Review

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Doppler applications in testicular and scrotal disease

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Abstract

The paper reviews the current knowledge on the use of Doppler ultrasound in disease of the testis and scrotal contents.

The first part presents fundamentals on vascularization and normal Doppler appearance of the testis as well as examination technique.

The review presents the applications of Doppler ultrasonography in the diagnosis of inflammation, torsion and ischemia, varicocele, venous thrombosis, tumors, hydrocele, trauma and assessing fertility disturbance.

Key words: ultrasonography, Doppler, testis, scrotum

Rezumat

Lucrarea prezintă o trecere în revistă a stadiului actual al cunoştinţelor în ceea ce priveşte aplicarea ultrasonografiei Doppler în studiul patologiei testiculare şi a conţinutului scrotal.

Sunt prezentate noţiuni fundamentale privind vascularizaţia şi aspectul ultrasonografic Doppler normal al testiculului precum şi metodologia de examinare.

Sunt trecute în revistă aplicaţiile metodei Doppler în evaluarea inflamaţiilor, torsiunii şi ischemiei, varicocelului, trombozei venoase, tumorilor, hidrocelului, traumatismelor şi aportul în diagnosticul problemelor de fertilitate.

Cuvinte cheie: ultrasonografie, Doppler, testicul, scrot

Recent advances in the use of Doppler ultrasonography for assessing disease of the testis and scrotum have extended the usefulness of this technique beyond the classic differentiation between torsion and inflammation and provide a better understanding of the spectral tracing. The aim of this paper is to provide an update on the current use of scrotal Doppler ultrasound.

Vascular supply

Three main vessels provide the arterial supply of the scrotal contents.

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The internal spermatic artery, a branch of the abdominal aorta, courses along the inguinal canal and divides into two main branches: testicular and epididymal. The testicular artery courses along the posterior aspect of the gland and penetrates the tunica albuginea in the vicinity of the lower pole, at the level of the testicular ligament, forming the capsular artery. The tunica vasculosa is a plexus of blood vessels that clothes the inner surface of the tunica albuginea. Branches of the capsular artery course in the septations of the testicular parenchyma as centripetal arteries, directed to the testicular mediastinum. Recurrent or centrifugal arteries course from the mediastinum to the periphery, inside the parenchyma of the lobules [1] (fig 1). The epididymal branch supplies the epididymis.

The external spermatic – also called cremasteric- artery is a branch of the inferior epigastric artery and it supplies the coverings of the cord.

The deferential artery originates from the superior vesical artery and supplies the deferent duct.

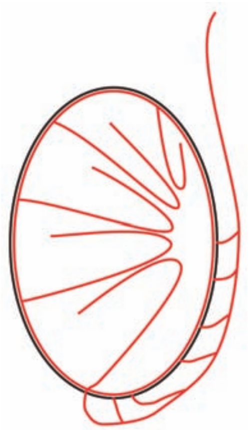

Fig 1. Arterial supply of the testis.

Smaller branches of the internal and external pudendal arteries also contribute to the arterial supply of the coverings of the testes. Multiple anastomoses develop between the three main branches, mainly at the level of the cord and on the surface of the epididymis.

The venous drainage of the testis is accomplished through the plexus pampiniformis. As they course through the cord and along the inguinal canal, the venous channels of the plexus join to form the internal spermatic vein draining directly into the inferior vena cava on the right side and the left renal vein, on the left side. The smaller posterior spermatic, or cremasteric, plexus drains the epididymis in the external spermatic vein [1].

Examination technique

High resolution 7,5 – 13 MHz linear transducers are used. The imaging parameters are set to increase the detection of low-velocity, low-volume flows within the small testicular vessels. Such parameters include PRF ranging from 1500 to 600 Hz, low wall filters ranging from 25 to 50 Hz, color gain maximized for optimal sensitivity while avoiding excessive color noise, color vs. echo priority ranging from 70 to 90% and color persistence adjusted to high values [2].

Normal ultrasonographic appearance

a. In the adult, low resistance flow, with broad systolic component and holodiastolic antegrade flow is recorded in the intratesticular and capsular arteries. Normal mean resistance index (RI) is 0.6, ranging from 0.5 to 0.7. Some asymmetry between the two testes may be encountered. The peak systolic velocity in the centripetal, intratesticular arteries is less that 15 cm/sec. Supratesticular, cremasteric and deferent arteries show higher impedance flow pattern [1,3,4] (fig 2).

On color Doppler, both centripetal and centrifugal arteries are seen as short vessels or simple color dots (fig 3). Transtesticular – also named transmediastinal – arteries are seen in approximately 50% of the subjects, as thicker and relatively long vessels that cross the testicular parenchyma, joining the mediastinum to the subcapsular space. They may be asymmetric and are observed, more frequently, in the upper third of the testis. Half of them are accompanied by a vein [5] (fig 4). Flow in these arteries may be either centripetal or centrifugal [6]. The epididymis shows almost no vascularity.

b. In the pediatric age group, flow is more difficult to depict, due to physiologic hypovascularization of the testes. The mean value of RI was found to be 0.87 in children with testes less than 4cc in volume. Growth and

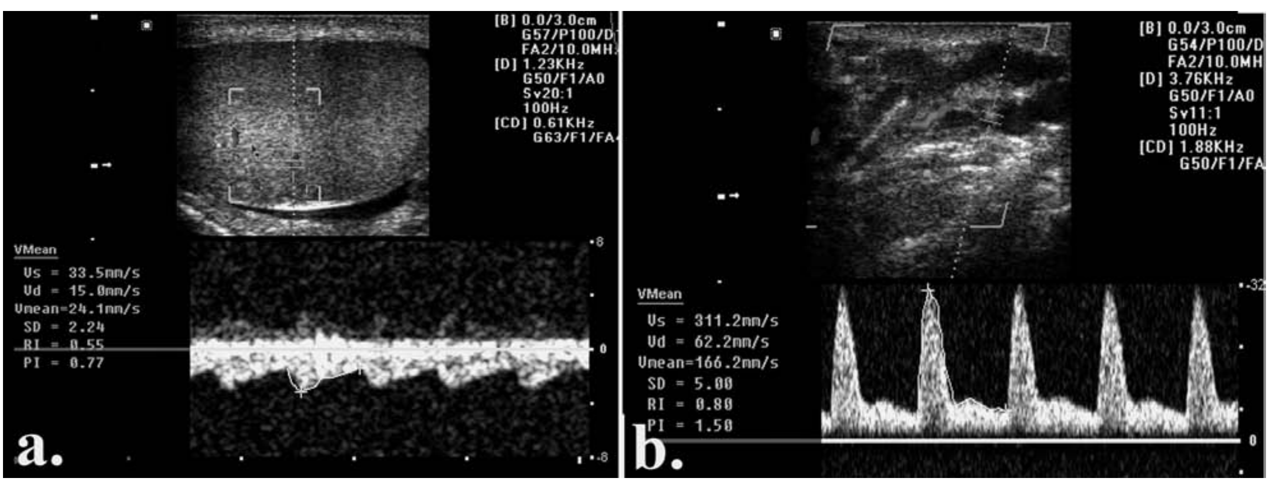

Fig 2. Normal spectral tracings of scrotal arterial supply. Typical, low impedance, high diastolic intratesticular flow (a) contrasts with much higher impedance deferential artery spectrum (b)

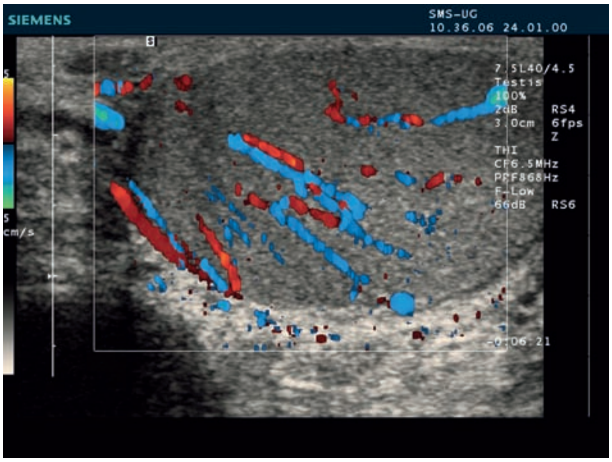

Fig 3. Appearance of normal intratesticular vessels on color Doppler.

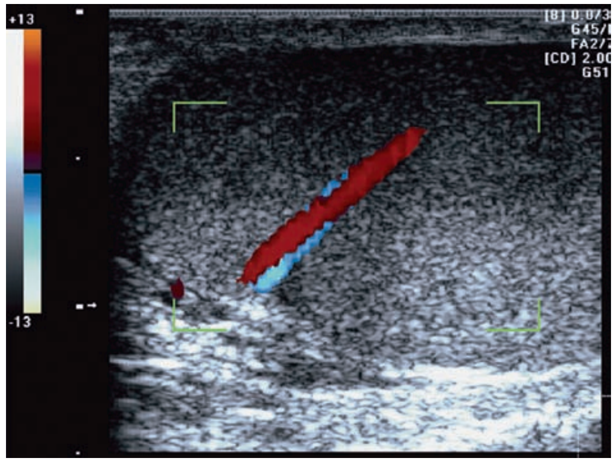

Fig 4. Transtesticular artery and vein.

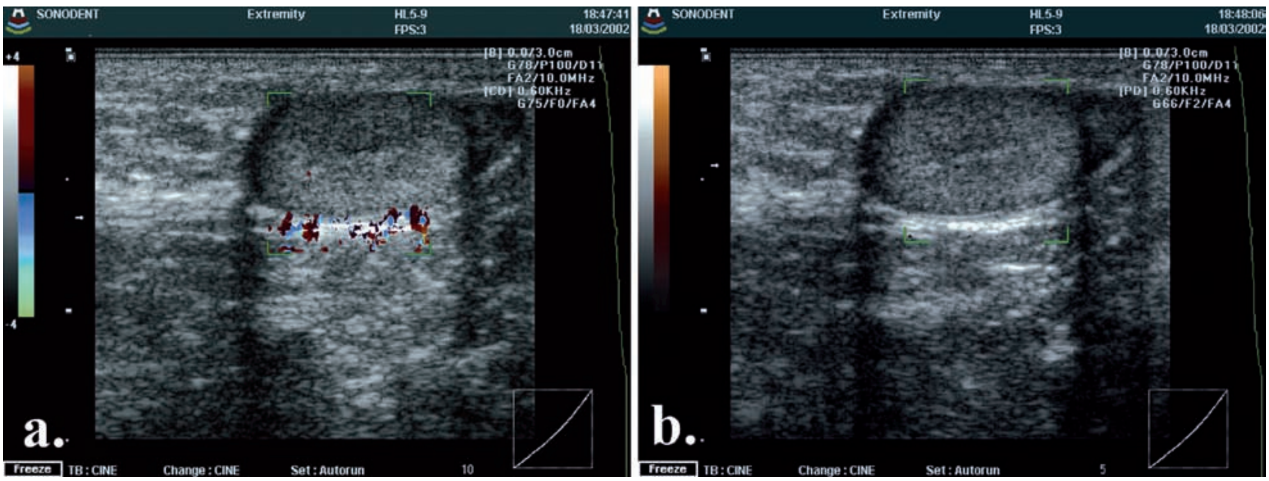

Fig 5. Failure to identify flow in normal pediatric testes: color Doppler (a) and power Doppler (b).

testicular volume increase are associated with decrease of mean RI values (0.57 in testes with volume greater than 4cc) [7]. In prepubertal boys the diastolic flow, often, cannot be identified.

Color Doppler fails to identify intratesticular flow in approximately 50% of the subjects, in this age group (fig 5). Supratesticular or subcapsular arteries are always identified. Demonstration of intratesticular arteries is inconsistent until 8 years of age at power Doppler sonography and until 12 years of age at color Doppler [8]. Some authors found that power Doppler is able to depict more vessels, in the normal pediatric testis, than color Doppler does [8,9] while others have failed to support this observation [10]. One explanation may reside in the constructive generation and low flow sensitivity of the ultrasound machines used by different groups.

Disease

Acute inflammation

Epididymitis and epididymo-orchitis are the most common causes of painful scrotal swelling over 18 years of age. The acutely inflamed part is, characteristically, hypervascular. The spectral tracing shows 1.7-2 fold increases in peak systolic velocity and a RI decrease both in the testicular branches (<0.5) and in the epididymal ones (< 0.7) [1]. The RI value of 0.5 separates normal from orchitis [11]. Increased or abnormally high values of RI in acute orchitis indicate ischemia due to edema occluding the venous outflow [12,13]. On color Doppler, the typical appearance of „testicular inferno” is seen (fig 6). Color ultrasound techniques are able to identify the inflamed structure within the scrotum and to localize the inflammation within a specific structure (fig 7). Acute

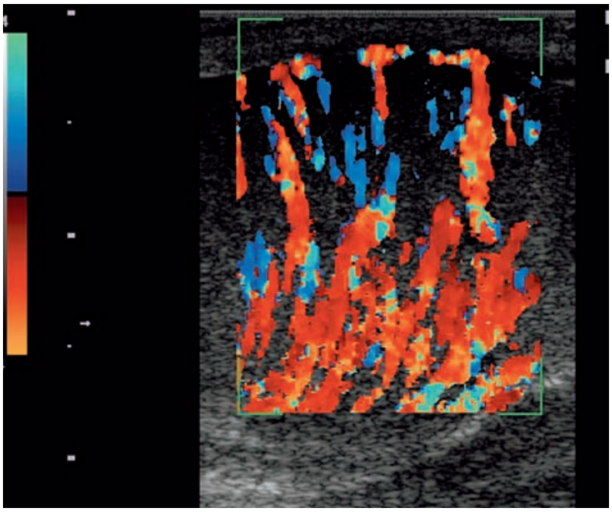

Fig 6. Color Doppler in acute orchitis: typical "testicular inferno" appearance.

post mumps orchitis in the adult has no specific features, showing diffuse hypervascularity of the affected testis associated with a significant decrease of the RI [14]. Under treatment, the severity of the Doppler changes diminishes in the 3rd day after diagnosis and the changes completely disappear within one week [15].

Focal orchitis requires a differential diagnosis with tumors.Color Doppler is useful in showing hypervascularity with normal branching and unaltered course of the arteries. It also provides a useful means for follow-up (fig 8).

In unspecific focal epididymitis, vascularity is more prominent than in epididymal inflammatory masses or tuberculosis [16].

Partial infarction, as a rare complication of orchi-epididymitis, is characterized by increased RI values in the diseased testis and an avascular, hypoechoic focal lesion in the testicular parenchyma [17] (fig 9).

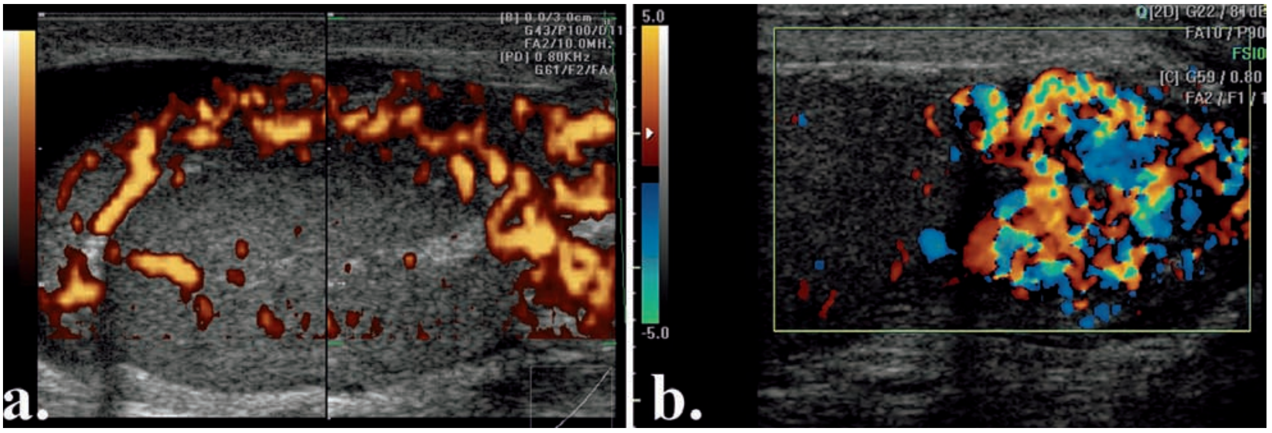

Fig 7. Epididymitis without orchitis. Complete epididymitis depicted by power Doppler (a) and epididymal tale inflammation as shown by color Doppler (b). On both images, neighboring testis displays normal vascular appearance.

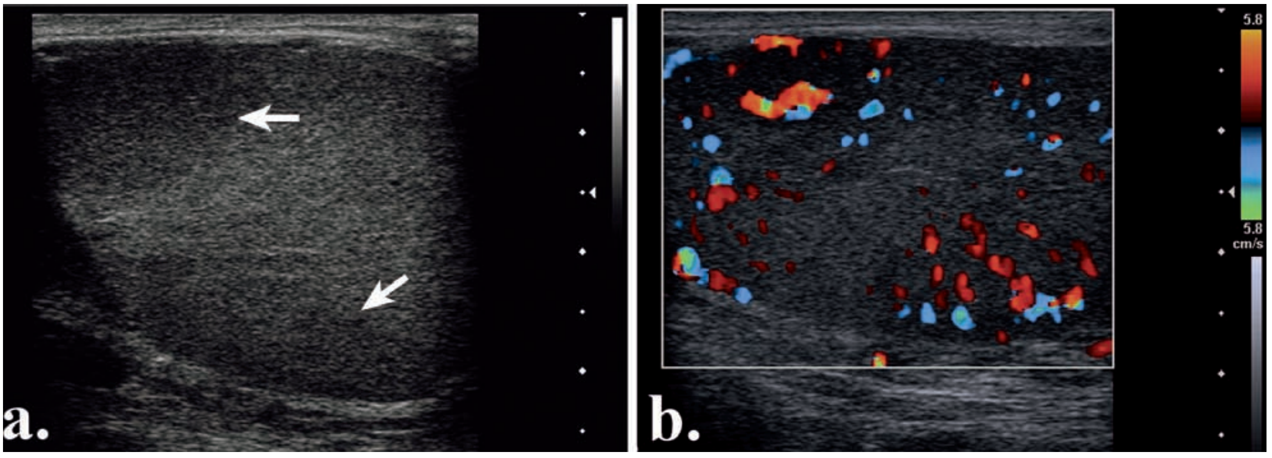

Fig 8. Focal orchitis. Gray-scale US depicts two intratesticular ill-defined hypoechoic areas (arrows) (a). On color Doppler (b), the areas appear hypervascular, with regular arterial branching.

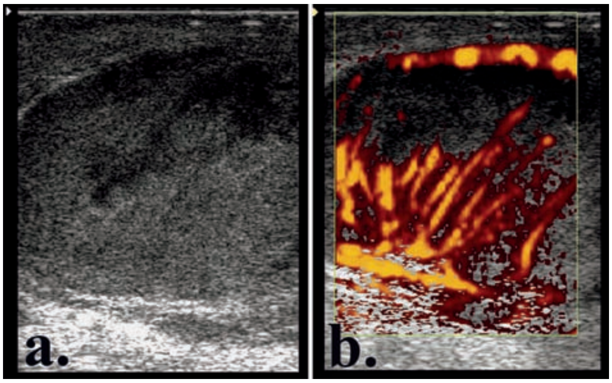

Fig 9. Partial infarction in acute orchitis. Irregular hypoechoic area (a) associated with complete loss of vascular signal, as compared to neighboring hyperemia (b).

Torsion and ischemia

Spermatic cord torsion usually results from the anatomical „bell-and-clapper" deformity. Classically, the ultrasonographic diagnosis is established by color or power Doppler, when there is not a detectable flow within the testicular parenchyma. Color Doppler was found to be 88.9% sensitive, with a specificity of 98.8% and 1% false positive results for torsion [18] (fig 10).

The Doppler appearance and aspects encountered in torsion depend on the evolutional phase and degree of twisting. At a 180^0 twist of the cord, venous flow stops, while arterial flow is still present. Resulting increased intravenous pressure is responsible for interstitial edema and increased arterial resistance [1]. At twists more than 360^0, the arterial inflow stops and there is a complete disappearance of the Doppler signal. Detection of flow around the testis does not exclude torsion (fig 11). In missed torsion (subacute phase), due to the anastomoses with the epididymal and deferential arteries, peritesticular hyperemia occurs [19]. Acute venous dilatation may be observed within two hours of the onset of acute torsion. Microvenous thrombosis secondary to torsion may induce bidirectional flow in the intratesticular arteries [20]. Transient torsion may result in testicular hypervas-

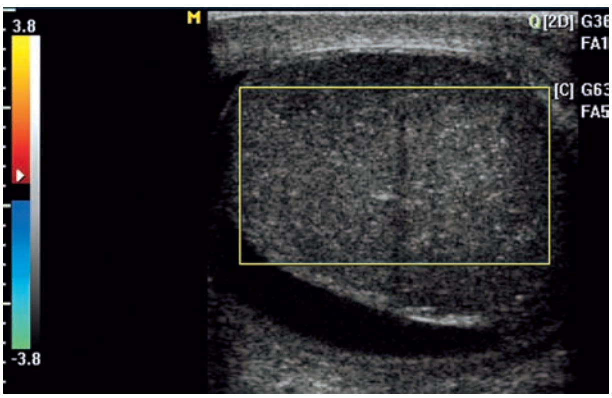

Fig 10. Acute cord torsion. Complete lack of intratesticular vascular signal.

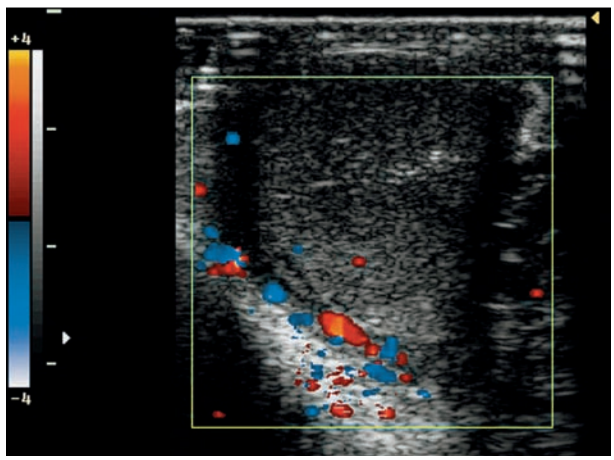

Fig 11. Complete torsion with present capsular flow.

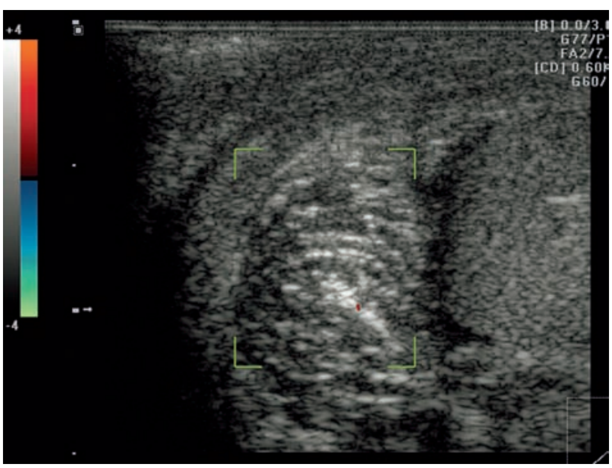

Fig 12. Typical avascular supratesticular "snail shell" torsion site.

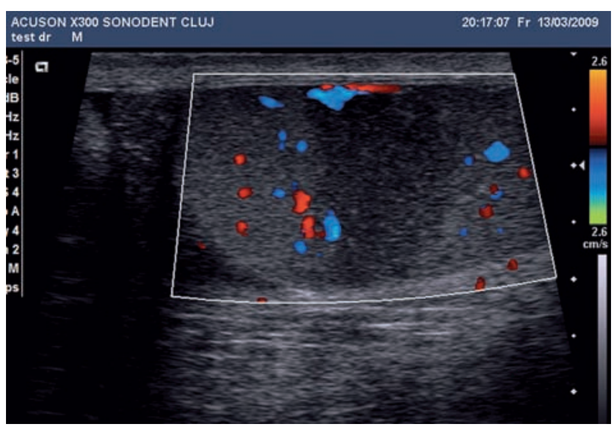

Fig 13. Testicular segmental infarction. Wedge shaped hypoechoic avascular area in the middle portion of the testis.

cularization after spontaneous detorsion, thus mimicking orchitis. Recent studies have demonstrated the possibility of detecting the torsion by examining the cord and searching the torsion site. The twist appears as a snail shell-shaped mass measuring 11 to 33 mm. This aspect was seen in all patients with torsion, although some of them had normal or equivocal intratesticular Doppler vascular appearance. Direct visualization of the torsion site allows for the diagnosis to be made even in patients with preserved intratesticular flow. Subsequently direct visualization of an untorsed cord excludes unnecessary surgical exploration [21, 22] (fig 12).

Torsion of the appendix testis accounts for 20 - 40% of cases of acute scrotum in the pediatric age group. On color Doppler, flow is absent both in normal and in torsed appendages. In torsion, however, the appendix has a spherical shape, with a diameter greater than 5 mm. Increased flow is seen around the torsed appendix [23].

Segmental infarction, a rare condition, appears as a hypoechoic wedge shaped area in the testicular parenchyma. The absence of Doppler signal in the infarcted area allows for differentiation from tumors [24,25] (fig 13). On a follow-up of one case, complete revascularization at three months was seen with color Doppler [26].

Varicocele

Abnormal dilatation of the peritesticular veins is more frequently encountered on the left side and is better seen when examining the patient in an upright position or during the Valsalva maneuver (fig 14). The main cause of left sided varicocele resides in the „nutcracker" phenomenon exerted by the superior mesenteric artery and the aorta on the left renal vein. The reduction of the aorto-mesenteric distance and a decrease of the aorto-mesenteric angle are positively associated with a mean flow velocity decrease in the left renal vein, increase of the testicular vein diameter above 3 mm and reflux during the Valsalva maneuver [27]. However, reflux is not the decisive factor in varicocele, since more than 50% of subjects without varicocele may present reflux during Valsalva maneuver, seventy percent of these being located on the left side. Reflux, in these subjects, has a duration of approximately 1 sec, mean velocity of 4.5 cm/sec and is, presumably, due to the fact that the diameter of the left testicular vein is greater than the right one [28].

At least three pathogenetic types of varicocele have been described. Reflux varicocele is easily recognized due to typical, long lasting (more than 2 seconds) reflux during the Valsalva maneuver or while the patient is standing (fig 14). Obstructive varicocele is characterized by a very slow flow, unaffected by respiration or position. Contrasting, varicocele due to arterio-venous malformation is characterized by a high venous flow [19] (fig 15).

Classic, two-dimensional sonographic criteria for the diagnosis of varicocele include a single vein diameter above 3mm and/or more than 1 mm increase in diameter during the Valsalva maneuver (fig 14). More refined diagnostic criteria form a score that includes maximal venous diameter, the presence of a visible venous plexus, the sum of the diameters of six veins within the plexus and the presence, duration and amplitude of Doppler changes induced by the Valsalva maneuver [29].

Recent studies have shown a much higher incidence rate (77%) of bilateral varicoceles in infertile men than formerly known [30]

Intratesticular varicocele is an entity that has only recently been described. It appears as an anechoic intratesticular mass with a slow flow on color Doppler. The mass disappears after the ligation of the spermatic vein [31]. Another possible appearance is that of dilated veins radiating from the mediastinum testis, with reflux during the Valsalva maneuver [32]. Subcapsular veins may be affected to a greater degree than mediastinal veins in intratesticular varicocele. The largest intratesticular vein may

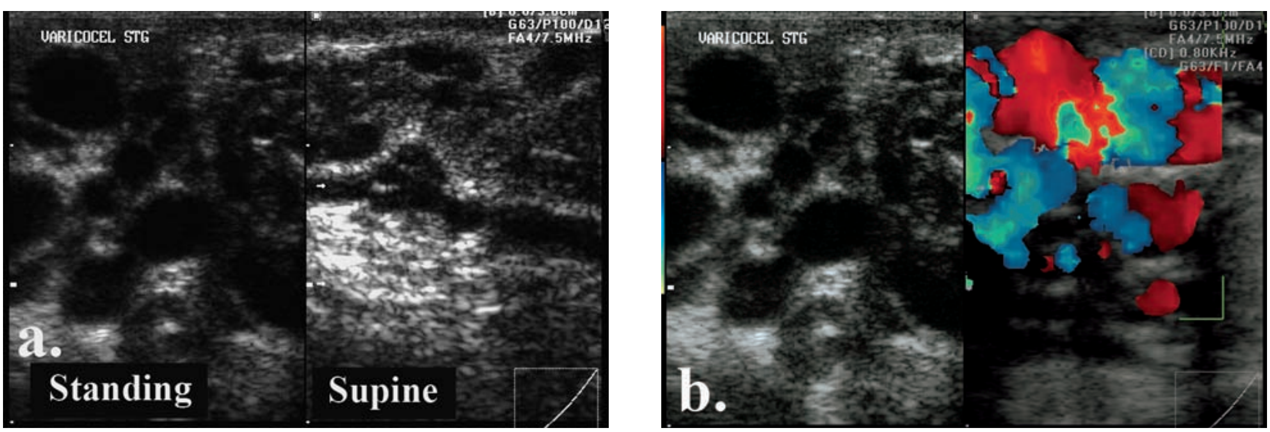

Fig 14. Reflux varicocele. Engorgement of the veins in the standing position (a) associated with obvious reflux (b).

measure less than 2 mm, but all intratesticular varicoceles are accompanied by the extratesticular form [33] (fig 16).

The effects of varicocele on the arterial blood flow are disputed. Initial studies have evidenced no effects [34] and even recent studies found no significant RI or volume changes in patients with subclinical varicocele [35]. However, in patients with a clinical diagnosis of varicocele, the mean arterial inflow, expressed in ml/min/100g tissue, was found to be significantly lower than in control subjects [36]. More recently, testicular arterial blood flow was found to be significantly decreased in men with varicocele. This may be a reflection of the impaired microcirculation [37].

Venous thrombosis is a rare condition, associated with trauma or severe infection. It may pass unnoticed due to the multiplicity of veins within the plexus (fig 17).

Tumors

On color Doppler, intratesticular tumor nodules display a nonspecific appearance, characterized by hypervascularity with irregular, chaotic branching patterns [19] (fig 18). The tumor containing side may show decreased RI or normal RI with increased peak systolic flow, in the testicular artery [13]. Leydig cell tumors show a peculiar appearance of hypoechoic nodules with peripheral hypervascularity and little or no internal color Doppler flow [38]. Sarcomas of the spermatic cord display marked hypervascularity of the solid parts [39]. Adrenal rests appear as avascular, echogenic masses in the central parts of the testis [40]. A basket pattern arrangement of intratumoral vessels has been described in primary testicular granulocytic sarcoma [41].

Hydrocele

In patients with hydrocele, the volume of the homolateral testis is increased and so are the RI and the pulsatility index (PI). Postoperatively, both volume and impedance indices decrease [42].

Trauma

Color Doppler has proved to be very useful for the assessment of testicular vascularization in scrotal trauma patients. Focal absence of vascularity, mainly if associated with morphologic signs suggestive for rupture, is a strong indicator for open surgery [19,43] (fig 19).

Fertility

In a study group, men with unobstructive azoospermia had the lowest peak systolic velocity (PSV) and RI in the testicular arteries. Subjects with obstructive azoospermia and male accessory glans inflammation had the highest PSV and RI, just as fertile controls or patients with varicoceles [44].

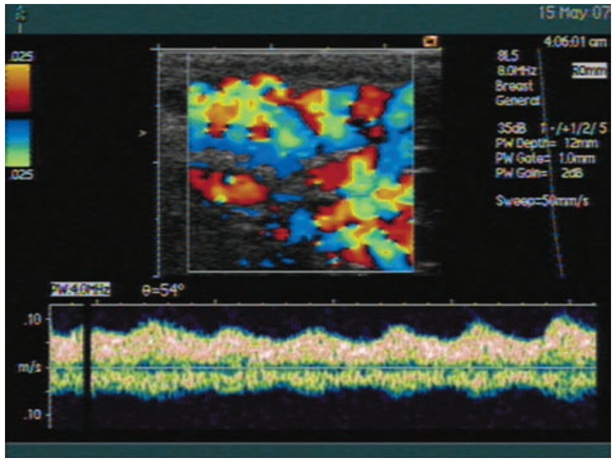

Fig 15. High velocity flow with arterial modulation varicocele due to arterio-venous malformation.

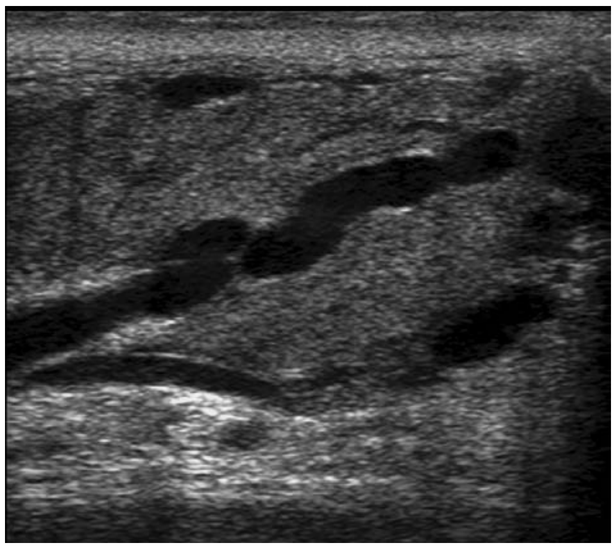

Fig 16. Intratesticular varicocele- gross dilatation of subcapsular and intratesticular venous branches.

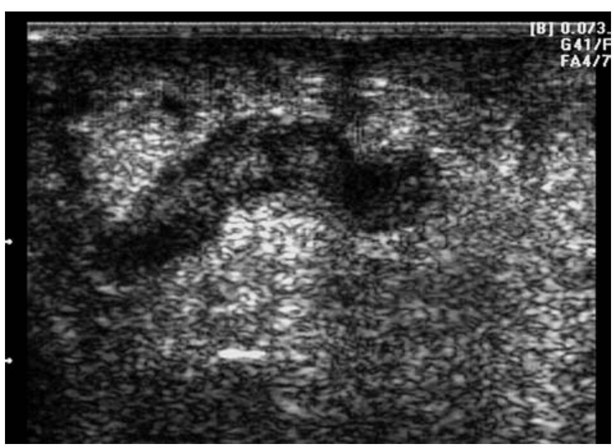

Fig 17. Spermatic vein thrombosis.

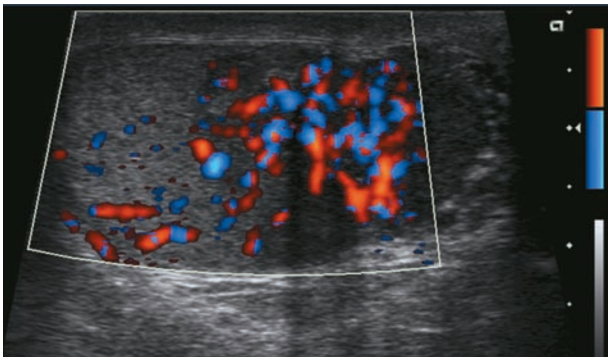

Fig 18. Seminoma. Focal increase in vascular signal with irregular branching.

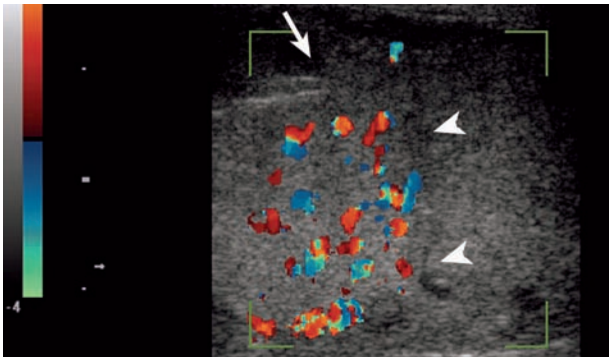

Fig 19. Testicular fracture shown by contour indentation (arrow) and hypoechoic fracture line in the parenchyma (arrowheads). Loss of vascular signals in the lower half of the testis.

At least one group of researchers uses power Doppler to build a three-dimensional map of testicular vascularization. The map is used to calculate a testicular vascularity index. The areas with the highest index are targeted for sperm extraction puncture. The method has high specificity but low sensitivity [45,46].

Doppler ultrasonography has been recently used to assess the effect of inguinal hernia repair on testicular perfusion. Whereas no difference between surgical techniques was found [47], transient changes (increase in intratesticular peak systolic velocity and resistive index) were shown in the early postoperative period, in a pediatric group, with complete resolution in a late period [48].

Contrast-enhanced ultrasound might be applicable for the investigation of vascular disorders of the testis. Pulse inversion US data can determine relative testicular perfusion and when compared with conventional Doppler US methods, provide superior assessment of testicular perfusion, by the use of time-intensity curves inclusively. The first published results show lower vessel density in atrophic testes and a difference in contrast dynamics in testes with impaired function [49]. The role of US elastography is yet to be established.

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