Use of Ultrasound in Urology

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1 Introduction

Ultrasonography is a relatively inexpensive and fundamentally important urological assessment modality that can be used from antenatal care to adulthood. It is referred to as urologist's stethoscope as it provides valuable information that traditional physical examination cannot offer. Advantages of ultrasound include but are not limited to an avoidance of ionizing radiation, portability allowing use at the bed side, intensive care units, operative rooms and real-time functional evaluation of various organs.

2 Brief History of Ultrasound in Urology

In 1952 Wild and Reid attempted sonography of the prostate transrectally (TRUS); however, they did not succeed [1]. In 1963 Japanese urologists Takahashi and Ouchi also attempted prostate ultrasound, but image quality was not interpretable [2]. In 1971 Goldberg and Pollack performed sonography of kidneys in 150 patients and they could differentiate solid, cystic and complex renal masses with 96% accuracy [3]. From here on, ultrasound has grown leaps and bounds to its present state with various novel uses.

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3 Basic Modes of Ultrasonography

3.1 Grey Scale B Mode Ultrasound

Grey scale is the primary mode of ultrasound used for the entire urinary tract. In spite of the development of multiple new ways and new modes of ultrasound, this remains the most important way to evaluate any organ in the body. Whether an ultrasound machine is considered being high end predominantly depends on its grey scale resolution. This uses pulse wave technology where ultrasound waves of broadband frequency are transmitted in pulses by a frequency transducer to the body and receives returning echoes from the body's tissues. These returning echoes produce real-time two-dimensional images in shades of grey. Each pixel's brightness is determined by the amplitude of the returning sound wave. Each frame is made up of multiple lines and each line is made up of multiple pixels. The set of data changes with time and it produces real-time image.

3.2 Doppler Sonography

Doppler sonography depends on the physical principle of frequency shift when an ultrasound beam strikes a moving object. When a sound wave of certain frequency strikes a moving object like blood, there is a change in frequency depending on the velocity of the moving object, the angle of isonation and the direction of the moving object. In colour Doppler, this change in frequency is measured and then colour coded and displayed on the screen. The colour code most commonly applied is blue indicating movement away from the transducer and red indicating movement towards the transducer. The greater the velocity of motion, the brighter the colour.

In power Doppler, the amplitude of frequency change is assigned to colour shade. It is less affected by backscatter wave and more sensitive for detecting blood flow. Hence the slowest velocity of a moving object can be detected by power

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Doppler. It is less angle dependent than colour Doppler. However, it does not measure the velocity neither indicates the direction. This is mainly used in diagnosing conditions which requires the presence of minimal flow like in renal artery thrombosis, testicular torsion renal vein thrombosis (Fig. 1).

Spectral Doppler includes two types: continuous wave and pulsed wave. These analyse a spectrum of frequency; therefore, it is able to record blood flow velocities over time and displays the blood flow measurements graphically in a continuous waveform (Fig. 2). There have been major advances in Doppler sonography since it was discovered in early 1980. There are various parameters for measurement of flow, mainly peak systolic velocity (PSV), end diastolic velocity (EDV), resistive index (RI) and pulse index (PI). These parameters help practitioners identify and quantify vascular stenosis and vascularity of masses. It is also used in diagnosing arterial insufficiency in erectile dysfunction.

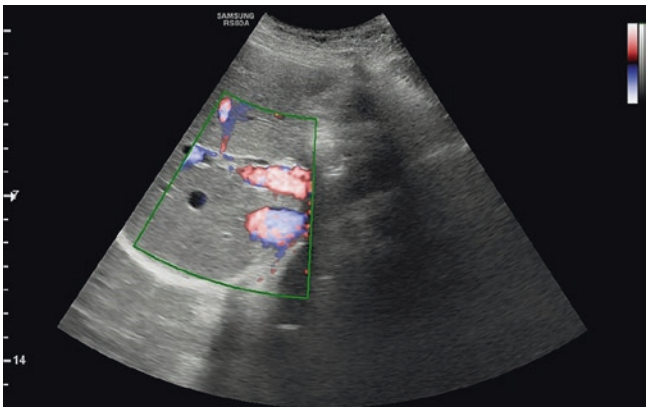

Fig. 1 Power Doppler of portal vein

3.3 Harmonic Scanning

When sound waves reach tissue, there are nonlinear propagations which generate fewer harmonics which are of higher amplitude. Because these harmonics are not subject to scattering at the frequency associated with the incident wave, there is less noise, artefact and better resolution (Fig. 3).

3.4 Spatial Compounding

Spatial compounding is a scanning mode where the direction of isonation is electronically altered and a composite image is generated. This reduces noise and artefact and improves the quality of image (Fig. 4).

There are various other modes of ultrasound which have specific applications. They are three-dimensional (3D) ultrasound, contrast-enhanced ultrasound (CEUS), sonoelastography, endoluminal sonography, high intensity focused ultrasonography (HIFU). Some of these are described later in this chapter.

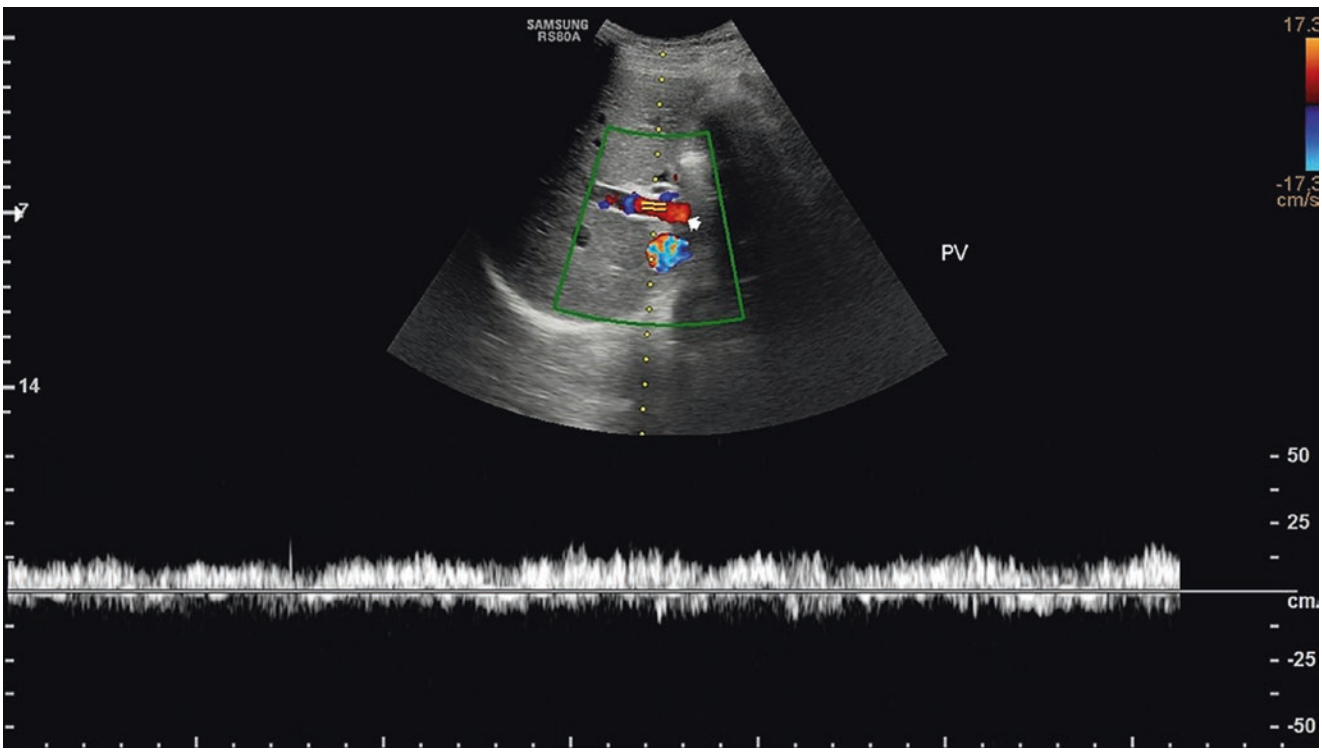

Fig. 2 Portal Vein Duplex Doppler showing flow within

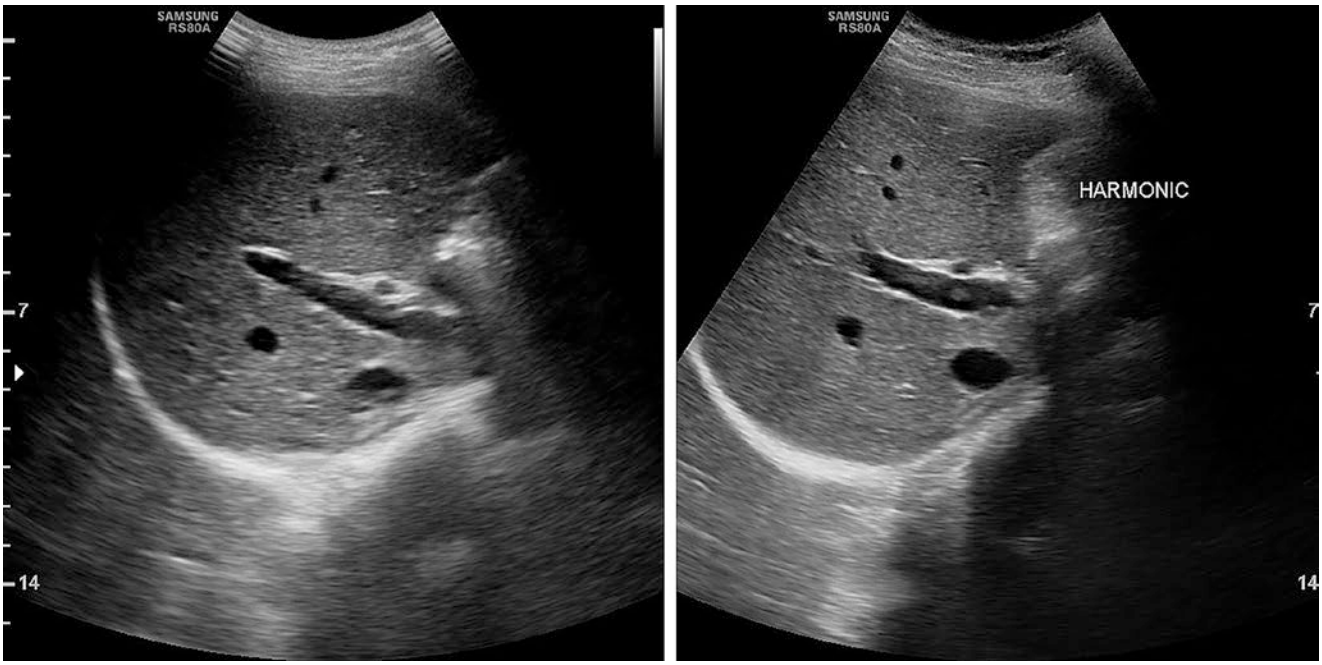

Fig. 3 Harmonic scanning of liver showing greater details as compared to normal grey scale B mode scanning

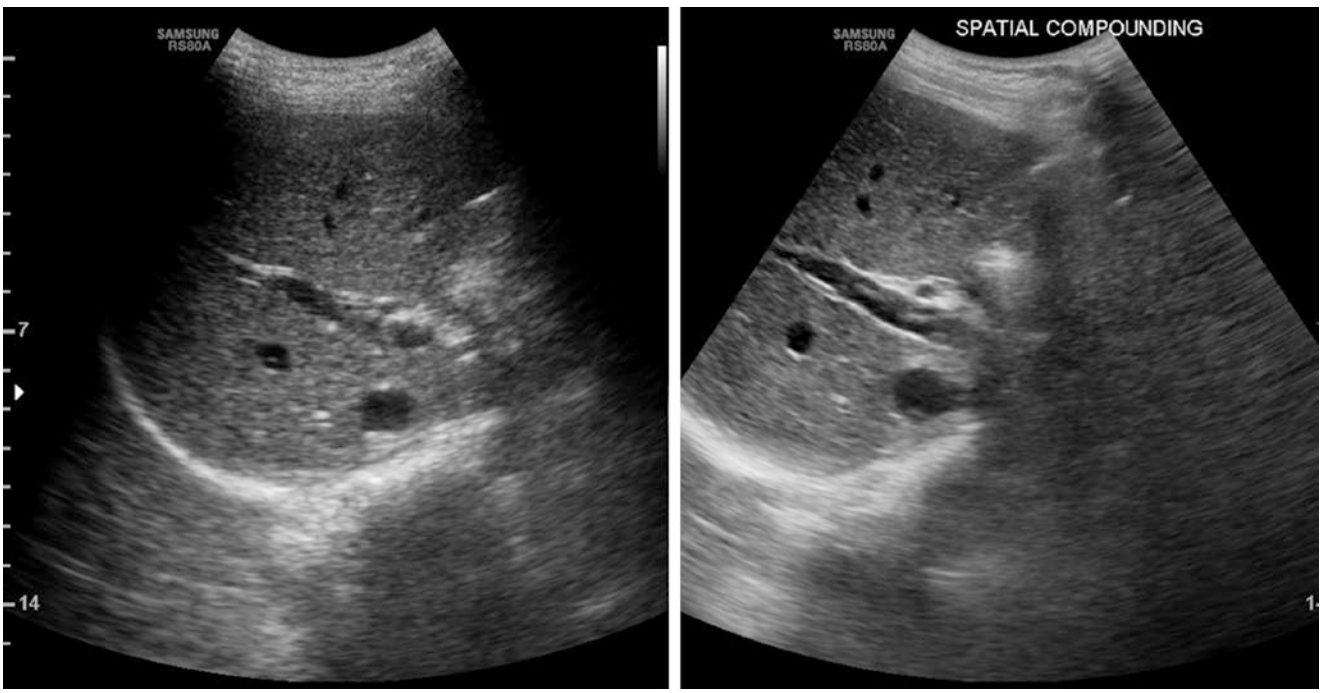

Fig. 4 Spatial compounding scanning mode showing better details

4 Documentation, Reporting and Image Management System

Appropriate image storage with standard nomenclature should be properly maintained. Since each image may contain patient information, such as name, gender, age, medical record number and examination results, proper management of stored images should be strictly monitored per institutional policy.

5 Patient Safety

Diagnostic ultrasonography transmits energy to the patient that has potential to produce biologic effects. Two main biologic effects are mechanical and thermal effects. These effects are measured by two indices namely mechanical index (MI) and thermal index (TI). These indices are safety limits and are usually mentioned at the top of the image display.

When sound waves enter tissue, they produce a phenomenon called cavitation. Tiny gas-filled bubbles are formed which upon breaking releases energy and causes damage and in turn causes cavitation. Tissue containing air has high risk of cavitation as compared to solid organs. Risk of cavitation is low in solid urologic organs if the MI is kept below 0.7.

Thermal index (TI) indicates the probability of tissue temperature increasing by 1 °C within the sonographic field. Increases in tissue temperature depend on many factors like scanning frequency, time period of scanning, beam focusing, scanning mode and tissue density. Tissue temperature of up to 6 °C is not likely to cause much harm at scanning times less than 60 seconds; however, the exact mechanism of tissue heating is not well understood.

6 Renal Sonography

6.1 Antenatal Ultrasound Findings

Both the kidneys are seen in the foetus with a well differentiated cortex and medulla. Foetal kidney size is dependent on gestational age. Both kidneys are seen in the renal fossa at the paravertebral location once they have ascended by 11 weeks of life. Urine production begins by 13 weeks of gestation. With ultrasound, kidneys can be visualized at 16–18 weeks of life. Foetal kidneys show foetal lobulation and are more hypoechoic due to the sparsity of sinus fat and the abundance of fluid in tubules (Fig. 5).

Renal arteries are seen arising from the foetal aorta on either side in coronal view. Unlike the adult, antenatal renal arteries have a high resistance to flow with an RI of 0.67–0.88 in the third trimester (Figs. 6 and 7).

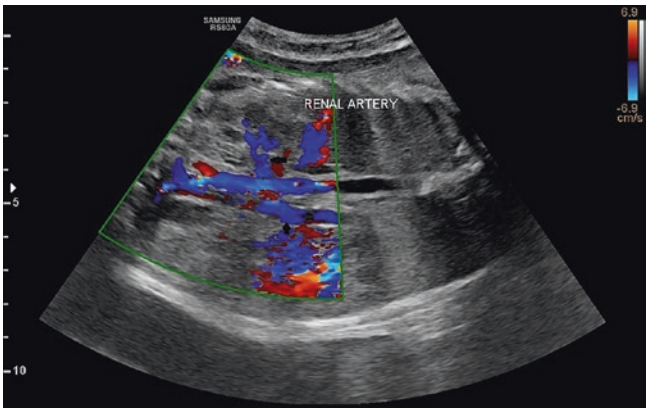

Fig. 6 Colour Doppler image of foetal kidneys, renal artery arising from aorta marked with black arrows

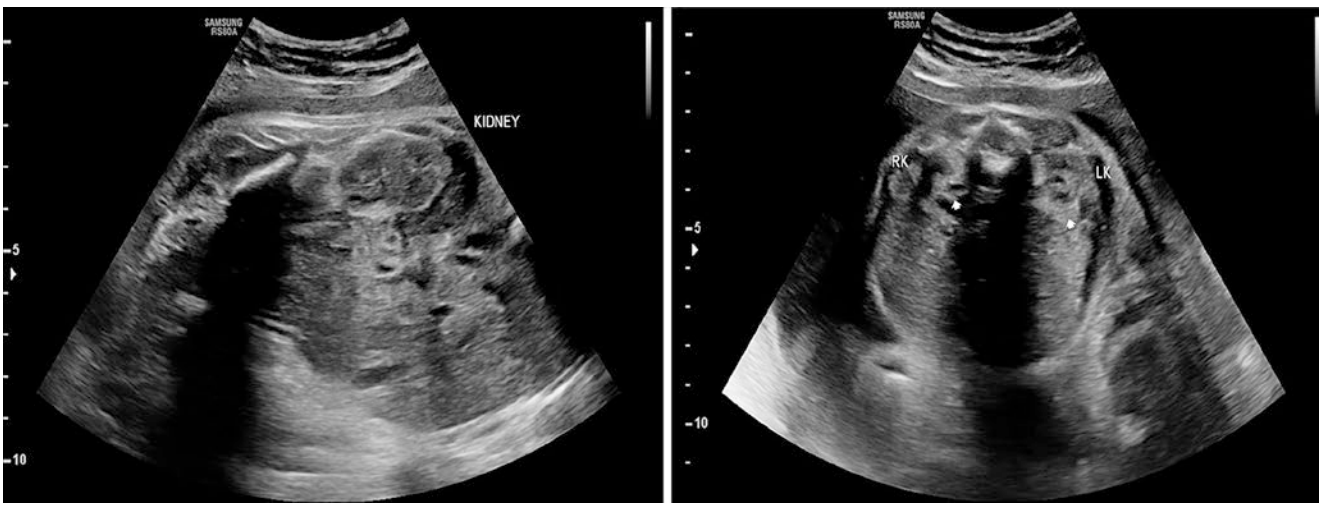

Fig. 5 Foetal kidneys in longitudinal and transverse scanning of foetal abdomen

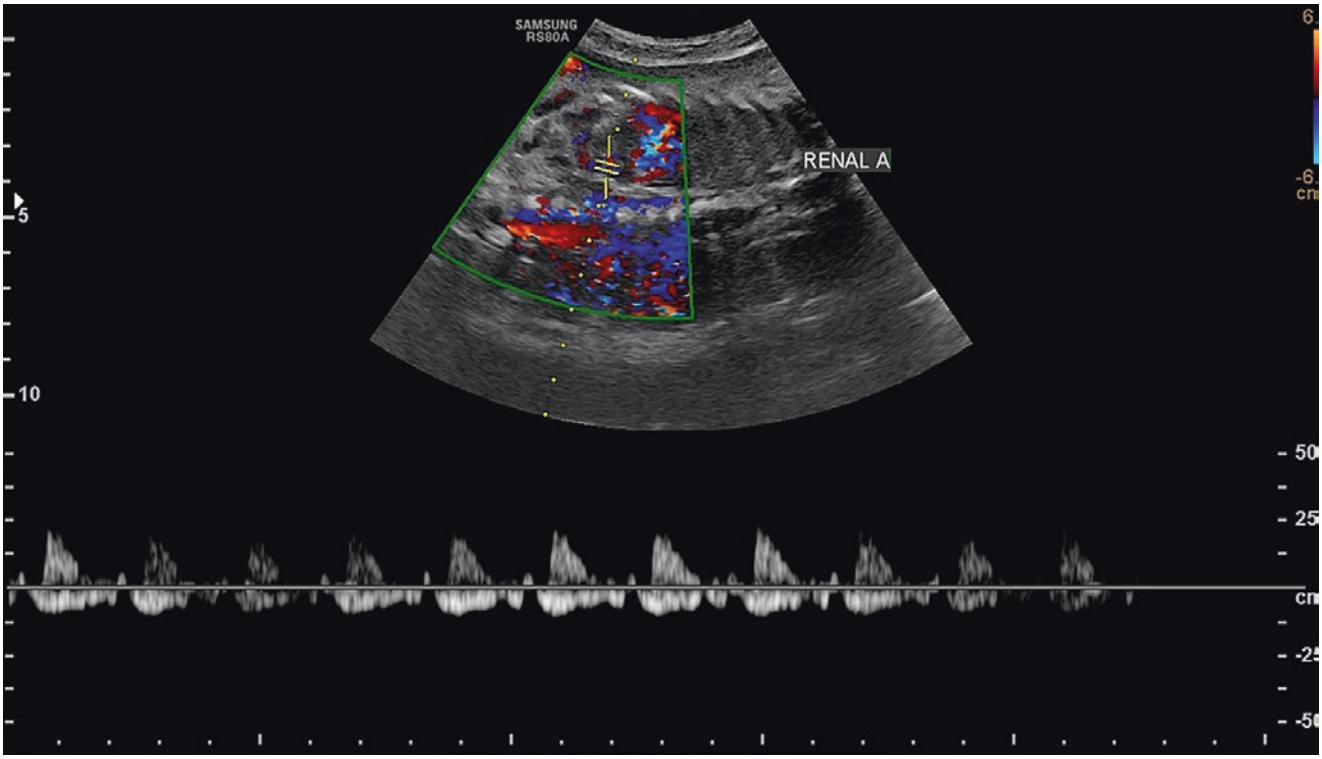

Fig. 7 Duplex Doppler of foetal renal artery showing high resistive index (RI)

Multiple congenital anomalies of the kidney can be detected on grey scale ultrasound, including the absence of a kidney, ectopic kidneys, crossed fused kidneys, ureteropelvic junction obstruction, ureteroceles and cystic diseases. Various associated anomalies, mainly VACTERAL anomalies, are also diagnosed on grey scale ultrasound. Foetal surgery such as a vesicoamniotic shunt is done under ultrasound guidance for posterior urethral valves.

6.2 Technique in Children and Adults

A curved array transducer frequency in the range of 1–7 MHz is frequently used in adult patients. For paediatric patients, a linear transducer frequency of 3–12 MHz is required. For intraoperative care, a 7–12 MHz high frequency transducer is commonly utilized.

Ultrasound of the right kidney is begun in the midclavicular line keeping the transducer longitudinal. The transducer is moved laterally until the entire kidney is visualized. After the longitudinal scan, the kidney is scanned transversely from the upper pole to the lower pole. The left kidney lies more cephalad than the right kidney and is better visualized with the patient positioned right side down and scanning from the anterior axillary line in longitudinal plane. Then the transducer is turned 90^0, and a transverse scan is done from left flank towards the anterior aspect.

6.3 Indications

1. Flank pain
2. Evaluation and monitoring of urolithiasis
3. Assessment of renal masses
4. Evaluation of perirenal structures
5. Evaluation of haematuria
6. Visualization of vesicoureteric reflux
7. postoperative evaluation
8. Ultrasound guidance to various intervention procedures like biopsies, cyst aspiration or as percutaneous access to collecting system
9. Evaluation of renal transplant
10. Renal trauma
11. Various congenital anomalies
12. Renal Doppler for renal artery stenosis

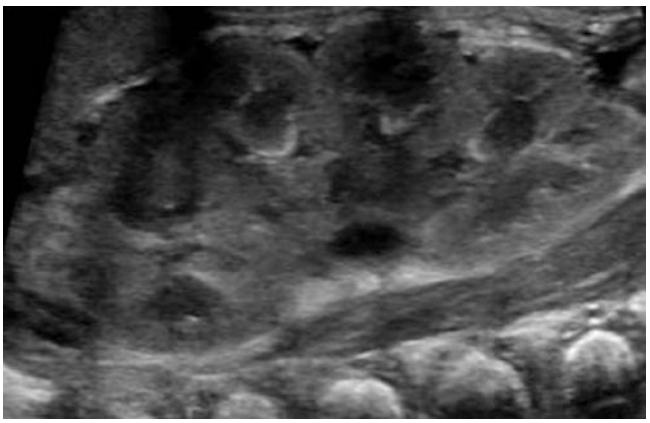

Fig. 8 Neonatal kidney showing prominent pyramids and scarcity of sinus echoes

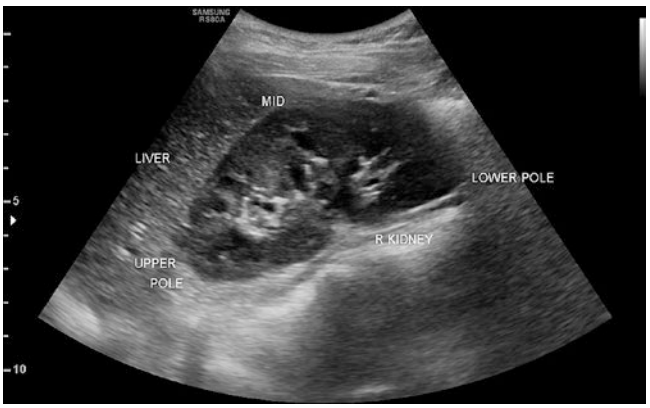

Fig. 9 Normal adult kidney

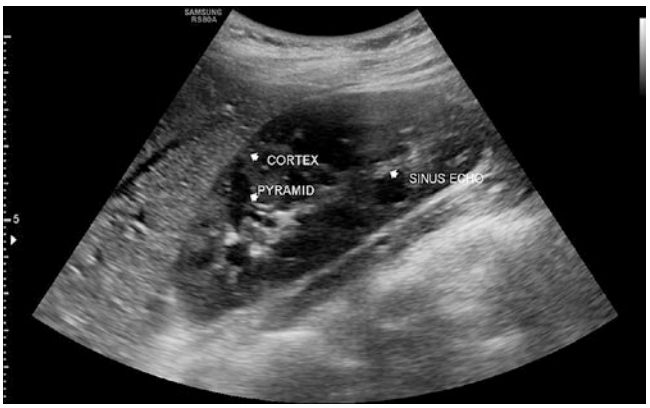

Fig. 10 Right kidney showing cortex, medulla and hyperechoic sinus echoes

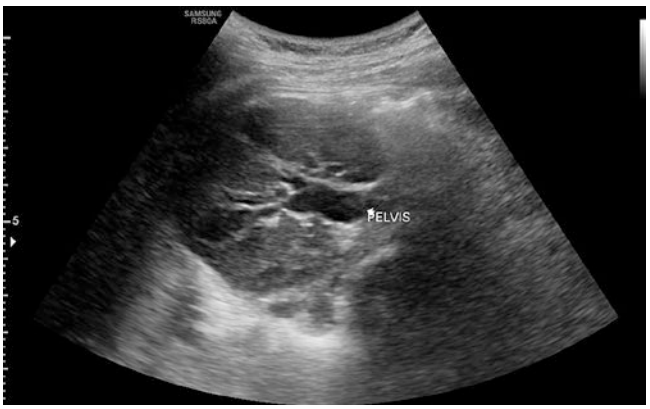

Fig. 11 Right kidney in transverse plane showing renal pelvis

6.4 Normal Ultrasound Findings

6.4.1 Neonate

Normal kidney size in the neonate is 3.5–4.5 cm in length and 2 cm in width. It gradually increases with age. The renal cortex is hyperechoic as compared with adult kidney due to the relative concentration and increased cellular volume of the glomeruli. Medullary pyramids appear more prominent as compared to the adult due to lower cortical size and its increased echogenicity. Also, there is sparsity of hyperechoic sinus echoes. As age increases, the hyperechogenicity of the sinus increases along with the size of the kidney. By 6 months of age, it assumes a normal adult pattern. The normal RI in a term neonate is <0.75 (Fig. 8).

6.4.2 Adult

The average adult kidney measures 10–12 cm in length and 4–5 cm in width. Measurements are done in the midsagittal plane where the maximum length is obtained. Each kidney shows a cortex which is hypoechoic as compared to the liver and further hypoechoic pyramids. Sinus echoes in the centre are hyperechoic. The thickness of parenchyma is the distance between the renal capsule and the central band of echoes. In the transverse plane, the renal hilum is seen with the renal vessels entering and exiting from it. The left renal hilum is visualized with the renal artery arising from aorta posterolaterally and the left renal vein anterior to it going across midline between the aorta and the superior mesenteric artery (SMA) to drain into the inferior vena cava (IVC). It is easier to visualize the right kidney as compared to the left kidney as bowel gas in the splenic flexure obscures the left kidney; however, the left renal origin is easier to visualize as the aorta lies on left side (Figs. 9, 10, 11, and 12).

6.4.3 Normal Doppler Waveform in Adult Renal Artery

Renal arteries on each side divide into segmental arteries. Segmental arteries are namely apical, upper, lower, middle and posterior. Each segmental artery divides into an interlobar artery which is present within the region of sinus echoes. These in turn divide into interlobular arteries present on either side of the pyramids. Interlobular arteries form arcades around the pyramids from which arise the arcuate arteries (Figs. 13 and 14). While evaluating for renal artery stenosis, the main renal artery at its origin, the trunk of the renal artery, the renal artery at the hilum and interlobar arteries at the upper mid and lower pole of the kidney are

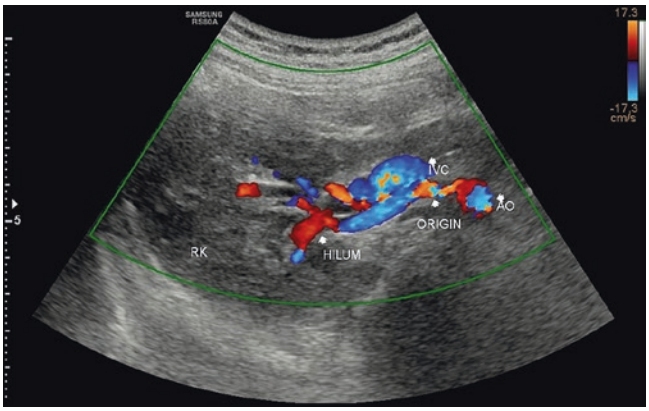

Fig. 12 Right renal artery arising from aorta entering into renal hilum

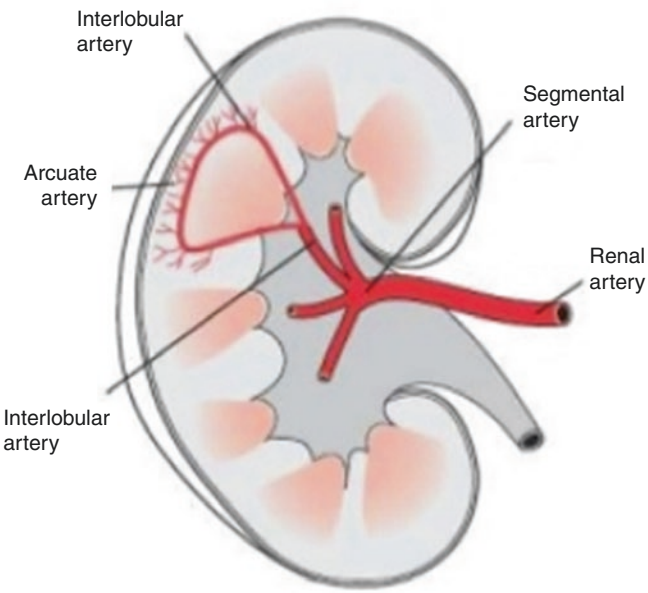

Fig. 13 Renal artery and its branches

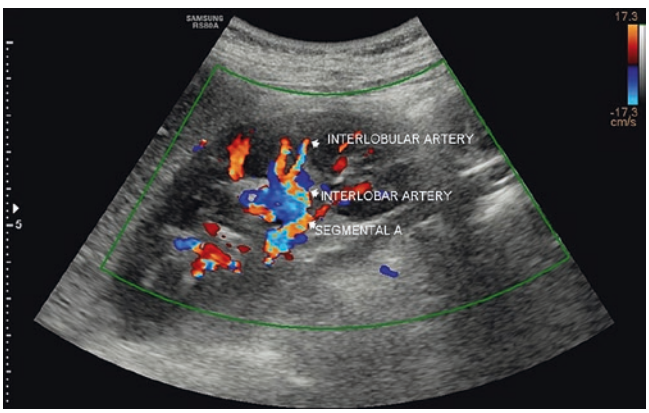

Fig. 14 Branches of intra-renal arteries

isonated. PSV, EDV and RI are measured at each artery. The normal renal artery has a sharp systolic upstroke, low resistance waveform and a continuous forward diastolic flow. The normal values of the renal artery at its origin are as follows: PSV <180 cm/s, renal aortic ratio of PSV (RAR) <3. At the level of the interlobar arteries RI <0.70, acceleration time (AT) <0.07 sec and acceleration index (AI) >3.5 m/s^2 (Fig. 15).

6.4.4 Renal Transplant

Grey scale, colour and spectral Doppler ultrasound are the prime modalities for renal transplant evaluation in the intra-operative period, immediate post-operative period and follow-up. Ultrasound is often performed with radionuclide imaging for medical and surgical evaluation [4].

6.4.5 Surgical Technique

Transplant kidneys, either cadaveric or from a living donor, are usually placed extraperitoneally in the right iliac fossa. It is placed in the left iliac fossa only if the right side is surgically contraindicated or a previous failed transplant is present.

In a cadaveric transplant, the main renal artery is harvested along with a cuff of cadaveric aorta and anastomosed usually end to end with recipient's internal iliac artery, or end to side with the external iliac artery. The renal vein of the donor is anastomosed end to side with recipient's external iliac vein. In a live donor, only the renal artery without an aortic cuff is anastomosed in the same way as in a cadaveric transplant. Urinary drainage is achieved with the donor ureter into the bladder dome. It can be also implanted into the native ureter or renal pelvis.

6.4.6 Normal Grey Scale Ultrasound Feathers of Transplant Kidney

Since the graft is placed extraperitoneal, it is superficial in location. With ultrasound, the transplanted kidney appears mildly hyperechoic due to its superficial location and can be scanned with standard curvilinear transducers and high frequency linear arrays. Normal collecting systems are mildly prominent in the immediate post-op period.

6.4.7 Doppler Features of Transplant Kidney

The origin or anastomotic site of the transplanted renal artery shows aliasing due to high velocity and mild narrowing at the anastomotic site. The normal parameters of a transplant renal artery are as follows: the PSV at the anastomotic site is <250 cm/s, the intrarenal RI is <0.5 and the AT is <0.07 sec (Figs. 16 and 17).

7 Ultrasound of Ureters

The ureters are paired muscular tubular structures that undergo peristaltic wave filling and emptying. In thin individuals, it is usually possible to visualize the ureters with a high frequency linear transducer (3–12 MHz) as the peristaltic wave fills and empties it. However, in obese individuals, a

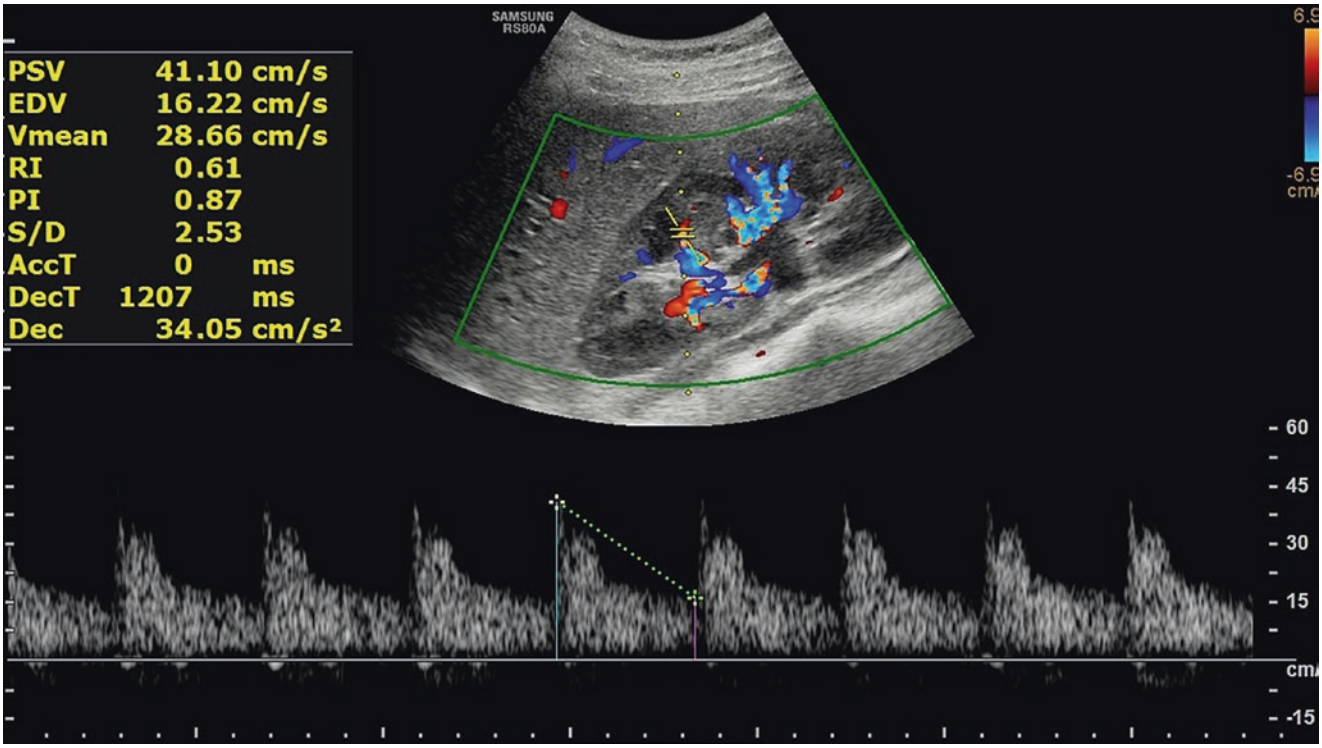

Fig. 15 Normal waveform pattern of renal artery

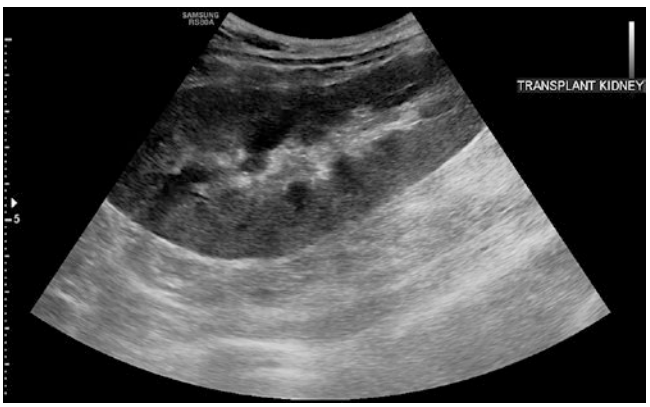

Fig. 16 Grey scale ultrasound of normal renal transplant kidney

curvilinear abdominal transducer is needed for visualization. In addition, dilated ureters are easier to be visualized with an abdominal transducer.

7.1 Technique

Gentle compression is applied at the ureteropelvic junction in a paramidline location close to the bladder. By using this method, it is possible to visualize the ureter by displacing bowel loops anteriorly. Usually it is possible to locate a ureteric calculus with grey scale ultrasound and can be correlated with radiographic imaging. The tinkling artefact of colour Doppler is useful for locating the site of a calculus. It is also possible to visualize the opening of the ureters within the bladder especially in those with vesicoureteral reflux.

8 Urinary Bladder

The urinary bladder is a muscular sac just above and behind the pubic bone. It is a triangular-shaped organ with a posterior base, anterior apex and an inferior neck with two inferolateral surfaces. It is lined by trabeculated transitional epithelium except at the trigone. It is an extraperitoneal structure located in the pelvis. Its main function is in the storage and release of urine.

8.1 Technique

Transabdominal pelvic sonography is done with a curved array transducer of 1–7 MHz frequency on a full bladder. In paediatric patients, a higher frequency transducer can be used. The patient is positioned supine and draped adequately. The scan is performed transversally from a cranial to caudal direction and then sagittal from right to left of the patient. Pre- and post-void bladder volumes are measured using the ellipse formula. Ureteric jets are observed on either side with

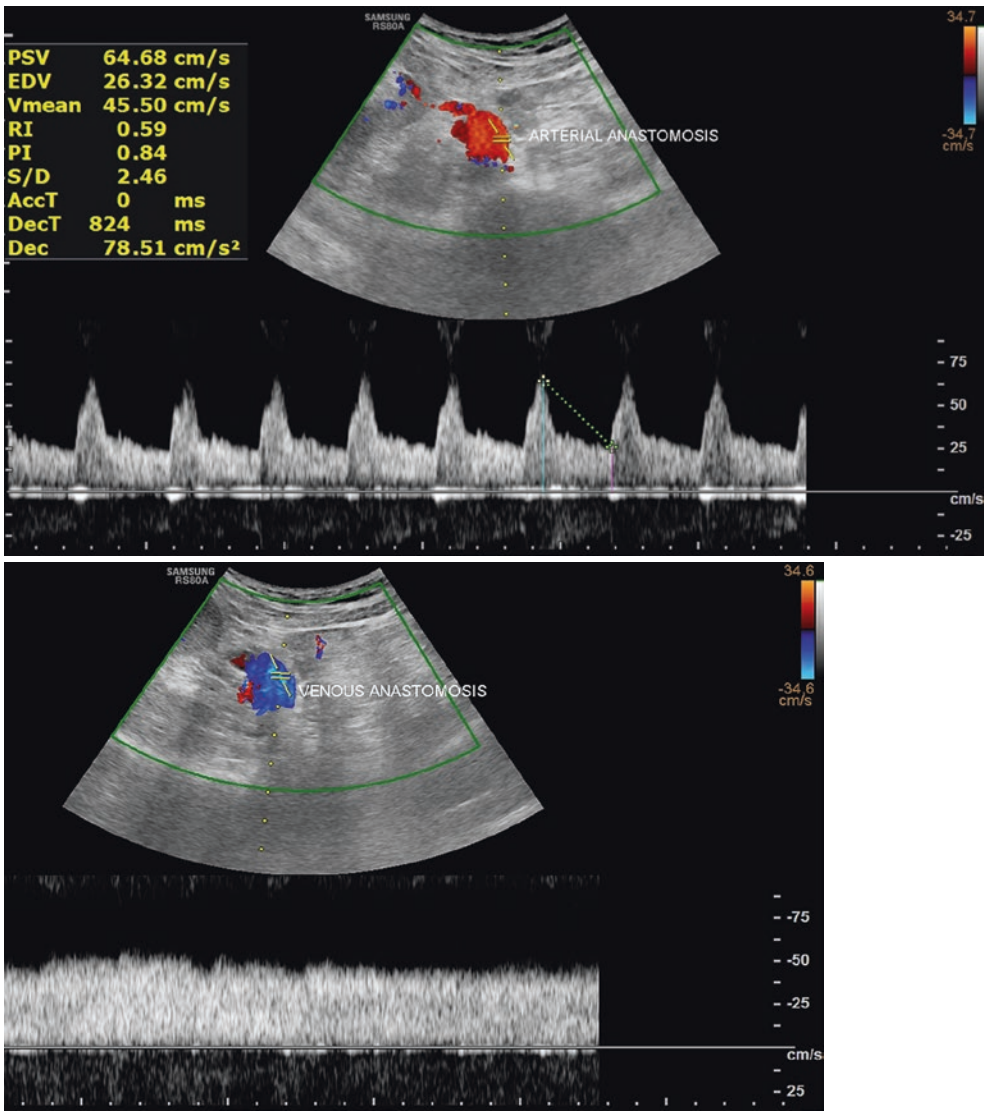

Fig. 17 Doppler features of transplant kidney

low PRF and low wall filter settings. In males the prostate is visualized, and its volume is measured. In females the uterus and ovaries can be seen. Vesicoureteral junctions are visualized at the trigone.

8.2 Indications

1. Measurement of pre and post void bladder volume
2. Assessment of prostate size and its morphology
3. Evaluation of haematuria
4. Evaluation of bladder outlet obstruction
5. Evaluation of bladder masses
6. Evaluation of lower ureters
7. Evaluation of lower urinary tract infection
8. For confirmation of catheter position and guide for removal of retained catheter

8.3 Normal Ultrasound Features

A full bladder volume can vary from 100 to 500 ml. Bladder volume is usually measured by the ellipse volume formula. The bladder wall thickness depends on bladder filling rather than on age. An empty bladder is 5 mm and a full bladder is 3 mm. A normal fluid filled bladder is anechoic with well-defined walls. As a rule of thumb, the bladder should empty at least approximately 10% of its pre-micturition volume. Ureteric jets can be visualized with the colour Doppler mode. The presence of a ureteric jet in a normal non-obstructed kidney means that the kidney is functioning adequately, and in the kidney with a calculus, it means the calculus is not fully obstructive. Transvaginal or transrectal scans can also be performed for the evaluation of the bladder. The posterior urethra is also evaluated in children with possible posterior urethral valves (Figs. 18 and 19).

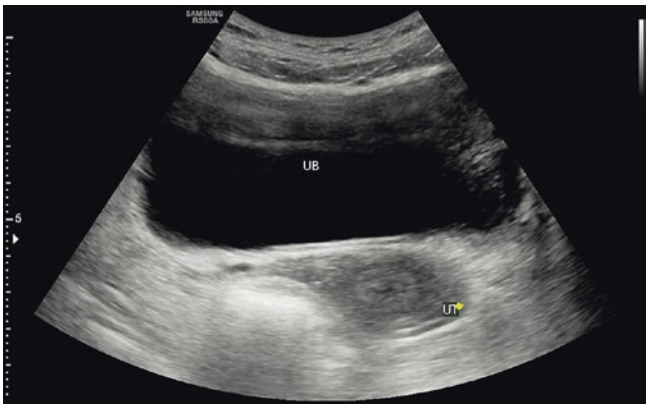

Fig. 18 Urinary bladder in transverse plane in a female patient showing uterus posterior to bladder

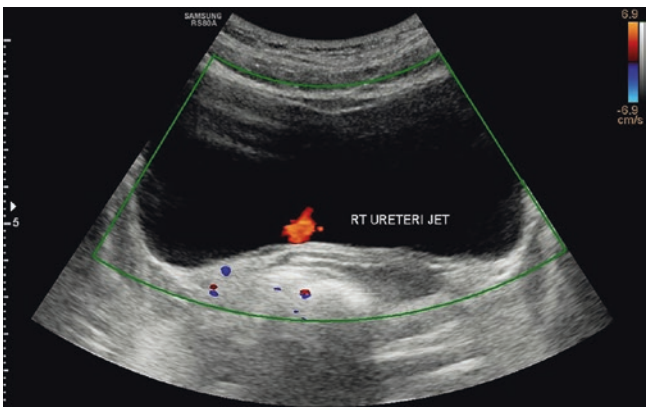

Fig. 19 Normal right ureteric jet

9 Ultrasonography of the Scrotum

The scrotum contains the testicles, epididymis and part of the spermatic cord. Because the scrotum and its contents are superficial in location, they are best evaluated by high frequency linear array transducers with frequencies in the range of 3–18 MHz. Grey scale ultrasound, colour and spectral Doppler are used to differentiate many acute and chronic pathologies involving the testicles and epididymis in addition to detailed anatomic evaluation.

9.1 Technique

The examination is carried out in a quiet and warm room which is comfortable to the patient. The patient is lying supine with the scrotum supported on a towel. Gentle contact is made after applying conducting gel. Both testicles are examined from the upper to lower pole in a transverse scanning pattern and then from medial to lateral in a sagittal scanning pattern. After scanning of the testes, the epididymis is seen in its entire extent starting with head, body and its tail. Examination is extended over the inguinal canal for the cord and its contents. After completing a grey scale examination, colour and spectral Doppler, examination is done and the vascularity of the testes and epididymis are evaluated.

9.2 Indications

1. Acute scrotal pain in children and adult
2. Evaluation of scrotal trauma
3. Assessment of scrotal swelling and masses
4. Evaluation of infertility
5. Postoperative scrotal evaluation

9.3 Normal Ultrasound of Tests

Both testes are oval structures in the scrotal sac with medium echogenicity, measuring approximately 4∗3∗2 cm in the adult. In the centre of each testicle, there is an echogenic linear septum which is called the mediastinum testes. Around the mediastinum testes, a hypoechoic area, rete testis, is seen, which drains into the epididymis through 10–15 efferent ductules. The peripheral echogenic line seen around the testicle is the tunica albuginea. The tunica vaginalis is a continuation of the peritoneum. A normal testicular appendix is a hypoechoic oval structure between the testicle and the head of the epididymis about 1–7 mm in size.

The vascular supply of the testes is from the testicular artery, a direct branch of the aorta. It enters into the inguinal canal as a supratesticular artery along with other cord structures. At the posterosuperior aspect of the testes, it divides into branches and pierces the tunica albuginea and forms the capsular artery around the testes. This in turn gives rise to centripetal branches which go up to the mediastinum testes. The supratesticular artery, the capsular artery and intratesticular centripetal arteries all show low impedance to flow with an RI in the range of 0.48–0.78.

9.4 Normal Ultrasound of Epididymis

The epididymis is a hypoechoic structure with nearly the same echogenicity as the testes situated posterolateral to it. It has a triangular-shaped head situated at the upper pole of the testicle, a linear body and tail at the lower pole of the testes. The appendix epididymis is a small oval structure attached to the head of the epididymis. Vascular supply is

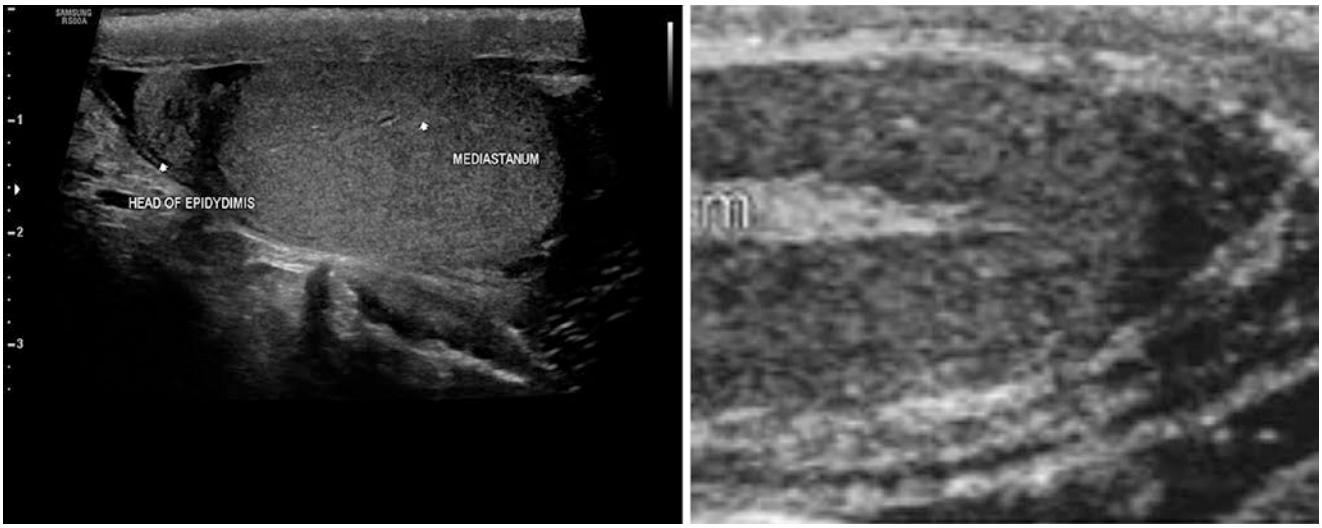

Fig. 20 Normal testicle with mediastinum of testis

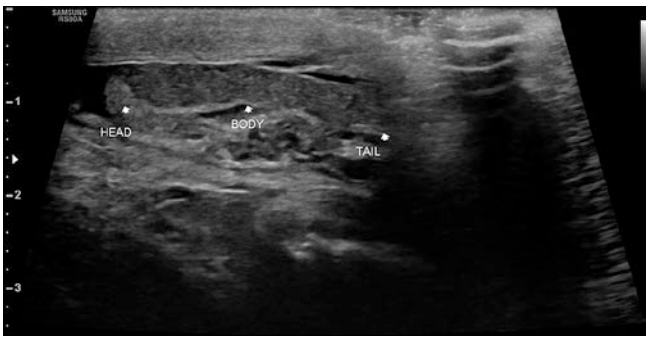

Fig. 21 Grey scale ultrasound of normal epididymis showing head, body and tail

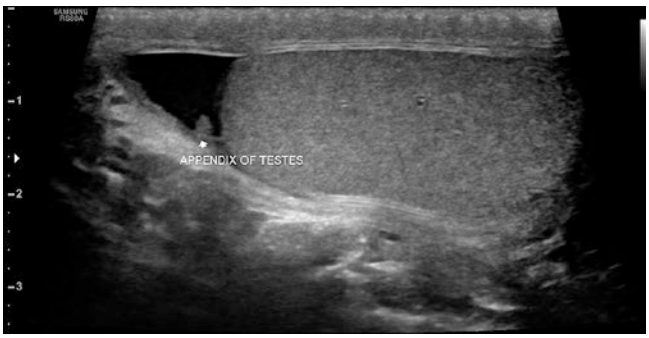

Fig. 22 Appendix of testicle

from the deferential artery, branches of the superior vesicle artery and from the testicular artery with a resistive index nearly identical to the testicular artery (Figs. 20, 21, 22, 23, 24, and 25).

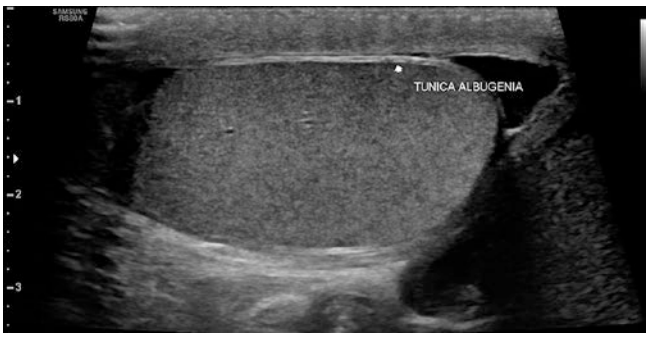

Fig. 23 Tunica albuginea around testicles

10 Ultrasonography of Prostate Seminal Vesicles and Vas Deference

The prostate is situated behind the urinary bladder and can be evaluated transabdominally and transrectally (TRUS). Along with prostate evaluation, the seminal vesicles and vas deferens evaluations are carried out which are situated behind prostate.

10.1 Technique

10.1.1 Transabdominal Scan

It is performed with a curvilinear transducer of 1–7 MHz frequency. The patient is asked to come with a full bladder or near full bladder. He is positioned supine and the transducer is kept transversely, longitudinally and angulated caudally till the prostate is visualized.

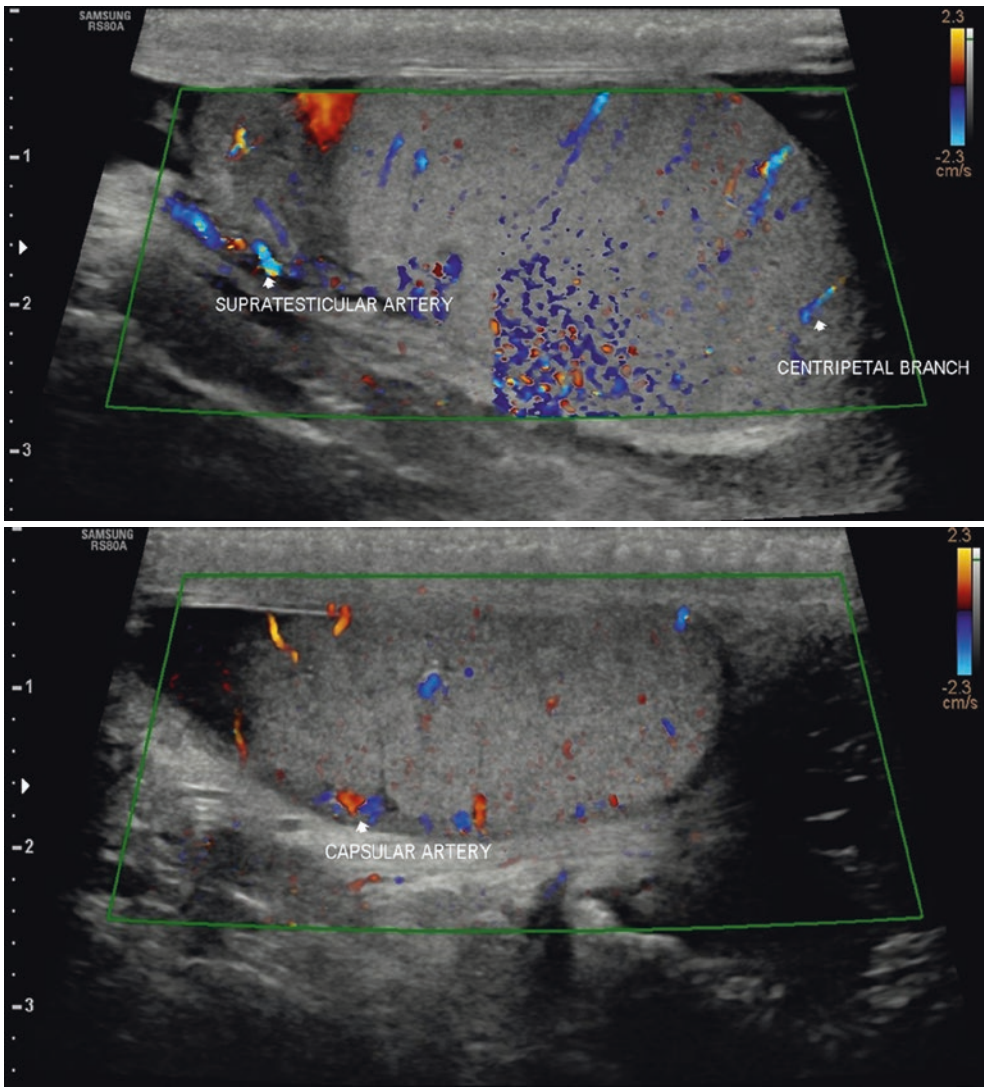

Fig. 24 Vascular supply of testicle showing supra testicular artery, capsular artery and centripetal arteries

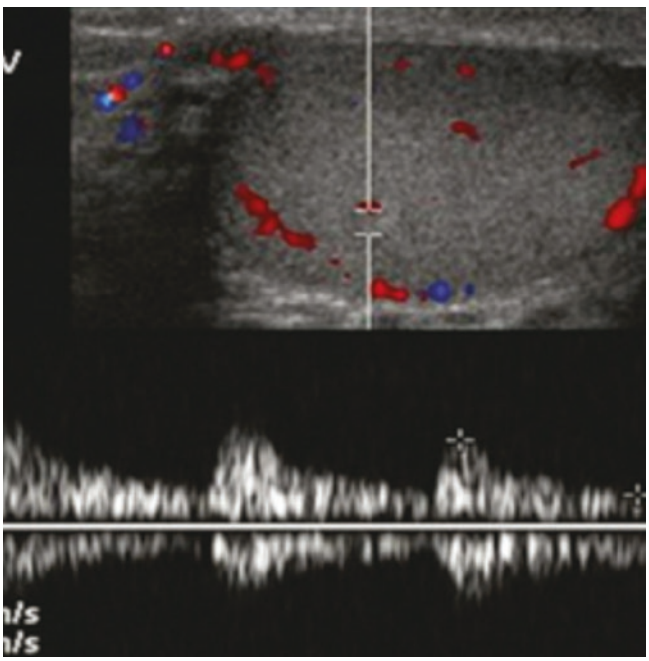

Fig. 25 Normal Doppler of the testicular arteries

10.1.2 Transrectal Ultrasound (TRUS)

TRUS is performed with an intracavitary end firing or side firing transducer of 4–9 MHz. It must have colour and spectral Doppler capability, with facility for 3D scanning if required. Before starting the examination, the patient is asked to go through a bowel preparation followed by a simple bowel enema. The patient is asked to empty their bladder before starting the examination. The patient is asked to lie in the lateral decubitus position with one knee extended and one knee flexed towards the chest. It is essential to perform digital rectal examination before inserting the ultrasound transducer. If the patient has local pain, or has a stricture, haemorrhoids, or a rectal mass that is picked up during digital exam, TRUS examination is relatively contraindicated. The transducer is covered with a plastic sheath with gel inside. Once covered with a plastic sheath, a generous amount of local anaesthetic gel is applied over the sheath before inserting the transducer in the anus. Introduce the transducer gently using mild pressure directed posteriorly. Once the anal sphincter resistance is overcome, the transducer is angulated anteriorly as the pros-

tate is situated anterior to the rectum. One should avoid applying too much pressure as it can be very uncomfortable and the peripheral zone of prostate (where most cancers are found) may get obscured. In transverse and sagittal planes, the prostate examination is carried out from right to left. Gradually the transducer is moved posteriorly for seminal vesicle and vas deferens evaluation. Again, the transducer is adjusted to visualize the periprostatic tissue as far laterally as possible. Once these organs are evaluated, the rectal wall is seen as much as possible for any focal mass or circumferential growth of the rectum. After carrying out grey scale examination, colour and spectral Doppler examination of the prostate is performed with adjusting the machine parameters to low scale and high colour gain.

10.2 Indications

1. Measurement of prostatic volume in benign enlargement of prostate
2. Focal lesion palpable on digital rectal examination
3. Symptoms of lower urinary tract infection including prostatitis, prostatic abscess
4. Abnormal transabdominal examination of prostate
5. Suspected congenital abnormality
6. Haematospermia
7. Male infertility evaluation
8. For carrying out various intervention procedures

10.3 Normal Ultrasound Features of Prostate, Seminal Vesicles and Vas Deference

10.3.1 Prostate Gland

Both lobes of the prostate gland are of similar echogenicity with a medium level of echogenicity. The gland is described based on zonal architecture. These divisions consist of the anterior fibromuscular stroma which is devoid of glandular tissue, a periurethral zone around the urethra, a predominantly anterior and cranially situated transition zone, a posterior and cranially situated central zone through which the ejaculatory duct passes and an anterior and posteriorly situated peripheral zone. The prominence of the urethra is due to the hypoechoic urethral muscles. The neurovascular bundle is situated bilaterally along the posterolateral aspect of the prostate in between the prostate and seminal vesicle. Normal adult prostatic volume is approximately 30 cc. About 70% of prostatic carcinoma is situated in the peripheral zone, 20% in the transition zone and 10% in the central zone. Benign prostatic hyperplasia (BPH) is a nodular hyperplasia of fibrous, muscular and glandular tissue within the periurethral zone and transition zone. In younger men, zonal anatomy is not well depicted with the peripheral zone appearing hyperechoic compared to central and transition zone. The peripheral zone is well differentiated from the transitional zone in the older male (Figs. 26, 27, 28, and 29).

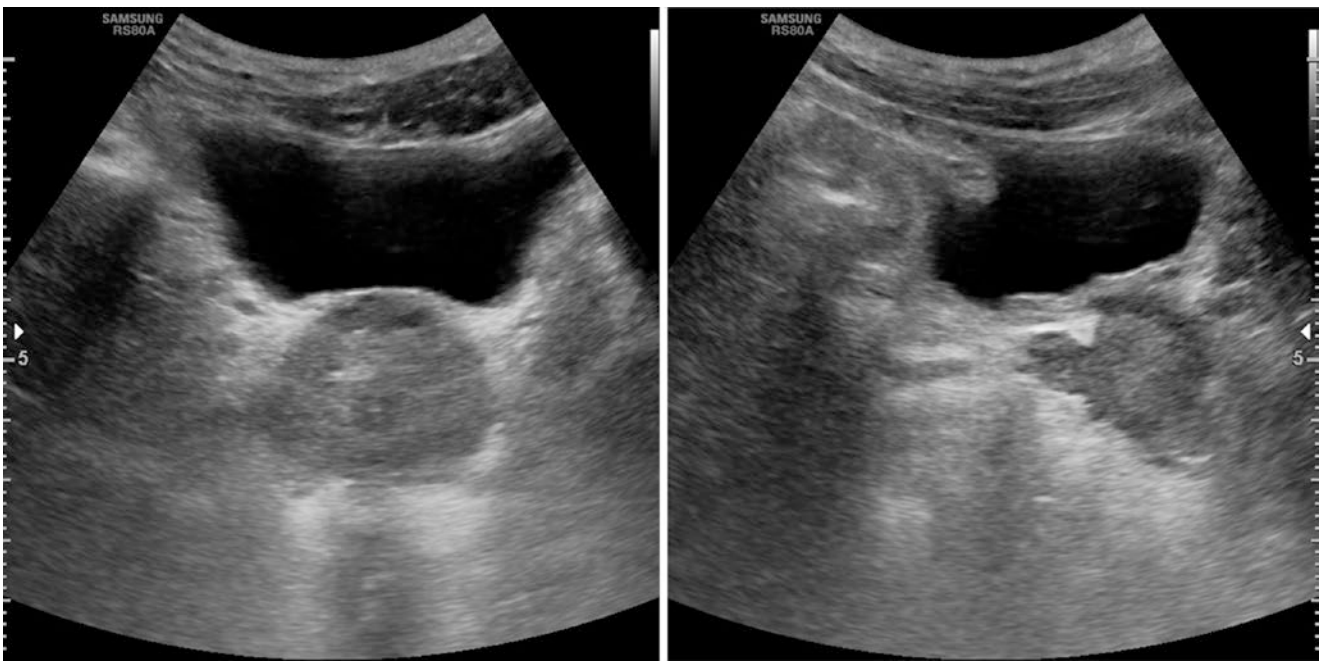

Fig. 26 Transabdominal scan of prostate gland, longitudinal and transverse scan

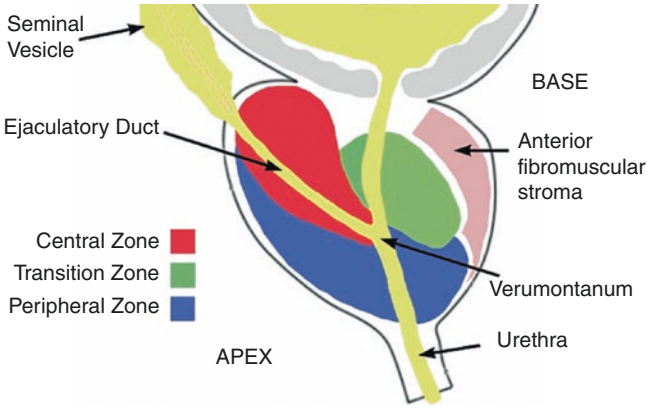

Fig. 27 Schematic diagram of zones of prostate gland

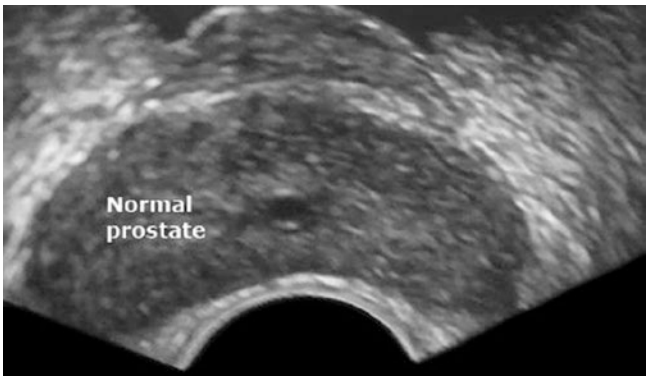

Fig. 28 TRUS showing prostate gland

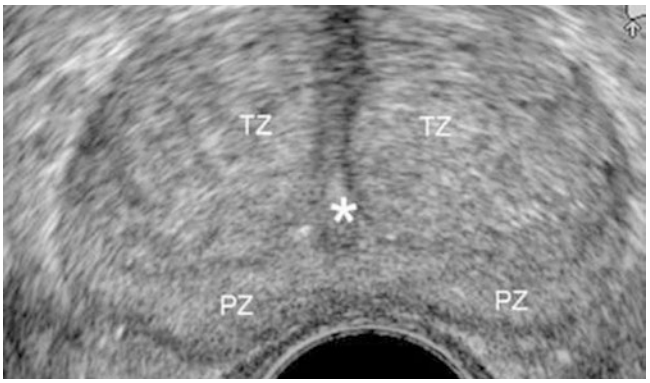

Fig. 29 TRUS of prostate gland showing zonal anatomy

10.3.2 Seminal Vesicle and Vas Deference

The seminal vesicles are situated posterior to the bladder and caudal to the distal ureters. It joins the distal ductus deferens to form the ejaculatory duct on either side to drain into the prostatic urethra at the verumontanum. They are elongated ovoid cystic septated structures measuring about 3–4 cm in length and 1.5–2 cm in width. It shrinks in size with very advanced age. Asymmetry is a common finding. The vas deferens continues from the tail of the epididymis, runs in the spermatic cord in the inguinal canal. Once it enters into the abdomen, it runs posteriorly into the lateral pelvis and inferiorly behind the bladder to the seminal vesicles and medial to the distal ureter to join the duct of SV to form the ejaculatory duct. The distal portion of the VD is mildly dilated and here it measures approximately 0.5 cm in width (Figs. 30 and 31). The ejaculatory duct is approximately 5–8 mm in size seen on oblique scan on TRUS as a joining of the SV and VD going to the verumontanum.

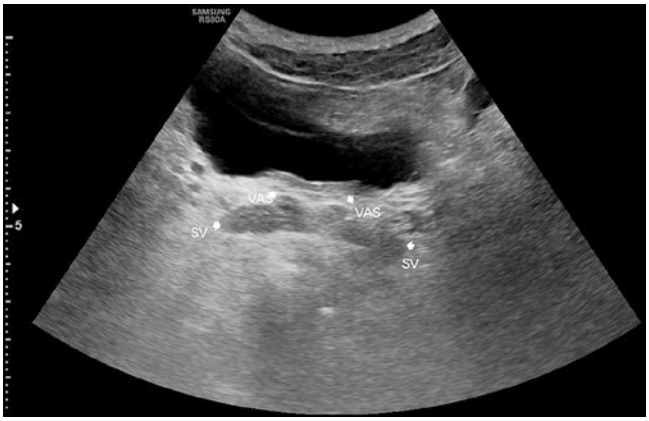

Fig. 30 Transabdominal scan showing seminal vesicle and vas deference in transverse scan

11 Ultrasound of Penis

Ultrasound with colour and spectral Doppler is an excellent way to evaluate the penis and erectile function. Since the penis is a superficial structure, it is best evaluated with a high frequency linear transducer.

11.1 Indications

1. Evaluation of erectile dysfunction
2. Penile trauma or pain
3. Penile curvature
4. Priapism
5. Evaluation of fibrosis of corpora cavernosa
6. Evaluation of urethral stricture

11.2 Technique

The examination is carried out in quiet room with dim light and the patient lying in supine position.

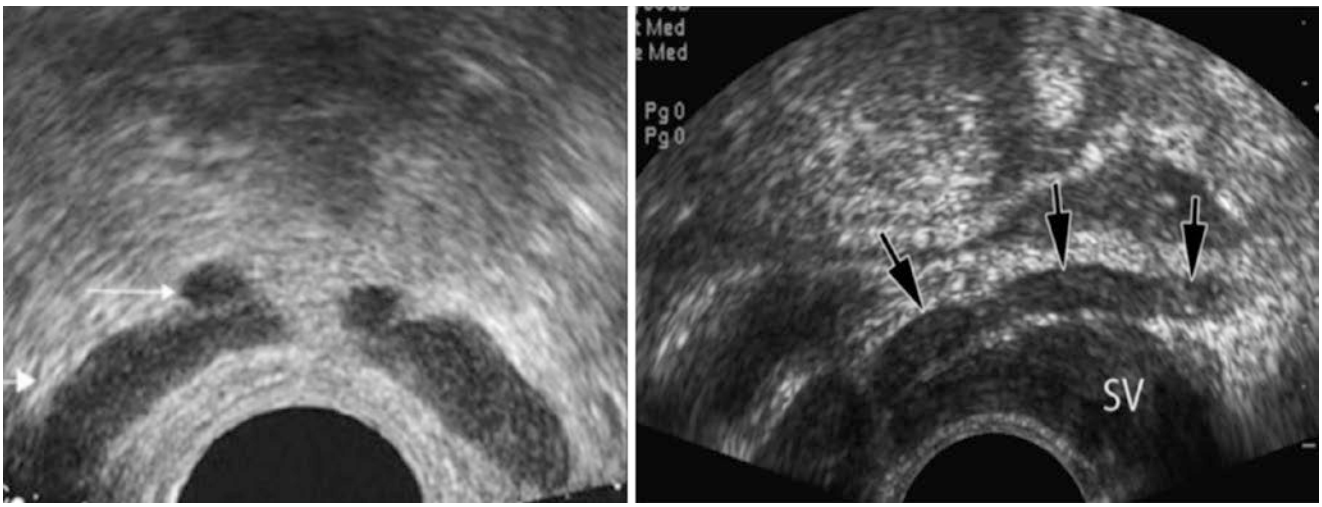

Fig. 31 TRUS showing seminal vesicle and vas deference in transverse and longitudinal scan

11.3 Grey Scale Ultrasound

The penis is placed in its anatomical position over the abdomen and evaluated in transverse and longitudinal directions with a high frequency transducer of 5–12 MHz. The transducer is moved from distal to proximal with the penis in a flaccid state.

11.4 Colour and Spectral Doppler Examination

For the evaluation of erectile dysfunction, a vasoactive drug is injected in the corpora cavernosa with a 26G needle in the corpora cavernosa unilaterally. Initially 1 ml of vasoactive drug is injected, and the dose can be repeated. Colour and spectral Doppler examination are carried out every 5 min for 20–25 min with each injection. Peak systolic velocity (PSV), end diastolic velocity (EDV) and resistive index (RI) are measured with each 5-min interval in both cavernosal arteries.

12 Ultrasound Anatomy of Penis

The corpora cavernosa are iso- to hypoechoic cylindrical structures covered by the tunica albuginea. It has a central cavernosal artery. The corpus spongiosum is a midline ventral cylindrical structure with a central urethra. It is more echogenic as compared to the corpora cavernosa, and it is also covered by tunica albuginea. Buck's Fascia covers the tunica albuginea circumferentially. The vascular supply to each cavernosa is through the cavenosal artery in its centre. The internal pudendal artery, a branch of the internal iliac artery, gives a branch to the bulb as the bulbourethral artery. After giving rise to this branch, it gives a branch to two dorsal arteries and two cavernosal arteries on the right as well as the left side. The bulbar and spongiosal veins along with the cavernosal vein drain into the internal pudendal vein. Also, venous drainage occurs through the superficial dorsal vein on either side and the deep dorsal vein in the centre (Figs. 32 and 33).

12.1 Normal Features on Colour and Spectral Doppler Evaluation

In the flaccid state, the normal cavernosal arteries show monophasic flow with a maximum PSV of 10–15 cm/s (Fig. 34). After injection of a vasoactive drug, the PSV as well as EDV increases. As the vein occlusion begins, PSV increases and diastolic flow EDV starts to decrease. At about 10–15 min after injection, PSV reaches a maximum of 40–60 cm/s and EDV becomes zero and then becomes reversed. This remains for another 5–10 min and then it returns to its initial flaccid state.

12.2 Sonourethrography

Urethral strictures or diverticulums can be evaluated by sonourethrography by injecting local anaesthetic gel into the urethra in a retrograde fashion. Gel distends the urethra as well as anaesthetizes its distal portion and delineates its pathology (Fig. 35).

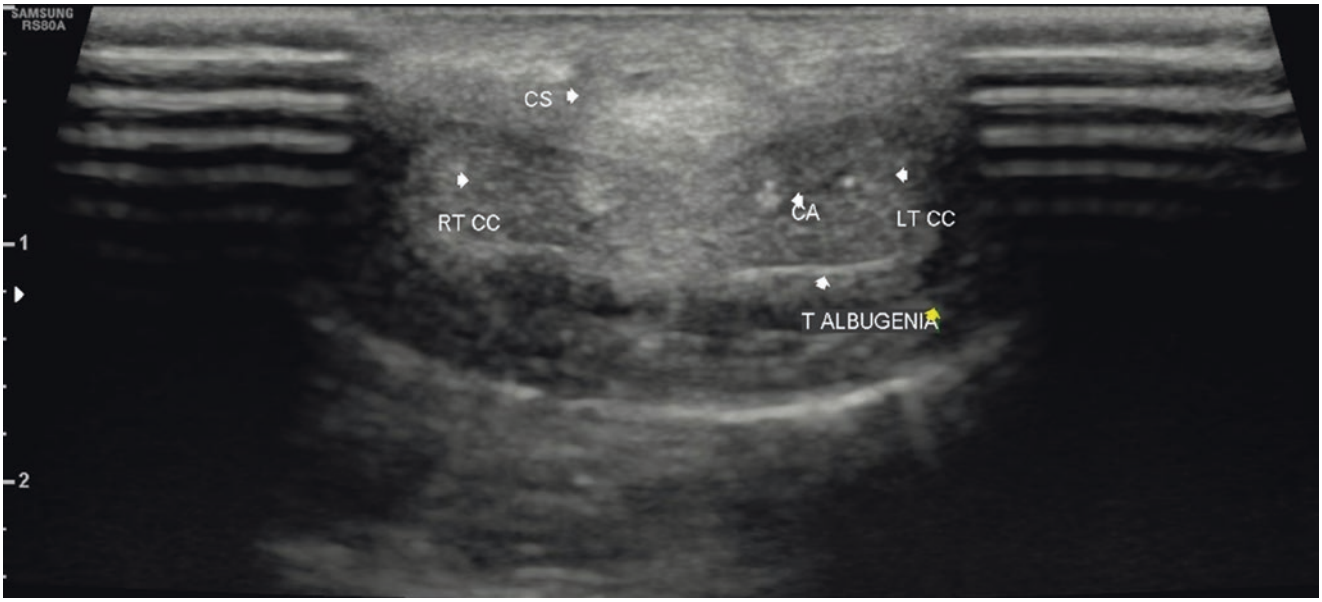

Fig. 32 Transverse scan of corpora cavernosa and spongiosa of penis

13 Ultrasound in Urological Intervention

13.1 Ultrasound Guided Per Cutaneous Renal Access

In older days, fluoroscopy was commonly used for any percutaneous renal access. Now with better ultrasound machines, ultrasound guided renal access is recommended.

13.1.1 Indications

- Obstructive nephropathy secondary to stone disease, malignancy, strictures requiring urgent decompression
- Renal access in PCNL procedure [5]
- Infected hydronephrosis or pyonephrosis
- Renal mass biopsy [6]
- Renal transplant biopsy when serum creatinine rises significantly or oliguria
- Renal cyst aspirations for cytology or sclerosis in symptomatic patients [7, 8]
- Renal or perirenal abscess or collection aspirations or drainage with pigtailing [9, 10]
- Pigtail drainage in psoas abscess

13.1.2 Prerequisites

- Prothrombin time or INR
- Serum evaluation for Hepatitis B, Hepatitis C or HIV virus
- Site confirmation
- Consent
- 10 ml 2% Lignocaine
- No. 11 Surgical blade
- Spinal needle 18 G/22 cm long for PCN or aspirations or 18G biopsy gun or coaxial gun for biopsy, pigtail catheter 10F for adult
- Sclerosant agent like tetracycline or absolute alcohol (95%)
- 0.035 Or 0.038 inch Straight tip or J tip guide wire
- Facial dilator no. 8, 9, 10
- Suture material

13.1.3 Procedures

All renal interventions can be done under local anaesthesia except PCNL surgery which requires general anaesthesia or spinal anaesthesia. Renal access can be achieved in supine, prone or lateral position. We at our institute prefer prone or lateral position for percutaneous renal access with scanning starting from a medial paraspinal area and gradually taken laterally. Transplant kidney biopsy is done in supine position. Once we decide the desired calyx, the entry site is marked with the needle hub. Local anaesthetic agent is injected. A small incision is made about 0.5 cm in length with an 11 blade. Haemostasis is achieved. An ultrasonography probe should be fixed at the site of entry point. For PCN an 18 G 15–22-cm-long needle is advanced under ultrasound guidance till it enters into the desired calyx. Entry into the desired calyx is confirmed with free flow of urine from the needle or aspiration of urine from the needle. After that a

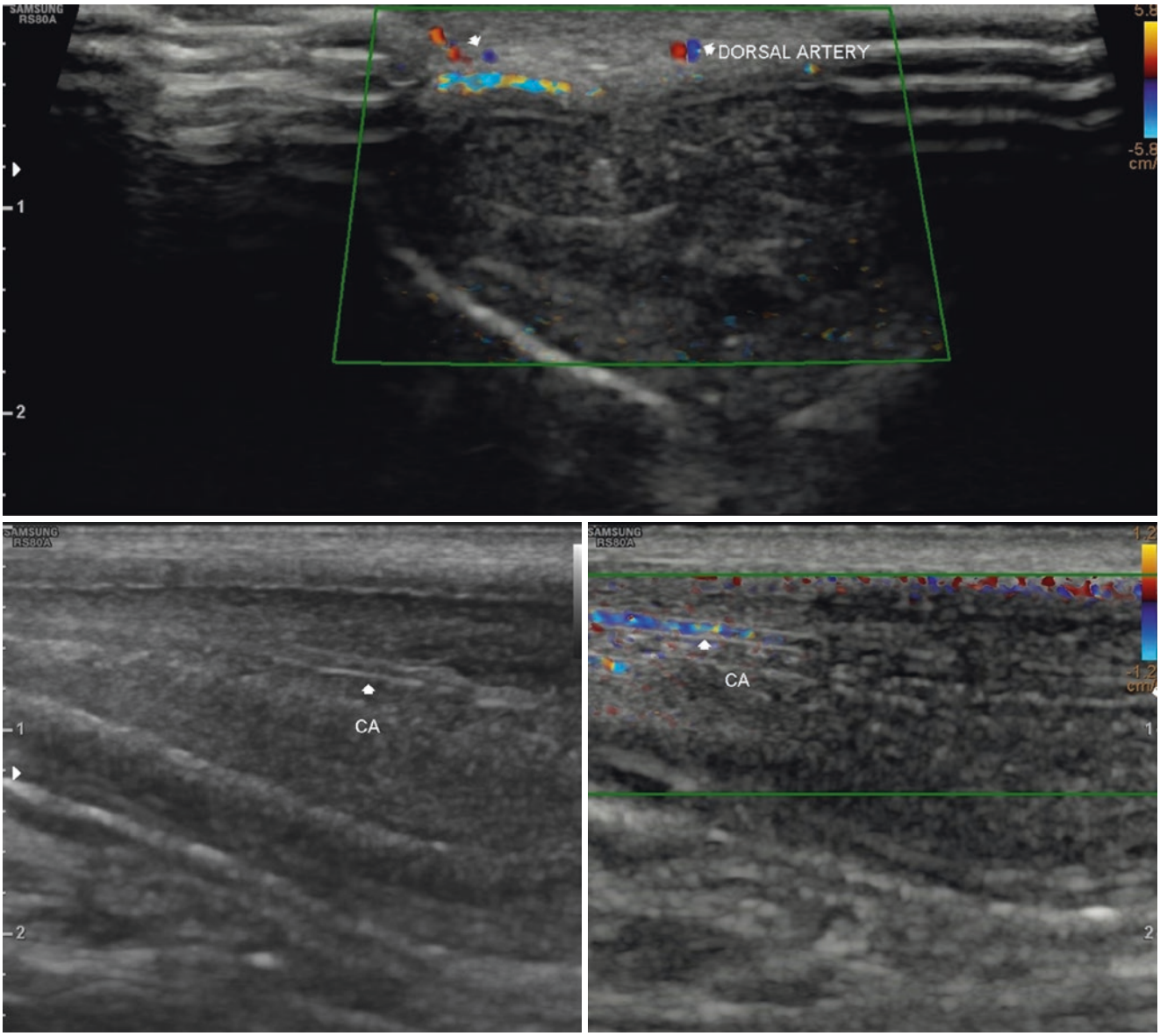

Fig. 33 Dorsal artery of penis and longitudinal scan of cavernosal artery

0.035-inch straight tip guide wire is introduced through needle into the pelvic collecting systems. Now we can serially dilate the tract under sonographic control. The ideal tract should be short, straight and avoid major vessels.

For biopsy, after making an incision either a core biopsy needle or coaxial biopsy gun is advanced into the target. Samples are taken and collected in a formalin jar [11–16].

For pigtail catheter placement, after dilating the tract sequentially with 8, 9 and 10 number dilators, a 10F pigtail catheter is introduced. Once inside the pelvicalyceal system, the catheter forms a curve and is left in place, it is sutured to skin and left to gravity.

For sclerosing a cyst, after aspirating cyst fluid, one fourth of the volume aspirated is irrigated in the form of a sclerosing agent. It is mixed thoroughly with residual fluid in the cyst and left in situ. Follow-up scan after 1 week and 4 weeks is done. If it has refilled, a second or third session may be required to achieve a desirable result [17–20].

13.1.4 Advantages of Ultrasound Over Fluoroscopic Guidance

- No radiation hazards.
- Real time monitoring of the needle
- With use of Doppler ultrasound, we can prevent injury to major vessels and prevent injury to the other organs.

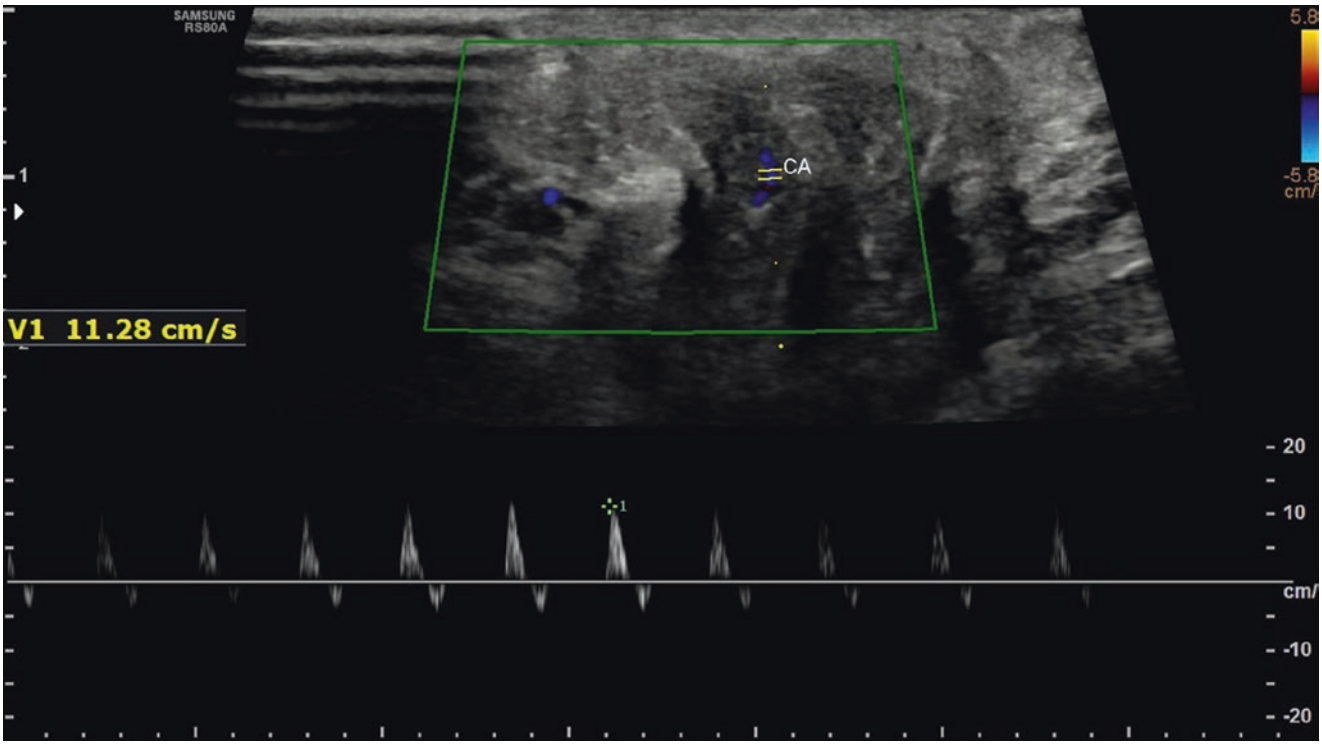

Fig. 34 Normal Doppler of corpora cavernosal artery in a flaccid state

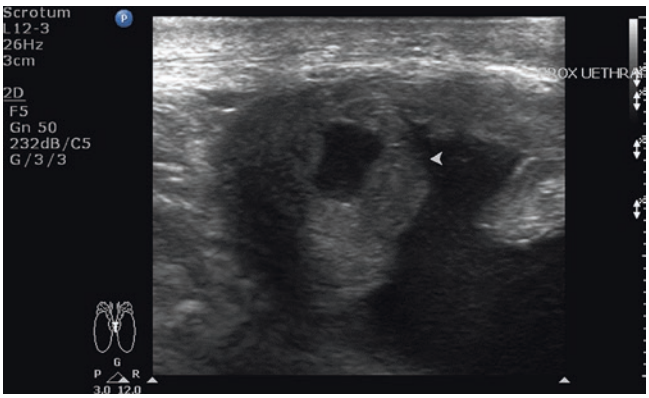

Fig. 35 Sonourethrography

14 TRUS Guided Prostate Biopsy

14.1 Indications

High PSA
Abnormal DRE

14.2 Contraindications

Coagulopathy
Acute prostatitis
Immunocompromised patients

14.3 Prerequisites

- Stop antiplatelet agents for 5–7 days before biopsy TRUS prostate biopsy can be safely performed in patients who are continuing aspirin without increasing the risk of significant bleeding.
- Use unfractionated heparin or low molecular weight heparin in patients with warfarin therapy. Ideally the INR must be less than 1.5.
- Antibiotic prophylaxis should be considered, and the choice of antibiotics depends upon local antibiotic policy. We routinely prescribe Ciprofloxacin 500 mg two doses. First dose around 2 hours before procedure and second dose 10 hours after procedure.
  All patients with prosthesis like joint prosthesis heart valves, pacemakers should receive antibiotics to prevent endocarditis or prosthesis infection as per standard guidelines
- Anaesthesia: Most urologists do TRUS biopsy under topical anaesthesia with 2% lignocaine jelly. We use topical anaesthesia with infiltration anaesthesia for biopsy. 22gauge 20cms Chiba needle is used for infiltration anaesthesia.

14.4 Procedure

Insert endorectal transducer with biopsy needle guide in rectum. After complete screening of the prostate for any pathol-

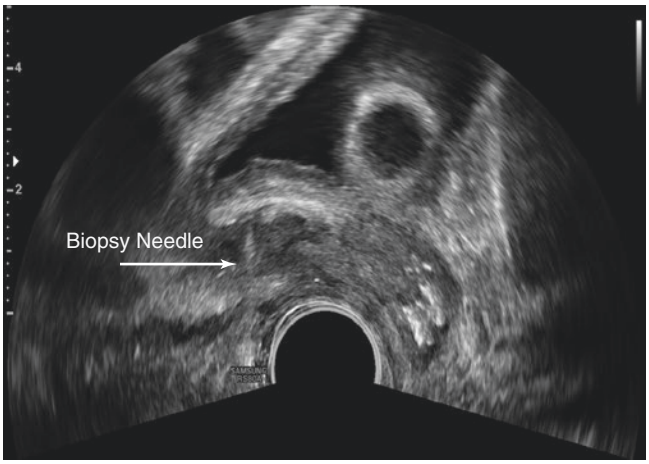

Fig. 36 TRUS biopsy with needle tip in right lobe

ogy, inject 5 ml lidocaine 2% on each side in the fat plane between the prostate base and SV.

For prostatic biopsy, various spring-driven biopsy guns are available. An 18 gz 22 cm biopsy gun is ideal for prostate biopsy.

The length of tissue sampled with these guns is 1.5 cm

Extended 12 core biopsy, six from each lobe, predominantly in the peripheral zone is targeted. If a focal lesion is seen, then a few more cores are obtained through that (Fig. 36) [21, 22].

14.5 Complications [23]

- Haematospermia – This is a common complication (35–40%). Most patients do not require any treatment, pre-procedure counselling and reassurance usually helps.
- Haematuria – This is the second most common complication (10–15%). Less than 1% patient require hospitalization for significant haematuria for which catheterization is required.
- Rectal bleeding
- Prostatitis, fever and epididymitis
- Urinary retention

15 Intra-operative Urologic Ultrasound

Use of intra-operative ultrasound is increasing over the last few years. It is routinely used in open surgeries and also in advanced laparoscopic and robotic surgeries.

15.1 Indications

- Tumour localization during partial nephrectomy
- Focal ablative therapy for SRMs
- Identification and confirmation of tumour thrombus in IVC during radical nephrectomy
- Renal transplantation and auto-transplantation to confirm normal flow in renal vasculature
- During testicular sparing surgery for testicular lesions
- To confirm viability of testes in torsion or testicular injuries
- For percutaneous access of pelvic calyceal system
- Failed urethral catheterization US guided suprapubic drainage of bladder

15.2 Transducers

Various transducers are available for intraoperative use. A curved or linear high frequency transducer is typically used.

Laparoscopic ultrasound transducers can be easily passed through 10–12 mm laparoscopic port. The diameter of the transducer is usually less than 10 mm and the length is usually 35–50 cm.

These are side firing transducers. LUS transducer screens the target organ by directly placing the probe with a frequency of 6–10 hz.

Most transducers can be sterilized by low temperature plasma sterilization. One should follow the instructions from manufacturers for sterilization of transducers for intraoperative use.

16 Sonoelastography

Sonoelastography is an ultrasound imaging technique where low-amplitude, low-frequency shear waves (less than 0.1 mm displacement and less than 1 kHz frequency) are propagated through internal organs, while real-time Doppler techniques are used to image the resulting vibration pattern. When a discrete hard inhomogeneity, such as a tumour, is present within a region of soft tissue, a decrease in the vibration amplitude will occur at its location. This forms the basis for tumour detection using sonoelastography. Sonoelastography is superior to colour Doppler imaging in identification of malignant areas in prostate, but at present it is not a replacement for standard random biopsies.

17 Endoluminal Ultrasonography

In this imaging technique, flexible catheters with high frequency transducers are inserted into a tubular structure such as the ureter, urethra, with the help of endoscopy. This high frequency transducer uses a frequency of 12.5–20 MHz. Endoscopy enables direct visualization of the lumen of the ureter, urethra and bladder, but it does not provide any information about submucosal tissues. With the help of high frequency endoluminal transducers, submucosal tissues can be imaged for various pathologies such as strictures and neoplasms, to name a few. It is also helpful in detection of crossing vessels and high insertion of the ureter [24, 25].

18 Contrast-Enhanced Ultrasound (CEUS)

Micrometre-sized, encapsulated, gas-filled microbubbles are used in contrast-enhanced ultrasonography (CEUS). These microbubbles help to enhance the ultrasonic signals. One of the characteristics of malignancy is neoangiogenesis. CEUS is helpful in imaging malignancies like kidney and prostate as intravascular microbubbles helps to identify altered perfusion pattern in areas of neoangiogenesis. At present its role in biopsy of prostate and kidney is under evaluation [26, 27] (Fig. 37).

CEUS in paediatric VUR

Ultrasound equipment with contrast-specific software is required

Before start of procedure, ask the patient to empty the bladder. Catheterize the patient with a 5–8 French catheter and empty the residual urine.

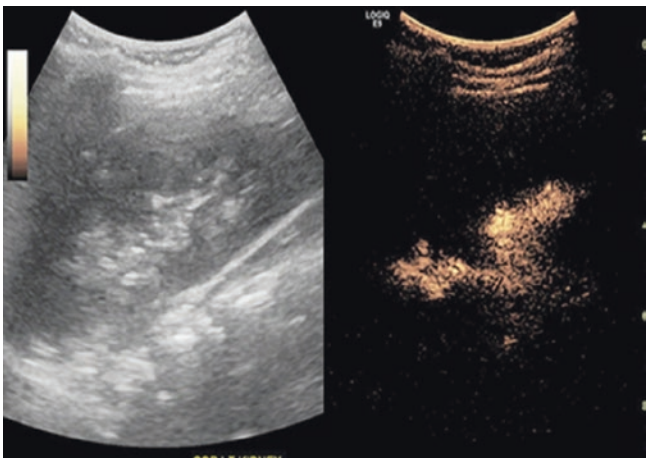

Fig. 37 CEUS showing grade 3 VUR

Fill the bladder with contrast in one of two methods

1. 1 ml of contrast is injected in 500 ml of saline. Connect the intravenous tubing to catheter and slowly fill the bladder till capacity.
   The bladder, ureter and kidneys are scanned while filling to identify passive reflux and during voiding to identify active reflux.
2. Fill the bladder with saline till capacity and then directly inject the contrast through catheter into the bladder.

Advantages No radiation

Disadvantage Difficult to identify grade 1 reflux

CEUS has also become a powerful additional tool for imaging renal lesions. With its lack of nephrotoxicity, the absence of ionizing radiation and the ability to evaluate the enhancement pattern of renal lesions quickly and in real-time, CEUS has unique advantages over traditional modes. Established applications are differentiation between solid tumours, pseudolesions and complex cysts; characterization of complex cysts with different malignant potential; and evaluation of tumour ablation [28].

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