



*This document was last amended in September 2020 to reflect literature that was released since the original publication of this content in May 2012. This document will continue to be periodically updated to reflect the growing body of literature related to this topic.*

## **ERECTILE DYSFUNCTION (ED)**

**KEYWORDS:** Erectile dysfunction, phosphodiesterase inhibitors, sexual dysfunction, impotence.

### **LEARNING OBJECTIVES:**

**At the end of medical school, the medical student will be able to...**

1. Draw, identify and name the major anatomic regions of the penis involved with erections
2. Describe the physiology of the normal penile erection
3. List and briefly describe the major causes of erectile dysfunction (ED)
4. List the important components of the history when interviewing a patient with ED
5. Outline the important components of the physical exam of a patient with ED
6. List the treatment options for erectile dysfunction and describe the mechanisms by which they work
7. Describe the contra-indications and side-effects of phosphodiesterase inhibition for ED
8. Describe when a patient with ED should be referred to a urologist

### **Introduction**

Erectile dysfunction is defined as the inability to achieve and maintain an erection sufficient for satisfactory sexual intercourse. It is estimated to affect 20 to 30 million men in the US. ED may result from impairment of one or most commonly, a combination of factors: psychological, neurologic, hormonal, arterial, and venous. More recently it has become clear that, in many cases, ED may be a “silent marker” for the later development of endothelial dysfunction and eventually, cardiovascular disease.

### **Physiology and Anatomy of an Erection**

An erection is a complex neurovascular event subject to psychological and hormonal modulation. Upon sexual stimulation, nerve impulses release neurotransmitters from the cavernous nerve terminals and relaxing factors from the endothelial cells in the penis. Resultant smooth muscle relaxation in the arteries and arterioles (Figure 1a) supplying the erectile tissue results in a several-fold increase in blood flow. Concomitantly, there is (Figure 1b) relaxation of the sinusoidal smooth muscle within the paired corporeal bodies, facilitating rapid filling and expansion of the sinusoidal system. As a result, (Figure 1c) venous plexuses located between the sinusoids and rigid tunic covering the penis are compressed resulting in almost total occlusion of venous

outflow. These events effectively trap the blood within the corpora cavernosa and raise the penis from flaccid to erect position. During full erection, intracavernous pressure of 100 mm Hg are achieved. Sensory stimulation triggers the bulbocavernosus reflex, causing the ischiocavernosus muscles to forcefully compress the blood-filled corpora cavernosa. During ejaculation, penile intracavernous pressures can reach several hundred mm Hg . During this phase, vascular inflow and outflow temporarily cease. Detumescence results when erectile neurotransmitter release stops, when there is breakdown of second messengers by phosphodiesterases, or due to sympathetic discharge during ejaculation.

The penis is innervated by autonomic and somatic nerves. In the pelvis, the sympathetic and parasympathetic nerves merge to form the cavernous nerves, which enter the corpora cavernosa, corpus spongiosum and glans penis to regulate the blood flow during erection. The pudendal nerve, the somatic component, is responsible for penile sensation and the contraction and relaxation of the bulbocavernosus and ischiocavernosus muscles that surround the penis.

Nitric oxide released from nonadrenergic-noncholinergic neurotransmission and the endothelium is likely the principal neurotransmitter for penile erection. Within the muscle, nitric oxide activates a guanylyl cyclase that raises intracellular concentrations of cyclic guanosine monophosphate (GMP). Cyclic GMP in turn activates a specific protein kinase, which results in the opening of the potassium channels and hyperpolarization and causes sequestration of intracellular calcium and blocks calcium influx. As a result of this drop in cytosolic calcium, smooth muscle relaxation occurs leading to erection. On return to the flaccid state, cyclic GMP is hydrolyzed to guanosine monophosphate by phosphodiesterase type 5 (PDE5). Sildenafil, vardenafil, tadalafil and other PDE5 inhibitors work by blocking phosphodiesterase enzyme activity and are currently FDA approved to treat erectile dysfunction.

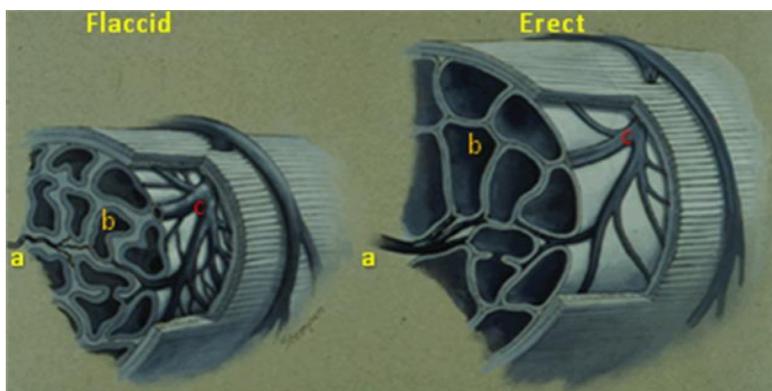


Figure 1. Anatomy of the penis. The penile erection occurs as a result of 3 processes: a) smooth muscle relaxation among arteries and trabecular tissue increases blood flow, which b) lengthens and enlarges penis through sinusoidal filling, and c) expanded sinusoids compress the subtunical venous plexus, reducing venous outflow.

## CAUSES OF ERECTILE DYSFUNCTION

Erectile dysfunction can be classified as psychogenic, organic (neurogenic, hormonal, arterial, venous or cavernosal and drug-induced), and mixed psychogenic and organic (Table 1). Mixed etiologies for ED are the most common. Typical causes of psychogenic erectile dysfunction include performance anxiety, strained relationship, lack of sexual arousability, and overt psychiatric disorders such as depression and schizophrenia. Neurologic disorders such as Parkinson's and Alzheimer's diseases, stroke, and cerebral trauma often cause erectile dysfunction by decreasing libido or causing inability to initiate the erectile process. In men with spinal cord injuries, the degree of erectile function depends largely on the nature, location and extent of the lesion. Hormonally, androgen deficiency results in a decrease in nocturnal erections and decreases libido. However, erection in response to visual sexual stimulation is preserved in men with hypogonadism, suggesting that androgens are not essential for erection but can augment the response. Hyperprolactinemia of any cause results in both reproductive and sexual dysfunction due to the inhibitory action of prolactin on gonadotropin-releasing hormone secretion, resulting in hypogonadotropic hypogonadism.

**TABLE 1. CLASSIFICATION AND CAUSES OF ERECTILE DYSFUNCTION**

<b>CATEGORY</b>	<b>DISORDERS</b>	<b>PROBLEM</b>
Psychogenic	Performance anxiety, Depression, Other psychiatric conditions	Loss of libido, overinhibition, Impaired nitric oxide release
Neurogenic	Stroke, Spinal cord injury, Diabetic retinopathy	Lack of nerve impulse, or Interrupted transmission
Hormonal	Hypogonadism, Hyperprolactinoma	Inadequate nitric oxide release
Vasculogenic (arterial or venous)	Atherosclerosis, Hypertension	Impaired arterial or venous flow
Medication-induced	Antihypertensives, Antidepressants, Alcohol, Tobacco use	Central suppression, Vascular insufficiency

Due to the intricate relationship between vascular function and erections as outlined above, systemic vascular problems can often manifest with compromised erectile function. Common risk factors associated with generalized penile arterial insufficiency include hypertension, hyperlipidemia, cigarette smoking, diabetes mellitus, and pelvic irradiation. Focal stenosis of the common penile artery most often occurs in men who have sustained blunt pelvic or perineal trauma (e.g., biking accidents or straddle injuries) and is a rare cause of arterial insufficiency. Poor venous occlusion during erection (veno-occlusive dysfunction or “venous leak”) can also result in erectile dysfunction. This can be caused by degenerative changes (Peyronie's disease, aging, and diabetes mellitus) or traumatic injury (penile fracture) to the tunica albuginea and structural alterations of the cavernous smooth muscle and endothelium.

Many drugs have been associated with erectile dysfunction. Central neurotransmitter pathways, including serotonergic, noradrenergic, and dopaminergic pathways involved in sexual function, may be disturbed by antipsychotics, antidepressants and centrally acting antihypertensive drugs. Beta-adrenergic blocking drugs may cause erectile dysfunction by potentiating alpha-1 adrenergic activity in the penis. Thiazide diuretics have been reported to cause erectile dysfunction, but the exact cause is unknown. Spironolactone can cause erectile failure as well as decreased libido and gynecomastia. Cigarette smoking may induce vasoconstriction and penile venous leak because of its vasoconstrictive effect via the cavernous smooth muscle. Alcohol in small amounts improves erection and increases libido because of its vasodilatory effect and the suppression of anxiety; however, large quantities may result in central sedation, decreased libido and transient erectile dysfunction. Cimetidine, a histamine-H2 receptor antagonist, has been reported to decrease libido and cause erectile failure due to its role as an antiandrogen. Other drugs known to cause erectile dysfunction are estrogens and drugs with antiandrogenic action such as ketoconazole and cyproterone acetate. Drugs that purposefully lower your androgen level, such as androgen deprivation therapy for prostate cancer will also cause ED.

Sexual function progressively declines in "healthy" aging men. For example, the latent period between sexual stimulation and erection increases, erections are less rigid, ejaculation is less forceful, ejaculatory volume decreases, and the refractory period between erections lengthens. Comorbid medical conditions demonstrate significant impact on the development of erectile dysfunction as well. About 50% of men with diabetes mellitus have erectile dysfunction due to compromised small vessels which may affect both blood flow and neurotransmitter delivery. Chronic renal failure has frequently been associated with diminished erectile function, impaired libido, and infertility. Men with angina, myocardial infarction, or heart failure may have erectile dysfunction from anxiety, depression, or concomitant penile arterial insufficiency and ED can be the presenting symptom for cardiovascular problems in many men.

## **ERECTILE DYSFUNCTION-DIAGNOSIS**

Erectile dysfunction can be the presenting symptom of a variety of diseases such as cardiovascular disease, diabetes mellitus, hyperlipidemia, hypertension, spinal-cord compression, and pituitary tumors. Therefore, a thorough history (medical, sexual and psychosocial), physical examination and appropriate laboratory tests aimed at detecting these diseases should be performed. A detailed psychosocial history may reveal chronic issues or acute relationship conflicts optimally treated by mental health professionals or even sex therapists. Standardized, validated survey instruments such as the Sexual Health Inventory for Men (SHIM) are valuable to assess erectile dysfunction in affected individuals and track response to therapy (Figure 2). Often, the particular characteristics of the erectile problem can help with the diagnosis: in cases of arterial problems, prolonged stimulation may be required to achieve an erection; with venous leak an erection is easily achieved but lost very quickly. Physical examination should include evaluation of the breasts, hair distribution, penis and testis, palpation of the femoral and pedal pulses and testing of genital and perineal sensation. Recommended laboratory tests include a morning testosterone level to evaluate for hypogonadism according to the most recent AUA guidelines. Urinalysis, complete blood count, fasting blood glucose, creatinine, cholesterol and triglycerides can all be considered if needed.

**OVER THE PAST 6 MONTHS:**

1. How do you rate your confidence that you could get and keep an erection?		VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
		1	2	3	4	5
2. When you had erections with sexual stimulation, how often were your erections hard enough for penetration (entering your partner)?	No SEXUAL ACTIVITY	ALMOST NEVER OR NEVER	A FEW TIMES (MUCH LESS THAN HALF THE TIME)	SOMETIMES (ABOUT HALF THE TIME)	MOST TIMES (MUCH MORE THAN, HALF THE TIME)	ALMOST ALWAYS OR ALWAYS
	0	1	2	3	4	5
3. During sexual intercourse, how often were you able to maintain your erection after you had penetrated (entered) your partner?	DID NOT ATTEMPT INTERCOURSE	ALMOST NEVER OR NEVER	A FEW TIMES (MUCH LESS THAN HALF THE TIME)	SOMETIMES (ABOUT HALF THE TIME)	MOST TIMES (MUCH MORE THAN, HALF THE TIME)	ALMOST ALWAYS OR ALWAYS
	0	1	2	3	4	5
4. During sexual intercourse, how difficult was it to maintain your erection to completion of intercourse?	DID NOT ATTEMPT INTERCOURSE	EXTREMELY DIFFICULT	VERY DIFFICULT	DIFFICULT	SLIGHTLY DIFFICULT	NOT DIFFICULT
	0	1	2	3	4	5
5. When you attempted sexual intercourse, how often was it satisfactory for you?	DID NOT ATTEMPT INTERCOURSE	ALMOST NEVER OR NEVER	A FEW TIMES (MUCH LESS THAN HALF THE TIME)	SOMETIMES (ABOUT HALF THE TIME)	MOST TIMES (MUCH MORE THAN, HALF THE TIME)	ALMOST ALWAYS OR ALWAYS
	0	1	2	3	4	5

Add the numbers corresponding to questions 1-5. TOTAL: \_\_\_\_\_

The Sexual Health Inventory for Men further classifies ED severity with the following breakpoints:

1-7 Severe ED      8-11 Moderate ED      12-16 Mild to Moderate ED      17-21 Mild ED

**Figure 2.** Sexual Health Inventory for Men (SHIM) that is used clinically to assess the degree of erectile dysfunction.

It is critical once a thorough history and physical is conducted to inquire regarding the goals and preferences of the man (and his partner if indicated), and discuss further diagnostic and therapeutic options. If the patient is utilizing a pharmaceutical known to cause erectile dysfunction or recreational drugs, or has vascular risk factors, a change in medication or life-style may be helpful. If primary hypogonadism is detected, androgen therapy may be indicated in select instances. Importantly, PDE5 inhibitors are contraindicated in those taking nitrate medication and also in men for whom sexual intercourse is inadvisable due to cardiovascular risk factors. These patients should consult with their cardiologist regarding PDE5 inhibitor use and sexual activity. This goal-directed approach to diagnosis and treatment of erectile dysfunction, tailored to the individual’s health status and goals, is outlined in Figure 3.

Importantly, erectile dysfunction is not just a sexual health issue. In many men, ED may be a serious harbinger of life-threatening cardiovascular conditions. A landmark study followed men age 55 and older over for 7 years and assessed them for both erectile dysfunction and cardiovascular disease, including heart attack and stroke. In patients with a new onset of erectile dysfunction there was an associated 25% increased risk for heart attacks, strokes, angina, or mini-strokes, compared to men with no erectile dysfunction. If men already had ED at the onset of the study, the risk for cardiovascular disease was 45% higher than those with no ED. In fact, ED is as important a

cardiovascular disease risk factor as smoking or a family history of heart disease. Physiologically, this associated risk makes sense, as the cells that form plaques in the arteries of the penis are the same cells that form plaques the arteries anywhere else in the body. Because the penile arteries are smaller than the cardiac arteries, plaque formation will preferentially show up first as ED. Indeed, previous research has shown that among patients who seek help for ED, nearly 20% had undiagnosed high blood pressure, 15% had diabetes, and 5% already had significant coronary artery disease. Particularly for younger patients presenting with ED, evaluation by cardiology may uncover occult cardiovascular disease and a referral should be considered by the clinician.

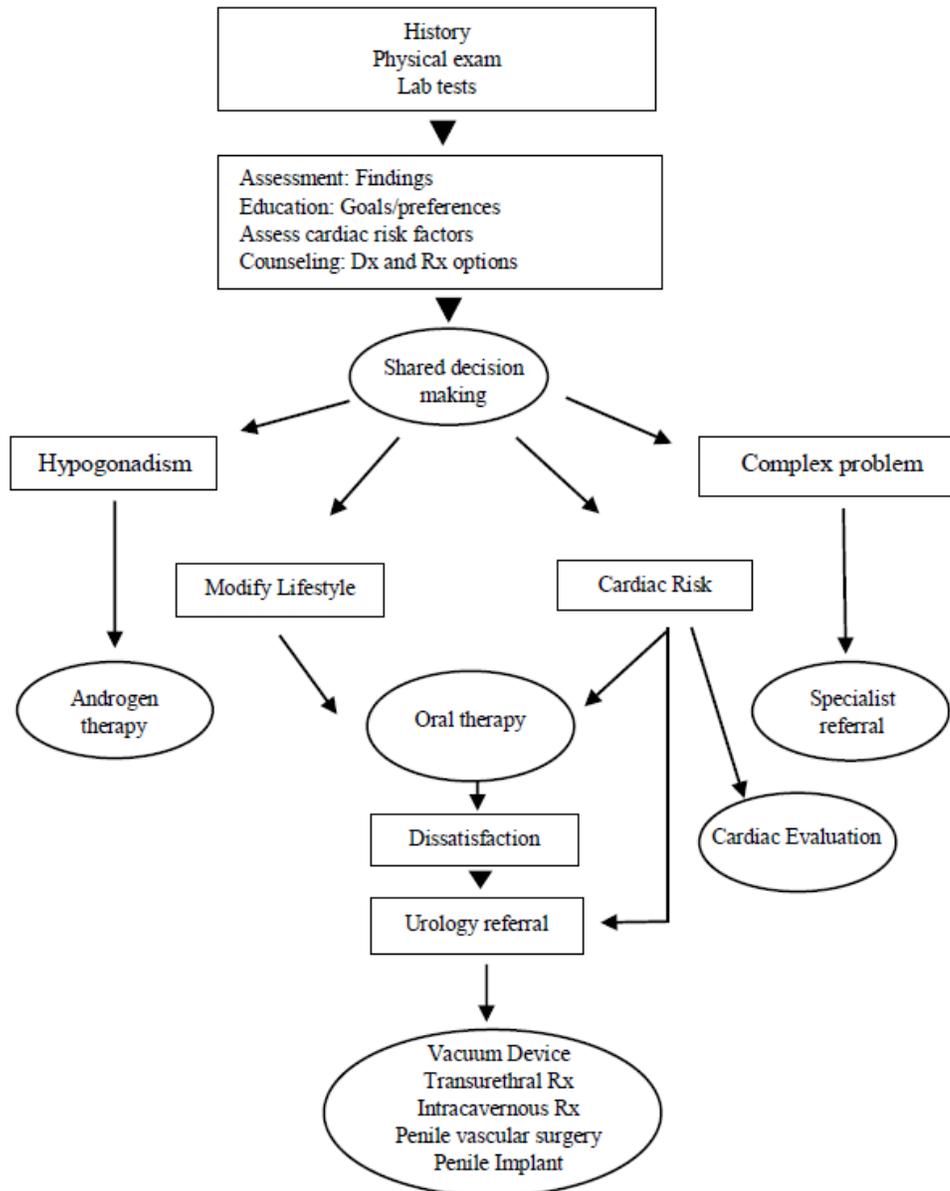


Figure 3. Goal-directed, algorithmic approach to the diagnosis and treatment of erectile dysfunction.

## **ERECTILE DYSFUNCTION-TREATMENT**

Life style changes: In general, most physicians suggest treatments that proceed from least to most invasive. Healthy lifestyle changes like quitting smoking, losing excess weight, and increasing physical activity may help some men regain sexual function or at least prevent further worsening. Discontinuing drugs with harmful side effects is another effective treatment if clinically appropriate.

Psychotherapy: Until other treatments became more popular in the 1980s and 1990s, psychotherapy was the mainstay of ED treatment as many clinicians at the time believed that ED was a predominately psychological diagnosis. Today, psychotherapy is a useful treatment for psychogenic ED and attempts to decrease the anxiety associated with intercourse. The patient's partner can help by gradually developing better intimacy and stimulation. Psychotherapy remains an option for select patients with ED from situational conditions.

Pharmaceutical Therapy: Drugs for treating ED can be taken orally, injected directly into the penis, or inserted into the urethra. In March 1998, the FDA approved sildenafil, the first oral therapy for ED treatment. Since that time, multiple additional phosphodiesterase (PDE) inhibitors have been approved. Taken before sexual activity, PDE inhibitors work by enhancing the effects of nitric oxide, relaxing penile smooth muscle during sexual stimulation and allows increased blood flow. While these medications improve the response to sexual stimulation, they do not trigger an automatic erection. The majority of men with ED will respond to these drugs and for this reason, they are considered first line therapy for ED.

No PDE inhibitor should be used more than once a day. Men who take nitrate-based drugs such as nitroglycerin for heart problems should not use these drugs because the combination can cause a sudden drop in blood pressure that may result in death. Additionally, clearance by cardiology may be required to approve therapy for men with significant cardiovascular disease for sexual activity. Caution should be practiced as several members of this class of medications may cause a sudden drop in blood pressure when taken with an alpha-blocker.

Testosterone can improve libido in some men with low natural testosterone levels, but it is often ineffective for erections and patients may need other treatment for their ED. Other drugs—including yohimbine hydrochloride, dopamine and serotonin agonists, and many over the counter supplements—may be effective for ED, but studies to substantiate these claims are inconsistent.

Intracavernosal Injections: Many men achieve stronger erections by injecting medications directly into the cavernous bodies of the penis, resulting in smooth muscle relaxation and engorgement with blood. Drugs such as papaverine hydrochloride, phentolamine, and alprostadil (a prostaglandin E2) all modulate endothelial function and can help induce and maintain erections. When all three of these compounds are used together the medication is usually referred to as “Tri-Mix”. These drugs may create unwanted side effects, however, including persistent erection (known as priapism) and corporal scarring that can lead to Peyronie’s disease. They can also be inconvenient as the medication must be refrigerated and the patient has to have the proper supplies (syringe, needles, etc.) to perform an injection in the penis.

Intraurethral Injections: A system for inserting a pellet of alprostadil into the urethra is marketed under the trade name MUSE. The system uses a prefilled applicator to deliver the pellet about an inch deep into the urethra. An erection will begin within 8 to 10 minutes and may last 30 to 60 minutes. The most

common side effects penile pain, warmth or burning sensation in the urethra; redness from increased blood flow to the penis; and minor urethral bleeding or spotting. Due to the excessive cost, this treatment has fallen out of favor with many urologists. Compounding pharmacies have begun making gels containing papaverine, phentolamine, and alprostadil that can be inserted into the urethra but this has not been well studied.

Vacuum Erection Devices: Mechanical vacuum devices induce erections by creating a partial vacuum, which draws blood into the penis, engorging and expanding it. The devices have three components: a plastic cylinder, into which the penis is placed; a pump, either manually or electronically actuated, which draws air out of the cylinder; and an elastic band, which is placed around the base of the penis to maintain the erection after the cylinder is removed and during intercourse by preventing venous return. This device allows a patient to avoid medications and surgery, but usually does not give the best erection. The patient must also be vigilant about removing the penile constriction band at the end of intercourse or risk penile ischemia.

Penile Surgery: Surgical procedures to improve erections are the oldest and most well established treatment for ED and are performed for 3 reasons: to implant a device that can cause the penis to become erect, to reconstruct arteries and increase penile blood flow, and to occlude veins that allow blood to leak out of the penis and cause ED. Implanted devices, known as penile prostheses, are excellent at restoring erections in men with medication refractory ED. Implants are devices, however and have complications that include mechanical failure (20% at 10 years), erosion and infection. Malleable implants consist of paired solid rods, which are inserted surgically into the corpora cavernosa. The user manually adjusts the position of the penis and, therefore, the rods. Adjustment does not affect the width or length of the penis. Inflatable implants consist of paired cylinders that are surgically inserted inside the penis and then expanded using pressurized fluid from a co-implanted fluid reservoir and a pump. The cylinders are inflated by squeezing the scrotal pump and deflated by pressing a release button located on the same pump. Inflatable prosthesis reproduce a more natural erection with expansion of both the width and length of the penis. It should be noted though, that even with the use of an inflatable device, the majority of patients will experience loss of penile length (either real or perceived) and preoperative counseling is crucial for setting realistic expectations and educating on potential risks and complications.

Surgery to repair arteries can reduce ED caused by blockages and is rarely performed in modern times. The best candidates for such surgery are young men with localized blockage of an artery due to pelvic injury or fracture. The procedure is almost never successful in older men with diffuse vascular disease. Surgery to ligate veins permitting blood to leak from the penis has the opposite goal: to reduce venous leak which causes poor erectile sustainability. Given the complexity of the venous drainage patterns from the penis, this type of penile surgery is rarely performed as well.

## **SUMMARY**

1. The normal penile erection involves relaxation of cavernous arteries, filling of venous sinusoidal spaces within the corpora cavernosal bodies and constriction of the subtunical venous plexus system.
2. Nitric oxide released from nonadrenergic-noncholinergic neurotransmission and the endothelium is the principal neurotransmitter for penile erection.
3. Erectile dysfunction is a common and very treatable urologic condition that can have

- psychogenic, arterial, venous, neurogenic and hormonal causes.
4. The clinical evaluation of ED involves a patient and goal-directed approach that incorporates a history and physical, the use of validated survey tools and laboratory testing as appropriate.
  5. Treatment with oral PDE5 inhibitors is effective for most men with mild to moderate ED.
  6. For men who fail treatment with a PDE5 inhibitor, implantation of a penile prosthesis is considered the gold standard.

For expanded information refer to the AUA guideline on erectile dysfunction: ([https://www.auanet.org/guidelines/erectile-dysfunction-\(ed\)-guideline](https://www.auanet.org/guidelines/erectile-dysfunction-(ed)-guideline)) and the AUA guideline on Peyronie's disease: (<https://www.auanet.org/guidelines/peyronies-disease-guideline>)

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