Sonography in male infertility: a look beyond the obvious

Prateek Sihag¹ · Anupama Tandon¹ · Raj Pal¹ · B. K. Jain² · Shuchi Bhatt¹ · Simranjeet Kaur¹ · Arpita Sinha¹

Received: 30 December 2017 / Accepted: 5 March 2018 / Published online: 28 March 2018

© Società Italiana di Ultrasonologia in Medicina e Biologia (SIUMB) 2018

Abstract

Infertility affects 15–20% of the reproductive age range population; the male factor accounts for up to 40–60% of these. With female factor infertility catching most of the limelight in research, diagnosis and treatment, the other half of the problem has not been duly addressed. Imaging has an important role to play in the evaluation of male infertility, especially to identify correctable (obstructive) causes. We review the scrotal, trans-rectal sonographic and Doppler findings in infertile men to aid in the accurate diagnosis and proper management of such patients.

Keywords Reproductive system · Male infertility · Azoospermia · Scrotal sonography · TRUS

Sommario

L'infertilità colpisce il 15–20% della popolazione in età riproduttiva e il sesso maschile rappresenta il 40–60% di questa percentuale. L'infertilità femminile continua ad essere il polo di attrazione principale della ricerca, della diagnosi e del trattamento mentre l'altra metà del problema non è stata ancora adeguatamente affrontata. L'imaging svolge un ruolo importante nella valutazione dell'infertilità maschile, specialmente per identificare le cause correggibili (ostruttive). In questo pictorial essay valutiamo i risultati dell'ecografia scrotale, trans-rettale ed eco-Doppler in uomini infertili per indicare una corretta metodologia per una diagnosi accurata e quindi per una efficace gestione di tali pazienti.

Introduction

Infertility is a relatively common problem affecting about 15–20% of reproductive-aged couples [1]. Historically, the cause of infertility was erroneously attributed to the female partner, while the male factor, which is either primary or a contributory factor in as many as 40–60% of cases, has largely been ignored [2]. Thus, it is important to evaluate men concurrently with women.

There are several investigations that can be used to evaluate infertile men with azoospermia, such as semen analysis, biochemical markers in semen, hormonal essays, testicular biopsy, vasography and cross-sectional imaging like sonography/MRI [3]. Though trans-rectal ultrasound (TRUS) has

been used to assess the distal tract, scrotal ultrasound is only sparingly utilized and that to primarily to address the presence/absence of varicocele. However, scrotal sonography has much more to offer in the evaluation of infertile men, and in combination with TRUS can image almost the entire genital tract, help in the differentiation of obstructive from non-obstructive causes and identify the level of obstruction, all of which have positive treatment implications.

This pictorial essay is an attempt to familiarize practicing radiologists with the spectrum of findings in infertile men on scrotal and trans-rectal sonograms, thus enhancing their knowledge and skills in evaluating this group of patients.

Pathogenesis of male infertility

Successful male fertility requires normal spermatogenesis, successful epididymal maturation, normal sperm transport and accessory glands' function. Oligo-spermia defined as a reduced sperm count of less than 15 million/ml of semen or azoospermia, i.e., the complete absence of sperm is usually the first abnormality detected in an infertile man on semen analysis [4].

✉ Prateek Sihag
prateeksihag@gmail.com

¹ Department of Radiology and Imaging, University College of Medical Sciences and GTB Hospital, University of Delhi, New Delhi, India

² Department of Surgery, University College of Medical Sciences and GTB Hospital, University of Delhi, New Delhi, India

The etiologies for oligo-spermia or azoospermia broadly fall into three categories: pre-testicular, testicular and post-testicular. The pre-testicular causes of azoospermia include endocrine abnormalities that adversely affect spermatogenesis, leading to secondary testicular failure. The testicular causes (primary testicular failure) involve disorders of spermatogenesis intrinsic to the testes. Post-testicular causes of azoospermia, such as ejaculatory dysfunction or the obstruction of sperm delivery, are found in approximately 40% of patients [5].

From a management perspective, the causes of male infertility can be broadly subdivided into obstructive causes (OC) and non-obstructive causes (NOC) [6]. The obstructive abnormalities that cause azoospermia are frequently amenable to surgical intervention, which can restore normal reproduction. In contrast, in most NOC, the damage is generally irreversible, with the exceptions of impaired spermatogenesis associated with varicocele and some endocrine abnormalities. Assisted reproductive techniques remain the only option in these cases. Table 1 provides a list of important causes of male infertility.

Evaluation of infertile men

Routine initial screening for male infertility involves semen analysis, repeated at a 4–6-week interval. The evaluation of the infertile man begins with a detailed clinical history and physical examination, followed by an array of laboratory investigations to identify possible correctable causes. Laboratory tests routinely include LH, FSH and testosterone levels. Hormonal levels can help narrow down the differential and plan further management strategies (Table 2).

Table 1 Causes of male infertility

Obstructive (post-testicular)	Non-obstructive
Epididymal obstruction	Pre-testicular
Idiopathic epididymal obstruction	Acquired endocrinopathies
Post-infective (epididymitis)	Congenital endocrinopathies
Post-surgical (epididymal cysts)	Pituitary failure
	Testosterone supplements
Vas deferens obstruction	Testicular
Congenital absence of the vas deferens	Genetic infertility
Post-vasectomy, post-surgical (hernia, scrotal surgery)	Idiopathic abnormal semen (OAT syndrome)
	Cryptorchidism
	Varicocele
	Exposure to gonadotoxins
Ejaculatory duct obstruction	Post-testicular
Prostatic cysts (Muellerian cysts)	Disorder of ejaculation
Post-surgical (bladder neck surgery)	Erectile dysfunction
Post-infective	Anti-sperm antibodies

Table 2 Hormone levels in patients (men) with different causes of infertility

Parameters	Primary testicular failure	Hypo-gonadotropic hypogonadism	Obstructive azoospermia
FSH level	High	Low	Normal
LH level	High	Low	Normal
Testosterone level	Low	Low	Normal

Role of imaging

The main role of imaging is to identify the cause of infertility and help categorize it into OC or NOC [7]. Besides being of diagnostic use, imaging is also used to guide methods for assisted reproduction, like sperm aspiration from the epididymis or seminiferous tubules for in vitro fertilization or intra-cytoplasmic sperm injection [8]. The imaging modalities routinely used to evaluate the male reproductive system include ultrasonography (US) and magnetic resonance (MR) imaging, as well as invasive techniques such as venography and vasography

Sonography

Scrotal ultrasound (US), being noninvasive, safe and inexpensive, is the first-line modality in male infertility evaluation [9]. Scrotal US is performed using a high-frequency linear array transducer with the patient in a supine position. Routine evaluation includes transverse and longitudinal sonograms of the testis, testicular volume measurement and color flow Doppler US of testis/spermatic cord. Scrotal US can directly demonstrate abnormalities of the testis and peri-testicular structures, while also helping to visualize changes secondary to distal genital duct obstruction.

Normal adult testes are oval-shaped, homogenous, low-level echogenic structures and measure approximately 3 cm (AP) × 2–4 cm (TR) × 3–5 cm (length), with a volume of 12.5–19 cc [10] (Fig. 1). A testicle is surrounded by a thin echogenic fibrous band, which represents the visceral component of the tunica vaginalis and the tunica albuginea. In the absence of intra-scrotal fluid, the tunica is usually visualized only at its hilum as an echogenic structure, where it invaginates into the testis to form the mediastinum testis, which also contains a network of tubules called rete testis for sperm transfer.

Trans-rectal ultrasound (TRUS) enables high-resolution imaging of the distal genital tract, including distal vas deferens, seminal vesicles, prostate and ejaculatory ducts [11]. This examination is performed with patient

Fig. 1 Normal testes showing uniform homogeneous echogenicity

positioned in a left lateral decubitus position using a high-frequency endo-rectal transducer. Routine examination involves systematic evaluation of the terminal vas deferens, seminal vesicles, ejaculatory duct and prostate in the axial and sagittal planes (Fig. 2). A seminal vesicle diameter greater than 15 mm and an ejaculatory duct diameter greater than 2.3 mm are suggestive of ejaculatory duct obstruction, especially if they are associated with cysts or calcification along the duct [12].

Magnetic resonance imaging (MRI)

MR imaging is superior to trans-rectal US for evaluating the distal genital tract and can serve as an alternative to traditional invasive vasography [13, 14]. With superior soft tissue contrast and multi-planar capabilities, MR imaging can help demonstrate the pathophysiologic features of the reproductive tract, including the prostate, seminal vesicles and ejaculatory ducts. MRI has a great role to play in male infertility evaluation and has practically replaced vasography for the evaluation of the distal genital tract, owing to the high-quality and multi-planar images that it can produce.

Computed tomography

Computed tomography (CT) has limited soft tissue resolution and is used infrequently to evaluate infertility. However, CT can be useful for evaluating obstructing calcifications and stones along the reproductive tract [15].

Vasography

This procedure requires either blind or ultrasound-guided puncture of the vas deferens and retrograde contrast injection with filling of the ducts and free spill into the bladder, confirming patency [16]. Once considered the reference standard for evaluating the male reproductive system, it is now

Fig. 2 **a** Axial section on TRUS shows seminal vesicles as hypo-echoic bow-tie-shaped structures. Parasagittal TRUS in normal adult showing the vas in long section (**b**), seminal vesicle, vas deferens (**c**) and ejaculatory duct (**d**)

used much less frequently because of its invasive nature, associated complications [17] and the widespread acceptance of safer modalities such as ultrasound, TRUS and MRI.

Obstructive infertility

Obstruction can occur anywhere along the ductal system in the epididymis, vas deferens, seminal vesicles, ejaculatory ducts and urethra. Sonography can aid in identifying the cause and level of obstruction. This information helps in planning the surgical treatment, as epididymal obstruction can be treated by microsurgery, like vaso-epididymostomy, and vas obstruction with vaso-vasostomy, which has reported post-procedure pregnancy rates of 20–40% [18]. Distal tract obstructions can be treated under sonographic guidance, e.g., TRUS-guided transurethral resection of the ejaculatory duct (TRU-ED) and prostatic cyst aspiration [19]

Sonography findings in obstructive infertility

Obstruction along the genital tract results in the retention of secretions leading to macroscopic changes proximal to the site of obstruction. These changes are “secondary signs of obstruction” that can be detected on sonography. Sonographic findings of ectasia of rete testis, dilation of epididymal ductules (seen as linear hypo/anechoic channels) and intra-testicular cysts clearly indicate an obstructive cause (Fig. 3). The severity of these appearances may vary depending upon the level, duration and severity of the obstruction. Such appearances might be confused with findings in intra-testicular varicocele, which can be differentiated from the former with the use of Doppler imaging.

In addition, testicular volume is higher in obstructive azoospermia, reported as 11.6 ml (range 7.7–25.8 ml) in OC versus 8.3 ml (range 1.2–16.4 mL) in NOC by

Moon et al. [20]. A similar observation was made in our study, with a significant difference in testicular volumes in patients with obstructive (mean volume 18.2 ml) and non-obstructive (mean volume 8.2 ml) causes of infertility. Epididymis was also found to be bulky in patients with obstructive azoospermia, having a mean size of 10 versus 7.9 mm in those non-obstructive causes. Besides gray-scale imaging, color Doppler evaluation usually reveals the presence of normal/comparable vascularity in the obstructive group and normal controls versus reduced vascularity in the non-obstructive group [21].

Epididymal obstruction

The causes of epididymal obstruction include idiopathic obstruction, infection, iatrogenic injury and epididymal cysts.

Infection along the male genital tract is quite common, particularly in developing countries. Acute gonorrhea and sub-acute/chronic chlamydial or granulomatous infections like tuberculosis can lead to scarring and subsequent obstruction. In addition to the secondary signs of obstruction described earlier, sonography usually reveals a bulky epididymis with heterogeneous echotexture and/or epididymal calcifications. In fact, a bulky epididymal tail with calcification is highly suggestive of tubercular etiology (Fig. 4).

Epididymal cysts are common and can be simple cysts seen as anechoic lesions containing clear fluid or spermatoceles containing fine internal echoes (Fig. 5). Isolated cysts are a common finding in healthy young men, but a multiplicity of such lesions should prompt further evaluation, as spermatoceles are commonly found in the obstructive group.

Fig. 3 Characteristic sonographic findings in infertile men with obstructive etiology. Ductal ectasia and dilated channels in epididymis, visualized as multiple anechoic tubular structures in rete testis (a) and epididymal head (b) and body (c), respectively

Fig. 4 Chronic infective epididymitis causing proximal obstruction: **a** dilated rete testis with **b** bulky heterogeneous epididymis showing **c** increased vascularity on Doppler. Another patient with chronic tuber-

cular epididymitis shows **d** epididymal tail calcification visualized as echogenic foci with distal shadowing

Vas deferens obstruction

Congenital absence of vas deference (CAVD) is the most common congenital abnormality causing obstructive azoospermia and is seen in 2% of patients under investigation for infertility [22, 23]. Up to 82% of patients with CBAVD have at least one mutation within the cystic fibrosis gene. Therefore, patients with CBAVD must be considered for cystic fibrosis screening and genetic counseling prior to sperm retrieval/intra-cytoplasmic sperm injection treatment [24].

Sonography reveals signs of obstruction, viz. rete testis ectasia, bulky epididymis and tubular ectasia. In addition, an abrupt termination of an epididymal tail into a rudimentary echogenic cord-like structure may be seen (Fig. 6). Absence of the ampulla of the vas deferens [25] and abnormalities of the seminal vesicle (hypoplasia/agenesis) and ejaculatory duct are associated with this anomaly and can be detected on TRUS [26, 27].

Vasectomy is another iatrogenic cause of vas deferens obstruction. Sonography in these patients reveals bilaterally bulky epididymis with a finely speckled appearance, representing multiple interfaces between the ectatic epididymal tubule wall and fluid [28]. Dilated rete testis

and intra-testicular cysts are also frequent in long-standing obstruction (Fig. 7).

Ejaculatory duct obstruction

Though an uncommon cause of infertility, with an incidence of less than 1% in infertile men, it remains an important correctable cause that can be diagnosed on TRUS [29].

In distal obstruction, TRUS often reveals dilatation of the proximal ejaculatory duct, distal vas and/or bulky seminal vesicles, often with multiple cysts. A seminal vesicle with an antero-posterior diameter greater than 15 mm and vas deference diameter greater than 5 mm at the level of the seminal vesicle is considered abnormal [30] (Fig. 8). Ejaculatory duct obstruction can be caused by *ejaculatory duct calculi*, which occur most frequently in the ampullary region. TRUS in such cases reveals echogenic foci with distal shadowing along the course of ED on the oblique sagittal planes (Fig. 9).

Prostatic lesions, such as prostatic utricles or Mullerian cysts, are visualized as midline anechoic cysts showing no communication with the urethra. It can be difficult to

Fig. 5 **a** Anechoic round lesion with posterior acoustic enhancement involving the head of the epididymis represents an epididymal cyst. **b** Spermatocoele in another patient with obstructive cause of infertility

seen as hypo-echoic cystic lesion with fine internal echoes. **c** Dilated rete testis in right testis of same patient (**b**)

distinguish them from each other on TRUS alone; however, these can sometimes cause infertility by ED compression. TRUS in these patients can demonstrate dilated ED/VD and bulky SV, along with the prostatic cyst. Chronic prostatic abscesses can also cause ED obstruction in a similar manner, with the additional effect of inflammation on ED (Fig. 10).

Non-obstructive infertility

Non-obstructive infertility results from defective sperm production or function. Though the exact cause cannot be determined in most of these cases, further laboratory investigations can be utilized for the same, e.g., endocrine evaluation, anti-sperm antibodies detection, etc.

Sonography findings in non-obstructive infertility

Common findings on sonography that indicate non-obstructive etiology include either normal- or small-sized testis, heterogeneous testicular echotexture, micro-calcifications and decreased vascularity on Doppler studies (Fig. 11).

Varicocele, defined as dilatation of the venous pampiniform plexus, occurs secondary to retrograde flow via the spermatic vein due to incompetent or absent valves [31]. It is the most common correctable and non-obstructive cause of male infertility. Varicoceles are a common finding in approximately 20% of adolescents and adult men and is found in about 40% of patients presenting with infertility [32].

Physical examination is still the standard diagnostic method for varicoceles, but it is usually difficult to estimate the existence of a varicocele with physical examinations

Fig. 6 Proximal obstruction (CBAVD). **a, b** Scrotal USG showing ectatic rete testis and tubules in epididymal head (**c, d**); dilated tubules in epididymal body and abrupt decrease in size with transfor-

mation into thin cord-like structure; **e** bilateral hypo-plastic seminal vesicle with non-visualization of distal vas

alone. Some varicoceles are impalpable and asymptomatic, and thus can only be diagnosed with sonography, owing to thick scrotal skin and a strong cremasteric reflex [33]. Significant evidence suggests that varicoceles have a harmful effect on the testis and that varicocelectomy can not only prevent but also reverse decline in testicular function and also reverse damage [34, 35].

Varicoceles are best imaged using gray-scale sonography supplemented with color Doppler sonography. In a series of 217 men with clinical and subclinical varicoceles, a venous diameter of >2.95 mm during Valsalva was associated with sensitivity and specificity of 84% each for clinical varicocele [36]. Besides mean maximum venous diameter, changes in diameter on rest and Valsalva and demonstration of venous

Fig. 7 A diffusely bulky epididymis with a fine speckled appearance due to ectatic tubules in a patient previous vasectomy

reflux are also used for the diagnosis. On sonograms, varicoceles are usually seen as serpiginous anechoic channels in a peri-testicular location having a diameter of more than 3 mm, which increase in size and show the presence of

venous reflux on Doppler during the Valsalva maneuver (Fig. 12).

Cryptorchidism refers to the absence of a testis (or testes) in the scrotal sac. It may refer to an undescended, ectopic, atrophic or absent testis. The failure of descent of the testis into the cooler environment of the scrotal sac is thought to impair spermatogenesis and predispose a patient to infertility and malignancy [37]. Even after its detection and subsequent orchidopexy, men may be sub-fertile.

Ultrasound is the first imaging modality used. US has 45% sensitivity, 78% specificity and 88% accuracy for the localization of an undescended testis and is more accurate than clinical examination [38]. The most common location of an undescended testis is the inguinal canal; however, it may also be found in an intra-abdominal, pelvic or retroperitoneal location.

An undescended testis appears as a homogeneously hypoechoic ovoid structure with reduced volume and vascularity lying outside the scrotal sac (Fig. 13). MRI is the best

Fig. 8 Secondary signs of distal genital tract obstruction as seen on TRUS: **a** bulky seminal vesicle with AP diameter > 15 mm and **b** dilated distal vas with a diameter > 6 mm

Fig. 9 ED calcification; parasagittal TRUS images showing **(a)** hyper-echoic foci with distal shadowing seen along the course of ejaculatory duct. **b** Seminal vesicle is bulky and has multiple small cysts due to the retention of secretions secondary to ED calculi

Fig. 10 Distal obstruction due to chronic prostatic abscess; **a, b** focal hypo-echoic lesion in prostate showing increased peripheral vascularity; **c** parasagittal TRUS image showing dilated distal vas deferens

Fig. 11 Common findings in infertile men with non-obstructive etiology (**a–c**). Reduced testicular volume with heterogeneous echotexture and reduced vascularity in different patients

Fig. 12 Varicocele; **a** gray-scale USG images showing dilated venous channels in scrotal sac. **b** Doppler confirmed the presence of varicoceles with increased diameter of venous channels on Valsalva

cross-sectional modality to assess cryptorchidism, especially in cases where a testis is located intra-abdominally and remains undetected by sonography.

Testicular atrophy presenting as reduced testicular volume has been associated with oligo/azoospermia in infertile men (Fig. 11) [39]. Causes of reduced testicular volume include endocrinopathies (pituitary adenomas,

syndrome, etc.), primary testicular failure, steroid abuse, or chromosomal disorders like Klinefelter's syndrome. On sonography, an altered testicular echotexture and high resistive index of intra-testicular vessels are frequent findings in these patients with atrophic testis. Epididymis is usually normal in contrast to that in patients with OC.

Fig. 13 Cryptorchidism; **a** empty scrotal sac; **b, c** undescended right and left testis lying intra-abdominally along postero-lateral aspects of the urinary bladder

Epididymo-orchitis Despite the absence of conclusive epidemiological data, infections and inflammations of the genital tract are considered the most frequent causes of reduced male fertility [29]. Chronic inflammatory conditions of the testis adversely affect spermatogenesis and irreversibly alter both the number and quality of sperm [40].

Gray-scale ultrasound findings of epididymo-orchitis include enlarged testis and heterogeneous echotexture associated with an enlarged hetero-echoic epididymis. In acute cases, color Doppler ultrasound shows increased blood flow in both testes and epididymis. Chronic cases reveal testes with altered echotexture, reduced volume and poor vascularity.

Other causes and associations

Microlithiasis is an uncommon condition in which calcifications form in the seminiferous tubules. These calcifications are seen as echogenic foci without shadowing, usually less than 3 mm. Microlithiasis has been associated with several conditions, such as Klinefelter's syndrome, cryptorchidism, varicocele, testicular atrophy, torsion, tumors and infertility [41]. The mechanism by which microlithiasis affects spermatogenesis remains unknown (Fig. 14).

Dysplastic or hypo-plastic seminal vesicles are common urogenital malformations that can cause reduced fertility. Decreased secretions from hypo-plastic seminal vesicles alter the chemical composition of semen, thus hampering successful fertilization. Though such malformations are best depicted on MRI/Uro-CT, TRUS can demonstrate the morphology of seminal vesicles as well and a size of less than 7 mm is taken as hypo-plastic [42] (Fig. 15).

Hydroceles are acquired or congenital serous fluid collection between the layers of the tunica vaginalis surrounding a testis or spermatic cord. On sonography, they are visualized as anechoic fluid collection surrounding the testis with occasional fine internal echoes. There is an increased prevalence of

Fig. 14 Grey-scale sonographic images showing multiple non-shadowing hyper-echoic foci representing diffuse microlithiasis

Fig. 15 Hypo-plastic seminal vesicle with an AP diameter < 5 mm

hydroceles in infertile men compared with their fertile counterparts, though its effects on fertility are not well established [43].

Fig. 16 A comparison of Doppler flow patterns in intra-testicular vessels in patients with obstructive (a) and non-obstructive etiologies (b). The last group shows increased resistance and consequently a raised resistive index

Role of Doppler imaging

Analysis of the spectral pattern of testicular and intra-testicular arteries can also help differentiate obstructive from non-obstructive infertility, with the latter showing increased resistance to blood flow (Fig. 16). An increased intra-testicular resistive index, as measured by color Doppler ultrasound, indicated abnormal testicular hemodynamics and thus suggests abnormal spermatogenesis or non-obstructive cause of infertility [44–46].

Conclusion

Thorough evaluation of infertile men is essential to identify potentially treatable causes of infertility and to guide therapy. With the use of sonography, advances in knowledge and timely detection of changes associated with various causes of infertility, categorization into obstructive/non-obstructive etiologies based on imaging appearances is now possible. Comprehensive evaluation with scrotal sonography, TRUS and Doppler can help us evaluate the nature and level of an obstruction. Thus, relevant corrective measures, such as vaso-epididymostomy or imaging-guided therapeutic intervention, for patients with obstructive causes of infertility and assisted reproductive techniques for those with non-obstructive causes might be offered to resolve problems. Hence, comprehensive sonographic evaluation should be routinely included in the evaluation of infertile men for timely diagnosis and management.

Acknowledgements None.

Funding None.

Compliance with ethical standards

Conflict of interest We have no conflict of interest to declare.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

- Boivin J, Bunting L, Collins JA, Nygren KG (2007) International estimates of infertility prevalence and treatment seeking: potential need and demand for infertility medical care. *Hum Reprod* 22(6):1506–1512
- Organization, World Health (1987) Towards more objectivity in diagnosis and management of male infertility. *Int J Androl* 7:1–53
- American Urological Association (2011) Best practice statement: The optimal evaluation of the infertile male. 2010
- Cooper TG, Noonan E, Von Eckardstein S, Auger J, Baker HW, Behre HM, Haugen TB, Kruger T, Wang C, Mbizvo MT, Vogel-song KM (2010) World Health Organization reference values for human semen characteristics. *Hum Reprod Update* 16(3):231–245
- Foresta C, Garolla A, Bettella A, Ferlin A, Rossato M, Candiani F (1998) Doppler ultrasound of the testis in azoospermic subjects as a parameter of testicular function. *Hum Reprod (Oxford, England)* 13(11):3090–3093
- World Health Organization (2010) WHO laboratory manual for the examination and processing of human semen, 5th edn. World Health Organization, Geneva
- Ammar T, Sidhu PS, Wilkins CJ (2012) Male infertility: the role of imaging in diagnosis and management. *Br J Radiol* 85(special_issue_1):59–68
- Belenky A, Avrech OM, Bachar GN, Zuckerman Z, Rafael ZB, Fisch B, Cohen M (2001) Ultrasound-guided testicular sperm aspiration in azoospermic patients: a new sperm retrieval method for intracytoplasmic sperm injection. *J Clin Ultrasound* 29(6):339–343
- Pierik FH, Dohle GR, van Muiswinkel JM, Vreeburg JT, Weber RF (1999) Is routine scrotal ultrasound advantageous in infertile men? *J Urol* 162(5):1618–1620
- Kim W, Rosen MA, Langer JE, Banner MP, Siegelman ES, Ramchandani P (2007) US–MR imaging correlation in pathologic conditions of the scrotum. *Radiographics* 27(5):1239–1253
- Kuligowska E, Fenlon HM (1998) Transrectal US in male infertility: spectrum of findings and role in patient care. *Radiology* 207(1):173–181
- Roberts M, Jarvi K (2009) Steps in the investigation and management of low semen volume in the infertile man. *Can Urol Assoc J* 3(6):479
- Donkol RH (2010) Imaging in male-factor obstructive infertility. *World J Radiol* 2(5):172
- Raza SA, Jhaveri KS (2012) Imaging in male infertility. *Radiol Clin* 50(6):1183–1200
- Mittal PK, Little B, Harri PA, Miller FH, Alexander LF, Kalb B, Camacho JC, Master V, Hartman M, Moreno CC (2017) Role of imaging in the evaluation of male infertility. *RadioGraphics* 37(3):837–854
- d’Ancona CL, Netto NR, Stedile JAG, Billis A (1989) Vasography: experimental study. *Int Urol Nephrol* 21(1):73–79

17. Solivetti FM, Drusco A, Pizzi G, Elia F, de Mutiis C, Teoli M, Bacaro D (2008) Percutaneous vesiculodeferentography in the diagnosis of male infertility: a review of our results and the data reported in the literature. *J Ultrasound* 11(3):102–106
18. Practice Committee of the American Society for Reproductive Medicine (2006) Report on management of obstructive azoospermia. *Fertil Steril* 86(5):S259–S263
19. Heshmat S, Lo KC (2006) Evaluation and treatment of ejaculatory duct obstruction in infertile men. *Can J Urol* 13:18–21
20. Moon MH, Kim SH, Cho JY, Seo JT, Chun YK (2006) Scrotal US for evaluation of infertile men with azoospermia. *Radiology* 239(1):168–173
21. Souza CAB, Cunha-Filho JSL, Fagundes P, Freitas FM, Passos EP (2005) Sperm recovery prediction in azoospermic patients using Doppler ultrasonography. *Int Urol Nephrol* 37(3):535–540
22. Spitz A, Kim ED, Lipshultz LI (2000) Contemporary approach to the male infertility evaluation. *Obstetrics Gynecol Clin* 27(3):487–516
23. Brugh VM III, Lipshultz LI (2004) Male factor infertility: evaluation and management. *Med Clin North Am* 88(2):367–385
24. Gazvani R, Lewis-Jones DI (2004) Cystic fibrosis mutation screening before assisted reproduction. *Int J Androl* 27(1):1–4
25. Brugh VM III, Matschke HM, Lipshultz LI (2003) Male factor infertility. *Endocrinol Metab Clin North Am* 32(3):689–707
26. Kuligowska E, Fenlon HM (1998) Transrectal US in male infertility: spectrum of findings and role in patient care. *Radiology* 207(1):173–181
27. Hendry WF (1998) Disorders of ejaculation: congenital, acquired and functional. *Br J Urol* 82:331–341
28. Saboo SS, Brodsky GL, Di Salvo D (2012) Sonographic-pathologic correlation of epididymal changes in a suspected case of postvasectomy pain syndrome. *J Ultrasound Med* 31(6):973–974
29. Jarow JP, Espeland MA, Lipshultz LI (1989) Evaluation of the azoospermic patient. *J Urol* 142(1):62–65
30. Kim ED, Lipshultz LI, Howards SS (2002) Male infertility. In: Gillenwater JY, Grayhack JT, Howards SS, Mitchell ME (eds) *Adult and pediatric urology*, vol 2, 4th edn. Lippincott Williams & Wilkins, Philadelphia, pp 1683–1758
31. Ahlberg NE, Bartley O, Chidekel N, Fritjofsson Å (1966) Phlebography in varicocele scroti. *Acta Radiol Diagn* 4(5):517–528
32. Weidner W, Pilatz A, Altinkilic B (2010) Varicocele: an update. *Andrology* 49:163–1655
33. Kocakoc E, Serhatlioglu S, Kiriş A, Bozgeyik Z, Ozdemir H, Bodakci MN (2003) Color Doppler sonographic evaluation of inter-relations between diameter, reflux and flow volume of testicular veins in varicocele. *Eur J Radiol* 47(3):251–256
34. Zorba UO, Sanli OM, Tezer M, Erdemir F, Shavakhabov S, Kadioglu A (2009) Effect of infertility duration on postvaricocelectomy sperm counts and pregnancy rates. *Urology* 73(4):767–771
35. Romeo C, Santoro G (2009) Varicocele and infertility: why a prevention? *J Endocrinol Invest* 32(6):559–561
36. Pilatz A, Altinkilic B, Köhler E, Marconi M, Weidner W (2011) Color Doppler ultrasound imaging in varicoceles: is the venous diameter sufficient for predicting clinical and subclinical varicocele? *World J Urol* 29(5):645–650
37. Kurpisz M, Havryluk A, Nakonechnyj A, Chopyak V, Kamieniczna M (2010) Cryptorchidism and long-term consequences. *Reprod Biol* 10(1):19–35
38. Adesanya OA, Ademuyiwa AO, Evbuomwan O, Adeyomoye AAO, Bode CO (2014) Preoperative localization of undescended testes in children: comparison of clinical examination and ultrasonography. *J Pediatric Urol* 10(2):237–240
39. Bujan L, Mieusset R, Mansat A, Moatti JP, Mondinat C, Pontonnier F (1989) Testicular size in infertile men: relationship to semen characteristics and hormonal blood levels. *BJU Int* 64(6):632–637
40. Schuppe HC, Pilatz A, Hossain H, Meinhardt A, Bergmann M, Haidl G, Weidner W (2010) Orchitis und Infertilität Orchitis and male infertility. *Der Urol* 49(5):629–635
41. Qublan HS, Al-Okoor K, Al-Ghoweri AS, Abu-Qamar A (2007) Sonographic spectrum of scrotal abnormalities in infertile men. *J Clin Ultrasound* 35(8):437–441
42. Engin G, Kadioglu A, Orhan I, Akdöl S, Rozanes I (2000) Transrectal US and endorectal MR imaging in partial and complete obstruction of the seminal duct system: a comparative study. *Acta Radiol* 41(3):288–295
43. Dandapat MC, Padhi NC, Patra AP (1990) Effect of hydrocele on testis and spermatogenesis. *Br J Surg* 77(11):1293–1294
44. Pinggera GM, Mitterberger M, Bartsch G, Strasser H, Gradl J, Aigner F, Pallwein L, Frauscher F (2008) Assessment of the intratesticular resistive index by colour Doppler ultrasonography measurements as a predictor of spermatogenesis. *BJU Int* 101(6):722–726
45. Herwig R, Tosun K, Schuster A, Rehder P, Glodny B, Wildt L, Illmensee K, Pinggera GM (2007) Tissue perfusion-controlled guided biopsies are essential for the outcome of testicular sperm extraction. *Fertil Steril* 87(5):1071–1076
46. Biagiotti G, Cavallini G, Modenini F, Vitali G, Gianaroli L (2002) Spermatogenesis and spectral echo-colour Doppler traces from the main testicular artery. *BJU Int* 90(9):903–908