Color Doppler Sonography in the Evaluation of Erectile Dysfunction[1]

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Color Doppler sonography can be useful in the evaluation of erectile dysfunction, which can result from psychogenic, endocrinologic, neurogenic, pharmacologic, and vasogenic causes. It is used to determine the integrity of the vascular mechanism. After an intracavernosal injection of a vasodilatory agent, color Doppler sonography is performed to evaluate cavernosal arteries and dorsal vessels. Color flow imaging allows direct visualization of intrapenile anatomy, vascular variants, and disease. It is also helpful in demonstrating transitions in cavernosal and dorsal blood flow. Color Doppler sonography is combined with spectral interrogation of the cavernosal arteries and dorsal veins to help determine peak systolic and end-diastolic velocities. Cavernosal artery size and systolic velocities help diagnose arterial insufficiency. Recent work on cavernosal artery diastolic flow and dorsal vein flow has indicated that color Doppler sonography, when correlated with cavernosographic findings, may be helpful in diagnosing venous incompetence. Temporal variations in transitions in cavernosal artery and dorsal vein flow during various stages of erection are important in the accurate diagnosis of vasogenic impotence.

■ INTRODUCTION

Male impotence or erectile dysfunction may occur as a result of psychogenic, endocrinologic, neurologic, pharmacologic, or vascular problems. Traditionally, most male impotence was considered to be psychogenic in origin and an accepted conse-

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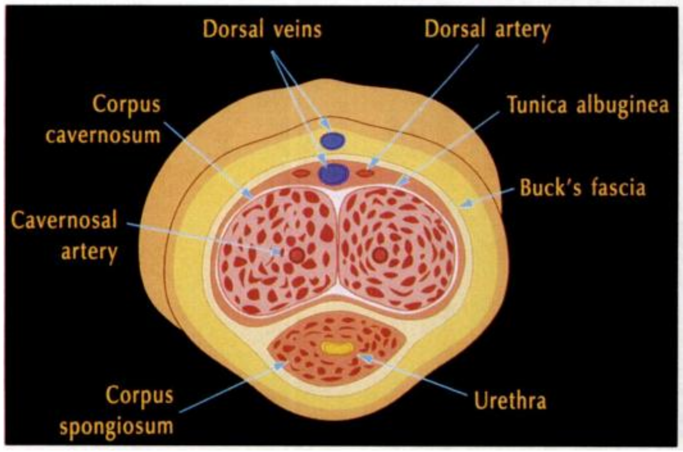

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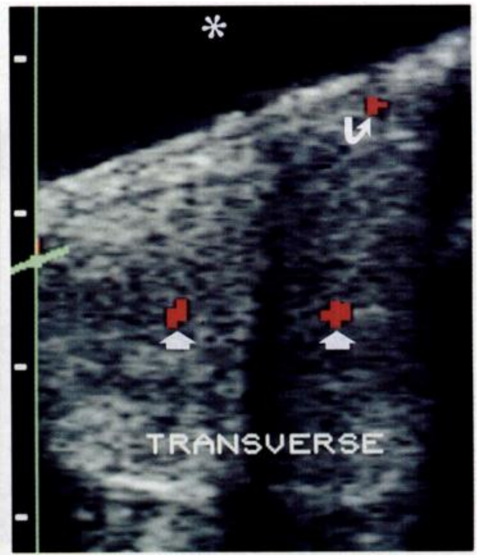


2.

Figures 1, 2. **(1)** Cross-sectional diagram of the penile shaft near the base demonstrates compartments of the penis. Corpora cavernosa are enclosed with the tunica albuginea and Buck fascia. Paramidline location of the cavernosal arteries within the corpora cavernosa is demonstrated in contrast to the dorsal arteries and veins. (Reprinted, with permission, from reference 15.) **(2)** Transverse color Doppler flow image obtained near the penile base demonstrates flow within the cavernosal arteries (straight arrows) and the left dorsal artery (curved arrow). Black triangle (*) represents the mechanical standoff wedge used to create the color Doppler angle. Base of the wedge is on the patient's right.

quence of aging. Recent research, however, indicates that vascular disease secondary to arterial, venous, or mixed vascular insufficiency may play a role in most cases of impotence. As the mechanism of penile erection has become better understood, venous incompetence or veno-occlusive failure has been recognized as a major factor in vasogenic impotence. Reflecting society's greater openness regarding sexual dysfunction, men and their partners are exploring diagnostic and therapeutic options. As nonprosthetic therapy options become available, the accurate diagnosis of vasogenic impotence allows for appropriate surgical intervention.

The sonographic evaluation of erectile dysfunction was pioneered by Lue et al (1). They used duplex sonographic determination of cavernosal artery velocities to accurately characterize arterial integrity. In the past several years, considerable attention has been focused on the Doppler evaluation of erectile dysfunction. In this article, we review penile vascular anatomy, the theory of the erectile mechanism, and the spectral characterization of erectile hemodynamics. We describe our experience with color Doppler sonography in 175 men with suspected vasogenic impotence. Sequential changes in cavernosal artery waveform patterns, peak systolic and end-diastolic velocities, and dorsal vein flow are demonstrated. Anatomic variants involving the dorsal and deep arteries are illustrated. Criteria for the diagnosis of venous incompetence and correlation with cavernosography are described. The advantages of color imaging are emphasized. The utility of color Doppler sonography in the evaluation of impotence is compared with that of more invasive techniques such as penile angiography and cavernosography.

■ ANATOMY

The penile shaft contains three longitudinal erectile bodies—two dorsal corpora cavernosa and the ventral corpus spongiosum, which surrounds the urethra. The corpora cavernosa are enclosed by a dense fascial layer, the tunica albuginea. Figure 1 illustrates the cross-sectional anatomy of the penis. The dorsal arteries, veins, and nerves are located centrally along the penile dorsum superficial to the tunica albuginea and deep to the Buck fascia. The cavernosal arteries lie in a paramidline position within the corpora cavernosa (Fig 2).

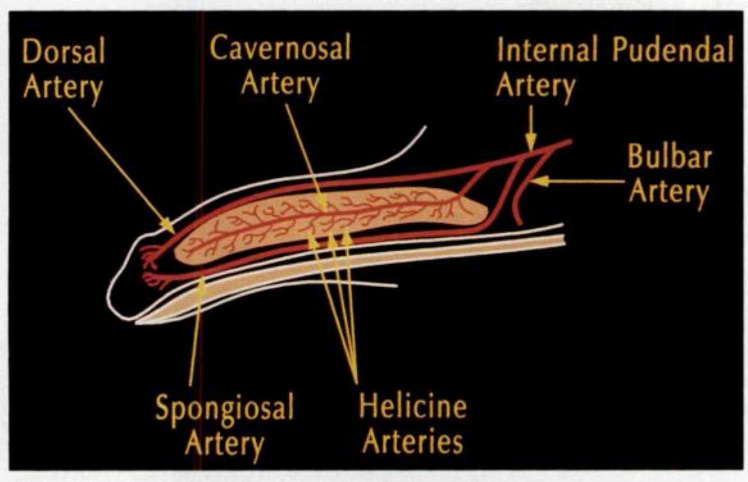
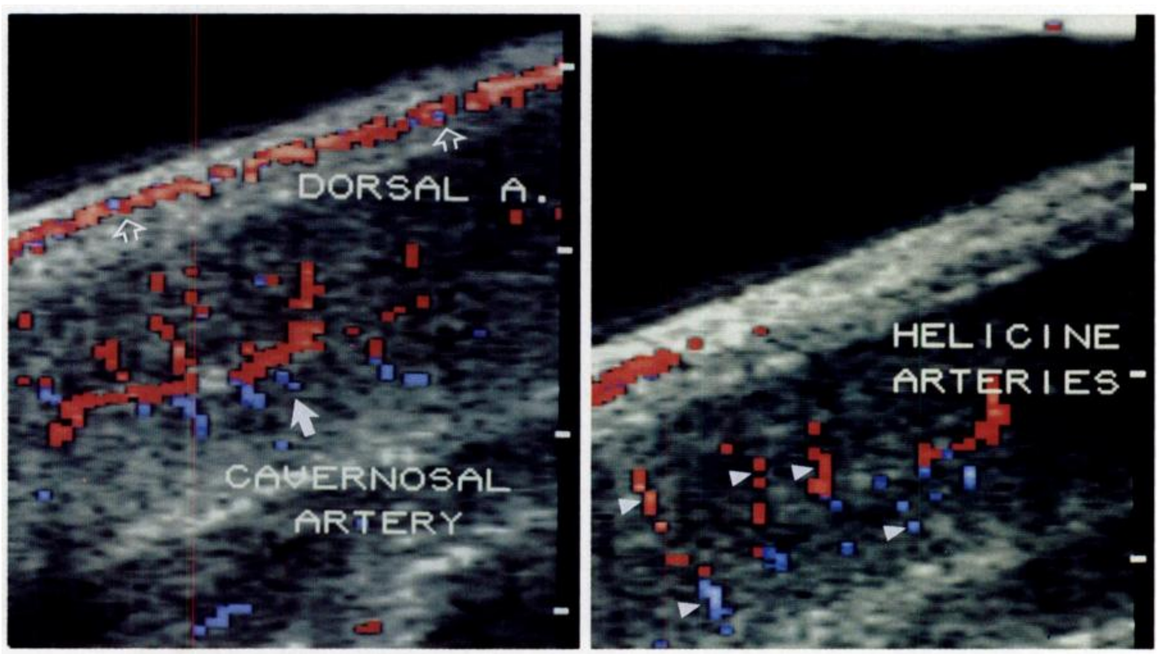


Figure 3. Diagram of the typical penile arterial anatomy. Intrapenile arteries arise as branches of the internal pudendal artery. Cavernosal arteries and their helicine branches supply the sinusoidal spaces of the corpora cavernosa.



a. **b.**

Figure 4. **(a)** Parasagittal color Doppler flow image of the left corpus cavernosum obtained with the transducer on the dorsal surface of the penis and the base of the wedge toward the penile base. There is good demonstration of color flow for the entire length of the dorsal artery (open arrows) and cavernosal artery (solid arrow). Flow within the helicine arteries is encoded red for flow toward the transducer face and blue for flow away. *A* = artery. (Reprinted, with permission, from reference 15.) **(b)** Companion color Doppler flow image obtained immediately lateral to the previous image offers a good demonstration of the helicine arteries (arrowheads) within the substance of the corpus cavernosum. These two images were obtained shortly after papaverine injection. As erection progresses, the helicine arteries can no longer be seen.

• Penile Arteries

The blood flow to the penis is supplied by branches of the internal pudendal artery (Fig 3). The bulbar artery supplies the proximal penile shaft. The dorsal artery supplies the skin, subcutaneous tissues, and glans. The cavernosal or deep penile artery pierces the tunica albuginea proximally and extends the length of the corpus cavernosum. Numerous side branches, the helicine arteries, supply the cavernosal space. The spongiosal artery similarly supplies the corpus spongiosum. Figure 4 demonstrates the typical arterial configuration, as seen on color flow images obtained after an injection of papaverine was administered.

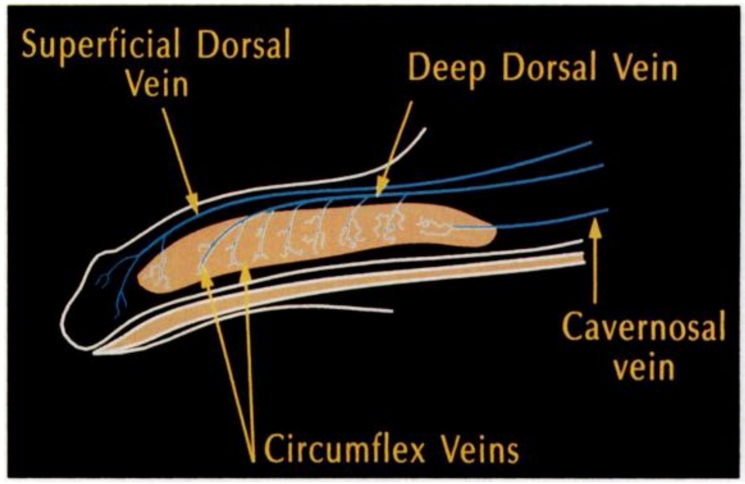


Figure 5. Diagram of penile venous anatomy. Superficial dorsal vein drains the distal corporal spaces, while most of the corporal sinusoidal outflow is carried by the deep dorsal vein. These two midline veins can be routinely visualized with color Doppler imaging. Proximal corporal spaces are drained by the cavernosal veins directly into the periprostatic plexus. Direct visualization of venous flow in the cavernosal veins is not routinely possible.

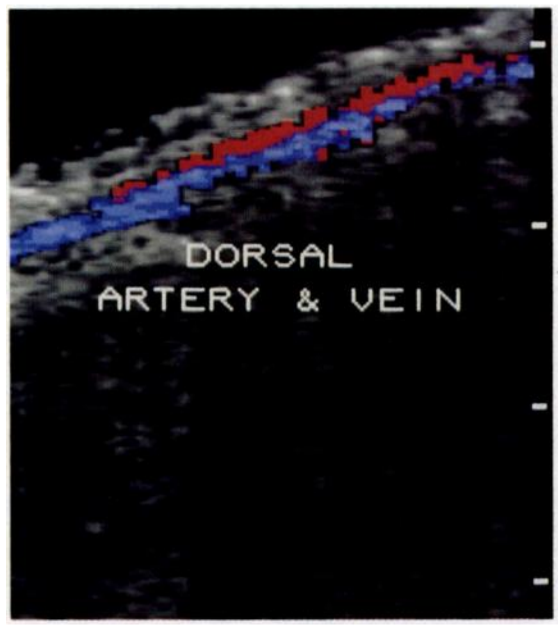


Figure 6. Paramidline longitudinal color Doppler flow image obtained 3 minutes after papaverine injection with the base of the wedge toward the penile base. Flow within the deep dorsal vein is encoded blue, and the dorsal artery is red. In the early transitional phases of erection, dorsal venous flow is common. Care must be taken to avoid compressing the vessels with the transducer.

• Penile Veins

The sinusoidal spaces of the corpora cavernosa communicate freely across the midline. The sinusoidal spaces drain through efferent venous channels to the circumflex veins and into the dorsal venous system. The most distal portion of the corpora cavernosa, as well as the skin and glans, drain into the superficial dorsal vein and the external iliac system. The primary drainage of the corpora cavernosa is into the deep dorsal vein and the internal iliac system. The most proximal portions of the corpora cavernosa drain through the cavernosal veins into the periprostatic plexus. Figure 5 illustrates the intrapenile venous system, and Figure 6 is a longitudinal image of the deep dorsal vein and the dorsal artery.

■ MECHANISMS OF ERECTION

Considerable work with animals has helped define the mechanism of penile erection (2,3). Erection begins with an autonomic neurogenic impulse that relaxes the cavernosal arterioles and sinusoidal spaces. This results in an increase in arterial flow into the corpora cavernosa, producing sinusoidal expansion and elongation. Compression of the efferent veins against the tunica albuginea limits venous egress. Ultimately, complete venous occlusion produces tumescence. This mechanism is represented at the cavernosal level anatomically in Figure 7 and schematically in Figure 8.

The specific vascular causes of erectile dysfunction are not completely understood. Proximal arterial disease within the pelvis and segmental penile arterial lesions can produce insufficient arterial inflow. Venous incompetence can occur in combination with arterial disease or in isolation. The precise mechanism of venous leakage is not fully understood.

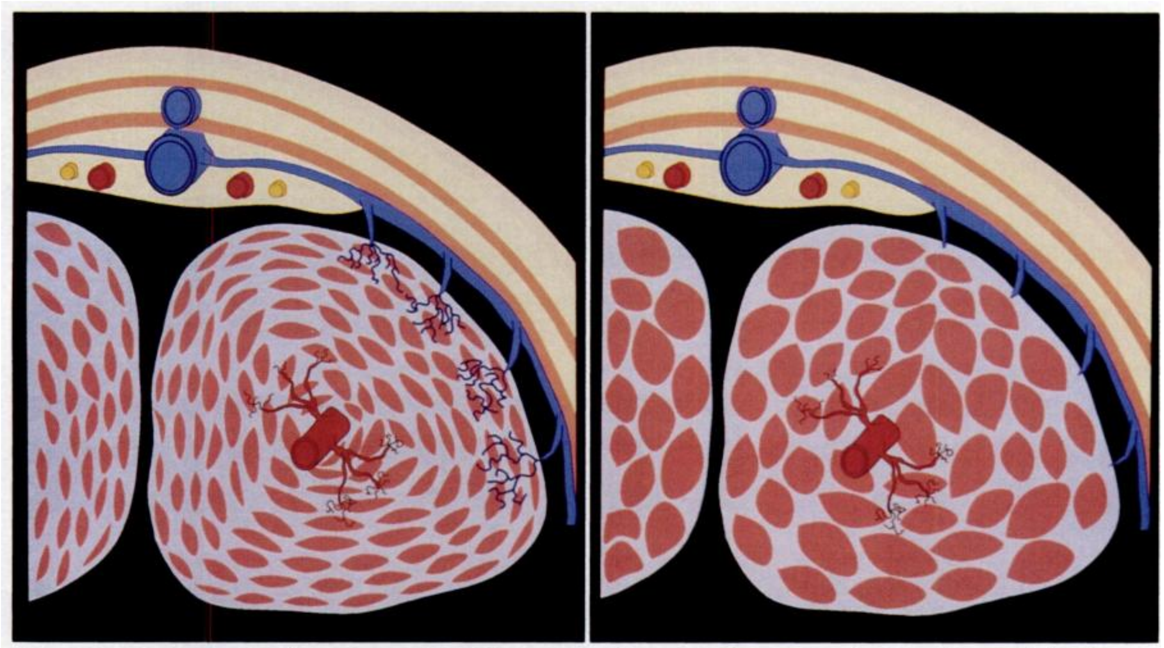


Figure 7. Cross-sectional representation of the veno-occlusive mechanism. In the flaccid state (left), the emissary veins drain the sinusoidal spaces and blood circulates into the dorsal venous system. As erection begins, the cavernosal arteries dilate and the sinusoidal spaces relax, expanding the cavernosal spaces. As the sinusoidal spaces become engorged, the veins are compressed against the tunica albuginea, venous outflow is obstructed, and erection is achieved (right). Veno-occlusive mechanism is dependent on neurologic stimuli, an adequate arterial supply, and normal function of the tunica albuginea. (Modified from reference 4; reprinted, with permission, from reference 15.)

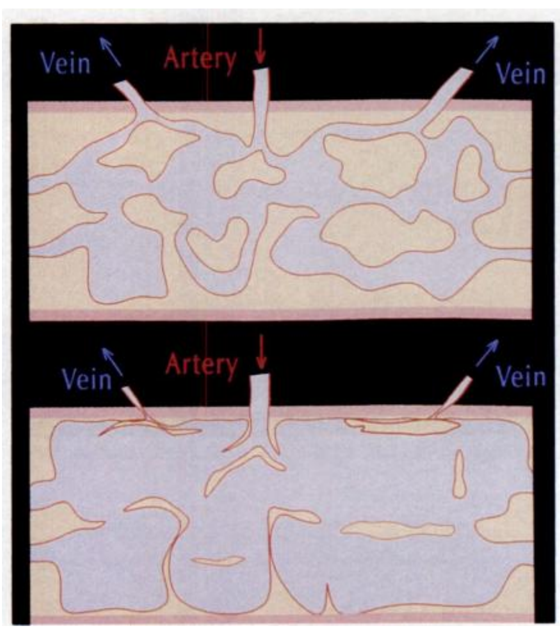


Figure 8. Schematic of the erectile mechanism. In the flaccid state (top), there is increased resting tone in the arterioles and sinusoidal spaces, which results in relatively higher resistance. Flow circulates through the sinusoidal spaces. As erection begins, the arterioles and the sinusoidal spaces become relaxed and the volume of flow into the corpora cavernosa increases. With the resultant sinusoidal expansion, the venules are compressed against the tunica albuginea, venous egress is prevented, and erection is achieved (bottom). (Modified from reference 3.)

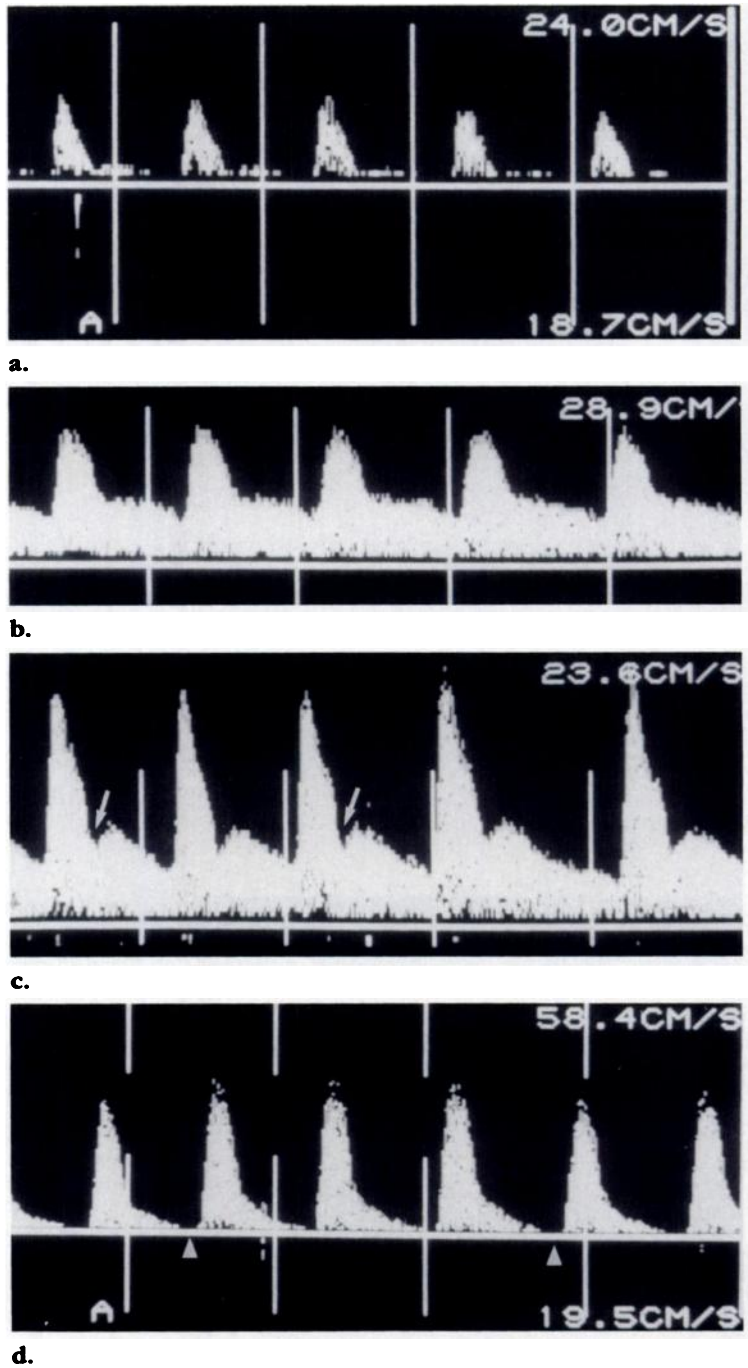


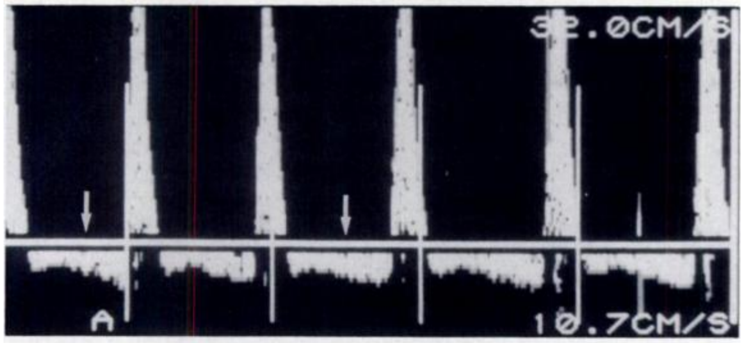
Figure 9. Spectral waveforms in the cavernosal artery depict the normal progression of erection after papaverine injection. **(a)** Spectral waveform demonstrates the typical appearance before papaverine is injected: dampened systolic envelope and minimal diastolic flow. **(b)** After papaverine injection, there is an abrupt increase in both systolic and diastolic flow in the cavernosal artery (phase IB). Minimal tumescence usually accompanies this phase. **(c)** As intracavernosal pressure increases, a transition in diastolic flow occurs, which is heralded by the development of a dicrotic notch (arrows) and a decrease in diastolic flow (phase II). **(d)** With a continued elevation of intracavernosal pressure, diastolic flow decreases to zero (arrowheads) (phase III). Systolic envelope narrows, and systolic velocity may fluctuate. Increasing tumescence is usually present (*Fig 9 continues*).

■ COLOR DOPPLER IMAGING EXAMINATION

• Assessment of Erection

A basic understanding of the erectile mechanism indicates that it is a complex, multiphasic event. To accurately assess patients with erectile dysfunction, it is necessary to demonstrate the progression of hemodynamic events leading to erection. Schwartz et al (5) determined this progression by simultaneously monitoring intracavernosal pressure and cavernosal artery spectral waveforms in normal volunteers; spectral waveform nomenclature and phase designation are based on their work.

The normal progression of cavernosal artery flow during tumescence is as follows: In the flaccid state, monophasic flow is present



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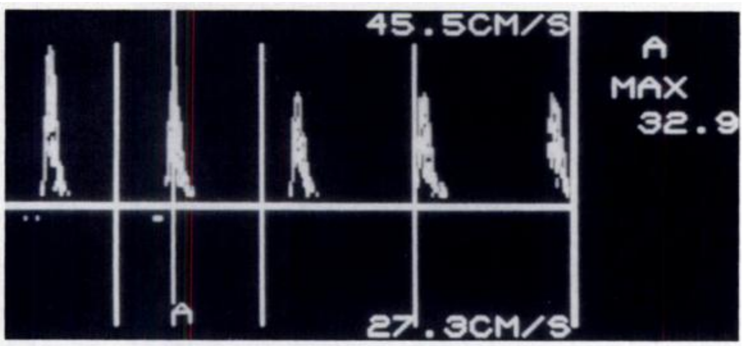


f.

Figure 9 (*continued*). **(e)** When intracavernosal pressure exceeds diastolic pressure within the artery, end-diastolic flow undergoes flow reversal (arrows) (phase IV). In many patients, maximal systolic velocity occurs at the time of diastolic flow reversal. This may be associated with penile rigidity. **(f)** Waveform obtained 15 minutes after papaverine injection. With maximal rigidity, intracavernosal pressure may approximate or exceed arterial systolic pressure, which results in further narrowing of the systolic envelope and usually a decrease in systolic velocity (phase V). Complete obliteration of systolic flow may occur transiently.

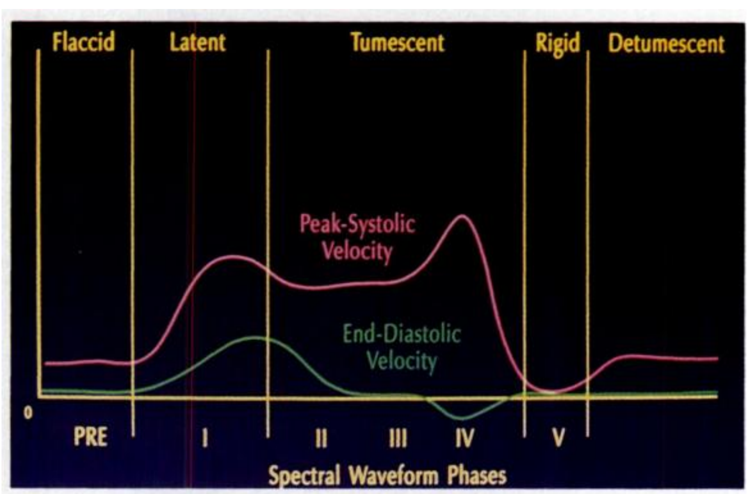
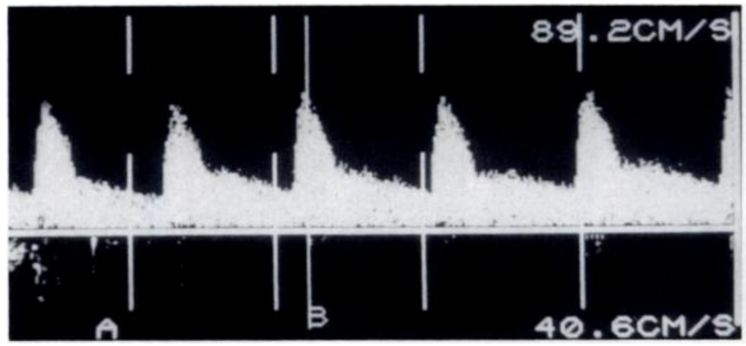


Figure 10. Graph shows the progression of cavernosal artery blood flow from the flaccid state to rigidity. X axis represents waveform progression toward complete erection. No specific time frame is shown because of the wide variation in temporal response to papaverine.

with minimal diastolic flow (Fig 9a). With the onset of erection or after papaverine is injected, there is an increase in both systolic and diastolic flow (Fig 9b). As intracavernosal pressures increase, a dicrotic notch appears at end systole and a decrease in diastolic flow occurs (Fig 9c). With continuously increasing pressures, end-diastolic flow declines to zero (Fig 9d) and then undergoes diastolic flow reversal (Fig 9e) indicative of high intracavernosal resistance. The systolic envelope is narrowed, and diastolic flow disappears completely (Figs 9f, 10) with firm erection.

• Techniques and Protocol

The performance of penile color Doppler imaging requires appropriate transducer choice and machine settings to produce high-quality images and accurate velocity data. We use a 7.5-MHz linear transducer (Quantum Medical Systems, Issaquah, Wash) with a mechanical standoff wedge to produce a favorable insonating angle throughout the entire field of view. Optimization of "slow flow" sensitivity



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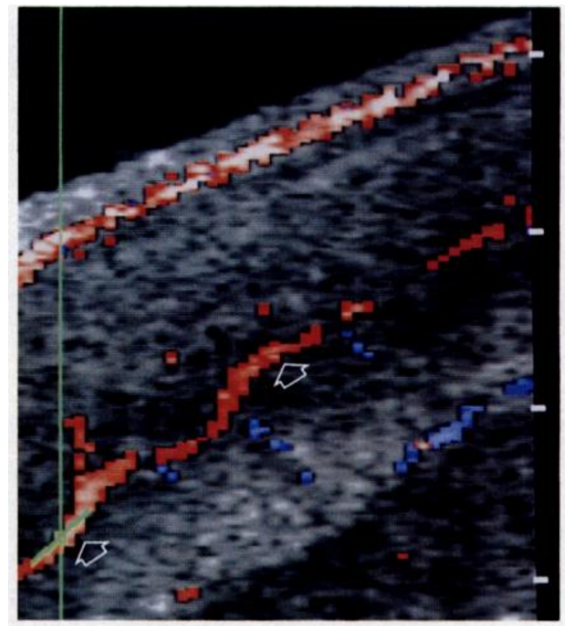


a.

Figure 11. (a) Paramidline color Doppler flow image of right cavernosal artery (arrows) demonstrates spectral cursor placement proximally. Sampling sites should be proximal to branch points. (b) Spectral trace obtained 2 minutes after papaverine injection from site shown in a. Peak systolic velocity is 52 cm/sec, with elevated diastolic flow typical of this early transitional period.

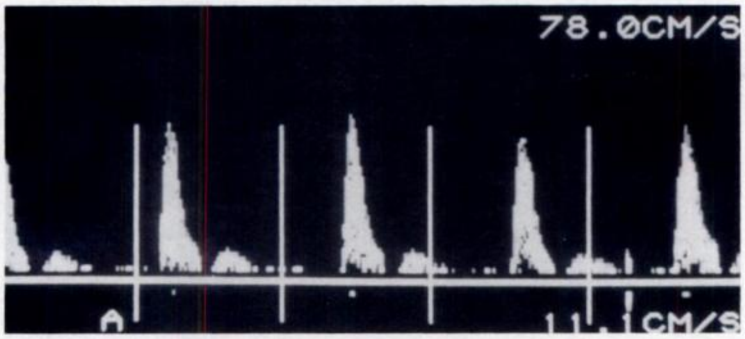
is crucial for the accurate depiction of diastolic flow transitions and dorsal vein flow.

We initially scan the flaccid penis to determine the presence of structural anomalies and plaques. Cavernosal artery diameters can be obtained and are used by some authors (6,7) in determining arterial integrity; however, obtaining arterial diameters can be time-consuming, and accuracy is operator dependent. Scanning before papaverine is injected provides optimal color parameters. This may be crucial in some individuals who have an immediate response to papaverine. A principal advantage of color imaging is the ease in identifying the cavernosal artery before and after papaverine injection.

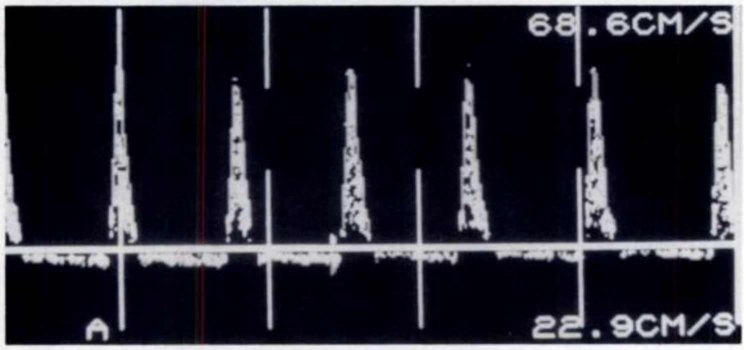
We currently inject 60 mg of papaverine intracavernosally near the penile base. Pharmacologic agents used at other institutions to induce erection include papaverine, phentolamine, prostaglandin E, and various combinations. We begin scanning dorsally, but ventral transducer placement may be necessary as erection progresses. We alternate scanning of each corpus cavernosum and the dorsum immediately after injection and at 5-minute intervals for 20–30 minutes. A typical real-time color image of the corpora cavernosa is presented in Figure 11a. Color imaging facilitates accurate cursor placement and precise angle correction and is the major advantage of color imaging. A sample spectral trace of the cavernosal artery is shown in Figure 11b.

• Temporal Response to Papaverine

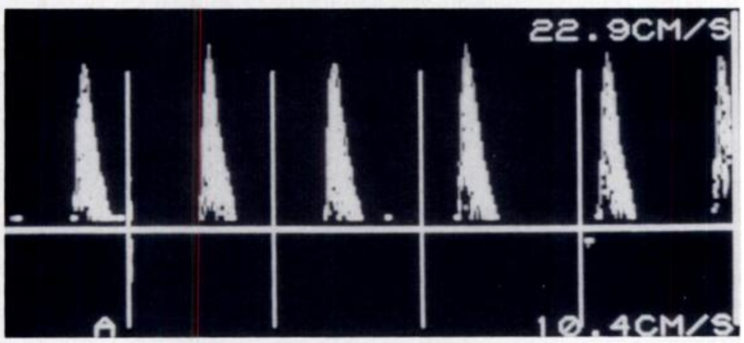
As previously mentioned, we routinely sample both cavernosal arteries at 5-minute intervals from 1 to 25 minutes after papaverine injection or until waveform progression ceases. This is in contrast to most of the literature on peak systolic velocity determination (1,6,8) in which imaging is terminated after 5–10 minutes. A typical papaverine response is illustrated in Figure 12. The early waveform in Figure 13a is suggestive of arterial insufficiency. Subsequent waveforms in Figure 13b



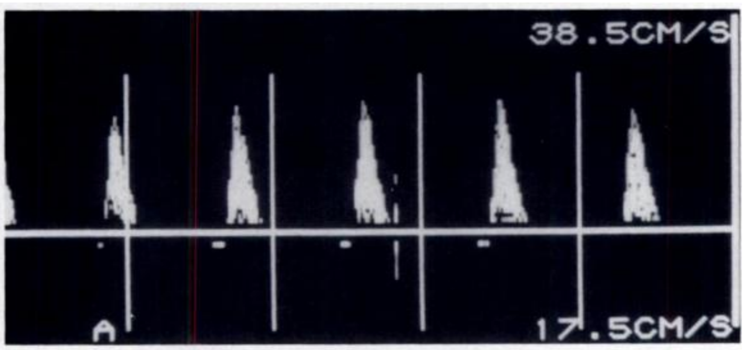
12a.



12b.



13a.

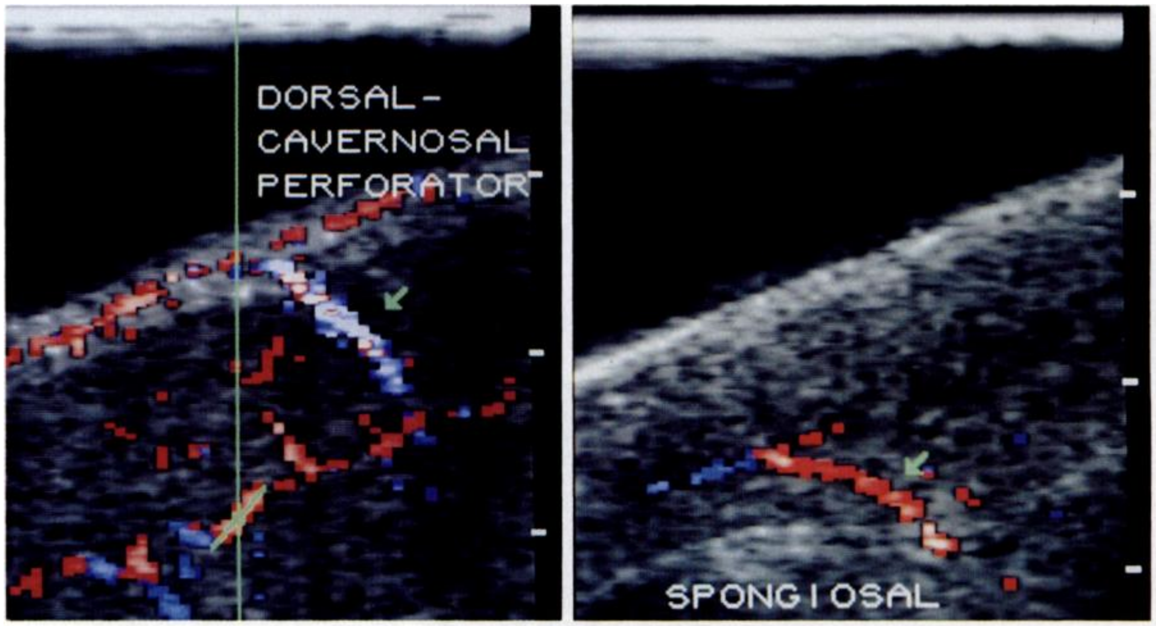


13b.

Figures 12, 13. **(12)** Cavernosal artery spectral waveforms demonstrate normal response to papaverine. **(a)** Waveform obtained 3 minutes after papaverine injection shows peak systolic velocity greater than 50 cm/sec and no diastolic flow. **(b)** Waveform obtained after 5 minutes demonstrates that end-diastolic flow reversal has occurred in concert with complete rigidity. **(13)** Cavernosal artery spectral waveforms demonstrate delayed response to papaverine. **(a)** Spectral waveform obtained 5 minutes after papaverine injection demonstrates peak systolic velocity of 20 cm/sec, suggesting arterial insufficiency. **(b)** Delayed scanning at 15 minutes after papaverine injection reveals transition to diastolic flow reversal and peak systolic velocity of greater than 25 cm/sec, which was accompanied by rigid erection.

demonstrate transition to diastolic flow reversal with delayed response.

Temporal variation in dorsal vein flow also occurs. In our experience, greater than 50% of patients manifest transient dorsal vein flow immediately after papaverine injection. As tumescence progresses to rigidity, we have occasionally observed retrograde dorsal vein flow. The importance of this finding remains unclear.



a. b.

Figure 14. **(a)** Parasagittal color Doppler flow image demonstrates an arterial communication (arrow) between the ipsilateral dorsal and cavernosal arteries. These dorsal-cavernosal perforators are commonly seen with color Doppler flow imaging. **(b)** Parasagittal color Doppler flow image from a different patient shows an arterial communication (arrow) arising from the corpus spongiosum and joining the cavernosal artery. Collateral or "shunt" vessels are also commonly seen with color Doppler flow imaging.

■ PENILE ARTERIAL VARIANTS

Intrapenile arterial variation has been demonstrated with selective pudendal angiography (9,10). Angiography has demonstrated communication between the dorsal and cavernosal arteries, dorsal-cavernosal perforators, in 90% of men (9). Color Doppler imaging can also depict these arterial variations. The arteries are color encoded blue because the blood flows away from the transducer face, but they should not be mistaken for draining veins (Fig 14a). A second common variant is spongiosal-cavernosal communications or "shunt" vessels (10) (Fig 14b), which course from the corpus spongiosum into the corpus cavernosum. Currently, the importance of these variations is under investigation; however, they do not necessarily indicate arterial insufficiency.

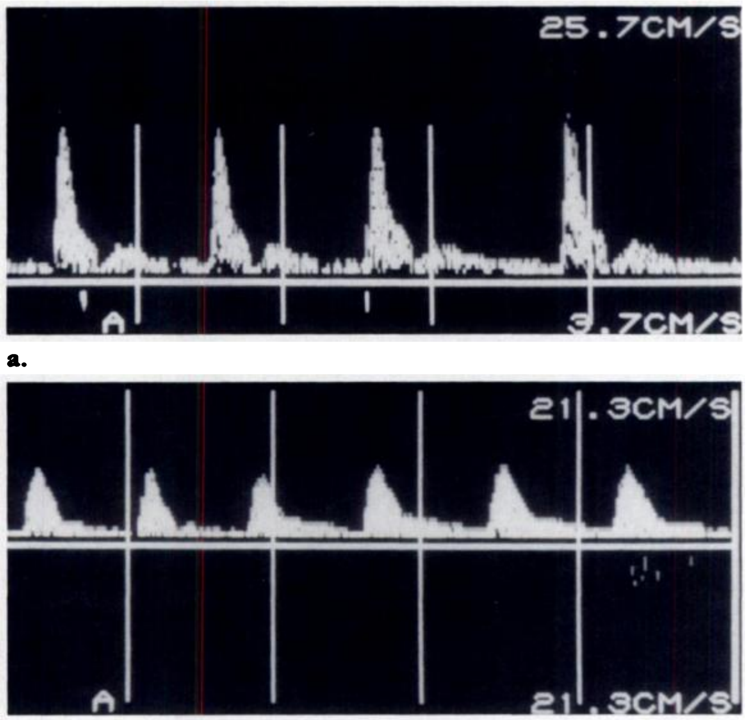
■ ARTERIAL INSUFFICIENCY

The initial application of duplex imaging in the diagnosis of arterial insufficiency was in systolic velocity determination. The addition of color techniques improves cavernosal artery localization and precise angle correction and facilitates the diagnosis.

Primary diagnostic criteria for arterial insufficiency include a peak systolic velocity of less than 25 cm/sec and waveform dampening (Fig 15). Angiographic correlation has shown that a systolic velocity threshold of 25 cm/sec has 92% accuracy in the diagnosis of arterial integrity (1,7). Some authors (11) report improved accuracy with a threshold of 35 cm/sec, with 25–35 cm/sec representing a gray zone.

Secondary diagnostic criteria include failure of cavernosal artery dilatation and asymmetry of cavernosal flow velocities of greater than 10 cm/sec (11). These parameters can be demonstrated with duplex or color Doppler imaging. Color imaging provides visual information about intrapenile arterial disease, such as focal stenosis, occlusions, or systolic arterial flow reversal (Fig 16) (12).

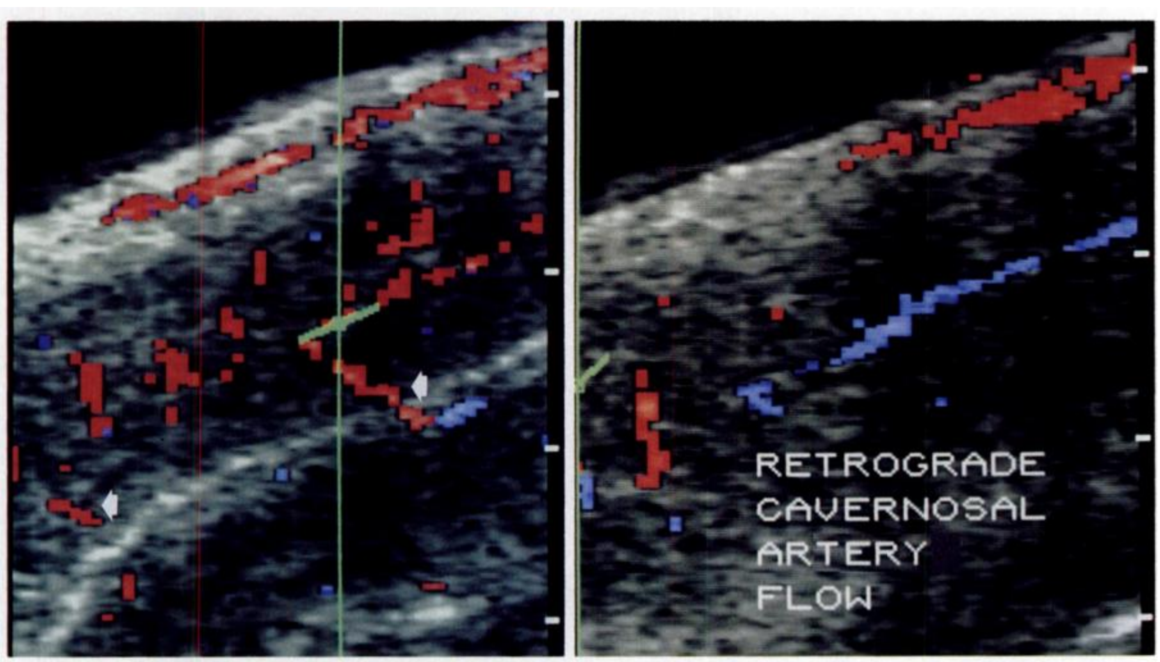
In addition to consideration of anatomic variation, the temporal response after papaverine injection also varies, as described previously. If peak systolic velocity measurements are used to determine arterial integrity, we believe temporal variation must be considered. Extended data acquisition beyond 5 minutes after injection is necessary to avoid false-positive diagnoses of arterial insufficiency.



a.

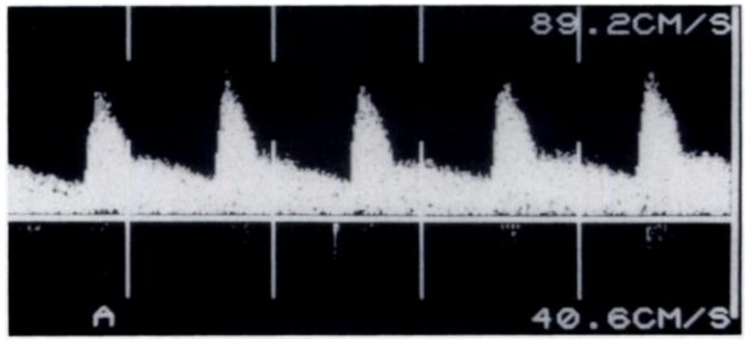
b.

Figure 15. **(a)** Spectral waveform obtained 11 minutes after papaverine injection. Although the waveform reveals a dicrotic notch and loss of end-diastolic flow, the peak systolic velocity is less than 20 cm/sec, indicating arterial insufficiency. **(b)** Spectral waveform from a different patient obtained 5 minutes after papaverine injection shows another common waveform pattern in arterial insufficiency. Peak systolic velocity at 15 cm/sec is subthreshold, and the systolic envelope remains broad.



a. b.

Figure 16. **(a)** Parasagittal color Doppler flow image in a diabetic man for whom the appearance of spectral waveforms was consistent with arterial insufficiency. Cavernosal artery was interrupted at various sites, and several prominent spongiosal collateral arteries (arrows) were present. **(b)** Parasagittal color Doppler flow image of the contralateral cavernosal artery (same patient as in **a**) demonstrates retrograde flow within the cavernosal artery, presumed secondary to proximal occlusion.



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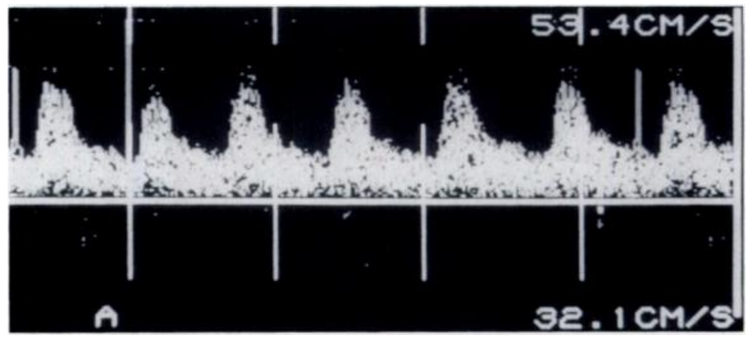
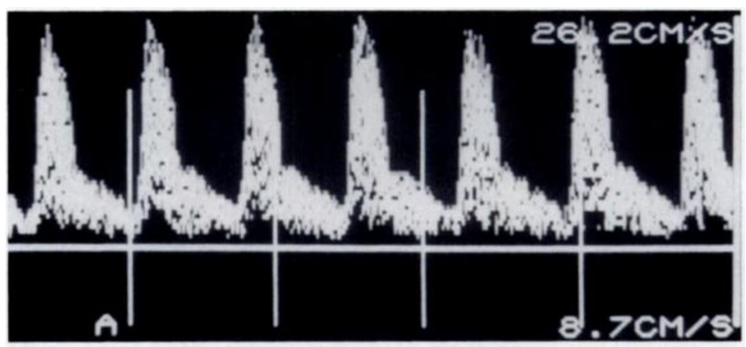
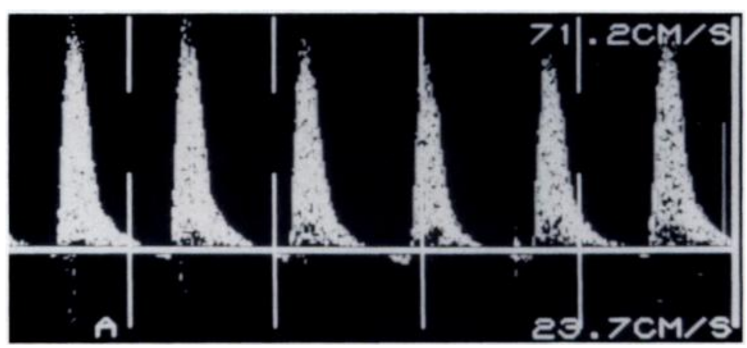


18a.



18b.

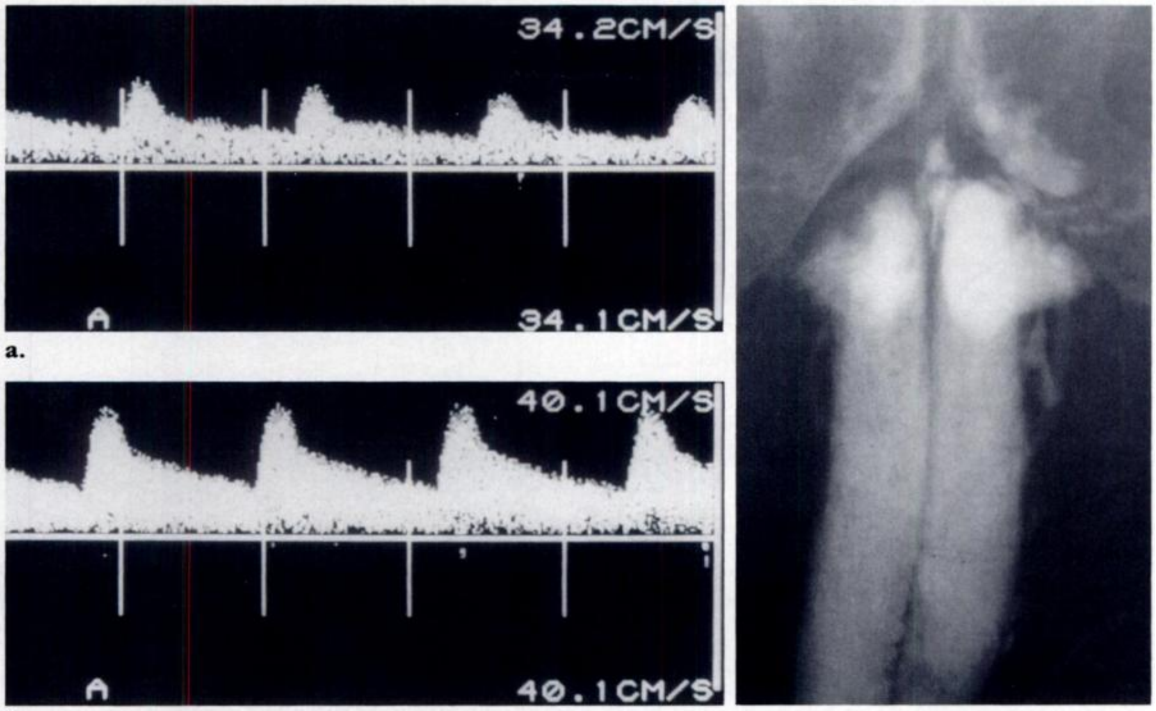


18c.

Figures 17, 18. **(17)** Spectral waveform obtained from cavernosal artery 2 minutes after papaverine injection shows continuous diastolic flow and a broad systolic envelope. End-diastolic velocity exceeds the 5-cm/sec threshold. **(18)** Progression of spectral waveforms demonstrates another component of temporal response to papaverine. **(a)** At 4 minutes after papaverine injection, a normal peak systolic velocity and elevated end-diastolic velocity (18 cm/sec), consistent with venous leakage, were observed. **(b)** At 11 minutes after papaverine injection, some waveform progression has occurred, but there are features consistent with venous leakage. End-diastolic velocity is 5 cm/sec. **(c)** At 23 minutes after papaverine injection, there has been progression to end-diastolic flow reversal. Clinically, full tumescence has occurred. Termination of data collection at 5–10 minutes would have resulted in a false-positive diagnosis of venous incompetence. Results of cavernosography were normal.

■ VENOUS INSUFFICIENCY

Venous incompetence or veno-occlusive failure may represent the most common cause of vasogenic impotence. Literature on the color Doppler diagnosis of venous incompetence is scant. The principal investigators (7) used an arterial end-diastolic velocity of greater than 5 cm/sec to diagnose venous leakage. We had the opportunity to examine a large number (n = 115) of men with suspected venous incompetence, and results from these examina-



a.

b.

c.

Figure 19. Progression of spectral waveforms demonstrates a second pattern of temporal response to papaverine that influences diagnosis of venous incompetence. **(a)** At 4 minutes after papaverine injection, peak systolic velocity is subthreshold and end-diastolic velocity is less than 5 cm/sec, suggesting arterial insufficiency. **(b)** At 13 minutes after papaverine injection, an increase in overall cavernosal artery flow occurred, which results in classification as venous incompetence. **(c)** Cavernosogram helps confirm veno-occlusive failure.

tions form the basis for the following comments on veno-occlusive failure.

As we discussed previously, with increasing intracavernosal pressures, there are specific transitions in spectral waveforms, principally a progressive loss of diastolic flow and ultimately diastolic flow reversal. Therefore, the presence of persistent diastolic flow and elevated end-diastolic velocities are indirect indicators of veno-occlusive failure. Figure 17 illustrates a case in which the patient's elevated diastolic flow persisted throughout the examination. It should be emphasized that the diagnosis of venous incompetence is made only if the patient has normal peak systolic velocity (> 25 cm/sec). When end-diastolic velocity is used to diagnose venous incompetence, it requires accurate angle correction.

The temporal response to papaverine also influences the accurate diagnosis of venous integrity (13). A substantial number of patients in our series (13%) had progression of cavernosal artery flow after 5 minutes, which influenced the diagnosis of venous leakage. One common pattern is illustrated in Figure 18, with initially normal peak systolic velocities and an elevated end-diastolic velocity. Over a variable time period (5–25 minutes), an orderly transition to diastolic flow loss and flow reversal was observed. Results of cavernosography and cavernosometry were normal in this patient and other similar patients. Termination of data acquisition at 5–10 minutes may produce false-positive diagnoses of venous incompetence.

A second pattern of diastolic flow progression was also observed. Initial measurements revealed low peak systolic and end-diastolic velocities. Over time, however, an increase in peak systolic velocity that was accompanied by an increase in diastolic flow was demonstrated. Cavernosography helped document venous leakage (Fig 19). In this case, early data termination would have resulted in a false-negative diagnosis of venous incompetence.

Although we believe transient dorsal vein flow is a normal occurrence, persistent dorsal vein flow may reflect veno-occlusive failure. In our experience, dorsal vein flow that persisted throughout the examination had an 80% sensitivity and 100% specificity for venous leakage at cavernosography.

Figure 20 is a representative example of persistent dorsal vein flow found in our patients with venous incompetence. Figure 21 demonstrates a typical spectral trace obtained from the dorsal vein. In our experience and that of others (14), determination of dorsal vein flow velocities has not proved to be useful in the diagnosis of venous incompetence. The combination of persistent dorsal vein flow and elevated end-diastolic arterial flow resulted in 93% accuracy for venous leakage when correlated with cavernosographic findings. Data from the cavernosal arteries and dorsal veins should be obtained for 20–30 minutes after papaverine injection. Premature termination of the examination may lead to false-positive and false-negative diagnoses, as previously illustrated.

Clinical experience with the diagnosis of venous incompetence is building, and diagnostic criteria will continue to evolve. Currently, we believe that the presence of elevated diastolic flow in the cavernosal artery as defined by end-diastolic velocity, spectral indexes, and failure of diastolic flow progression remain the best indicators of venous leakage. Experience with the diagnosis of venous incompetence is limited to date, and there is considerable uncertainty about the precise role of Doppler imaging in the diagnosis of venous leakage as a cause of impotence. Although color Doppler imaging can be useful in diagnosing venous incompetence, cavernosography is necessary in patients for whom venous surgery is being considered. Cavernosography provides a more complete preoperative road map and allows for assessment of venous integrity in patients with arterial insufficiency. Both cavernosography and cavernosometry are performed at most institutions to detect venous leakage. Diagnostic criteria for these studies are also being continually revised.

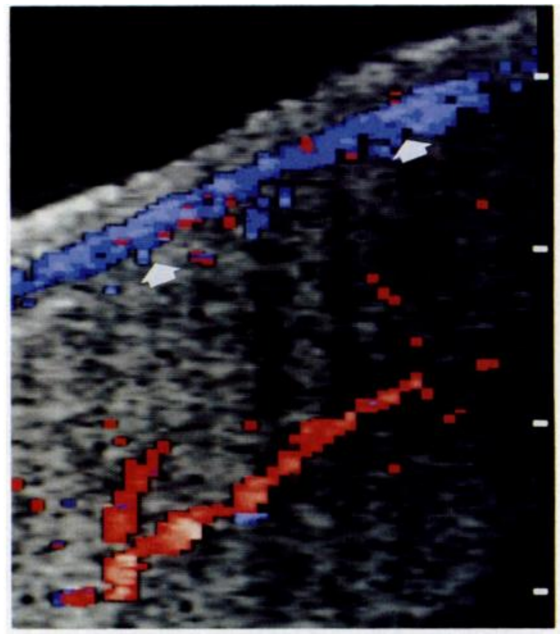


Figure 20. Midline oblique sagittal color Doppler flow image demonstrates flow within the deep dorsal vein (arrows) at 16 minutes after papaverine injection.

■ SUMMARY

The ability of color Doppler sonography to accurately demonstrate both arterial insufficiency and venous incompetence makes it a valuable tool in the diagnostic evaluation of erectile dysfunction. Color Doppler imaging offers several advantages over duplex imaging, including rapid localization of the cavernosal artery and accurate angle correction; depiction of cavernosal artery and dorsal vein flow progression; and demonstration of venous flow, arterial variants, and arteriosclerotic disease. The diagnosis of venous incompetence is enhanced by obtaining data from the dorsal veins and the cavernosal arteries at 1–30 minutes after papaverine injection. When compared with limited data acquisition within the first 5 minutes after injection, a substantial improvement in diagnostic accuracy is realized.

Further evolution in diagnostic criteria is likely, and important modifications in examination technique are currently under investigation. These include new vasoactive agents, use of visual stimuli, and simultaneous cavernosometry and color Doppler imaging. Fur-

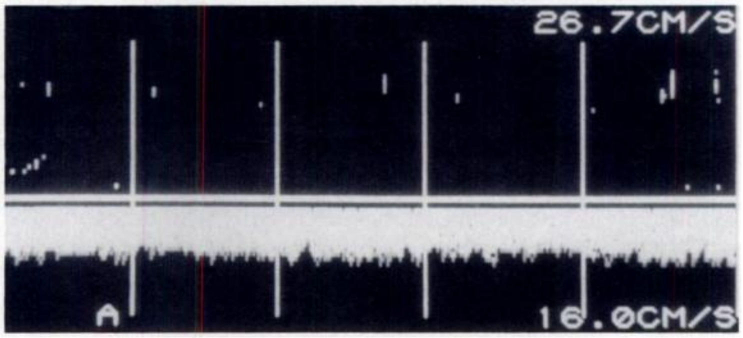


Figure 21. Spectral waveform obtained from the dorsal vein does not provide any additional information for the diagnosis of venous leakage.

ther advances in transducer technology and vascular imaging will improve our ability to assess the status of the vascular component of the erectile mechanism.

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