Pathophysiology of Stress Urinary Incontinence

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All cases of stress urinary incontinence (SUI) are not the same; urethral pressures, prolapse conditions, and congenital and acquired sphincteric dysfunction all contribute to SUI pathophysiology. In order to optimally manage SUI, a thorough understanding of the pathophysiology behind the condition is necessary. Unsuccessful treatment of incontinence can result from the procedure itself or from a poor fit between the patient's condition and the treatment chosen. Proper patient evaluation, including videourodynamics and measurement of Valsalva leak point pressure, is key to making the best treatment decisions and obtaining optimal patient outcomes.
[Rev Urol. *2004;6(suppl 5):S11-S17*]

Key words: Stress urinary incontinence • Detrusor pressure • Intrinsic sphincter dysfunction • Videourodynamics • Urethral hypermobility • Bulking agents

Brief involuntary urine loss associated with an increase in abdominal pressure is the *symptom* "stress incontinence." Most persons with this problem experience leaking with coughing, sneezing, or vigorous effort. However, in some cases, minimal effort is required to induce involuntary urine loss, which may be more or less continuous but still classified as stress incontinence the *condition*.

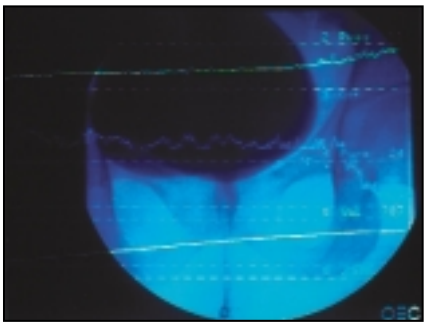


Figure 1. *Video study of a patient with a poorly compliant bladder: Volume increments result in an abrupt increase in detrusor pressure (P_{det}), which ultimately overcomes the closing forces in the proximal sphincter. Because both areas are isobaric, minimal effort will cause leakage, but the major expulsive force here is P_{det}, and a urethral procedure will not resolve the leakage.*

Specific Conditions

The *condition* stress incontinence exists when involuntary leakage is produced by an increase in total vesical pressure (P_{ves}), a value that includes abdominal pressure (P_{abd}) and detrusor pressure (P_{det}). To be "genuine," stress incontinence must involve little or no P_{det} component in the expulsive force. If the detrusor contracts or there is poor compliance, the expulsive force is not mainly P_{abd} but includes a significant P_{det} component. In these cases, one cannot be sure that sphincteric dysfunction and abdominal pressure interact to induce leakage. Therefore, in any case when P_{abd} causes leakage and P_{det} at the time is minimal, true stress incontinence is present.

Clinically, a stress leakage test is sufficiently accurate in that it demonstrates that coughing or straining induces visible urine leakage, often associated with rotational descent of the urethra into the vagina. However, the test does not rule out a detrusor component to the expulsive force and does not provide information on the severity of the stress incontinence condition—that is, the relative weakness of the urethral sphincter. Because the test is usually performed in the supine position, a negative result does not rule out stress incontinence. Moreover, the standard way to "rule out" a detrusor pressure component within an expulsive force is with a twin-channel subtracted cystometrogram (CMG) in which rectal pressure is subtracted from P_{ves} continuously and true P_{det} is recorded. This test, however, has little meaning if performed alone; only if done in conjunction with a stress maneuver can the test provide evidence of a phasic detrusor contraction–generated pressure component.

Detrusor Pressure as a Complicating Factor

Of the 2 sources of P_{det}—an actual phasic contraction of the bladder and poor compliance—poor compliance, in which bladder volume increments are associated with progressive increases in P_{det}, is by far the most important (Figure 1). The CMG is precise and accurate in the determination of altered compliance. Poor compliance is associated with symptoms that are similar to those of stress incontinence. The condition occurs as the rising P_{det} begins to approach the closing pressure in the proximal sphincter, which creates a situation identical to intrinsic sphincteric deficiency (ISD), although the expulsive force is actually P_{det} and not P_{abd}.

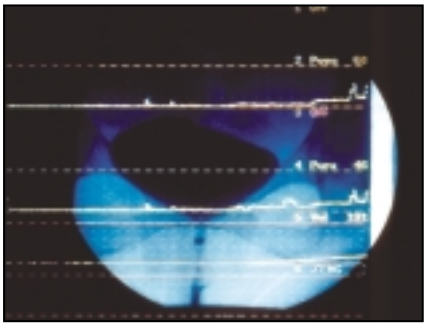
On the other hand, the CMG is wildly inaccurate in the diagnosis of motor urge incontinence. It is not possible to eliminate a detrusor contraction–related incontinence component with a CMG, because the test misses at least 50% of cases of this condition. Clinically, it is more practical to define bladder compliance with a CMG and perform a stress test in the upright position or a video leak-point pressure test to establish the presence and severity of stress incontinence, rather than to worry about a phasic detrusor contraction as a hidden cause of a leakage that appears to be stress incontinence but is not (Figure 2)

According to the International Continence Society (ICS) definition, stress incontinence is present when P_{ves} is greater than urethral pressure (P_{ura}), when it is simultaneously determined that the detrusor pressure is nearly zero. This definition is misleading for a number of reasons. P_{ura} measured during straining or coughing is not truly a pressure; in fact, no urethral measurement is an actual pressure. During videourodynamic testing, leakage is frequently recorded when P_{ves} is less than P_{ura} (Figure 3) and, oftentimes, no leakage is seen when P_{ves} is much greater than P_{ura} (Figure 4). The sensitivity and specificity of urethral pressure measurements have never been demonstrated, nor is it established that any recorded urethral luminal "pressure" value has a relationship, linear or otherwise, with the ability of the urethra to resist an upstream bolus of urine acted on by P_{abd}.

Abdominal and Detrusor Pressure as Forces Opposed by the Urethra

Many years ago, Schafer[1] and Griffiths[2] demonstrated that the P_{det} required to induce flow in the urethra was a measure of urethral resistance at that instant and not an indicator

Figure 2. *Stress incontinence on an upright video study: There is some mobility of the urethra and bladder base. Abdominal leak-point pressure is 50 cm H_2O or lower. This is objectively identified leakage, and the cystometrogram is flat, indicating no detrusor pressure component.*



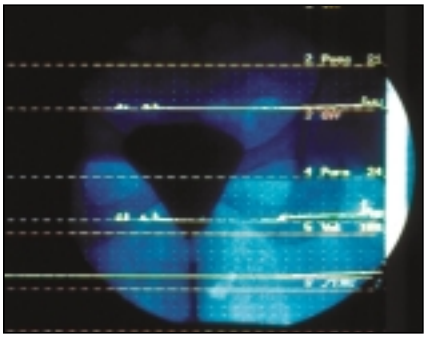


Figure 3. *Videourodynamics in an elderly woman with stress and motor urge incontinence symptoms: There is a lateral detachment-type small cystocele. Gross leakage with stress is seen. At the instant of leakage, vesical pressure is 21 cm H_2O and urethral pressure 24 cm H_2O.*

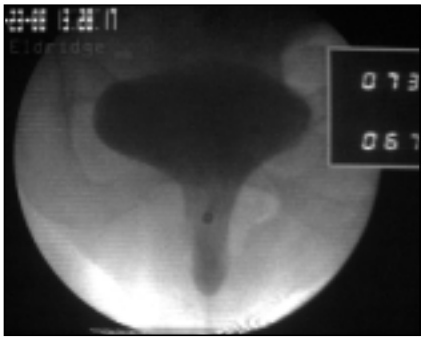


Figure 4. *Videourodynamic study of a patient with a central cystocele: With straining, the cystocele descends, vesical pressure reaches 73 cm H_2O, and urethral pressure reaches 67 cm H_2O, but there is no leakage.*

of the character or strength of the detrusor contraction. Similar observations apply to the P_{abd} required to induce leakage, which is a reflection of the strength or weakness of the urethral sphincter.[3] In this regard, P_{det} and P_{abd} are to the urethra quite different forces. A study of the detrusor and abdominal pressures required to induce leakage in a myelodysplastic population demonstrated that the 2 pressures were never the same.[4] P_{det} must force a urine bolus down the urethra and, in so doing, must overcome all urethral resistance from the bladder neck to the meatus. As it happens, urethral relaxation is part of normal voiding. Thus, P_{det} during voiding is normally relatively low (<30 cm H_2O).

The abdominal pressure required to cause the urethra to leak is neither the same nor related to voiding pressure. Videourodynamic studies demonstrate that a weak or absent proximal urethral closure mechanism requires little P_{abd} to induce leakage, even if the distal volitional sphincter works completely normally, reflexively and volitionally (Figure 5). This absence of proximal urethral function occurs in both men and women and is associated with severe stress incontinence. These findings indicate that midurethral closing function has an uncertain relationship with the ability of the urethra to resist P_{abd} as an expulsive force.

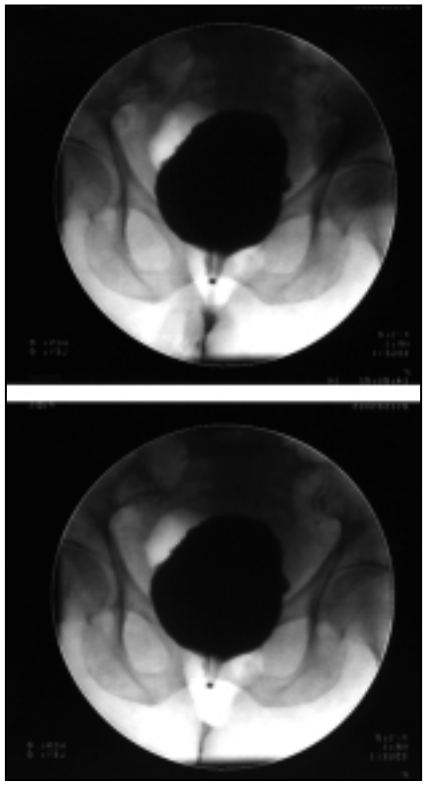
Indeed, there are many examples of congenital and acquired absence of urethral function involving only the proximal urethra in which severe stress urinary incontinence (SUI) is nonetheless present. These include myelodysplasia; T_{12}-L_1 spinal cord injuries (Figure 6); and pelvic nerve injury associated with abdominal-perineal resection (Figure 7) and, occasionally, radical hysterectomy.[5-7] Children with myelodysplasia often have enough fixed urethral resistance to require high detrusor pressures to induce voiding. If voiding pressures are greater than 40 cm H_2O, a direct risk to renal and ureteral function exists, but there is nonetheless severe SUI with coughing, straining, and transfers (Figure 8).[8]

These findings underscore the fact that, as far as the urethra is concerned, P_{abd} and P_{det} are entirely different expulsive forces. Moreover, it is clear that the worst variety of urethral dysfunction and SUI occurs when proximal urethral sphincter function is lost or very weak, regardless of the function of the midurethral high-pressure zone.

Intrinsic Sphincter Dysfunction and Urethral Hypermobility

Jeffcoate and Roberts[9] and Green,[10] among many others, noted that most women with primary SUI had urethral mobility that could be measured by upright cystourethrography. Green[10] used the degree of mobility to guide selection of an appropriate operative procedure. Currently, most gynecologists use the Q-tip test to determine whether urethral mobility is present. The existence of urethral mobility suggests that achieving better urethral support with an operation might cure the leakage. If the urethra is not mobile but nonetheless leaks, there may be a problem with intrinsic closure of the urethra and, thus, a support

Figure 5. *Videourodynamics in a boy with myelodysplasia and congenital absence of proximal sphincter function: Note the open proximal sphincter. The distal sphincter works. The abdominal leak-point pressure (LPP) is 45 cm H_2O, and the detrusor LPP is 34 cm H_2O. This patient has leaking with effort, walking with crutches, and coughing.*



operation may be unsuccessful.

Although the above basic observations are correct, an evaluation performed with the patient supine is less accurate than one performed with the patient upright. In addition, because the excursion in P_{abd} is not measured, the expulsive force is unknown. Therefore, the examiner does not know how vigorous the effort made by the patient is or whether leakage would occur at the same pressure with the patient upright. Although this type of evaluation is clinically acceptable, it is relatively insensitive and not specific. Should a patient who was evaluated in this manner have failure of surgery, the data are insufficient to determine whether the failure was due to the procedure itself or whether the treatment chosen was simply unsuitable for the patient's condition.

Videourodynamic studies performed with the patient in an upright position are much more accurate in defining the stress incontinence problem and determining the presence of a bladder prolapse condition. For example, videourodynamic studies in women who had failure of a retropubic suspension (Figure 9), a bone anchor sling (Figure 10), or a tape-type procedure (Figures 11 and 12) often show a well-supported, immobile urethra that nevertheless leaks at relatively low P_{abd}. Oftentimes, the proximal sphincter in these women is open or partially so.

Figure 6. *Upright video study in a patient with a traumatic T_{12} spinal cord injury: This patient has severe stress incontinence. His proximal sphincter does not function. The abdominal leak-point pressure is 16 cm H_2O.*

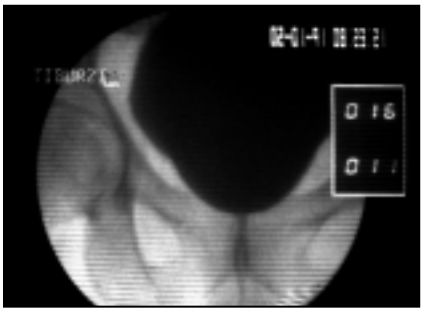


Figure 7. *Videourodynamics in a 65-year-old man after an abdominoperineal resection for rectal carcinoma: The proximal sphincter does not function. There is severe stress incontinence. The distal volitional sphincter is fully functional, and the detrusor leak-point pressure is elevated.*

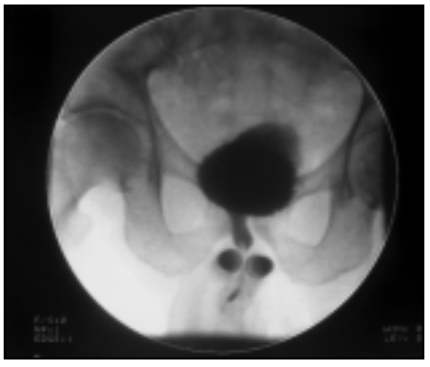
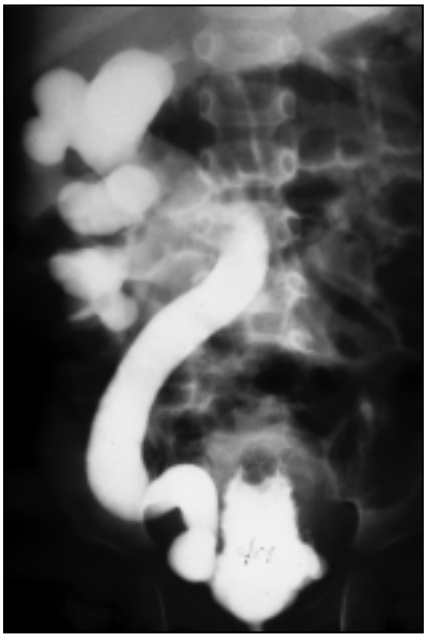


Figure 8. *Late outcome of untreated neurogenic vesical dysfunction in a girl with myelodysplasia: There is gross reflux into the right ureteral-renal system. The right renal unit is destroyed, and the left is at risk. Note the open bladder outlet and the nonfunctional sphincter. The patient has severe incontinence related to her decentralized bladder and nonfunctional urethra. Her detrusor leak-point pressure (LPP) is 68 cm H_2O, and abdominal LPP is 75 cm H_2O. Incontinence does not ameliorate risk here; the detrusor LPP is too high.*



Women with incontinence who have never had surgery for the condition and in whom an open bladder neck at low bladder volumes is shown on a video study all have SUI, and most have type III SUI, with a low Valsalva leak-point pressure.[11] For practitioners who use videourodynamics, intrinsic sphincter dysfunction (type III SUI) is defined as stress incontinence identified on the video study and associated with little or no urethral mobility, at low Valsalva leak-point pressures and often with a partially open proximal sphincter. Slings, placed so as to close the open bladder outlet, are quite successful in both of these groups of patients.[12]

Recognition of poor proximal urethral function in some women with SUI was followed by the observation that similar conditions existed in other patient populations. In men, proximal urethral weakness or loss of function is seen after T_{12}-L_1 spinal cord injury, as it is in women with the same injury. Slings, placed either around the prostatic urethra or under the bulbous urethra via a perineal approach, have been used successfully in men with ISD. Most women and men with neuropathic ISD have low Valsalva leak-point pressures. In neuropathic ISD, slings have been highly effective. In these patients, outcomes are rather stark: either wet or dry.[3]

An isolated measurement of leak-point pressure is not very useful; however, integrated with other data based on the patient history, physical examination, and a video study, this measurement helps to precisely define the urethral problem. Moreover, the videourodynamic diagnosis of ISD is completely focused on the closure of the proximal sphincter and ignores the distal urethral high-pressure zone; the gynecologic diagnosis of ISD is focused on the midurethral high-pressure zone and ignores the proximal sphincter. These are,

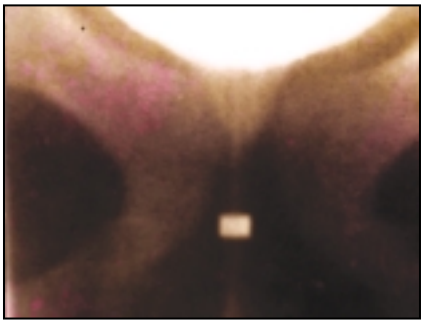


Figure 9. *An upright cystogram made during a videourodynamic study in a 65-year-old woman following failure of 2 retropubic suspensions: Note the normal urethral position and the open proximal sphincter. This patient had severe stress incontinence.*

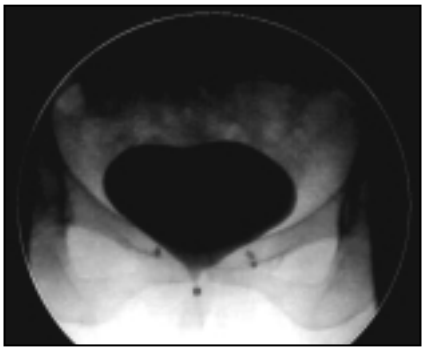
therefore, different conditions.

In patients with non-neuropathic conditions and symptomatic SUI, recognition of a fixed immobile urethra with an open proximal segment is important, because such patients do poorly with a support-type operative procedure. In these cases, a sling, a circumferential sling, or a urethral bulking agent can be useful, whereas additional urethral support is usually not.

ISD and Gynecology

Gynecologists have long recognized childbirth as a factor in the development of SUI and prolapse conditions.

Figure 10. *Upright image during a video study in a 34-year-old woman in whom severe postpartum stress incontinence was treated with a bone anchor fascial sling: Note the open proximal urethra. The abdominal leak-point pressure is 38 cm H_2O. The sling is actually in position and readily identifiable where it touches the posterior wall of the urethra, but there is not enough compression to affect continence.*



Weakness of the levator ani complex and poor function or poor strength of the volitional urethral sphincter were found to be related to childbirth and the secondary development of SUI and genital prolapse.[13] Preliminary data from studies conducted by John O. L. DeLancey, MD, and colleagues at the University of Michigan on damage to levator muscle function by vaginal delivery suggest that profound levator muscle damage, even complete and bilateral, has no fixed relationship with SUI (unpublished data, 2004). In addition, severe type III SUI can develop immediately postpartum, which is not associated with any levator muscle injury or with prolapse.

It appears that the injury (childbirth) in these cases is common but the results disparate depending on the nature and extent of the injury. Whereas prolapse seems to be associated with levator muscle injury, this is not true of the severe type III postpartum SUI, which appears to be associated with a loss of function of the proximal sphincter.

In part because of the emphasis on closure of the urethra by the skeletal sphincter and levators and the putative role of the pelvic floor muscular function in the pathogenesis of SUI, gynecologists have made a considerable effort to measure urethral function.[14,15] In an early paper, Sand and colleagues[16] suggested that a low-

Figure 11. *Recurrent stress incontinence after a tension-free vaginal tape procedure: Note the impression of the tape on the urethra; it appears to be closer to the bladder neck than we would expect. The proximal urethra is open and leaks easily with straining. The abdominal leak-point pressure is 46 cm H_2O, and there is no urethral mobility. A standard autologous fascial sling would have the same appearance, at least the position where the sling appears to compress the posterior aspect of the urethra.*

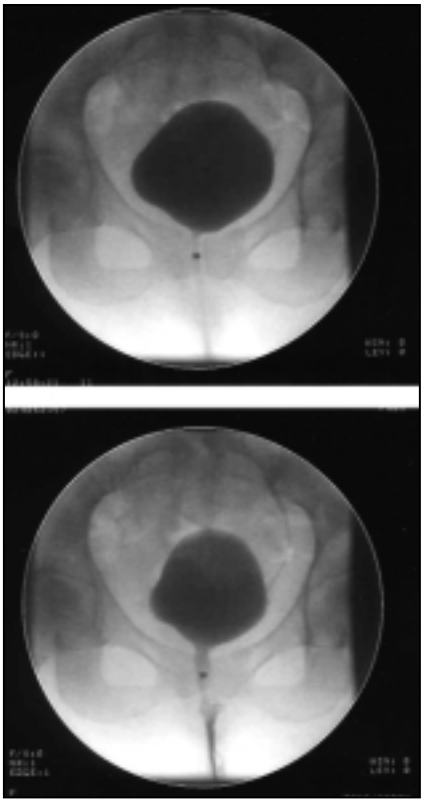
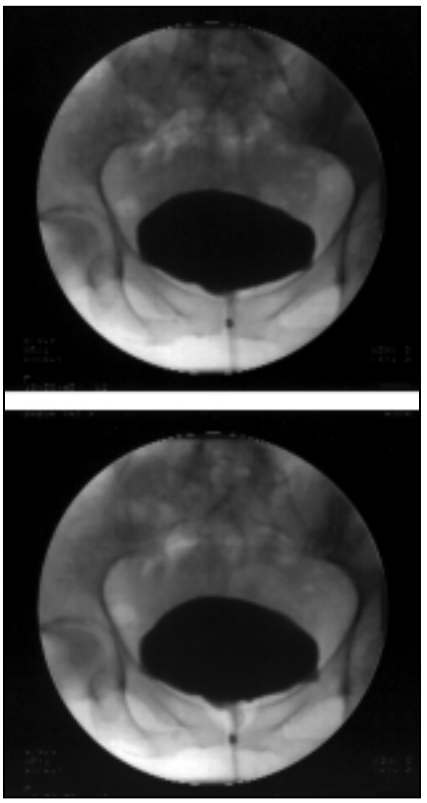


Figure 12. *Recurrent stress incontinence after a tension-free vaginal tape procedure in a 79-year-old woman: The bladder outlet is slightly open. Leakage occurs at pressures less than 50 cm H_2O. There is no urethral mobility at all.*



pressure urethra was a risk factor for failure of a retropubic suspension. At the time, retropubic suspension was the gold standard procedure for the treatment of SUI. Patients with a low-pressure urethra were identified by urethral pressure profilometry, which concentrated on the high-pressure zone of the midurethra. If the pressure recorded in this area was less than 20 cm H_2O, a low-pressure urethral condition (ie, ISD) was said to exist.

Thus, ISD as defined by profilometry and videourodynamics are different conditions, and correlation between the 2 measurements is poor. On the other hand, the precise role of volitional urethral sphincter function or dysfunction in stress incontinence remains unclear and poorly defined. To some extent, the emergence of the new tension-free vaginal tape (TVT) procedures has led to a situation in which preoperative investigations are considered nonessential, because the procedures are associated with excellent outcomes in most cases.[17] However, although most procedure outcomes are successful, there are some failures, and it is these patients that we must better understand. Prospective data for patients undergoing TVT procedures are needed to determine which patients with which variety of SUI are best treated with the procedure and which are not.

Stress Incontinence Associated With Hypermobility of the Urethra

Urethral hypermobility does not have a 1-to-1 relationship with SUI; however, if present in patients with SUI symptoms, it is presumptive evidence of a condition related to a loss of urethral support. In young nulliparous women without symptoms, the urethra is quite immobile in the upright position with straining and coughing. Thus, a lack of urethral support is putatively associated with most cases of SUI.

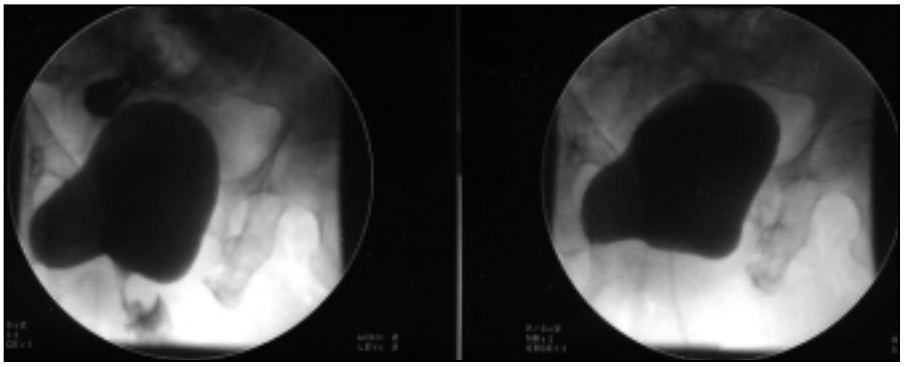


Figure 13. *Persistent stress incontinence after a retropubic suspension: There is no urethral mobility at all. The impression of the Burch sutures on the bladder lateral to the urethra is obvious, yet the urethra leaks with straining. This is an ideal situation for use of a bulking agent.*

Part of the support mechanism is resident in the attachments of the periurethral fascia to the arcus tendineous fascia pelvis laterally and anteriorly. The arcus also supports the vagina on either side of the urethra and contributes to the hammock support described by DeLancey.[13] Urethral suspension by the method of Burch involves vaginal fixation to Coopers ligament, resulting in partial re-creation of the hammock support mechanism.

The Petros-Ulmsten unified theory, which led to the development of the TVT procedure, places emphasis on the midurethral complex, which attaches the urethra to the symphysis and arcus and, in effect, compresses the urethra during excursions in abdominal pressure.[18] The TVT is placed around the distal urethra in an effort to support the urethra at that precise point without obstructing it. The proximal urethra is said to remain freely mobile and unobstructed while the tape effects closure and backing of the midurethra and conveys continence. On both sides, the tape passes through the endopelvic fascia immediately adjacent to the arcus and, thus, like a standard sling, conveys urethral support. In most cases, I cannot tell the difference between a successful TVT and a fascial sling on an upright video study. In addition, ultrasound determinations of proximal urethral mobility after the TVT procedure were performed in the supine position, which is not the best position for such studies.

The various tape procedures have been shown in multiple reports to be highly effective—more so than a retropubic suspension. In a large blinded study conducted in several centers in England and Ireland, patients were randomly assigned to undergo the TVT or Burch procedure, performed by surgeons of wide variability in experience in SUI surgery.[19] Results revealed almost identical outcomes with the 2 procedures, suggesting that selection bias or surgeon experience may have contributed to the results of the earlier reports.

Bulking Agents

The best and most durable results with bulking agents have been demonstrated in elderly women with limited urethral mobility and SUI. Bulking agents have been used to successfully treat recurrent incontinence after a suspension or other procedure for SUI in which a normal urethral position was achieved but the urethra nevertheless continued to leak (Figure 13).

Although bulking agents have been successfully used in patients with hypermobility, the duration of effect in younger women has prevented widespread applicability in this pop-

ulation. At the moment, bulking agent use is in part driven by patient preference for a less invasive treatment. There are, however, circumstances for which bulking agents are ideal. These include cases in which urethral resistance cannot be safely increased; for example, in patients with poor detrusor function who do not empty or in those with abnormal compliance for whom an increase in urethral closing pressure can be associated with a dangerous elevation in bladder pressure. Most patients who request treatment with a bulking agent do so to avoid surgery. Some persistence on the part of the surgeon is required, since most patients require 2 or 3 injections to achieve continence.

The various bulking agents appear to have comparable short-term success rates; that is, approximately 65% of women so treated will achieve dryness, at least for some time. Better results are achieved with transurethral rather than paraurethral injection. That the immediate effects of the various agents are almost equal appears to be related to tissue factors and not to the material used. The duration of the effect on urethral function, however, does appear to be related to the bulking material.

The effects of bulking agents on urethral function are detectable by leak-point pressure testing only and not by urethral pressure testing. Even in patients who achieve continence, the urethral pressure profilometry values do not change. Each injection is associated with a 20- to 50-cm increase in the abdominal leak-point pressure, or around what is achievable with a sling procedure in children with ISD. ■

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Main Points

- Total vesical pressure consists of abdominal pressure (P_{abd}) and detrusor pressure (P_{det}); true stress incontinence occurs when P_{abd} causes leakage and the expulsive force involves little or no P_{det}.
- A weak or absent proximal urethral closure mechanism requires little P_{abd} to induce leakage, even if the distal volitional sphincter works completely normally. This absence of proximal urethral function occurs in both men and women and is associated with severe stress incontinence.
- Videourodynamic studies performed with the patient in the upright position are much more accurate in defining the stress incontinence problem and determining the presence of a bladder prolapse condition than are supine evaluations.
- Intrinsic sphincter dysfunction as defined by urethral pressure profilometry and videourodynamics are different conditions, and correlation between the 2 measurements is poor.
- Bulking agents have been used to successfully treat recurrent incontinence after a suspension or other procedure for SUI in which a normal urethral position was achieved but the urethra nevertheless continued to leak. They are also ideal for patients in whom urethral resistance cannot be safely increased.