FEcal INCONTINENCE

Robert D. Madoff, MD, and Sarah A. Vogler, MD

Overview and Taxonomy

Fecal incontinence is defined as the involuntary loss of gas, liquid, or solid stool through the anal canal. It is a relatively common condition, occurring in an estimated 18 million adults in the United States. Its exact prevalence is unknown, however, and appears to vary with the population being studied. For example, nearly 50% of nursing home patients are incontinent to stool. However, it is not just the elderly who are affected. A recent study of women ages 45 years and older found that nearly one in five had an episode of fecal incontinence at least once a year, and for nearly half, the frequency was once a month or more.

The chronic involuntary loss of bowel control is humiliating. Although bowel incontinence is not technically life threatening, it is certainly life altering. It strikes in a full range of degrees, from leakage of small amounts of fecal matter when passing gas to complete loss of bowel and rectal control. Fecal incontinence causes social isolation and confines patients to their homes. Additionally, it makes a significant contribution to medical morbidity, including urinary tract infections, perianal skin breakdown, and decubitus ulcers.

Fecal incontinence is often treated inadequately, either because of underreporting of symptoms to the physician or because of ignorance or disinterest on the physician’s part. With a growing elderly population, this condition will be an increasing challenge to both health care providers and home care services.

Normal continence depends on a chain of interdependent processes, and disruption of any of the links in the chain can lead to incontinence. Frequently, a combination of factors is responsible for the incontinence. Causes for fecal incontinence can be broken down into three broad categories: neurologic disease; functional gastrointestinal (GI) diseases or abnormalities; and structural injuries or abnormalities in the pelvic floor, rectum, or anal sphincter.

Individuals must have adequate mental function to care about continence, and they must have an intact neurologic arc from the brain to the anal sphincter to maintain normal continence. A wide array of neurologic disorders can lead to incontinence, including dementia, strokes, spinal cord injury, multiple sclerosis, and diabetic autonomic neuropathy. So-called idiopathic fecal incontinence is caused by pelvic floor denervation resulting from traction injury to the pudendal nerves. The injury is usually caused by straining and consequent pelvic floor descent during obstetric delivery or by chronic straining at stool.

Conditions characterized by abnormal GI function, especially diarrheal states, can cause or exacerbate incontinence. Common causative conditions include infectious diarrhea and inflammatory bowel disease. Diarrhea-predominant irritable bowel syndrome can contribute to incontinence in patients with other associated disorders. Fecal impaction and subsequent “overflow” leakage are an important cause of incontinence, particularly in older and institutionalized populations.

Abnormalities of the pelvic floor are frequent causes of incontinence. Some such abnormalities are congenital malformations (e.g., imperforate anus, rectal agenesis, and cloacal defect). More often, abnormalities are attributable to acquired sphincter injuries. Common causes of sphincter injury include obstetric injury, pelvic fracture, and traumatic impalement. One of the most frequent causes is anorectal surgery, such as hemorrhoidectomy, fistulotomy, sphincterotomy, or anal dilatation. Sphincter-sparing rectal resections can also lead to incontinence as a consequence of both the loss of the normal rectal reservoir and the sphincter injury caused by transanal introduction of intraluminal staplers.

Clinical Evaluation

HISTORY

A careful patient history and a directed physical examination are the most important elements of clinical evaluation for a patient with fecal incontinence. The patient should be asked about the onset and nature of the incontinence (e.g., whether incontinence is to gas, liquid, or solid stool), any changes in stool consistency or bowel habits, and the frequency of incontinence. It is important to ask about associated symptoms such as urinary incontinence, prolapse of tissue from the vagina or anus, and pain or bleeding with defecation. A pertinent but thorough medical, surgical, and obstetric history should be obtained, and any underlying contributory conditions (e.g., colitis) should be treated. The impact of the incontinence on the patient’s quality of life should be assessed, at least qualitatively. It is helpful to have patients keep a diary to document the frequency of incontinent episodes and regularity of bowel habits.

Questionnaires and validated scoring systems are additional tools to help define the severity of fecal incontinence. The Fecal Incontinence Severity Index (FISI) is a commonly used and simple scoring system to assess the severity of symptoms. The Fecal Incontinence Quality of Life Index (FIQL) is a longer scoring system that assesses the impact of incontinence on the patient’s quality of life. Other scoring systems include the Fecal Incontinence Severity Index (FISI) and the Fecal Incontinence Quality of Life Index (FIQL).

Table 1: Common Causes of Sphincter Injury

<table>
<thead>
<tr>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetric injury</td>
</tr>
<tr>
<td>Pelvis fracture</td>
</tr>
<tr>
<td>Traumatic impalement</td>
</tr>
<tr>
<td>Anorectal surgery</td>
</tr>
<tr>
<td>Hemorrhoidectomy</td>
</tr>
<tr>
<td>Fistulotomy</td>
</tr>
<tr>
<td>Sphincterotomy</td>
</tr>
<tr>
<td>Anal dilatation</td>
</tr>
<tr>
<td>Sphincter-sparing rectal resection</td>
</tr>
</tbody>
</table>

Table 2: Common Causes of Sphincter Injury

<table>
<thead>
<tr>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstetric injury</td>
</tr>
<tr>
<td>Pelvis fracture</td>
</tr>
<tr>
<td>Traumatic impalement</td>
</tr>
<tr>
<td>Anorectal surgery</td>
</tr>
<tr>
<td>Hemorrhoidectomy</td>
</tr>
<tr>
<td>Fistulotomy</td>
</tr>
<tr>
<td>Sphincterotomy</td>
</tr>
<tr>
<td>Anal dilatation</td>
</tr>
<tr>
<td>Sphincter-sparing rectal resection</td>
</tr>
</tbody>
</table>

Scientific American Surgery
DOI 10.2310/7800.2079

08/14
Investigative Studies

A complete colonoscopy should be performed on all incontinent patients to exclude a neoplastic or inflammatory condition. Anoscopy can also assist in evaluating the distal rectum and anal canal for evidence of large hemorrhoids, fistula, distal rectovaginal fistula, or thickening of the distal rectal mucosa caused by intermittent mucosal prolapse.

Anorectal testing is indicated for most patients with significant incontinence, particularly if operative treatment is being considered. The most important test is endoanal ultrasonography (EAUS), which yields a highly accurate assessment of sphincter integrity. EAUS will allow for identification and measurement of an anal sphincter injury and measurement of the rectovaginal septum. Some centers use magnetic resonance imaging (MRI), rather than EAUS, to evaluate the muscular integrity of the pelvic floor and anal sphincter complex.

Anal manometry provides a quantitative assessment of resting and squeeze anal pressures, which serve as indicators of internal anal sphincter function and external anal sphincter function, respectively. Electromyography (EMG) may be used to diagnose neuropathic injury of the pelvic floor. Although concentric-needle EMG is the most accurate technique, most centers employ a glove-mounted intra-anal electrode to measure pudendal nerve conduction time (i.e., pudendal nerve terminal motor latency [PNTML]). The practical utility of PNTML testing is debatable, however, and opinions vary regarding the test’s ability to predict successful outcomes after anal sphincter repair.

Dynamic imaging of the pelvic floor with fluoroscopic or MRI defecography depicts the effectiveness of rectal emptying with defecation. Defecography can also reveal an occult pathologic state that can contribute to incontinence but is not evident on physical examination (e.g., occult rectal prolapse, rectocele).

Management

CONSERVATIVE MANAGEMENT

Minor incontinence should be treated first with conservative measures. Dietary changes (e.g., avoidance of foods that cause diarrhea or urgency), fiber supplementation, and bowel habit training are helpful for most patients, as is regular use of loperamide. Perianal skin excoriation should be treated with a barrier cream, and seepage may be controlled either with placement of a small cotton wick at the anal orifice or, occasionally, with rectal washouts.

BIOFEEDBACK

Biofeedback appears to be an effective therapy for fecal incontinence in highly motivated patients. It is an inherently attractive approach because it is simple, painless, and risk free. However, the biofeedback literature consists mostly of small, uncontrolled, retrospective studies, and its specific efficacy has been questioned. A randomized controlled trial from 2003 found that biofeedback had no advantages over standardized medical and nursing care (i.e., advice) or advice plus sphincter exercises. In contrast, a more recent randomized trial showed that manometric biofeedback with pelvic floor exercises was more effective.

Figure 1 An obstetric sphincter injury.
Patient presents with fecal incontinence

Evaluate patient.

**History:** Determine onset, nature, and frequency of incontinence. Obtain thorough medical, surgical, and obstetric history.

**Physical examination:** Focus particularly on perineum. Perform digital rectal examination. Perform endoscopy to exclude neoplasm or inflammation.

Patient has diarrhea

Assess and treat cause of diarrhea (colitis, hypersecretory tumor, radiation exposure, overflow). Provide medical treatment (fiber, dietary changes, barrier cream, antidiarrheal agents, bowel regimen).

- Incontinence is mitigated or resolves
- Incontinence persists

Patient does not have diarrhea

Perform anorectal physiology testing:
- Anorectal manometry
- EAUS
- Defecography (optional)

- Consider biofeedback.

Patient has major sphincter defect

- Overlapping sphincteroplasty
- Sacral nerve stimulation

- Failure of conventional treatments

- Consider salvage options:
  - Colostomy
  - Artificial bowel sphincter
  - Stimulated graciloplasty

Patient has minor sphincter defect or no defect at all

- Injectables

---

*Figure 2*  Algorithm outlining the workup and management of fecal incontinence. EAUS = endoanal ultrasonography.
The FISI is based on four types of leakage (gas, mucus, liquid stool, and solid stool) and five frequencies (one to three times per month, once a week, two or more times a week, once a day, and two or more times a day). The patient indicates how often in the past month he or she has experienced any amount of accidental bowel leakage, and the patient’s scores for each row are combined. The total FISI score ranges from 0 (never having any type of incontinence) to 20 (incontinence to gas, mucus, liquid stool, and solid stool two or more times a day).

### SPHINCTEROPLASTY

Until recently, anal sphincter repair has been the most widely accepted operation for fecal incontinence. Sphincteroplasty is still the only treatment option that allows for anatomic correction of sphincter injuries. However, it is associated with significant morbidity, such as wound breakdown, fecal impaction and urinary tract infection, and poor long-term functional outcome.20,21 A systematic review of 16 studies reporting short- and long-term outcomes for more than 900 patients after sphincteroplasty found that all but one of the studies showed a decline over time in the number of patients who considered themselves to have a “good” outcome.21 The more promising long-term efficacy and safety profile of sacral nerve stimulation (SNS) compared with sphincteroplasty has prompted a change in the surgical treatment algorithm for fecal incontinence [see Figure 2].

In acute situations (e.g., when an obstetric sphincter injury is recognized), immediate direct repair is generally recommended. Unfortunately, as many as 75% of women have persistent external anal sphincter defects after primary repair, and about 60% have some degree of incontinence.22 If immediate repair is not attempted, surgical treatment should

---

### Table 2  The Fecal Incontinence Severity Index (FISI)10

<table>
<thead>
<tr>
<th>Type of Fecal Incontinence</th>
<th>2 or More Times a Day (Score = 5)</th>
<th>Once a Day (Score = 4)</th>
<th>2 or More Times a Week (Score = 3)</th>
<th>Once a Week (Score = 2)</th>
<th>1–3 Times per Month (Score = 1)</th>
<th>Never (Score = 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mucus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid stool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid stool</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The FISI is based on four types of leakage (gas, mucus, liquid stool, and solid stool) and five frequencies (one to three times per month, once a week, two or more times a week, once a day, and two or more times a day). The patient indicates how often in the past month he or she has experienced any amount of accidental bowel leakage, and the patient’s scores for each row are combined. The total FISI score ranges from 0 (never having any type of incontinence) to 20 (incontinence to gas, mucus, liquid stool, and solid stool two or more times a day).

### Table 3  Daily Life Factors Measured by FIQoL Questionnaire11

<table>
<thead>
<tr>
<th>Daily Life Factor</th>
<th>Example of Negative Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifestyle</td>
<td>Not getting out of the house</td>
</tr>
<tr>
<td>Coping behavior</td>
<td>Always staying close to restrooms</td>
</tr>
<tr>
<td>Depression or self-perception</td>
<td>Feelings of worthlessness</td>
</tr>
<tr>
<td>Level of embarrassment</td>
<td>Worries about getting to toilet in time</td>
</tr>
</tbody>
</table>

FIQoL = Fecal Incontinence Quality of Life. Each aspect is described as a score measured on a scale between 1 and 4, where 1 is very affected and 4 is not affected.
be delayed at least 3 to 6 months to permit resolution of local tissue inflammation and edema. Overlapping sphincteroplasty is performed under general anesthesia. A complete bowel preparation is carried out before the procedure, and prophylactic antibiotics are administered.

Operative Technique

Step 1: initial dissection  The patient is placed in the prone jackknife position, with the buttocks taped apart and a large roll beneath the hips. A curvilinear incision is made over the perineal body, and the anoderm and the anal canal mucosa are raised as an endodermal flap [see Figure 4a]. The vaginal wall is mobilized anteriorly.

Step 2: mobilization of sphincter muscle  It is often easiest to first identify normal muscle laterally in the ischiorectal fossa and then to work medially toward the attenuated tissue in the midline. Lateral dissection is extended back on either side until enough healthy muscle is mobilized to allow overlapping without tension. Generally, however, lateral dissection should not extend beyond the midcoronal line so as not to risk injury to the inferior rectal branches of the pudendal nerves, which cross the ischiorectal fossae posterolaterally. Dissection is then carried out cranially in the rectovaginal septum to the level of the puborectalis. The muscle is divided through its midline scar, but the scar is preserved to help prevent the sutures from tearing through.

Step 3: overlapping repair  The tapes on the buttocks are then released, and an overlapping sphincter repair is performed with mattress sutures [see Figure 4, b, c]. A snug plication is universally advocated, but, unfortunately, there are no generally accepted objective criteria to define exactly what “snug” means in this context. Many authorities advise plication of the puborectalis (so-called levatorplasty) at the cranial aspect of the repair to maximize the length of the anal canal. Others favor individual dissection and repair of the internal and external sphincter muscles, but at

Figure 4  Sphincteroplasty. (a) With the patient in the prone jackknife position, a curvilinear incision is made. Inferior rectal nerves cross the ischiorectal fossa posterolaterally. (b) Anterior levatorplasty is performed, and overlapping sphincter repair is then initiated. (c) Sphincter repair is completed. (d) The incision is closed, with drains in place (optional), and V-Y plasty is done to restore the perineal body.
present, there is no compelling evidence for the superiority of this approach.

**Step 4: restoration of perineal body** The skin incision is closed in a V-Y configuration to restore the perineal body and maximize the distance between the anus and the vaginal introitus. The wound is left partially open or closed loosely over small Penrose drains to minimize the risk of surgical site infection [see Figure 4d]. A diverting stoma is not generally indicated but may be considered in special situations (e.g., multiple previous failed repairs, Crohn disease, or various chronic diarrheal states).

**Outcome Evaluation**

In young patients with a large sphincter defect, overlapping sphincteroplasty yields clinical improvement in approximately 65 to 80% of patients and restoration of more normal anatomy.24,25 Unfortunately, current data indicate that the results deteriorate significantly over time.20,26,27 When sphincteroplasty fails, repeat EAUS evaluation should be performed to confirm that the muscle wrap is intact, and another sphincteroplasty fails, repeat EAUS evaluation should be done to confirm that the muscle wrap is intact, and another repair can be performed after 6 to 12 months if a significant defect persists.24 However, better immediate and long-term functional success will likely be achieved with SNS rather than a repeat sphincteroplasty. The safety and efficacy profile of SNS makes it an appealing option in these patients.

**POSTANAL REPAIR**

Sir Alan Parks devised the postanal repair in 1975 to treat patients with incontinence and intact sphincters. The initial results were encouraging but tended to deteriorate over time. Consequently, despite evidence of lasting improvement in some patients, this operation is rarely performed today.29,30

**SACRAL NERVE STIMULATION**

SNS, or neuromodulation, was first reported to treat fecal incontinence by Matzel and colleagues in 1995.31 SNS gained Food and Drug Administration (FDA) approval for treatment of fecal incontinence in 2011. Over the last several years, institutions worldwide have reported impressive safety and efficacy results with SNS.32 This minimally invasive approach involves implantation of a pulse generator, which stimulates the sacral nerve to influence the behavior of the pelvic floor, lower urinary tract, anal sphincters, and rectum [see Figure 5].

One of the benefits of SNS compared with most other therapies is that implantation involves a two-stage procedure. During stage 1, the efficacy of the device can be determined for each patient before proceeding with implantation of chronic components in stage 2. Both procedures are performed under local anesthesia with sedation in the prone position. The patient can return home the same day and resume regular activity.

During the first procedure, the S3 foramen is located using bony landmarks and fluoroscopy. A needle is placed through this foramen, and a tined lead is threaded through the needle. This lead is then tested to ensure appropriate position by confirming reflex responses to lead stimulation. Stimulation of each foramen leads to a typical response: S3 causes a bellows-type contraction of the pelvic floor and dorsiflexion of the ipsilateral great toe. This lead is then connected to an external stimulator, which is left in place for a 10- to 14-day trial period. The patient is asked to keep a bowel diary during this time, and if a more than 50% improvement in frequency of incontinence episodes is documented, then the patient proceeds with permanent implantation.

The second procedure involves implantation of the pulse generator in a subcutaneous pocket. Once the pulse generator is implanted, its stimulation parameters are set using a telemetric programmer. If problems (e.g., pain) develop or if the results of stimulation are inadequate, the system can be reprogrammed in a variety of ways: stimulation frequency can be altered, voltage can be increased or decreased, and the configuration of the stimulating electrodes can be modified.

SNS has been shown to be a highly effective treatment and to significantly improve fecal incontinence–related quality of life.33–37 A multicenter prospective trial showed that 83% of patients experienced a more than 50% decrease in incontinent episodes per week compared with baseline at 12 months following SNS; 41% of patients attained full continence.38 Seventy-six percent of these patients were followed for 5 years, and 89% of patients reported a more than 50% decrease in the number of incontinent episodes per week; perfect continence was achieved in 36% of patients.37

For many years, overlapping sphincteroplasty was considered to be the standard of care for patients with anal sphincter defects. Thus, SNS was initially used to treat fecal incontinence in those patients without a sphincter defect. However, SNS has been shown to also be effective in patients with a sphincter defect. Additionally, SNS has the advantage of being a minimally invasive procedure, with an effectiveness trial during stage 1, and promising long-term functional outcomes. Accordingly, because of its high success rate and excellent safety profile, many surgeons now favor SNS as the initial treatment of choice for fecal incontinence patients with and without a sphincter defect. Unfortunately, to date, there have been no randomized controlled trials comparing SNS with overlapping sphincter repair.

**INJECTABLE BIOMATERIALS**

A number of studies have explored the use of injectable biomaterials to provide bulk around the anal sphincter and thereby improve continence. The materials employed have included autologous fat, cross-linked collagen, silicone, carbon-coated beads, and non-animal stabilized hyaluronic acid/dextranomer (NASHA/Dx, Q-Med AB, Uppsala, Sweden).39-41 A Cochrane review in 2010 identified only four randomized controlled trials investigating the efficacy of injectables for treatment of fecal incontinence.42 This review concluded that due to an absence of well-designed trials with an adequate number of individuals, a definite conclusion about the effectiveness of injectable substances could not be made. This review did not include the results seen with the newest injectable, NASHA/Dx. A recent randomized, double-blind, sham-controlled trial showed that patients receiving NASHA/Dx had a greater than 50% improvement in the number of incontinence episodes at the
6- and 12-month follow-ups. This improvement in continence was significantly better than in those patients who received the sham treatment. The role of injectables in the treatment of fecal incontinence is not well defined given the lack of well-designed studies. However, the ease and safety of injectables as a treatment option make this an important area of further investigation in the future.

Nonstimulated Muscle Transposition

Attempts to restore continence by creating a neosphincter from transposed skeletal muscle date back to the early 20th century. Most such attempts have made use of either the gluteus maximus or the gracilis. Good results have frequently been reported, but many authorities believe that the quality of the resulting continence is poor. One of the main limitations of nonstimulated muscle transposition is that patients are typically unable to maintain voluntary contraction of the transposed muscle over the long term.

Stimulated (Dynamic) Graciloplasty

Successful electrical stimulation of a transposed gracilis by means of an implantable pulse generator was first reported in 1988. Such stimulation has two main effects. First, it converts the fast-twitch, rapidly fatigable gracilis to a slow-twitch, fatigue-resistant muscle that is capable of...
tonic contraction for prolonged periods.\textsuperscript{46} Second, electrical stimulation maintains tonic muscle contraction without the need for continuous voluntary control on the part of the patient. A small number of centers with particular expertise in dynamic graciloplasty and high patient volumes have reported good results with acceptable morbidities\textsuperscript{47}; however, three large multicenter trials have reported less encouraging results with prohibitive morbidities.\textsuperscript{48–50} In the United States, dynamic graciloplasty is not available because it has not been approved by the FDA. Elsewhere in the world, the operation can be considered a salvage option at centers with the requisite expertise and experience.

\section*{Artificial Anal Sphincter}

The artificial anal sphincter is an implantable system consisting of three parts: an inflatable perianal cuff, a pressure-regulating balloon, and a control pump that is implanted in the scrotum or the labia majora [see Figure 6]. Good results have been reported in individual case series,\textsuperscript{51} but device infection has been a problem.\textsuperscript{52,53} In a large multicenter trial, 46\% of patients required surgical revision of the device, including 25\% who required revision or explantation because of infection.\textsuperscript{53} Of the patients who underwent implantation, 53\% had successful results; among those with a functioning device in place, the success rate was 85\%.

\section*{Colostomy}

Although creation of a colostomy does not restore continence, it does provide a degree of bowel control in a manner that allows patients to resume their normal activities without fear of accidents. Surprisingly few data are available regarding colostomy for incontinence; however, one questionnaire study of patients who underwent colostomy for incontinence reported extremely high levels of patient satisfaction and marked improvements in subjective quality of life.\textsuperscript{54} In most cases, a simple end sigmoid colostomy with a Hartmann pouch is the appropriate procedure, and it can often be performed with relatively little operative trauma by using a laparoscopic or minilaparotomy technique. Patients should receive preoperative counseling from an enterostomal therapist, and the optimal stoma site should be marked before the procedure is initiated.

\section*{Conclusion}

Fecal incontinence is a lifestyle-limiting condition that is relatively common but often goes unreported by patients and undetected by physicians. Taking a careful patient history helps determine the severity of incontinence and impact of these symptoms on the patient’s daily life. Physical examination and pelvic floor physiology testing help rule out other conditions that can be treated to alleviate symptoms of incontinence. Examination and testing also help determine the most appropriate treatment options for the patient. Conservative measures to improve stool consistency and minimize stool frequency should always be the first step in treating fecal incontinence.

Once conservative treatment options have been maximized, surgical treatment options can be considered for persistent fecal incontinence. Newer surgical options, most notably SNS, have changed the outlook for patients with incontinence and the overall surgical treatment algorithm.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig6.png}
\caption{Artificial anal sphincter. (a) A three-part implantable system is used (shown is Acticon, American Medical Systems, Minneapolis, MN). (b) The recommended placement of the artificial sphincter device in the patient.}
\end{figure}
SNS is a minimally invasive procedure with excellent long-term treatment efficacy in patients both with and without sphincter defects. In comparison, sphincteroplasty has historically been the mainstay of surgical treatment for incontinence with an associated sphincter defect but is a more invasive procedure with higher morbidity. Long-term studies of sphincteroplasty efficacy show some deterioration in continence over time. Sphincteroplasty is still the only option for restoring more normal sphincter anatomy and is a viable treatment option in young women when it can delay the need for a neurostimulating device for several years. Other new treatment options, such as injectable biomaterials, stimulated graciloplasty, and artificial anal sphincter implantation, may prove to be appropriate treatment options for certain patients.

Financial Disclosures: Robert D. Madoff, MD, and Sarah A. Vogler, MD, have no relevant financial relationships to disclose.

References


Scientific American Surgery

Acknowledgment

Figures 4, 5b, and 6b  Alice Y. Chen