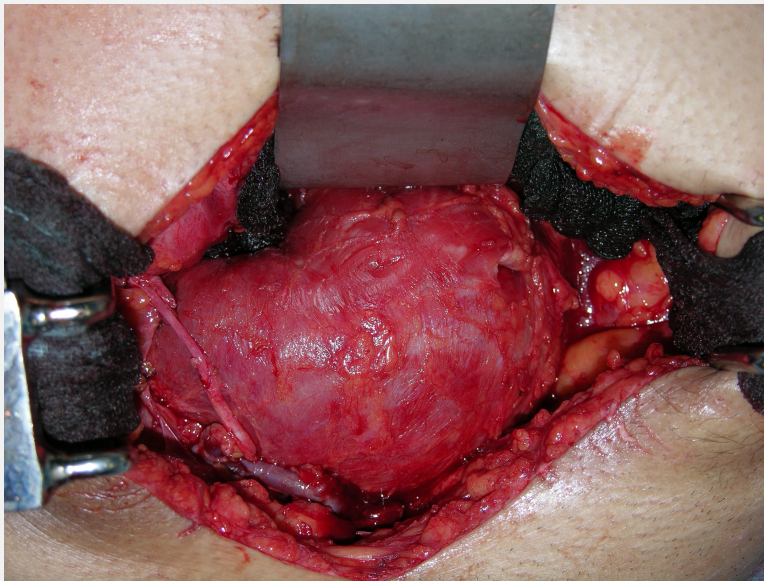


Fig. 15: Position of the Latissimus dorsi muscle covering the bladder after the fixation to the pelvis. The neurovascular pedicle can be seen on the left.

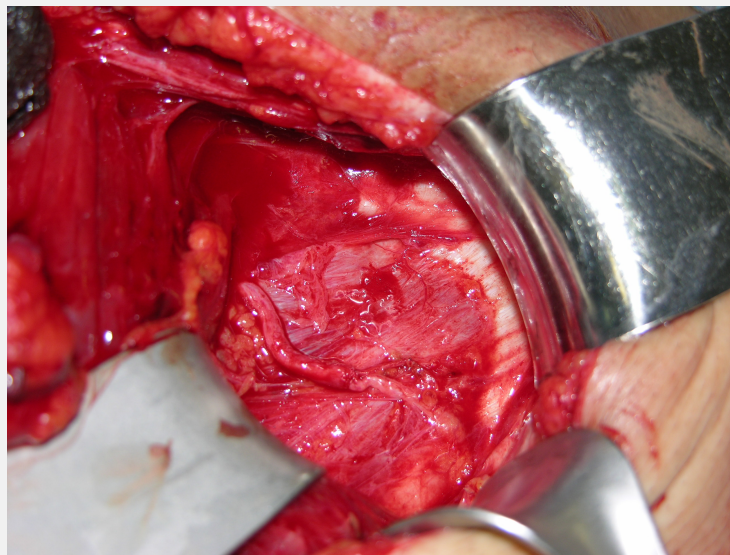


Fig. 16: After fixation to the pelvis the microneuroanastomosis between the thoracodorsal nerve and two intercostals is performed (in this case between thoracodorsal nerve and two intercostals)

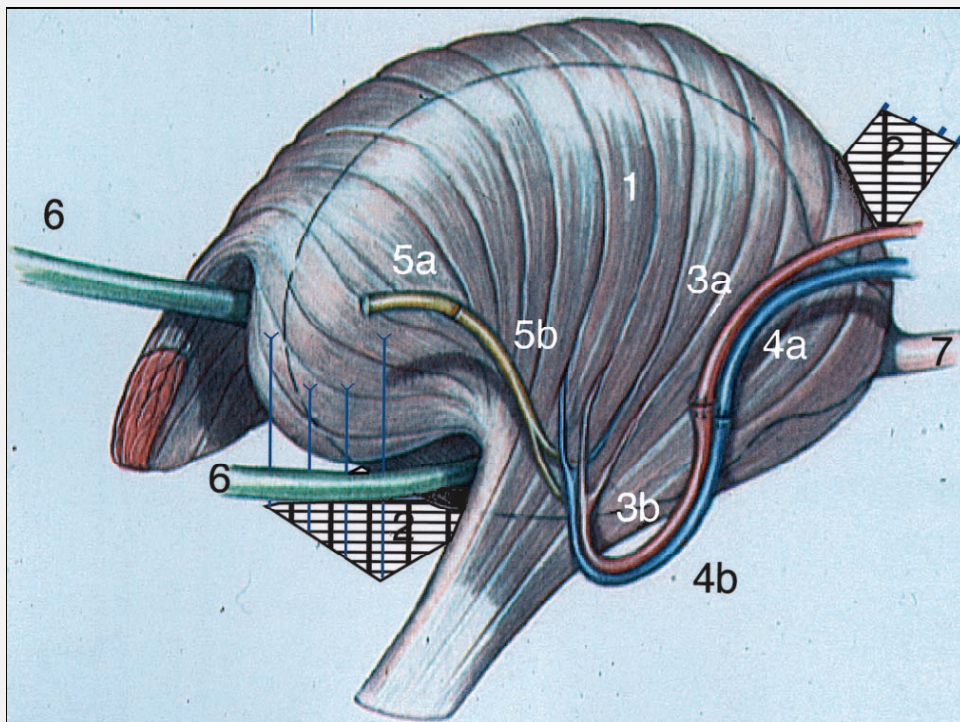
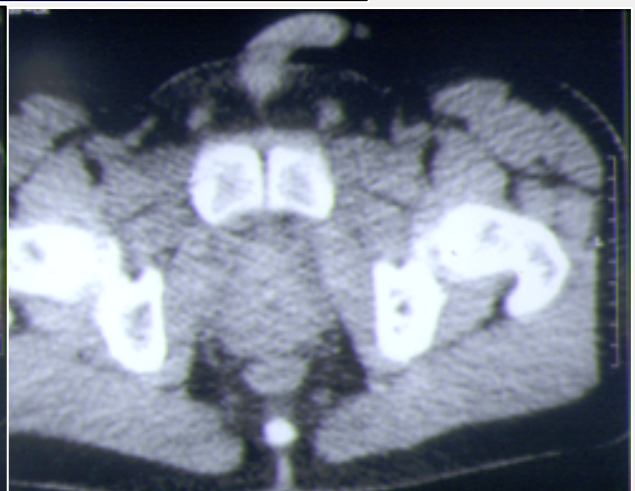
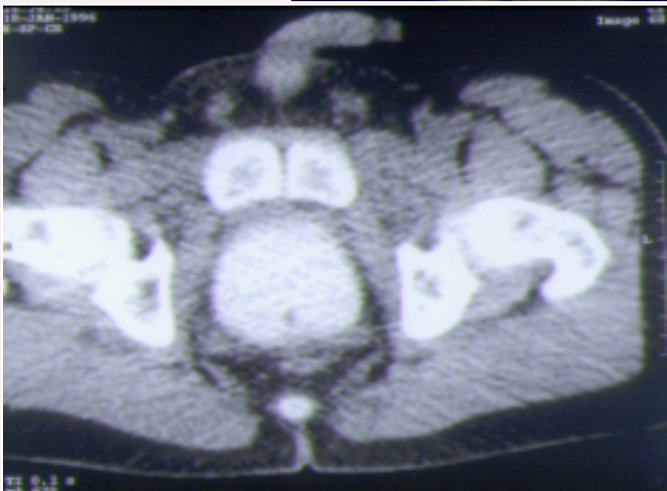
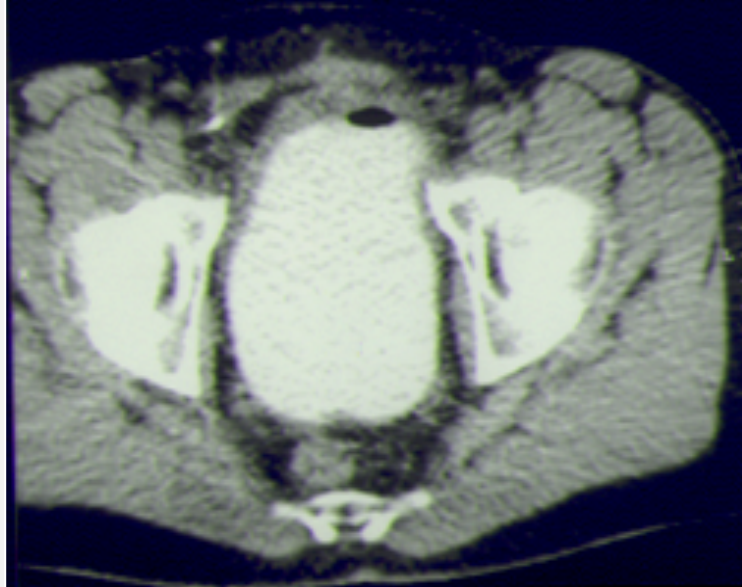


Fig.17: Schematic drawing of latissimus dorsi detrusor myoplasty in male patient. 1, shape and location of latissimus dorsi muscle at end of procedure. 2, polyglycolic acid mesh, which is attached to dorsal wall of bladder (vertical lines), is fed through tunnel underneath prostate and attached to Cooper's ligament on either side. 3 a, inferior epigastric (donor) artery. 3 b, thoracodorsal (recipient) artery. 4 a, inferior epigastric (donor) vein. 4 b, thoracodorsal (recipient) vein. 5 a, motor branch of 12th intercostal (donor) nerve. 5 b, thoracodorsal (recipient) nerve. 6, ureters. 7, urethra.

From: Ninkovic M, Stenzl A, Schwabegger A, Bartsch G, Esser R. Free Neurovascular Transfer of Latissimus dorsi Muscle for the Treatment of Bladder Acontractility:II. Clinical Results. J Urol 169, 1379–1383, April 2003.

6.3 Postoperative Treatment

In the first postoperative week the perfusion of the transferred latissimus dorsi muscle was monitored with an intramuscular probe measuring the pO₂ (Lycox,GSM, Kiel, Germany). The bladder was initially drained with an indwelling catheter and subsequently by intermittent catheterization for a total of 12 weeks in all adults and for 8 weeks in 2 children (9 and 12 years old). At 12 or 8 weeks after latissimus dorsi detrusor myoplasty, respectively, the patients were instructed to void under physiotherapeutic guidance by voluntarily contracting the lower abdominal muscles. After voiding the residual urinary volume was checked by self-catheterization. Catheterization intervals were gradually increased depending on the residual urinary volumes. Muscle vascularization and contractility were confirmed by Doppler ultrasonography at 3, 6 and 12 months, and yearly thereafter. Dynamic computerized tomography of the bladder and the substituted detrusor was performed at 6 and 12 months. Subsequently, renal imaging with either excretory urography or ultrasonography was performed annually. In addition, videourodynamic evaluation was performed at 6 and 12 months postoperatively.



Figs.18-20: Dynamic Computer Tomography 12 months postoperative: Full Bladder.

(below left) Contraction of Latissimus dorsi Muscle during the miction process.

(below right) Empty Bladder.

6.4 Results

Biannual Doppler ultrasonography and annual dynamic computerized tomography revealed vascularization and contractility in all patients. After a post-operative catheterization period of 3 months 27 of the 34 patients (79%) were able to void spontaneously with less than 100 cc postvoid residuals. Three patients were able to void after unilateral or bilateral bladder neck incision and transurethral esfincterotomies. Four patients still need to catheterize themselves, one of them each 2 or 3 days, two of them once a day, and one noted no improvement with 4 to 5 daily catheterizations (Table 4).

Surgery Date	Bladder capacity (ml.)	Residual Urine (ml.)	Maximal detrusor Pressure (cm H ₂ O)	Micturition Frequency	Nocturia	Incontinence
May-95	728	0	218	4-5	0	no
Mar-96	605	0	43	5	0	no
Aug-96	420	420	19	5(CI ct)	0	no
Dec-96	720	450	116	CI	0	no
Apr-97	500	5	21	6-7	1	no
May-97	650	80	39	5-6	0	no
Jun-97	440	0	40	4-5	0	no
Aug-97	586	18	71	4-5	0	no
Aug-97	250	0	30	5-6	0	no
Sep-97	500	18	106	5	0	occasional
Sep-97	400	0	56	5-6	1	no
Feb-98	476	0	55	5-6	0	no
Nov-98	561	15	91	4-5	0	no
Jan-99	800	35	5	3-4	0	Artificial sphincter
Sep-99	442	0	50	4-5	0	no
Oct-99	700	100	n	5-6	0	no
Oct-99	395	72	n	5	1	yes
Dec-99	650	65	n	4-5	1	no
Oct-99	490	0	35	5-6	1	no
May-00	320	0	147	4-5	0	no
Dec-02	N	0	n	5	0	no
Jun-03	500	30	n	4-5	1	no
Aug-03	500	0	n	7	0	no
Aug-03	405	30	n	4-6	0	no
Dec-03	300	30	n	6	0	no
Feb-04	400	0	83	3-4	0	yes
Mai-04	500	80	n	5	0	occasional
Jul-04	N	N	n	5	0	no
Jul-04	N	N	n	4-5 CI OD	0	yes
Nov-04	500	0	80	7 – 8	0	no
Nov-04	560	0	100	6	1	yes
Jun-05	N	N	n	5	0	no
Jun-05	N	N	n	4	0	no
Jun-05	500	N	n	5	0	occasional

Table 4: Postoperative results (n: data non available ci: intermittent catheterization)

7 Discussion

The pedicled or free neurovascular transfer of skeletal muscle to replace or increase the function of another diminished muscle group is well established as a clinical principle in the practice of reconstructive surgery. The early successes of myoaugmentation have inspired new and exciting techniques which utilize the enhanced capacity of the transplanted muscle unit. Presently, we are able to restore facial expression, (Re)extension/flexion function of the extremities, augment cardiac compression [Moreira and Stolf 2001] , and with the LDDM, restore detrusor function [Stenzel and Ninkovic 1997].

Several experimental and clinical investigations on the use of various local or regional muscle flaps for the treatment of a malfunctioning bladder detrusor have been undertaken [Parkash 1982; Baniel 1991; Robertson 1986]. Some interesting clinical results with gracilis, rectus abdominis and rectus femoris muscle flap have been published. The use of rectus abdominis muscle in the clinical treatment of bladder extrophy was described in a report by Zhang and associates [1990]. The insertion of both rectus abdominis muscles are transferred thereby placing the bladder between rectus abdominis sheath anteriorly and rectus abdominis muscle posteriorly. Contraction of the transposed muscle flap compresses the bladder against the remaining anterior rectus fascia. Voiding can also be supported more easily by applying manual compression onto the bladder which is better suspended and rotated anteriorly by the dorsally transposed muscle. Despite possible improvements in voiding, the considerable morbidity associated with the loss of both rectus abdominis muscles, is of no small concern.

In a recent report an inferiorly based rectus abdominis muscle flap was proposed for detrusor myoplasty. The entire width of the rectus muscle was unilaterally elevated

and transected cranially above the level of umbilicus, preserving the tendonous attachment to the pubic symphysis, the vascular supply of the inferior epigastric vessels and some branches of the lowermost intercostal nerves. In a clinical application the muscle was used to enclose and augment the bladder. Looking at the anatomy of the rectus muscle with its craniolaterally inserting motor nerves, partial denervation during dissection must be assumed. With the muscle segment reaching the inferior part of the bladder being denervated and atrophic the remaining innervation in the caudal part of the rectus abdominis muscle does not leave sufficient contractile muscle to restore the original detrusor function of the bladder. The denervated part of the rectus muscle does not only undergo severe atrophy, but will eventually become contracted and fibrotic. This, in turn, will lead to diminished bladder compliance, decreased bladder volume, increased bladder pressures with negative consequences for the upper urinary tract.

Messing et al. [1985] applied bilateral rectus femoris pedicle flaps for detrusor augmentation in the Prune-Belly syndrome. This procedure has resulted in spontaneous voiding with complete bladder emptying, however, it does have inherent pitfalls. Firstly, the donor site morbidity associated with harvesting the rectus femoris is high. Secondly, the transferred muscle, which is innervated by the femoral nerve, does not exhibit a synergistic response with respect to bladder emptying. Upon reviewing the data surrounding the successes and failures associated with these local flaps, we concluded that none were ideal. The ideal muscle for bladder myoplasty has to have appropriate tissue architecture, anatomical arrangement (strap muscle configuration), fibre length for excursion, sufficient cross section and muscle mass for exerting force [Ninkovic and Stenzl 1996, 2000].

Taking into consideration all these requirements, and based on experimental works and the works of other investigators we felt that the LDM had the appropriate anatomy and dynamic structure to meet the functional needs of bladder myoplasty [Ninkovic and Stenzl 1996] .

A prerequisite for the successful clinical application of LDDM, or any myoaugmentation procedure for that matter, is a well functioning urinary sphincter. In patients who have not voided for a long period of time, a preoperative functional evaluation of the urinary sphincter is essential. A misjudgement of the urinary sphincter, especially a failure to exclude a pre-existing detrusor-sphincter-dyssynergia may result in an unsatisfactory outcome. This is due to the fact, that even though appropriate muscle force is applied, the failure of sphincter relaxation thwarts normal micturition.

The analysis of these clinical results confirm a reliable and functioning LDDM. Flow-mode computed-tomography and ultrasound examination at 18 months demonstrate synchronous contraction of the transplanted LDM and rectus abdominis muscle (figs. 18-20) . The normal co-ordination between bladder detrusor and urethral sphincter is obligatory for normal micturition. It is not clearly understood how the coordination between the transferred LDM and the native sphincter functions. One explanation may be a trigger function of the sphincter whose relaxation in conjunction with an increase in the intraluminal pressure of the bladder starts the voiding process. In LDDM patients this increase of the bladder pressure, leading to sphincter relaxation, can be achieved by voluntarily contracting the caudal rectus abdominis muscle leading to a contraction of the LDM, which is supplied by the same nerve. Patients with a normal fluid balance void 4 – 5 times per day, each micturition lasting approximately 30 – 60 seconds. The urodynamic postoperative evaluation showed

that the normally functioning transferred LDM is able contract and maintain an increased bladder pressure for 30-60 seconds required for normal micturition.

A co-ordination in the voluntary contraction of the LDDM wrap is achieved by using the lowermost motor branch of the rectus abdominis muscle as a recipient nerve. The functional synergism between the abdominal wall (i.e. rectus abdominis muscle) contraction, synchronous LDM contraction, and subsequent bladder pressure increase restores a voluntary emptying of the bladder. Under normal circumstances abdominal wall contraction or the “Valsalva maneuver”, which is abdominal wall contraction in conjunction with contraction of the diaphragm, may be used to support bladder emptying. The patients learn therefore, without difficulties, how to perform voluntary bladder emptying after LDDM. In contrast to the Valsalva manoeuvre, which only leads to a parallel rise of intra-abdominal pressure and bladder pressure without any true increase in the intraluminal pressure of the bladder, the urodynamic measurements in our patients, revealed an increase in true detrusor pressure ranging from 21 cm H₂O to 82 cm H₂O. These pressures were practically zero before the operation. The unsuccessful preoperative attempt to achieve regular spontaneous micturition by simple practice of the Valsalva maneuver in our patients is an additional confirmation of the active role of the freely innervated LDM by LDDM.

An added advantage of the LDDM technique is that it allows for modification of the bladder shape and capacity during the operative procedure. A tight wrap will decrease the volume of the overdistended atonic bladder. While a loose wrap may serve to maintain a larger bladder capacity. In all but one of our cases, it was possible to reduce the volume of the overdistended atonic bladder and thus minimize the risks of post voidal residuals that can lead to urinary tract infections and renal demise.

At the donor area, no functional restrictions or chronic pain of the upper extremity were observed in any patient.

In conclusion, dynamic functional detrusor myoplasty using innervated free LDM proved to be successful clinically. After reinnervation and intensive muscle training, the transplanted LDM offers enough capacity and strength to replace the function of the missing urinary bladder detrusor muscle. Post-operatively, we have noted a positive psycho-social response in all our patients. The end of self-catheterization has led to marked gains in self confidence and the patients have been able to return to their usual professional and daily activities.

This clinical study confirms that LDDM is an effective treatment option in patients with acontractile bladder and can restore bladder function completely.

8 Summary:

Bladder acontractility or permanent detrusor dysfunction is a debilitating disorder affecting relatively young people. The underlying abnormality may be due to damage to the detrusor muscle itself, its autonomic nerve supply, the spinal micturition center or the upper motor neuron system. Possible causes include congenital anomalies (meningomyelocele, myelodysplasia), acquired infectious or inflammatory diseases, autoimmune diseases and central or peripheral nerve injuries secondary to trauma or degenerative disease.

Initial attempts to use pedicled flaps like rectus abdominis, gracilis or rectus femoris as a substitute for the acontractile detrusor have been hampered either by their size, configuration or neurovascular supply. Latissimus dorsi muscle transfer provides a suitable neurovascular pedicle, muscle size and configuration of muscle fibers.

Patients and Methods

Thirty-four patients with ages between 9 and 60 years old underwent Latissimus dorsi Detrusor Myoplasty (LDDM) between May 1995 and June 2005. The causes of detrusor dysfunction were spinal cord injury in 19 patients, spina bifida in 7, idiopathic and other causes in 8 patients. All patients were followed for at least 12 months after the operation. Professor Stenzl and Professor Ninkovic, as head of the urology and plastic surgery teams, performed all surgeries.

In the first postoperative week the perfusion of the transferred LDM is monitored with an intramuscular pO₂ probe (Lycox tm, GSM, Kiel, Germany). The bladder is initially drained with an indwelling catheter and subsequently by intermittent catheterization for 12 weeks. At this time the patients are instructed to void under physiotherapeutic guidance by contracting the lower abdominal muscles. After voiding the residual

urinary volume is checked by self-catheterization. Catheterization intervals are gradually increased depending on the residual urinary volumes.

No free flap failure occurred. Biannual Doppler ultrasonography and annual dynamic computerized tomography revealed vascularization and contractility in all patients. After a post-operative catheterization period of 2 – 3 months 27 of the 34 patients (79%) were able to void spontaneously with less than 100 cc postvoid residuals. Four patients still need to catheterize themselves, one of them each 2 or 3 days, two of them once a day, and one noted no improvement with 4 to 5 daily catheterizations.

Discussion

The long-term urodynamic results of detrusor myoplasty demonstrate its impact on the entire urinary tract. Of the 34 patients voluntary voiding was restored by latissimus dorsi detrusor myoplasty alone in 27, thereby eliminating the need for catheterization to empty the bladder. An additional 3 patients were able to void and discontinue catheterization after additional unilateral or bilateral bladder neck incision. In 2 patients latissimus dorsi detrusor myoplasty had an insufficient or no effect. The etiology of bladder acontractility was unclear in this male and female, muscle vascularization and contractility as well as an increase in intraluminal bladder pressure were observed in both but no funneling or opening at the bladder neck. Both patients still require self-catheterization, and there was no improvement compared to the preoperative status except for longer catheterization intervals owing to incomplete spontaneous voiding. Voiding against a closed sphincter must be assumed in these 2 patients, and may have been the reason why 3 patients were able to void after unilateral or bilateral bladder neck incision. Even when LDDM fails, the situation will not be worse than before the procedure and clean intermittent catheterization will continue to be performed.

Apart from the psychological burden, long-term catheterization has been reported to be associated with recurrent urinary tract infections, urethral laceration and even stricture requiring surgical intervention.

Dynamic functional detrusor myoplasty developed by Ninkovic and Stenzl using innervated free latissimus dorsi muscle has proved clinically successful in 10-year experience. Following reinnervation and adequate muscle training, the transplanted latissimus dorsi muscle provides sufficient capacity and strength to replace the missing urinary detrusor muscle. Elimination of the need for self-catheterization has led to growing self-confidence among patients and enabled many of them to return to their usual daily and occupational activities. Hence, skeletal muscle transplantation may be used to substitute for dysfunctional detrusor smooth muscle.

9 Zusammenfassung

Die Inkontraktilität der Blase oder die permanente Dysfunktion des M. Detrusor vesicae ist eine folgenschwere Störung, die schon relativ junge Patienten betrifft.

Diesem Krankheitsbild können Schäden am M. detrusor vesicae selbst, an seiner vegetativen Innervation, am spinalen Miktionszentrum oder am ersten Motorneuron zu Grunde liegen. Mögliche Ursachen können kongenitale Anomalien, wie Meningomyelozele oder Myelodysplasie, erworbene infektiöse oder entzündliche Krankheiten, Autoimmunerkrankungen sowie zentrale oder periphere Nervenläsionen in Folge eines Traumas oder einer degenerativen Erkrankung sein.

Erste Versuche, den inkontraktilen M. detrusor vesicae durch gestielte Lappen des M. rectus abdominis, des M. gracilis oder des M. rectus femoris zu ersetzen, scheiterten entweder an ihrer Größe, ihrer Konfiguration oder ihrer neuromuskulären Versorgung.

Beim Transfer des M. latissimus dorsi sind jedoch ein geeigneter neuromuskulärer Stiel sowie passende Größe und Konfiguration der Muskelfasern gegeben.

Patienten und Methoden

34 Patienten in der Alterskategorie von 9 bis 60 Jahren unterzogen sich im Zeitraum von Mai 1995 bis Juni 2005 einer Latissimus-dorsi-detrusor-Myoplastik (LDDM). Es gab unterschiedliche Indikationen bei den verschiedenen Patienten mit Detrusordysfunktion: Bei 19 Patienten lag eine Rückenmarksverletzung nach Trauma vor, bei 7 Patienten eine Spina bifida und bei 8 der Patienten war die Ursache idiopathischer und anderer Natur. Alle Patienten wurden postoperativ mindestens 12 Monate nachbeobachtet. Alle Operationen wurden von Professor Stenzl und Professor Ninkovic als Leiter der urologischen und plastisch-chirurgischen Teams durchgeführt.

Unter Sonographie- und Dopplerkontrolle sowie mit Hilfe bildgebender Verfahren (dynamische Computertomographie) wurden der Therapieerfolg sowie die Muskelkontraktilität bei allen Patienten dokumentiert. 3-6 Monate nach dem operativen Eingriff waren 27 von 34 Patienten (79%) in der Lage, ihre Blase spontan auf ein Restvolumen von unter 100 ml zu entleeren. 4 Patienten müssen nach wie vor in unterschiedlichen Zeitabständen auf die Selbstkatheterisierung zurückgreifen, einer im Abstand von 2 – 3 Tagen, zwei Patienten täglich. Bei einem Patienten konnte durch die Operation keine Verbesserung erzielt werden, weshalb die Selbstkatheterisierung nach wie vor 4-5 Mal täglich erfolgen muss.

Diskussion

Die urodynamischen Langzeitergebnisse der LDDM zeigen ihren Einfluss auf den Urogenitaltrakt. Bei 27 von 34 Patienten konnte durch den operativen Eingriff eine spontane Blasenentleerung durch Muskelkontraktion wiederhergestellt werden. Drei weitere Patienten waren nach einer uni- oder bilateralen Inzision des Blasenhalses zur selbständigen Blasenentleerung ohne Katheterisierung fähig.

Bei einem Patienten und einer Patientin hatte die LDDM einen ungenügenden oder gar keinen Effekt. Bei beiden ist die Ätiologie der Blaseninkontraktilität ungeklärt.

Bei beiden konnten die Vaskularisierung und die Kontraktilität des Muskels sowie eine Erhöhung des intravesikalen Druckes, jedoch kein Öffnen des Blasenhalses beobachtet werden.

Beide Patienten sind nach wie vor auf Selbstkatheterisierung angewiesen und, es war bis auf die Verlängerung der Intervalle zwischen den Katheterisierungen keine Verbesserung verglichen mit dem präoperativen Zustand festzustellen.

Es muss angenommen werden, dass bei diesen zwei Patienten ein Urinieren gegen einen verschlossenen Sphinkter vorlag, was auch der Grund dafür sein kann, dass

drei Patienten nach uni- oder bilateraler Inzision des Blasenhalses zum Entleeren der Blase fähig waren.

Selbst wenn die LDDM fehlschlagen sollte, ist der postoperative Zustand nicht schlechter als der präoperative Zustand. Die intermittierende Katheterisierung muss in diesem Fall weiterhin durchgeführt werden.

Die von Ninkovic und Stenzl entwickelte dynamische funktionelle LDDM hat sich in zehn Jahren als eine klinisch erfolgreiche Methode bewährt. Nach der Reinnervation und adäquatem Muskeltraining bietet der transplantierte M. latissimus dorsi genügend Kapazität und Kraft, um den fehlenden M. detrusor vesicae zu ersetzen.

10 Review of literature

Abrams P., Blaivas J.G., Stanton S.L., Andersen J.T. The standardisation of terminology of lower urinary tract function. The International Continence Society Committee on Standardisation of Terminology. *Scand J Urol Nephrol.* 114 (1988) 5-19.

Amendola M.A., Sonda L.P., Diokno A.C., Vidyasagar M. Bladder calculi complicating intermittent clean catheterization. *AJR Am J Roentgenol.* 141(1983) 751-753.

Andresen E.M., Bowley N., Rothenberg B.M., Panzer R., Katz P. Test-retest performance of a mailed version of the Medical Outcomes Study 36-Item Short-Form Health Survey among older adults. *Med.Care* 34 (1996) 1165-1170.

Arap S., Giron A.M., de Goes G.M. Complete reconstruction of bladder exstrophy. Experimental program. *Urology* 7 (1976) 413-416.

Arap S., Nahas W.C., Giron A.M., Bruschini H., Mitre A.I. Incontinent epispadias: surgical treatment of 38 cases. *J Urol* 140 (1988) 577-581.

Bailey B.N., Godfrey A.M. Latissimus dorsi muscle free flaps. *Br J Plast Surg* 35 (1982) 47-52.

Bakke A. Clean intermittent catheterization--physical and psychological complications. *Scand.J.Urol.Nephrol.Suppl* 150 (1993) 1-69.

Bakke A., Malt U.F. Psychological predictors of symptoms of urinary tract infection and bacteriuria in patients treated with clean intermittent catheterization: a prospective 7-year study. *Eur.Urol.* 34 (1998)

Baniel J, Schein M. Delayed post-traumatic rupture of the bladder: management with rectus abdominis muscle. *Isr J Med Sci* 27(1991) 575-576

Barbalias G.A., Nikiforidis G., Liatsikos E.N. Vesicourethral dysfunction associated with multiple sclerosis: clinical and urodynamic perspectives. *J.Urol.* 160 (1998) 106-111

Barrett D.M. The effect of oral bethanechol chloride on voiding in female patients with excessive residual urine: a randomized double-blind study. *J.Urol.* 126 (1981) 640-642

Bartolin Z., Gilja I., Bedalov G., Savic I. Bladder function in patients with lumbar intervertebral disk protrusion. *J.Urol.* 159 (1998) 969-971

Baudet J., Guimberteau J.C., Nascimento E. Successful clinical transfer of two free thoraco-dorsal axillary flaps. *Plast.Reconstr.Surg.* 58 (1976) 680-688

Benson G.S., Sarshik S.A., Raezer D.M., Wein A.J. Bladder muscle contractility. Comparative effects and mechanisms of action of atropine, propantheline, flavoxate, and imipramine. *Urology* 9 (1977) 31-35

Blanc P., Girard C., Vedrinne C., Mikaeloff P. e Estanove S. Latissimus dorsi cardiomyoplasty. Perioperative management and postoperative evolution. *Chest* 103 (1993) 214-218

Breza J., Dzurny O., Borowka A., Hanus T., Petrik R., Blane G., Chadha-Boreham H. Efficacy and acceptability of tadenan (*Pygeum africanum* extract) in the treatment of benign prostatic hyperplasia (BPH): a multicentre trial in central Europe. *Curr.Med Res.Opin.* 14 (1998) 127-139

Brindley G.S., Rushton D.N. Long-term follow-up of patients with sacral anterior root stimulator implants. *Paraplegia* 28 (1990) 469-471,

Broecker B.H., Klein F.A., Hackler R.H. Cancer of the bladder in spinal cord injury patients. *J Urol.* 125 (1981) 196-197.

Brown J.H., Taylor P. Muscarinic receptor agonists and antagonists. In: Goodman & Gilman's *The Pharmacological Basis of Therapeutics*, edited by J.G.Hardman, et al. McGraw-Hill Professional Publishing, New York 2002. 155-174

Chancellor M.B., Kaplan S.A., Blaivas J.G. The cholinergic and purinergic components of detrusor contractility in a whole rabbit bladder model. *J.Urol.* 148 (1992) 906-909

Chancellor M.B., Rivas D.A., Acosta R., Erhard M.J., Moore J. and Salzman S.K. Detrusor-myoplasty, innervated rectus muscle transposition study, and functional effect on the spinal cord injury rat model. *Neurourol Urodyn* 13 (1994) 547-550

Decter R.M. Intravesical electrical stimulation of the bladder. *Urology* 56 (2000) 5-8

Decter R.M., Snyder P., Laudermilch C. Transurethral electrical bladder stimulation: a followup report. *J.Urol.* 152 (1994) 812-814

Delaere K.P., Thomas C.M., Moonen W.A., Debruyne F.M. The value of intravesical prostaglandin E2 and F2 alpha in women with abnormalities of bladder emptying. *Br.J.Urol.* 53 (1981) 306-309

Derby L.D., Bartlett S.P., Low D.W. Serratus anterior free-tissue transfer: harvest-related morbidity in 34 consecutive cases and a review of the literature. *J.Reconstr.Microsurg.* 13 (1997) 397-403

Diokno A.C., Sonda L.P., Hollander J.B., Lapidus J. Fate of patients started on clean intermittent self-catheterization therapy 10 years ago. *J.Urol.* 129 (1983) 1120 - 1122

Djavan B., Madersbacher S., Klingler C., Marberger M. Urodynamic assessment of patients with acute urinary retention: is treatment failure after prostatectomy predictable? *J.Urol.* 158 (1997) 1829-1833

Donkervoort T., Sterling A., van Ness J., Donker P.J. A clinical and urodynamic study of tadenan in the treatment of benign prostatic hypertrophy. *Eur.Urol.* 3 (1977) 218-225

Donovan J.L., Peters T.J., Abrams P., Brookes S.T., Rosette J.J., Schafer W. Scoring the short form ICSmaleSF questionnaire. International Continence Society. *J.Urol.* 164 (2000) 1948-1955

Ebner A., Jiang C., Lindstrom S. Intravesical electrical stimulation-an experimental analysis of the mechanism of action. *J.Urol.* 148 (1992) 920-924

Erol A., Ozgur S., Erol U., Ozgun F., Akman Y., Ozguven V. Partial bladder reconstruction with pedicled rectus and gracilis muscle flaps: an experimental study in dogs. *Br J Urol* 74 (1994) 775-780

Finkbeiner A.E. Is bethanechol chloride clinically effective in promoting bladder emptying? A literature review. *J.Urol.* 134 (1985) 443-449

Ger R. The technique of muscle transposition in the operative treatment of traumatic and ulcerative lesions of the leg. *J.Trauma* 11(1971) 502-510.

Germann G., Sauerbier M., Steinau H.U., Wood M.B. Reverse segmental pedicled ulna transfer as a salvage procedure in wrist fusion. *J.Hand Surg.[Br.]* 26 (2001) 589-592.

Glahn B.E. Manual provocation of micturition contraction in neurogenic bladders. *Scand J Urol Nephrol.* 4 (1970) 25-36

Gomes C.M., DiSanto M.E., Horan P., Levin R.M., Wein A.J., Chacko S. Improved contractility of obstructed bladders after Tadenan treatment is associated with reversal of altered myosin isoform expression. *J.Urol.* 163 (2000) 2008-2013

Gomes C.M., Rovner E.S., Banner M.P., Ramchandani P., Wein A.J. Simultaneous upper and lower urinary tract obstruction associated with severe genital prolapse: diagnosis and evaluation with magnetic resonance imaging. *Int.Urogynecol.J.Pelvic Floor Dysfunct.* 12 (2001) 144-146.

Graham S. D., Keane, T.E., Glenn, J.F. "Anatomy of the Bladder". Glenn's Urologic Surgery, 6th Edition. Lippincott Williams & Wilkins, 2004

Guelinckx P.J., Sinsel N.K. Muscle transplantation for reconstruction of a smile after facial paralysis past, present, and future. *Microsurgery* 17 (1996) 391-401

Hald T., Agrawal G., Kantrowitz A. Studies in stimulation of the bladder and its motor nerves. *Surgery* 60 (1966) 848-852

Harii K., Ohmori K., Torii S. Free gracilis muscle transplantation with microneurovascular anastomoses for the treatment of facial paralysis. A preliminary report. *Plast.Reconstr.Surg.* 57 (1976) 133-143

Hellstrom P., Tammela T., Lukkarinen O., Kontturi M. Efficacy and safety of clean intermittent catheterization in adults. *Eur.Urol.* 20 (1991) 117-121

Hollabaugh R.S., Steiner M.S., Sellers K.D., Samm B.J., Dmochowski R.R. Neuroanatomy of the pelvis: implications for colonic and rectal resection. *Dis.Colon Rectum* 43 (2000) 1390-1397

Jezernek S., Craggs M., Grill W.M., Creasey G., Rijkhoff N.J. Electrical stimulation for the treatment of bladder dysfunction: current status and future possibilities. *Neurol.Res.* 24 (2002) 413-430

Kaplan S.A., Chancellor M.B., Blaivas J.G. Bladder and sphincter behavior in patients with spinal cord lesions. *J.Urol.* 146 (1991) 113-117

Kaplan S.A., Te A.E., Blaivas J.G. Urodynamic findings in patients with diabetic cystopathy. *J.Urol.* 153 (1995) 342-344

Kaplan W.E. Intravesical electrical stimulation of the bladder: pro. *Urology* 56 (2000) 2-4

Kaplan W.E., Richards I. Intravesical bladder stimulation in myelodysplasia. *J.Urol.* 140 (1988) 1282-1284

Kirby R.S., Fowler C., Gilpin S.A., Holly E., Milroy E.J., Gosling J.A., Bannister R., Turner-Warwick R. Non-obstructive detrusor failure. A urodynamic, electromyographic, neurohistochemical and autonomic study. *Br.J.Urol.* 55 (1983) 652-659

Koleilat N., Sidi A.A., Gonzalez R. Urethral false passage as a complication of intermittent catheterization. *J Urol* 142 (1989) 1216

Kuhn W, Rist M e Zaech GA. Intermittent urethral self-catheterisation: long term results (bacteriological evolution, continence, acceptance, complications). *Paraplegia* 29 (1991) 222

Laitung JK, Peck F. Shoulder function following the loss of the latissimus dorsi muscle. *Br.J.Plast.Surg.* 38 (1985) 375-379

Lapides J. Urecholine regimen for rehabilitating the atonic bladder. *J Urol.* 91 (1964) 658-659

Lapides J., Diokno A.C., Gould F.R., Lowe B.S. Further observations on self-catheterization. *J.Urol.* 116(1976) 169-171

Lapides J., Diokno A.C., Silber S.J., Lowe B.S. Clean, intermittent self-catheterization in the treatment of urinary tract disease. *J.Urol.* 107 (1972) 458-461

Levin R.M., Levin S.S., Zhao Y., Buttyan R. Cellular and molecular aspects of bladder hypertrophy. *Eur.Urol.* 32 Suppl 1 (1997) 15-21

Lyne C.J., Bellinger M.F. Early experience with transurethral electrical bladder stimulation. *J.Urol.* 150 (1993) 697-699

Mandal A.K., Vaidyanathan S. Management of urethral stricture in patients practising clean intermittent catheterization. *Int.Urol.Nephrol.* 25 (1993) 395-399

Manktelow R.T., Zuker R.M. The principles of functioning muscle transplantation: applications to the upper arm. *Ann.Plast.Surg.* 22 (1989) 275-282

Manktelow R. Microvascular muscle transfer for the extremity and for facial paralysis. In: *Recent Advances in Plastic Surgery*. Edited by I. Jackson and B. Sommerlad. Edinburgh 1985, vol. 3, 123

Maynard F.M., Diokno A.C. Urinary infection and complications during clean intermittent catheterisation following spinal cord injury. *J.Urol.* 132 (1984) 943-946

McKee N.H., Kuzon W. Jr. Functioning free muscle transplantation: making it work? What is known? *Ann Plast Surg* 23 (1989) 249

Messing E.M., Dibbell D.G., Belzer F.O. Bilateral rectus femoris pedicle flaps for detrusor augmentation in the prune belly syndrome. *J.Urol.* 134 (1985) 1202-1205

Michielsen D.P., Wyndaele J.J. Management of false passages in patients practising clean intermittent self-catheterisation. *Spinal Cord.* 37 (1999) 201-203

Mitchell, M.E. *Surgical Anatomy Of The Genitourinary System: Pelvis Part 1 Adult & Pediatric Urology*, 4th Edition

Moore K.N., Jensen L. Testing of the Incontinence Impact Questionnaire (IIQ-7) with men after radical prostatectomy. *J Wound Ostomy Continence Nurs* 27 (2000) 304-312

Moreira L.F, Stolf N.A. Dynamic cardiomyoplasty as a therapeutic alternative: current status. *Heart Fail Rev.* 6 (2001) 201-212

Nashold B.S. Jr, Grimes J., Friedman H., Semans J., Avery R. Operative stimulation of the neurogenic bladder. *Neurosurgery* 1 (1977) 218-20

Nashold B.S. Jr, Friedman H., Grimes J. Electrical stimulation of the conus medullaris to control the bladder in the paraplegic patient. A 10-year review. *Appl. Neurophysiol.* 44 (1981) 225-232

Nigro D.A., Haugaard N., Wein A.J., Levin R.M. Metabolic basis for contractile dysfunction following chronic partial bladder outlet obstruction in rabbits. *Mol.Cell Biochem.* 200 (1999) 1-6

Ninkovic M., Stenzl A., Schwabegger A., Bartsch G., Prosser R., Ninkovic M. Functional urinary bladder wall substitute using a free innervated latissimus dorsi muscle flap. *Plast Reconstr Surg* 100 (1997) 402-413

Ninković M, Kronberger P, Harpf C, Rumer A, Anderl H. Free innervated latissimus dorsi muscle flap for reconstruction of full-thickness abdominal wall defects. *Plast Reconstr Surg*. 101 (1998) 971-8

Ninkovic M., Strasser H., Schwabegger A.H., Ninkovic M., Bartsch G., Stenzl A. The concept of functioning free skeletal muscle transfer in combination with tissue engineering for bladder substitution. *World J Urol*. 18 (2000) 359-363

Ninkovic M., Sucur D., Starovic B., Markovic S. A new approach to persistent traumatic peroneal nerve palsy. *Br J Plast Surg* 47 (1994) 185-193

Ninkovic M., Stenzl A., Schwabegger A., Bartsch G., Prosser R, Ninkovic M. Free Neurovascular Transfer of Latissimus Dorsi Muscle for the Treatment of Bladder Acontractility:II. Clinical Results. *J Urol* 169 (2003) 1379–1383

Olivari N. The latissimus flap. *Brit J Plast Surg* 29 (1976) 126-132

Parkash S, Bhandari M. Rectus abdominis myocutaneous island flap for bridging defect after cystectomy for bladder exstrophy. *Urology* 20 (1982) 536-537

Peters C.A., Bauer S.B. Evaluation and management of urinary incontinence after surgery for posterior urethral valves. *Urol Clin.North Am*. 17 (1990) 379-387

Perkash I., Giroux J. Clean intermittent catheterization in spinal cord injury patients: a follow-up study. *J Urol* 149 (1993) 1068-1071

Pohl H.G., Bauer S.B., Borer J.G., Diamond D.A., Kelly M.D., Grant R, Briscoe C.J., Doonan G., Retik A.B. The outcome of voiding dysfunction managed with clean intermittent catheterization in neurologically and anatomically normal children. *BJU.Int*. 89 (2002) 923-927

Raz S., Kaufman J.J., Ellison G.W., Mayers L.W. Methyldopa in treatment of neurogenic bladder disorders. *Urology*. 9 (1977) 188-190

Raz S., Smith R.B. External sphincter spasticity syndrome in female patients. *J.Urol*. 115 (1976) 443-446

Reisman E.M., Preminger G.M. Bladder perforation secondary to clean intermittent catheterization. *J.Urol*. 142 (1989) 1316-1317

Rijkhoff N.J., Wijkstra H., van Kerrebroeck P.E., Debruyne F.M. Urinary bladder control by electrical stimulation: review of electrical stimulation techniques in spinal cord injury. *Neurourol Urodyn.* 16 (1997) 39-53

Roberts J.P., Moon S., Malone P.S. Treatment of neuropathic urinary and faecal incontinence with synchronous bladder reconstruction and the antegrade continence enema procedure. *Br J Urol.* 75 (1995) 386-389

Robertson C., Riefkohl R., Webster G. Use of the rectus abdominis muscle in urologic reconstructive procedures. *J Urol* 135 (1986) 963

Ruch T.C., Tang P.C. Localization of brain stem and diencephalic areas controlling the micturation reflex. *J. Comp. Neurol.* 106 (1956) 213-245

Sassoon E.M, Poole M.D., Rushworth G. Reanimation for facial palsy using gracilis muscle grafts. *Br J Plast Surg* 44 (1991) 195-200

Seckel B.R., Upton J., Jones H.R, Jr., Murray J.E. Rapid regeneration of the chronically damaged facial nerve following ipsilateral free gracilis transfer. *Plast. Reconstr. Surg.* 71 (1983) 845-854

Siroky M.B., Olsson C.A., Krane R.J. The flow rate nomogram: II. Clinical correlation. *J. Urol.* 123 (1980) 208-210

Siroky M.B., Olsson C.A., Krane R.J. The flow rate nomogram: I. Development. *J Urol.* 122 (1979) 665-668

Stanton S.L., Cardozo L.D., Kerr-Wilson R. Treatment of delayed onset of spontaneous voiding after surgery for incontinence. *Urology* 13 (1979) 494-499

Steers W.D. Physiology and pharmacology of the bladder and urethra. In: "Campbell's Urology", edited by P.C.Walsh, et al, W.B. Saunders Co, Philadelphia 1998, 870-915

Stein R., Hutcheson J.C., Krasnopolsky L., Canning D.A., Carr M.C., Zderic S.A. The decompensated detrusor V: molecular correlates of bladder function after reversal of experimental outlet obstruction. *J.Urol.* 166 (2001) 651-657

Stenzl A., Ninkovic M., Kollé D., Knapp R., Anderl H., Bartsch G. Restoration of voluntary emptying of the bladder by transplantation of innervated free skeletal muscle. *Lancet* 351 (1998) 1483-1485

Stenzl A., Strasser H., Klima G., Eder I., Frauscher F., Klocker H., Bartsch G., Ninkovic M. Reconstruction of the lower urinary tract using autologous muscle transfer and cell seeding: current status and future perspectives. *World J.Urol.* 18 (2000) 44-50

Stenzl A., Ninkovic M., Willeit J., Hess M., Feichtinger H., Schwabegger A. Free neurovascular transfer of latissimus dorsi muscle to the bladder. I. Experimental studies. *J Urol* 157 (1997)1103-1108

Tamai S., Komatsu S., Sakamoto H., Sano S., Sasauchi N. Free muscle transplants in dogs, with microsurgical neurovascular anastomoses. *Plast Reconstr Surg*. 46 (1970) 219-225

Tanagho E.A., Schmidt R.A. Electrical stimulation in the clinical management of the neurogenic bladder. *J Urol* 140 (1988) 1331-1333

Tang P.C., Ruch T.C. Non-neurogenic basis of bladder tonus. *Am J Physiol*. 181 (1955) 249-57

Timm G.W., Bradley W.E. Electrostimulation of the urinary detrusor to effect contraction and evacuation. *Invest Urol* 6 (1969) 562-567

Vaidyanathan S., Krishnan K.R., Soni B.M., Fraser MH. Unusual complications of intermittent self-catheterisation in spinal cord injury patients. *Spinal Cord* 34 (1996) 745-748

von Heyden B., Anthony J.P., Kaula N., Brock G.B., Jakse G., Tanagho E.A. The latissimus dorsi muscle for detrusor assistance: functional recovery after nerve division and repair. *J Urol* 151 (1994) 1081

Wein A.J. Neuromuscular dysfunction of the lower urinary tract. In: "Campbell's Urology", edited by P.C.Walsh, W.B. Saunders Company, Philadelphia 1998, 953-1006

Wein A.J, Barrett D.M. Voiding function and dysfunction: a logical and practical approach. Year Book Medical Publishers, Chicago 1988

Wheeler J.S., Robinson C.J., Culkin D.J., Nemchausky B.A. Naloxone efficacy in bladder rehabilitation of spinal cord injury patients. *J Urol*. 137 (1987) 1202-1205

Zhang YH, Shao QA, Wang JM. Enveloping the bladder with displacement of flap of the rectus abdominis muscle for the treatment of neurogenic bladder. *J Urol*. 144 (1990) 1194-1195

Zancolli E., Mitre H. Latissimus dorsi transfer to restore elbow flexion. An appraisal of eight cases. *J Bone Joint Surg Am*. 55 (1973) 1265-1275

Zuker RM, Manktelow RT. Functioning free muscle transfers. *Hand Clin*. 136 (2007) 57-72

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