**1.1 BACKGROUND**

Grey scale / B-mode ultrasonography (US) and color Doppler imaging are combined to create color Doppler ultrasound (CDUS). Because it may show anatomy and perfusion in real time, color Doppler ultrasound is an invaluable diagnostic tool for testicular disorders. It is helpful in assessing blood flow in testicular vessels in addition to detecting broad-spectrum grey scale changes (Weatherspoon, Polansky & Catanzano, 2017).

In 1.74% of individuals having an ultrasonography (US) examination, testicular masses are seen. The majority of individuals frequently suffer non-localizing pain or find a scrotal "lump." The scrotum is frequently brought to the patient's notice by mild trauma episodes, causing them to palpate a lump that was previously present but unnoticed. Testicular masses can occasionally manifest as a hydrocele or as severe pain. When people are being evaluated in the US for infertility or other unrelated issues, some testicular tumors are unintentionally found (Morse & Whitmore, 2015; Henriques et al., 2022).

High-quality grayscale images when it comes to the imaging assessment of testicular masses, US has long been the gold standard. Since most intratesticular masses are assumed to be malignant until proven otherwise, the primary function of ultrasound examination is to differentiate testicular from extratesticular abnormalities. Although they play a great role in tumor staging, computed tomography and magnetic resonance imaging provide little further information when imaging primary testicular tumors (Ulbright & Roth, 1999; Parenti et al., 2018).

Although testicular cancers are rare (rank 29), accounting for 1% to 2% of all cancers in men, they are the most prevalent cancer in men aged 15 to 35. The GLOBOCAN 2022 fact sheet for Bangladesh states that the 5-year prevalence of testicular cancer was 1.5 cases per 100,000. Primary germ cell tumors (GCT) account for around 90–95% of testicular cancers. Seminomatous and non-seminomatous kinds are the two main categories into which they fall. The remaining primary and secondary testicular malignancies are non-germ cell tumors, which include lymphoma, metastases, and sex cord stromal tumors (Leydig or Sertoli cell tumors) (Gorman et al., 2005, Siegel et al., 2011, Huang & Sidhu, 2012, Ferlay et al., 2024).

Although benign testicular tumors are uncommon, they must be identified in order to prevent unpleasant biopsy or, worse, orchiectomy. Cysts of the tunica albuginea, simple cysts, epidermoid cysts, tubular ectasia of the rete testis, and intratesticular spermatocele are among the nearly all benign intratesticular cystic lesions. Given that there won't be any internal blood flow, CDUS may be able to determine that these lesions are benign. Most sex cord stromal tumors (90%) are benign (Dogra, Gottlieb & Rubens, 2001).

Dermoid cysts, which include mature teratomas, focal orchitis, abscesses, hematomas, infarctions, and granulomas, are examples of focal intratesticular lesions that can resemble solid malignancy. One characteristic shared by all of these entities is the lack of internal vascular flow on color Doppler. To confirm involution and rule out cancer, these cases must be thoroughly monitored. Rare benign masses known as testicular adrenal rests have imaging characteristics that are comparable to those of testicular cancer, with the exception of bilaterality (Allan, Baxter & Weston, 2011; Hodler, Wibmer & Vargas, 2018).

In the US, testicular torsion typically manifests as enlarged heterogeneous testicles without color Doppler flow and painful scrotal enlargement. Uguz et al. (2015) found a 6.4% correlation between testicular torsion and testicular cancer in a retrospective research involving 32 individuals.

Varsamidis et al. discovered that follow-up CDUS is useful for distinguishing between testicular tumors and orchitis in patients experiencing acute scrotal pain. Eleven of the 18 individuals who underwent evaluation had testicular tumors, and seven had inflammation in their testicles (2001).

In 83% of cases, testicular tumors appear hypoechoic compared to normal testes. Tumors that are comparatively isoechoic to the testicular parenchyma can be identified with the aid of color Doppler. More than 95% of primary testicular tumors having a diameter greater than 1.5 cm have increased vascularity. Blood vessels are typically distributed in an unorganized manner with erratic, chaotic branching patterns inside the tumor (Horstman et al., 1992; Luker & Siegel, 1994; Dogra et al., 2004). Color Doppler vascularity detection may be useful in distinguishing between benign conditions (mainly avascular or peripheral vascularity) and malignant conditions (increase in central vascularity and changes in the pattern of vascularity) (Lung & Sidhu, 2011). The intratumoral blood vessels exhibited a nonbranching linear pattern in the majority of testicular lymphoma cases (Kachramanoglou et al., 2017).

With the same RI, the symptomatic (mass-containing) side may exhibit either an elevated PSV or a lowered RI. There have been reports of elevated PSV of >10 cm/sec (normal, 5-10 cm/sec) with RI ranging from 0.47 to 1.0 (mean, 0.70). The low-resistance tumor vascular beds are the cause of an asymmetric increase in EDV of >5 cm/sec (normal, 3-5 cm/sec) (Coursey et al., 2015; Singh et al., 2016).

However, intra-testicular architectural distortion is always present when a tumor is present, making it challenging to classify color Doppler features. Color Doppler is difficult to measure because of its qualitative nature. Furthermore, there is currently no standard morphological taxonomy system for testicular cancers, such as endometrial diseases (IETA), ovarian tumors (IOTA), and thyroid nodules (ACR-TIRADS, ATA) (Necas et al., 2021).

According to a retrospective study by Song et al. on 325 cases with testicular tumors, vascularity increases the likelihood of malignancy and is a key sign for differentiating between benign and malignant conditions. They came to the conclusion that CDUS can accurately assess vascular status for superficial organs like the testes (2019).

In detecting testicular neoplasia, one study found that US was 90% sensitive and 55% specific (Derouet et al., 1993). In contrast, another study found that CDUS had a sensitivity of 87.5% and a specificity of 66.7% (Gallardo et al., 1996). According to Rizvi et al. (2011), CDUS had an 87.5% sensitivity and a 66.7% specificity in diagnosing testicular cancers. CDUS demonstrated a sensitivity of 84.6%, a specificity of 76.2%, a positive predictive value of 19.6%, and a negative predictive value of 98.6% for the diagnosis of scrotal malignancies in a retrospective research in a large case series of 181 patients (Almassry et al., 2020).

In a another study, Fazal et al. found that CDUS has 88.8% sensitivity, 78.1% specificity, and 83.6% diagnostic accuracy when used to diagnose testicular cancer (2022). According to a recent observational study by M. Borhan Uddin et al. on the examination of scrotal pathology, CDUS had 80% specificity, 97.80% sensitivity, and 96.10% accuracy in identifying various intra-scrotal illnesses (Uddin MB et al., 2024). CDUS had sensitivity, specificity, PPV, NPV, and accuracy of 89.1%, 47.4%, 50%, 88.1%, and 62.9%, respectively, according to a ten-year retrospective assessment on 124 cases with localized testicular lesions (Huang et al., 2024).

Therefore, unless clear-cut imaging results point to a benign diagnosis, solid testicular tumors with internal vascular flow must raise a high level of suspicion for testicular cancer. In order to facilitate appropriate therapy and avoid needless surgical intervention, a precise non-invasive characterization of the testicular mass is essential (Schwarze et al., 2020). Although intratesticular masses provide a diagnostic difficulty, color Doppler and B-mode ultrasound may provide sufficient details to differentiate between benign and malignant masses.

**1.2 RATIONALE OF THE STUDY**

When a mass is discovered in the testis, it presents a therapeutic rather than a diagnostic difficulty. Such a mass may be the result of non-neoplastic lesions or benign or malignant neoplasms. The ability to differentiate between benign and malignant masses is a prerequisite for the management plan. The most important stage in managing testicular masses is diagnosis, which is heavily focused on imaging appearance because clinical diagnosis alone is insufficient to distinguish between benign and malignant masses.

A provisional diagnosis based on morphological criteria can be aided by the substantial additional diagnostic information provided by more recent inventions like CDUS, which have revolutionized the imaging sector. In addition, it is inexpensive, non-invasive, readily available, time-efficient, and free of ionizing radiation. Features shown by this technique can aid in early detection and improved characterization of testicular masses, even though no ultrasound appearance is completely diagnostic. Clinicians can use this pre-operative diagnosis of benign and malignant testicular masses to assist them decide on a sensible therapy strategy. The conventional therapy for all testicular solid masses, radical orchiectomy, may cause patients with benign masses to receive needless overtreatment. Early, suitable therapy with fewer invasive procedures would be feasible if CDUS could provide a definitive diagnosis.

There aren't many studies on this topic as of now. Since histological testing is the gold standard for evaluating testicular masses, the current study aims to ascertain the role of CDUS as a major investigational method.

**1.3 RESEARCH QUESTION**

What is the role of color Doppler ultrasound (CDUS) in evaluation of testicular masses?

**1.4 OBJECTIVES**

**General Objective:**

* To assess the role of color Doppler ultrasound (CDUS) in evaluation testicular masses comparing with histopathology.

**Specific Objectives:**

* To observe the findings of CDUS of different testicular masses eg. type (focal or diffuse), size, margin, echotexture, and vascularity (grades, pattern, PSV, EDV and RI).
* To evaluate testicular masses by CDUS findings.
* To record the histopathological diagnosis of testicular masses.
* To determine the accuracy, sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio and negative likelihood ratio of CDUS in evaluation of testicular masses, using histopathological findings as gold standard.

**2. LITERATURE REVIEW**

**2.1 PREVIUOS RELATED STUDIES**

The use of color Doppler ultrasonography (CDUS) in the assessment of testicular malignancies was investigated by Horstman et al. (1992). In order to ascertain the appearance at color Doppler ultrasound (CDUS) scanning, a study of 28 individuals with surgically confirmed testicular tumors was conducted. Vascularity and tumor size were generally correlated. Of the 21 tumors larger than 1.6 cm, 20 (95%) were hypervascular. Hypovascularity was present in six out of seven (86%) tumors that were less than 1.6 cm. One little seminoma, measuring 1.1 cm in diameter, was hypervascular, whereas another, measuring 2.8 cm, was hypovascular. Color Doppler US revealed that the tumor's histologic findings did not correlate with the lesion's vascularity, with resistive indexes ranging from 0.476 to 1.0 (mean, 0.70). The mean systolic velocity was 9.8 cm/sec, with a range of 8.4 cm/sec to 64.9 cm/sec. Venous flow was detected in eight tumors. The gray-scale findings, as well as history and physical examination data, properly supported a tumor in all patients. In 27 cases, the color Doppler US results were prospectively evaluated as suggestive of malignancy, and in one case, as suggestive of inflammation. The authors come to the conclusion that the use of color Doppler US scanning in the assessment of testicular cancers is somewhat limited.

According to Varsamidis et al. (2001), Doppler ultrasonography (US) could be   
helpful when assessing testicular neoplasms that cause sudden, intense scrotal pain. A   
total of 18 patients evaluated, 11 were found to have testicular tumors and 7 testicular   
inflammation. End-diastolic and peak systolic velocities dramatically rose in   
patients with testicular tumor (p<0.002) and orchitis (p<0.01) versus normal controls.   
A follow-up Doppler US examination is useful in patients with acute scrotal pain submitted to antibiotic treatment because it may help distinguish between orchitis and testicular tumor that was supported by the results of a follow-up examination after a one-week course of antibiotic treatment, which showed persistently high velocity values in tumor patients and normalization of velocity values in orchitis patients.

The value of color Doppler ultrasonography (CDUS) as a standard investigative technique for the identification of scrotal diseases was demonstrated by Rizvi et al. (2011). Over the course of 16 months, they conducted a cross-sectional study (case series) on 122 patients with scrotal swellings who ranged in age from 13 to 70. Hydrocele (26), varicocele (16), testicular cancer (16), orchitis (6), testicular torsion (4), spermatic cord damage (2), hematocele (2), pyocele (2), and epididymitis or epididymo-orchitis (46), were the final diagnosis. With 100% sensitivity and 100% specificity, color Doppler ultrasound correctly identified all cases of testicular torsion, varicocele, hydrocele, spermatic cord damage, and epididymitis or epididymo-orchitis. Only 14 of the 16 participants who had a CDUS diagnosis of testicular cancer later had malignancy. Overall, CDUS had a 98% sensitivity and a 66.7% specificity in identifying scrotal illnesses.

Using histological findings as the gold standard, Naz et al. (2018) performed a cross-sectional study on 413 patients between the ages of 20 and 50 to assess the diagnostic accuracy of color Doppler ultrasound in the diagnosis of testicular cancer. According to the study, color Doppler ultrasound revealed malignancy in 58.8% of the patients. In 48.4% of these individuals, testicular tumors were confirmed by histopathology. The results showed that the color doppler ultrasound had an overall diagnostic accuracy of 77.0%, a sensitivity of 87%, a specificity of 67.6%, a PPV of 71.6%, and an NPV of 84.7%. They came to the conclusion that color Doppler ultrasound had a higher diagnostic accuracy when it came to testicular tumors.

A retrospective analysis of 325 consecutive testicular mass patients who had either testicular conserving surgery (15/325) or radical orchiectomy (310/325) between January 2001 and June 2016 was conducted by Song et al. (2019). Tumor diameter, history of cryptorchidism, ultrasound findings, serum alpha-fetoprotein, and human chorionic gonadotropin (HCG) levels were among the clinicopathological characteristics that were gathered retrospectively for statistical analysis. Additionally, a predictive nomogram was created in order to assess the quantitative probability. Out of all the patients, 78 (24.0%) had benign histology and 247 (76.0%) had malignant testicular tumors. All patients with testicular masses had significant predictive factors for malignant disease: higher ultrasound blood flow (HR = 3.320, P < 0.001), lower ultrasound echo (HR = 3.191, P = 0.001), larger tumor diameter (per cm increased, hazard ratio [HR] = 1.284, P = 0.036), and abnormal blood HCG (HR = 10.550, P < 0.001). The nomogram that was produced was accurately calibrated for every malignancy probability prediction. Their findings showed that a significantly higher percentage of patients (24.0%) had radical orchiectomy for benign tumors than was previously thought (10.0%). According to their findings, the malignancy in patients with testicular masses may be predicted by the diameter, ultrasonic echo, ultrasonic blood flow, and serum HCG levels.

A prospective study was carried out by Drumadala et al. (2020) on 200 patients who were referred for scrotal disease over two-year period. The purpose of the study was to assess how well color Doppler and high frequency ultrasonography diagnose scrotal diseases. When evaluating testicular cancers, the study's sensitivity was 75% and its positive predictive value was 100%.

In order to assess the diagnostic validity of grayscale and CDUS for scrotal swelling, Almassry et al. (2020) conducted a retrospective study with 181 patients. The investigation included imaging and clinical follow-up, surgical findings, and histological data as reference standards. For the diagnosis of scrotal tumors, they discovered that grayscale and CDUS had a sensitivity of 84.6%, a specificity of 76.2%, a positive predictive value of 19.6%, and a negative predictive value of 98.6%.

Using histology as the gold standard, K. Fazal et al. (2022) assessed the diagnostic accuracy of color Doppler ultrasound in the detection of testicular cancer. 311 participants between the ages of 30 and 50 participated in their cross-sectional study. Only 160 participants (48.55%) were later discovered to have testicular cancer out of 175 subjects (56.27%) who had been diagnosed with the disease on CDUS. In the diagnosis of testicular cancer, CDUS had a 88.8% sensitivity and a 78.1% specificity.

Between July 2004 and June 2005, Uddin et al. (2024) conducted a prospective observational study on 52 patients at Dhaka Medical College Hospital in Bangladesh to compare the efficacy of duplex color Doppler ultrasonography and grayscale ultrasound in assessing scrotal disease. The two methods' diagnostic accuracy differed, with color Doppler performing best under particular circumstances like testicular torsion (100% accuracy, sensitivity, and specificity). All things considered, color Doppler showed better accuracy (96.10%) than grayscale (80%). They came to the conclusion that whereas duplex color Doppler ultrasonography and grayscale ultrasound are both useful methods for assessing scrotal disease, the latter is superior in terms of precision, sensitivity, and specificity.

Huang et al. (2024) examined the utility of strain elastography (SE) and contrast enhanced ultrasonography (CEUS) as supplements to traditional greyscale and CDUS in a retrospective study conducted at a tertiary center in London, UK, to assess 124 patients of localized testicular lesions over a ten-year period. According to their findings, CEUS + SE had 86.9%, 60.2%, 56.3%, 88.6%, and 70.1% sensitivity, specificity, PPV, NPV, and accuracy, respectively. In contrast, CDUS had 89.1%, 47.4%, 50%, 88.1%, 62.9%, sensitivity, specificity, PPV, and NPV, respectively. They came to the conclusion that CEUS+SE had more specificity than CDUS and that CEUS had a higher sensitivity than CDUS.

**2.2** **ANATOMY**

**2.2.1 TESTIS**

The male gonad is called the testis. It is analogous to the female ovary. The spermatic cord hangs it in the scrotum. Its upper pole is angled forward and medially due to its oblique position. Compared to the right testis, the left is somewhat lower. The testis is squeezed from side to side and has an oval form. It measures 3.75 cm in length, 2.5 cm in width from front to back, and 1.8 cm in thickness from side to side. According to Garg (2016), an adult testis weighs roughly 10 to 15 gm.

**External Features**

**The testis has:**

1. An upper and a lower pole or terminal.

2. Anterior and posterior margins.

3. A medial and lateral surface

Both the top and bottom poles are smooth and convex. The spermatic cord is attached to the higher pole. The tunica vaginalis completely covers the anterior edge, which is smooth and convex. The tunica vaginalis only partially covers the posterior border, which is straight. The lateral portion of the posterior border is where the epididymis is located. An expansion of the tunica vaginalis cavity divides the testis from the lateral portion of the epididymis. The sinus of epididymis is the name given to this extension. Both the lateral and medial surfaces are smooth and convex. The appendix of the testis is a little, oval body that is connected to the upper pole of the organ. It is the paramesonephric duct's remnant (Garg, 2016).

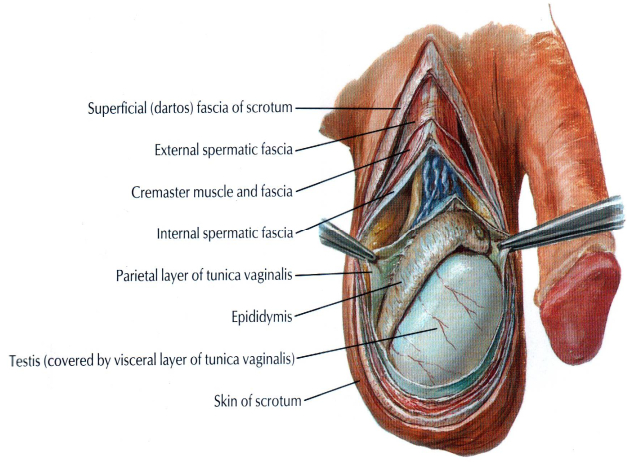
**Coverings of the Testis**

Three coatings are applied to the testis. These are the tunica vaginalis, tunica albuginea, and tunica vasculosa, viewed from the exterior inward.

The lower persistent part of the processus vaginalis is known as the tunica vaginalis. It has a parietal and a visceral layer with a cavity between them because the testis invaginates it from behind. With the exception of the posterior border, it covers the whole testis.

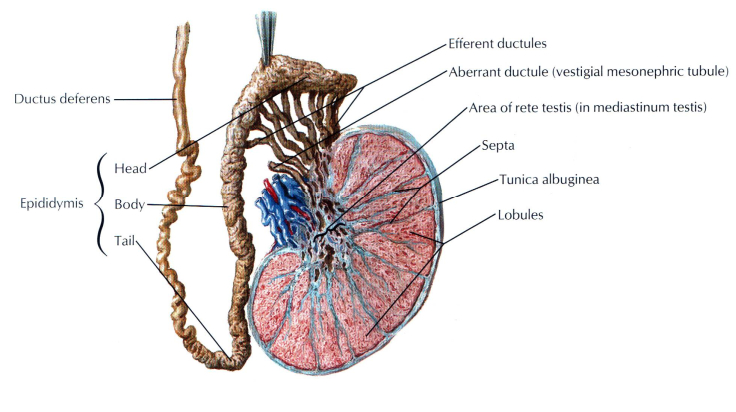
The testis is completely covered in a thick, white, fibrous layer called the tunica albuginea. Except for the posterior region, where the testicular arteries and nerves enter the gland, it is encased in the visceral layer of the tunica vaginalis. The mediastinum testis, an imperfect vertical septum that is wider above than below, is formed by thickening the posterior border of the tunica albigina. From the mediastinum to the inner surface of the tunica albuginea, many septa are present. The testis is not fully divided into 200–300 lobules.

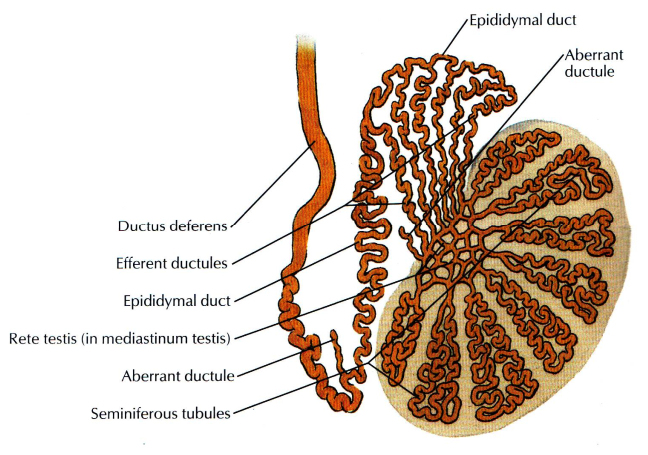
The testis' innermost vascular coat, which lines its lobules, is called the tunica vasculosa (Garg, 2016).

** Figure1: External Genitalia (Netter, 1989).**

**Structure of the Testis**

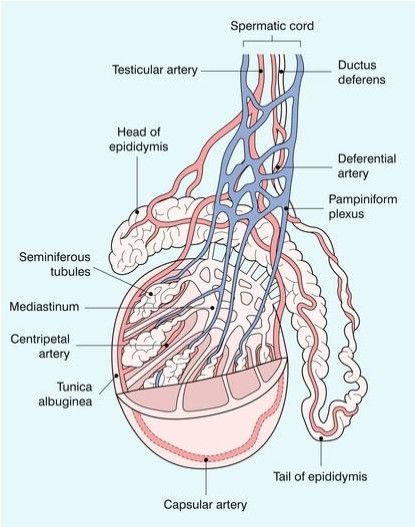
There are 200–300 lobules in the glandular portion of the testis. There are two to three seminiferous tubules in each lobule. The tubules are tightly wound around one another. Each tubule has a diameter of roughly 0.2 mm and a length of roughly 60 cm when stretched. Cells that reflect different phases in the development of spermatozoa line the tubules. Twenty to thirty straight tubules that enter the mediastinum are formed when the seminiferous tubules unite at the lobule apices. In this instance, they anastomose to create the rete testis, a network of tubules. Twelve to thirty efferent ductules are produced by the rete testis, which then emerges close to the testis' top pole and enters the epididymis. Each tubule gets extremely coiled at this point, forming a lobe of the epididymis' head. The body and tail of the epididymis are formed by the tubules ending in a single duct that is wound around itself. Alongside the ductus deferens, it is continuous (Garg, 2016).

** Figure 2: Frontal section through the testis (Netter, 1989).**

** Figure 3: Schematic diagram of testis (Netter, 1989).**

**Arterial Supply**

At the level of vertebra L2, the testicular artery emerges as a branch of the abdominal aorta. It enters the spermatic cord in the deep inguinal ring after descending on the posterior abdominal wall. It splits into branches at the testis's posterior border. While larger branches, medial and lateral, breach the tunica albuginea and run along the testis' surface before ramifying in the tunica vasculosa, some smaller branches enter the posterior border (Garg, 2016).

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**Figure 4: Schematic diagram of blood supply of testis (Garg, 2016).**

**Venous Drainage**

The pampiniform plexus, which means "like a vine," is made up of the veins that emerge from the testis. The testicular artery is surrounded by the front portion of the plexus, the ductus deferens and its artery by the middle portion, and the posterior portion is left alone. At the superficial and deep inguinal rings, the plexus condenses into two and four veins, respectively. The testicular artery is accompanied by these veins. In the end, a single vein forms that empties into the left renal vein on the left side and the inferior vena cava on the right.

**Lymphatic Drainage**

At the second lumbar vertebra, the lymphatics from the testis ascend along the testicular arteries and empty into the preaortic and paraaortic groups of lymph nodes.

**Nerve Supply**

Sympathetic nerves that emerge from spinal cord segment T10 supply the testis. They go via the aortic and renal plexuses. The nerves are efferent to the blood vessels (vasomotor) and afferent for testicular sensation (Garg, 2016).

**Histology of Seminiferous Tubule**

In a healthy testis, the seminiferous tubule is made up of cells layered four to eight. These cells can be divided into two categories:

(a) the spermatogenic cells, which make up the great bulk.

(b) Sertoli's supporting/sustentacular cells.

Spermatogonia, primary spermatocytes, secondary spermatocytes, spermatids, and spermatozoa are examples of spermatogenic cells. Tall and columnar in shape, Sertoli cells stretch from the central lumen to the basal lamina. They aid in the maturation of spermatozoa and support and shield the growing germ cells.   
The anterior pituitary gland's follicle stimulating hormone (FSH) regulates spermatogenesis.

Between the seminiferous tubules are tiny clusters of interstitial cells, also known as Leydig cells. They release androgen, or testosterone (I make man). The anterior pituitary gland's interstitial cell stimulating hormone (ICSH) regulates Leydig cell function (Garg, 2016).

**2.2.2 EPIDIDYMIS**

The heavily coiled tube that makes up the epididymis serves as a sperm storage organ.   
Parts:   
The head refers to its higher end. The expanded head is joined to the testis's higher pole via efferent ductules. The body is the center section. The tail is the lowest portion. Highly coiled efferent ductules make up the head. The epididymis duct, which is tightly wound around itself, is the only duct that connects the body and tail. This duct joins the ductus deferens at the lower end of the tail to form a continuous structure.

**Vessels and Nerves:**

The testicular artery supplies the epididymis via a branch that joins and strengthens the small artery leading to the ductus deferens. The lymphatic and venous drainage systems resemble the testis. Similar to the testis, sympathetic nerves supply the epididymis through the testicular plexus, whose fibers originate from spinal cord segments T11 to LI.

**Histology of Epididymis:**

The pseudo-stratified columnar epithelium with stereocilia lines the tubules of the epididymis. Connective tissue envelops the tubules.

**2.2.3 DEVELOPMENT OF TESTIS**

Leydig's cells, Sertoli cells, and spermatogenic cells make up the testis.   
  
The dorsocaudal endoderm of the yolk sac is the source of the spermatogenic series of cells.   
Sertoli cells are generated from coelomic epithelial cells, which are epithelial cells.   
  
Leydig’s cells: Mesoderm. The testis has a thick tunica albuginea, originated from the growing gland's medulla is primarily (Garg, 2016).

**2.3 BASIC PRINCIPLE OF ULTRASONOGRAPHY**

Sound that has a frequency higher than 20,000 cycles per second (Hertz, Hz) is considered ultrasound. Frequencies used in medical sonography range from 1 to 20 megahertz (MHz). A piezoelectric crystal, a unique ceramic material, is exposed to a brief voltage spike to produce very high frequencies. The previously employed piezoelectric crystal materials have been replaced by a class of artificial piezoelectric materials known as "ceramic ferroelectrics." Research indicates that some plastic polymers may soon take the place of PZT, despite the fact that PZT is now the most extensively used material in the production of ultrasound transducers. The voltage spike's electric field realigns the ceramic's crystalline elements, or dipoles, abruptly altering the crystal's thickness. Waves are created when a sequence of vibrations is initiated by this abrupt shift in thickness.

A transducer, a plastic box that shields the piezoelectric crystal from mechanical damage and offers electrical and acoustic insulation, houses the crystal at its front. To shield the patient from electrical shock, electrodes are plated onto the crystal's surface, with the external electrode grounded. The transducer may produce several brief sound pulses because a backing block reduces vibrations in between voltage spikes. Another transducer with the proper frequency must be chosen if a clinical circumstance requires a different frequency. Heat has the potential to harm piezoelectric crystals. Over a certain point, known as the "Curie temperature," a crystal loses its piezoelectric qualities and turns into a useless ceramic object. The purity of tone (narrowness of frequency range) is gauged by the Q factor. The time it takes for a transducer to cease vibrating is known as the ring down-time.

An energy-transmitting sequence of longitudinal waves is called an ultrasonic beam. These waves move at a speed of 1540 m/sec through typical bodily tissue. Their speed is not affected by frequency. The velocity of sound is equal to the frequency times the wavelength and is dependent on the density and compressibility of the conducting medium. A sound beam's intensity is decreased as it travels through the body due to a mixture of diffusion, reflection, refraction, and absorption. In the close, or Fresnel, zone, the acoustic beam has parallel sides and is reasonably coherent. The beam enters the far, or Fraunhofer, zone and starts to flare out and scatter after a specific critical distance, also known as the changeover point. The close zone's length is inversely related to the sound's wavelength and proportional to the square of the transducer's diameter. In the remote zone, dispersion quickly attenuates the beam. Tissue interfaces are where reflection takes place. Angles of incidence and reflection are equal. The angle of incidence of the beam and the difference in the acoustic impedance of the two surfaces determine how much reflection occurs. The density of sound in the conducting medium multiplied by its velocity is known as acoustic impedance. When the two media's acoustic impedances differ much and the incidence angle is minimal, reflection is at its highest. At a 90° incidence angle, transmission is maximum and reflection is minimum.

The frequency stays the same but the wavelength varies when sound travels through different media at different speeds. The sound is bent, or refracted, if the wave front hits the second medium at an angle. The angle of incidence and the variation in sound velocity between the two mediums determine the degree of refraction. The frequency of the sound as well as the viscosity and relaxation time of the conducting medium affect absorption, which is the process by which sound is transformed into heat. Because absorption in tissue is frequency-dependent, moving from 1 to 2 MHz doubles absorption and reduces the beam's penetrating strength by half. As a result, bulky body components cannot be examined using high-frequency sound.

In order to create bands of compression and rarefaction in the conducting medium, a longitudinal wave is transmitted by many particles (molecules) oscillating in the direction of propagation. These bands alter the thickness of the piezoelectric crystal when they are back-scattered as echoes, creating an electrical signal.   
The ultrasonic picture is based on this signal. The sound travels in brief pulses, or bursts, typically at a speed of 1000 Hz. The pulses are brief, lasting only 0.000001 seconds. The transducer records returning echoes while functioning as a receiver in between pulses. In every imaging mode, the interval between the start of a pulse and the return of an echo is translated into depth. There are multiple ways to view the image. Weaker echoes can be enhanced with a variety of adjustments. The temporal gain compensator, which logarithmically amplifies echoes from specific depths following an adjustable delay, is the most crucial control.

The spatial pulse length, which is the number of waves in a pulse multiplied by the wave-length, determines depth resolution, or the capacity to separate two objects simultaneously. Lateral resolution, or the capacity to distinguish between two nearby objects, is dependent on the width of the sonic beam, while depth resolution is best achieved with transducers that have a short spatial pulse length. An acoustic lens can be used to narrow the beam by bending the sound in the direction of a focal point.

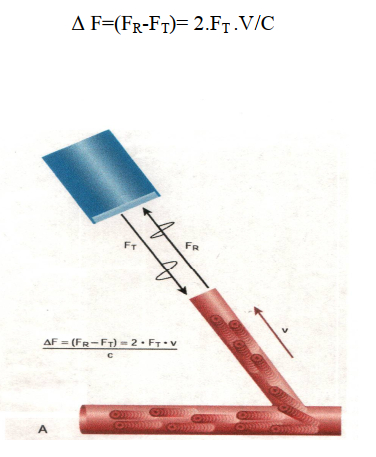
A shift in the apparent frequency of a sound coming from a moving source is known as the Doppler effect. Motion is detected via Doppler instruments. They do this by sending out a sound beam and then capturing and demodulating the echoes that come back. For the majority of physiological motions, the difference between the two frequencies often falls within the audible range. The difference is converted to an audio signal after amplification. Continuous wave Doppler sensors don't have any kind of depth resolution, but they can give velocity information. Pulsed Doppler instruments concurrently offer velocity and depth data. Typically, a "piggybacked" system consists of a pulsed Doppler device and another type of ultrasonic imaging equipment. By enabling the assessment of the spectrum of frequencies that comprise a Doppler signal, spectral analysis of a Doppler signal enables the assessment of the characteristics of blood flow in both normal and stenotic blood vessels.

Motion can be tracked by means of real-time imaging systems' ability to generate image frames quickly. There must be a balance struck between frame rate and line density per frame. Typically, frame rates are at least six frames per second. Either an electrical array setup or a mechanical scanner can produce the real-time image. Mechanical scanners use a rotating wheel transducer or an oscillating transducer to create a sector format image. Electronic array real-time scanners can employ either a guided array transducer, which creates an image in sector format, or a linear array transducer, which creates a rectangular scan format. Both electronic focusing and a concave plastic lens are necessary for concentrating the electronic array ultrasonic beam. In order to achieve satisfactory beam geometry, each group of individual elements in a linear array transducer must pulse—typically four elements at a time—producing one line in the final image. Every transducer element is pulsed to create each line of the image when using a guided array transducer (Curry et al 1990).

**2.4 DOPPLER SONOGRAPHY**

Techniques for pulse-echo transmission, detection, and display are used in conventional B-mode ultrasound imaging. The transducer emits brief ultrasonic energy pulses, which are reflected from the body's acoustic interfaces. The depth from which the echo originates can be ascertained with precise time. The backscattered (reflected) signal from an interface that reflects pulsed wave ultrasound includes information on frequency, phase, and amplitude. The position, characteristics, and mobility of the interface reflecting the pulse can be inferred from this information. Differences in reflector strength are shown in the image as different shades of gray in B-mode ultrasonic imaging, which creates the image solely from the amplitude information in the backscattered signal. Targets moving quickly, like red blood cells, create low-amplitude echoes that are not typically visible, giving the lumens of big vessels a comparatively anechoic appearance (Rumack et al 2011).

Even though grayscale display depends on the backscattered ultrasound signal's amplitude, moving targets' motion can be assessed using additional information found in the returning echoes. The reflected ultrasound has nearly the same frequency or wavelength as the transmitted sound when high-frequency sound strikes a stationary contact. However, the frequency of the sound scattered by the moving object changes if the reflecting interface moves in relation to the sound beam coming from the transducer. The Doppler effect causes this frequency shift, which is precisely proportional to the reflecting interface's velocity with respect to the transducer. The Doppler equation describes how the velocity of the reflector and the returning ultrasonic frequency relate to each other, as follows:

****

**Figure: Doppler Effect** (Rumack et al 2011).

FT is the frequency of sound emitted from the transducer; V is the velocity of the target toward the transducer; C is the velocity of sound in the medium; FR is the frequency of sound reflected from the moving target; and ΔF is the Doppler frequency shift. As previously mentioned, the Doppler frequency shift (ΔF) only occurs when the object is traveling straight toward or away from the transducer. The ultrasonic beam typically approaches the moving object at an angle known as the Doppler angle in most clinical contexts, rarely traveling directly toward or away from the direction of flow. In this instance, ΔF is decreased proportionately to this angle's cosine, as seen below:

Δ F=(FR-FT)= 2.FT .V. cosθ/C

where θ is the angle formed by the incident ultrasonic beam and the axis of flow.

Flow velocity can be estimated if the Doppler angle can be detected. Both the Doppler frequency shift and the angle of insonation to the target movement direction must be precisely measured in order to estimate the target velocity accurately. The cosine of θ approaches zero as the Doppler angle (θ) gets closer to 90 degrees. There is no discernible Doppler frequency shift and no relative movement of the target toward or away from the transducer when the angle is 90 degrees. Doppler measurements must be taken at angles less than 60 degrees in order to achieve accurate angle correction since the cosine of the Doppler angle changes quickly for angles greater than 60 degrees. A tiny error in Doppler angle estimation can lead to a big error in velocity prediction because, beyond 60 degrees, relatively slight changes in Doppler angle are linked to large changes in cosθ. When using both color and duplex Doppler devices, these factors are crucial. Maximum Doppler frequency differences are achieved when the transducer axis and the direction of flow are at a relatively small angle, whereas optimal imaging of the vessel wall is achieved when the transducer axis is perpendicular to the wall (Rumack et al 2011).

It is ideal for measured Doppler frequencies to be adjusted for the Doppler angle in peripheral vascular applications in order to enable velocity measurement. This removes errors in the interpretation of frequency data acquired at various Doppler angles and enables comparison of data from systems using various Doppler frequencies. Angle-corrected velocity measurements are recommended for abdominal applications, even though Doppler frequency shift data alone is frequently used for qualitative evaluations of flow. When using Doppler equipment in a clinical setting, it is crucial to understand how the transducer frequency (FT), Doppler angle (θ), Doppler frequency shift (ΔF), and target velocity are related by the Doppler equation (Rumack et al 2011).

**Doppler Signal Processing and Display**

The Doppler frequency shift, or ΔF, can be processed in a number of ways to yield valuable data about the velocity and direction of blood. Clinically observed Doppler frequency shifts fall within the hearing range. With practice, the operator can recognize a variety of flow characteristics by using their ears to examine this audio information. The Doppler shift statistics are typically shown graphically as a time-varying representation of the returned signal's frequency spectrum. The frequency analysis is carried out using a rapid Fourier transform. The following is seen in the generated Doppler frequency spectrum:

• Changes in the Doppler frequencies in the sampled volume with time.   
• The spectrum's envelope, which shows the highest frequencies that are present at any particular moment.

• The spectrum's width at any given location, which shows the variety of frequencies present.

The number of targets traveling at a specific velocity is correlated with the Doppler signal's amplitude. Each frequency component's amplitude is shown in grayscale as part of the spectrum in many instruments. Spectral broadening occurs when there are many distinct frequencies present at a particular moment in the cardiac cycle.

A depiction of the Doppler frequency shift is shown as an aspect of the image itself in color Doppler imaging systems. Apart from identifying Doppler frequency shift information from every pixel in the picture, these systems might potentially offer range-gated pulsed waves Doppler for displaying Doppler data with spectral analysis (Rumack et al 2011).

**Doppler Instrumentation**

Doppler ultrasound devices are designed to show flow information, as opposed to A-mode, M-mode, and B-mode grayscale ultrasonography, which show information from tissue interfaces. The most basic Doppler devices use two transducers that continually send and receive ultrasound (continuous wave or CW Doppler), which uses continuous wave rather than pulsed wave ultrasound. At a certain distance from the transducer face, the broadcast and receive beams overlap in a sensitive volume. Even while CW Doppler can identify the direction of flow, these instruments are unable to distinguish between motion originating from different depths, and it is difficult, if not impossible, to pinpoint the exact source of the signal being detected. Portable and reasonably priced, the main applications for CW Doppler equipment are intraoperatively or at the patient's bedside to verify the existence of flow in superficial vessels.

The majority of applications use range-gated, pulsed wave Doppler due to the limitations of CW devices. Pulsed wave Doppler devices release short bursts of ultrasonic energy as opposed to a continuous wave. When sound pulses are used, the time gap between a pulse's transmission and its return can be used to calculate the depth at which the Doppler shift occurs. The concepts are comparable to those of imaging's echo-ranging. It is possible to alter the shape, depth, and position of the sensitive volume from which flow measurements are taken in a pulsed wave Doppler system. The position of the Doppler sample can be precisely controlled and tracked when a 2-D, real-time, B-mode imager is integrated with pulsed wave Doppler to create a duplex scanner.

Color Doppler imaging is the most widely used type of Doppler ultrasonography in radiology applications. Frequency shift data derived from Doppler measurements is shown as an image feature in color Doppler imaging systems. The B-mode image is based on targets that are stationary or move slowly. The existence and direction of motion, as well as variations in echo signal frequency correlated with the target's velocity, are all indicated by the signal phase. As red blood cells move toward or away from the transducer, their backscattered signals are shown in color. The relative frequency shift that the moving red blood cells cause is indicated by the color's saturation level.

**Color Doppler Flow Imaging (CDFI)**

By offering more features, Color Doppler Flow Imaging (CDFI) enhances traditional duplex sonography. Relative velocity can be estimated from the image alone by using color saturation to show differences in Doppler shift frequency, as long as variations in the Doppler angle are observed. The position and direction of the vessel of interest can always be noticed thanks to the flow display across the imaging area. The ability to display spatial information in relation to velocity is perfect for revealing small, localized regions of turbulence inside a vessel, which can reveal signs of stenosis or irregularities in the vessel wall brought on by trauma, atheroma, or other illnesses. Everywhere in the vessel, flow is seen, and stenotic jets and concentrated turbulence are visible that could be missed by duplex instruments. Small vessels that are invisible with traditional imagers can be seen thanks to the contrast of flow within the vessel lumen, which also makes irregularities in the wall more noticeable. CDFI facilitates Doppler angle measurement and flow direction determination (Rumack et al 2011).

**Pulsatility Measurements:**

Only two of the several waveform analysis indices that have been developed are regularly used in clinical settings. These are the pulsatility index (PI), also called the Gosling index, and the resistance index (RI), also called the Pourcelot index. Since they are ratios, they are not affected by the beam/vessel angle, albeit a beam/vessel angle of less than 600 is necessary to generate a high-quality Doppler trace from which to take the measurement.

Their derivations are:

Peak systolic velocity-End diastolic velocity

Pourcelot’s Resistivity index = -----------------------------------------------------------------

Peak systolic velocity

Peak systolic velocity-End diastolic velocity

Gosling’s Pulsatility index= ------------------------------------------------------------------

Temporal mean velocity

Its primary drawback is that, in contrast to the RI, which simply needs two values to be measured, it necessitates calculating the mean peak frequency. The RI was employed to measure variations in diastolic flow in low-resistance vascular beds because it is very sensitive to changes in downstream flow resistance. Vascular stenosis or disease in the organ that the vessel supplies can increase resistance, but because it also depends on "end diastolic" velocity, the RI rises as heart rate falls, giving the diastolic flow more time to fall. In theory, the RI can be adjusted for a normal heart rate, but this is rarely done in practice (Cosgrove, 2001).

**Vascular Resistance:**

To distinguish benign from malignant tumors, color Doppler results of intralesional vascularity, vascularity type and grade, PSV, RI, and PI are helpful. To investigate the vascularity in the gland and the lesion, color Doppler, power Doppler, and pulse wave Doppler are used. When using Power Doppler Sonography (PDS), the Pulsed Repetition Frequency (PRF) is set at 700 Hz to detect small vessels, and the Doppler settings are optimized at high sensitivity, low wall filter, and medium persistence. The color gain is raised until noise or artifacts are visible. After that, it gradually diminishes until it vanishes. Color Doppler sonography images of intratumor vascularity are subjectively rated using a four-step analog scale.

The mass's vascular distribution pattern can be classified as mixed, hilar (branching), or peripheral (basket-like). Using spectral Doppler, the more noticeable vessels are typically chosen for the test in order to assess the vascular resistance [Resistive Index (RI), Pulsatility Index (PI)] of lesions. Peak Systolic Velocity (PSV) is measured at an angle of 60 degrees or less after angle correction. After evaluating the lesion's Doppler characteristics and comparing them with greyscale features, the final CDUS diagnosis is created.

**2.5 RADIOPATHOLOGICA CONSIDERATION:**

**Malignant testicular masses:**

**Seminoma**

The most typical pure GCT is seminoma. It makes up between 35 and 50 percent of all GCTs. Compared to NSGCTs, it occurs in a population that is older, with an average patient age of 40.5 years. A seminoma is often homogeneous and evenly hypoechoic on B-mode ultrasonography. Heterogeneity may be higher in larger tumors. Their sizes range from tiny incidental nodules to massive infiltrative masses that completely replace the testicular parenchyma. There is clearly more vascularity inside the lesion on color Doppler (Woodward et al., 2002; Lung & Sidhu, 2011).

**Non-seminomatous germ cell tumors**

About 60% of GCTs are NSGCTs, which are frequently encountered together as mixed germ cell tumors. The most frequent component is embryonal carcinoma, which frequently coexists with one or more elements of yolk sac tumor, seminoma, and teratoma. With areas of necrosis, bleeding, calcification, and mixed reflectivity, B-mode characteristics are typically far more varied in nature. A rise in color Doppler flow is a characteristic shared by all malignant testicular tumors (Woodward et al., 2002; Lung & Sidhu, 2011).

**Non-primary malignant tumors**

An ambiguous testicular mass can be a symptom of non-primary malignant tumors such lymphoma, leukemia, and metastases. The most prevalent testicular tumor in men over 60 is testicular lymphoma. Secondary testicular involvement is more frequent than primary testicular leukemia. Both leukemia and lymphoma can have sonographic findings that are similar to GCTs, such as focal or multifocal hypoechoic lesions (Lung & Sidhu, 2011).

**Benign Testicular masses:**

**Simple testicular cyst with debris**

Testicular cysts are distinct, uniformly hypoechoic lesions with posterior acoustic amplification on ultrasound, just as those in other organs. There is some internal echogenicity in complex cysts. On Doppler US, all cysts, however, lack interior vascularity. Simple cysts, which range in size from 2 mm to 2 cm in diameter, are discovered by accident and typically affect men over 40. Usually isolated, the cysts might be connected to spermatoceles (Dogra et al. 2001).

**Ectasia of rete testis**

Located near the mediastinum testis, the rete testis is a network of several seminiferous tubules that empty into the epididymal head. Retinal ectasia, which manifests as a collection of several tiny cysts and tubules along the testicular mediastinum, usually affects older males. It can show as a coarse tubular structure with finger-like protrusion into the parenchyma or as a barely discernible, ill-defined area of diminished reflectivity on ultrasonography. Despite being a benign entity, this could be significant in a patient with azoospermia since it suggests that the ipsilateral spermatic ducts are blocked (Sellars and Sidhu, 2001).

**Epidermoid cyst**

The most prevalent benign testicular tumor, epidermoid cysts, usually appear in mid-adulthood (the second to fourth decades). It appears as a well-marginated intratesticular mass that is non-vascular on ultrasound. It may also have a distinctive lamellated "onion skin" or "whorled" appearance with alternating rings of hyperechoic and hypoechoic signals.

**Mature teratoma**

Approximately 4–9% of all testicular tumors are pure testicular teratomas, which are benign. Prepubescent boys are more likely to experience them. Mature teratomas typically have a cystic shape with diverse echoes in the fluid, which can be either sebaceous or mucinous and may or may not contain hair follicles. There are solid components with varying echogenicity, such as fatty and hyper-echoic components.

**Sex cord stromal tumor**

Most sex cord stromal tumors are not harmful. Leydig cell tumors and Sertoli cell tumors are the two primary forms of stromal tumors. Leydig cell tumors are the most prevalent sex-cord stromal tumor, accounting for 1-3 percent of all testicular malignancies. tend to be bimodal, with a peak in adults (20–30 years old) and another in children (5–10 years old). Although it is clinically linked to a serum hormonal imbalance, its ultrasound imaging look is generic and makes it challenging to distinguish it from other testicular cancers. Compared to Leydig cell tumors, sertoli cell tumors are less frequent. They typically appear as a single, poorly defined, hypoechoic intratesticular lesion on ultrasonography, sometimes accompanied by sizable calcification patches.

**Other Benign Tumours**

The testis may develop other benign tumor forms. These consist of fibromas, hemangiomas, and lipomas.

**Testicular tumor mimics:**

**Intratesticular abscess**

Severe epididymoorchitis is linked to uncommon intratesticular abscesses. They could also develop as a result of an infarction, trauma, or mumps. The ultrasonography shows a lesion with uneven boundaries and low reflectivity. On CDUS, a testicular abscess may have a hypervascular rim around it, but interior vascularity is absent. It may be easier to distinguish a testicular abscess from a segmental infarction since the anomaly seen there does not fit the lobular pattern (Stewart & Sidhu, 2007).

**Segmental testicular infarction**

Patients with acute testicular pain occasionally have segmental testicular infarction. An area of mixed or low reflectivity—which could be circular or wedge-shaped—is shown by ultrasound examination. The color Doppler flow is either nonexistent or very poor. Bundling of the perilesional parenchymal arteries and displacement of the surrounding testicular tissue are caused by oedema in the infarcted area. The benign character of the abnormality is frequently established by the ultrasound appearances, the lack of tumor markers, and a change in the abnormality's size or form during follow-up.

**Intratesticular haematoma**

An intratesticular hematoma should be suspected if there has been a history of trauma. The haematoma manifests as patchy enhanced reflectivity when seen acutely. It could show up as a low-reflectivity area on follow-up, shrinking in size as the hemorrhage retracts. Malignancy is the most crucial differential diagnosis, therefore a benign entity is indicated by a correct history, absence of vascularity on CDUS, absence of tumor markers, and shrinkage of the abnormality on consecutive scans (Purushothaman et al. 2007).

**Granulomatous lesion**

Extrapulmonary tuberculosis can occasionally present as scrotal TB. It encompasses epididymitis and tuberculous orchitis. Since scrotal TB manifests as a painless or mildly painful scrotal mass, it can be challenging to distinguish it from other disorders such tumors or infarction or from normal epididymo-orchitis. Epididymitis typically precedes or is linked to tuberculous orchitis. There are various sonographic patterns that have been reported : multiple tiny hypoechoic nodules in an enlarged testis (military type); a diffusely enlarged heterogeneously hypoechoic testis; a diffusely enlarged homogeneously hypoechoic testis; or a nodularly enlarged heterogeneously hypoechoic testis (Elfeky, Knipe & Skalina, 2024):

**Testicular sarcoidosis**

Sarcoidosis seldom affects the genital system. Although the testis may be affected, the epididymis is most frequently affected. Sarcoidosis lesions on ultrasonography usually appear as several tiny, bilateral low-reflectivity lumps. Clinical evidence of sarcoidosis elsewhere is necessary for a more confident diagnosis, as differentiation from cancer may be challenging. In the end, tissue biopsy for pathological assessment can be necessary if there are no related symptoms or characteristics (Stewart & Sidhu, 2007).

**materials and methods**

**3.1 Study design:** This was a cross sectional study.

**3.2 Place of study:** This study was carried out in the Department of Radiology and Imaging, Sylhet MAG Osmani medical college and Hospital, Sylhet in collaboration with Department of Surgery, Department of Urology and Department of Pathology of the same institute.

**3.3 Study duration:** March, 2023 to February, 2025

**3.4 Study population:** All patients who were clinically suspected for testicular mass referred to the Department of Radiology and Imaging, Sylhet MAG Osmani Medical College Hospital, Sylhet within this study periods will be the study population.

**3.5 Sample:** Among the study population who will fulfill the selection criteria.

3.6 Sampling method: Purposive sampling was used in this study.

**3.7 Criteria for the selection of the patients**

**Inclusion criteria:**

* + Patients who were provisionally diagnosed as case of testicular mass clinically.

**Exclusion criteria:**

* + Post postoperative patients of scrotal surgeries.
  + Post radiotherapy patients.
  + Patients having inguino-scrotal hernia.

**3.8 Sample size (N) calculation:**

According to a study, CDUS had 97.8% sensitivity for the diagnosis of different intra-scrotal diseases (Uddin MB et al., 2024). The sample size for this investigation was determined using a 95% CI and a 5% margin of error. Sample size was computed by the formula for the performance of the diagnostic test (Hoque, 2021) -

n

N

Z = 1.96 at 5% level of significance

P (sensitivity from previous study) = 97.8% = 97.8 (Uddin et al., 2024)

d (acceptable error) = 5% of 97.8 = 4.89

n = 25.11

As true prevalence of testicular masses was not clearly known, for convenience it was estimated about 50%.

N = = 50.22 ≈ 50

Therefore, for this study total 50 patients were included.

**3.9 Study variables:**

The following variables were studied:

**Demographic and clinical variables:**

* Age
* Marital status
* Testicular pain
* Testicular swelling
* Temperature
* H/O Trauma

**Sonographic and Doppler variables:**

* Type of testicular lesion (focal or diffuse)
* Size of the lesion
* Echogenicity of the lesion
* Margin of the lesion
* Grades of vascularity
* Pattern of vascularity
* PSV (Peak systolic velocity)
* EDV (End diastolic velocity)
* RI (Resistivity Index)

**Histopathological variables:**

* Benign
* Malignant

**3.10 Study procedure**

After receiving approval from the local ethical council, this cross-sectional investigation was carried out in the Radiology and Imaging department of the Sylhet MAG Osmani Medical College Hospital, Sylhet. The study population was chosen based on the selection criteria. A pre-made data sheet was used to collect the data. Following an explanation of the study's methodology and goal, the patient or his legal guardian provided signed informed consent. Every patient was evaluated by a thorough history and pertinent clinical examination. The data sheet, which contains the questionnaire, clinical results, radiological findings, and histological findings, was used to collect the patient's information.

This study involved a total of 50 patients who were chosen from the departments of surgery and urology at the Sylhet MAG Osmani Medical College and Hospital. Testicular mass cases with a clinical suspicion or a provisional diagnosis were referred to the Radiology and Imaging Department at the Sylhet MAG Osmani Medical College and Hospital in Sylhet.

Then, using color Doppler ultrasound, a thorough imaging was conducted.

The surgical findings of each patient were compared with color Doppler ultrasonography findings and assessment was made regarding confirmation of color Doppler finding with histopathology.

**Color Doppler Ultrasound Scanning Technique:**

* Before starting the examination, the patient was informed and his verbal consent was obtained.
* The Philips Affiniti 30 Ultrasound System with L-12-4 multi-frequency linear probe was used to perform the color Doppler ultrasound. The examination was conducted by a skilled radiologist.
* High resolution B-mode ultrasonography was used to assess the sonomorphology of each testicular mass. Color, spectral, and power Doppler sonography (PDS) were then used to analyze blood flow.
* The patient was examined in a supine position with a towel between his legs, and the penis was placed over the abdomen with the patient's left hand to ensure adequate contact.
* With little probe pressure, the area of interest was scanned gradually. Both transverse and longitudinal scanning planes were employed. Additional images in the oblique and coronal planes were also acquired. To compare parenchymal echogenicity, a transverse scan that included both testes in the same field of view was employed in each instance. The space-occupying lesion's dimensions, location, type, margin, and echotexture (mass) were recorded.
* The Doppler settings were adjusted for color Doppler imaging in order to identify low flow. The color Doppler gate was set as broad as possible, wall filters were set low or eliminated, and the pulse repetition frequency (PRF) scale was set as low as feasible. After setting the color boost to a high level, the background "noise" was simply eliminated. There was no steering and a small insonation beam angle in the pulsed Doppler spectrum analysis.
* The grade and pattern of vascularity were further described based on the flow data, which were noted as either absent or present. In order to detect artery pulsation and clearly observe color flow, a Doppler beam was positioned in the area of interest. Maximum peak systolic velocity (PSV), end diastolic velocity (EDV), and lowest resistive index (RI) aimed at any point in the mass were analyzed using spectral Doppler.
* The machine's built-in formula was used to calculate the vessels' RI values. Each patient's signal was recorded from different parts of the same mass, and the lowest values were chosen for the final analysis.

**Histopathology technique**

Pathological specimens were embedded in paraffin and formaldehyde. Hematoxylin and eosine-stained sections were examined under a conventional light microscope to determine the histological diagnosis in each instance. In the Department of Pathology at Sylhet MAG Osmani Medical College Hospital, histopathological slides were made, inspected, and interpreted by a skilled pathologist.

**Comparison with histopathology**

Histopathology reports were collected in each case from department of pathology by researcher himself. Then collected reports were compared with color Doppler ultrasonography findings.

**3.11 Data collection tool:**

Data was gathered using a standardized questionnaire that the researcher himself created after studying relevant literature and discussing with guide and experts.

**3.12 Contingency table**

To find out the relation between CDUS findings and histopathological findings,

a 2/2 contingency table construction will be the primary pre-requisite as follows -

|  |  |  |  |
| --- | --- | --- | --- |
| **CDUS findings** | **Histopathological findings** | | **Total** |
| **Malignant** | **Benign** |
| **Malignant** | a (TP) | b (FP) | a+b |
| **Benign** | c (FN) | d (TN) | c+d |
| **Total** | a+c | b+d | N (a+b+c+d) |

\* TP = true positive, FP = false positive, FN = false negative, TN = true negative

**3.13 Statistical analysis:**

Before doing any statistical analysis, the Statistical Package for Social Science (SPSS) version 25.0 for Windows (SPSS Inc., Chicago, Illinois, USA) was used to collect and arrange all pertinent data into a master table. In contrast to the frequencies and percentages of categorical data, the means and standard deviations of continuous variables were employed. Using cross tabulation, the categorical variables were analyzed using the Chi-Square test. Tables and graphs were used to display the findings.

The diagnostic validity of color Doppler ultrasound in determining testicular mass (benign and malignant) was assessed by evaluating its sensitivity, specificity, accuracy, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio. The results were then compared with those of other related studies. A P value of less than 0.05 was deemed statistically significant. After ROC analysis, the RI cut-off value was determined.

Using pertinent statistical methods, the following metrics were computed: sensitivity, specificity, accuracy, positive likelihood ratio (LR+), negative likelihood ratio (LR-), positive predictive value (PPV), and negative predictive value (NPV).

**3.14 Ethical consideration:**

Prior to collecting information, each patient provided written, informed consent. The study's goals and procedures, information confidentiality, the risks and benefits of taking part, and the participant's freedom to withdraw consent or decline participation at any time without affecting future treatment were all covered in detail in the consent form.   
Prior to the study starting, the "Institutional Ethical Review Board" of Sylhet MAG Osmani Medical College, Sylhet, approved the study protocol.   
All information was gathered in confidence, without coercion or pressure, and with full regard for the patient's wishes.

**3.15 Operational definitions**

**Testicular mass:** Any palpable testicular enlargement or lump that the patient or physician discovers during routine examination.

**Color Doppler ultrasound (CDUS):** It is a non-invasive imaging technology that utilizes combination of grey scale ultrasound and Doppler imaging. Conventional real-time B-scan along with variable combination of color Doppler, spectral Doppler or power Doppler are utilized.

**Peak systolic velocity (PSV):** It is an index that corresponds to each tall "peak" in a Doppler waveform and is measured in spectral Doppler. In intratesticular arteries, PSV ranges from 4.0 to 19.1 cm/sec (mean, 9.7 cm/sec); in capsular arteries, it ranges from 5.0 to 23.4 cm/sec (mean, 19.0 cm/sec).

**End-diastolic velocity (EDV):** This spectral Doppler index corresponds to the point at the end of the cardiac cycle, which is shortly before the systolic peak. In intratesticular arteries, EDV varies between 1.6 and 6.9 cm/sec (mean, 3.6 cm/sec), while in capsular arteries, it varies between 1.8 and 9.2 cm/sec (mean, 4.0 cm/sec).

**Resistive index (RI):** It is an ultrasonography flow parameter that is computed using the mean, minimum, and maximum Doppler frequency changes over a specific cardiac cycle. It is commonly employed to evaluate a pulsatile vascular system's resistance. The mean RI in intratesticular arteries is 0.6, with a range of 0.5 to 0.7.

**Grades of vascularity in color Doppler:** Subjective assessment to describe the amount of flow.

Grade 0 (Absent) : The ROI has no Doppler signals.

Grade 1 (Minimal) : Punctate Doppler signals in the ROI

(<2 vascular signals per 10 mm)

Grade 2 (Moderate) : Scattered Doppler signals in the ROI  
Grade 3 (High) : Continuous flow in the ROI

\* ROI (region of interest) (vascular signal >25mm in length).

**Patterns of vascularity in color Doppler:** Three types of vascularity pattern are usually detected in testicular lesions.

* Regular (branching linear)
* Non-branching linear
* Irregular chaotic / criss-cross

**Sensitivity:** Percentage of disease positives who are test positive [TP / TP+FN x 100 or, a / a+c x 100].

**Specificity:** Percentage of disease negatives which are test negative [TN / TN+FP x 100 or, d / b+d x 100].

**Positive predictive value:** Percentage of test positive who are truly disease positive [TP / TP+FP x 100 or, a / a+b x 100].

**Negative predictive value:** Percentage of test negative who are truly disease negative [TN / TN+FN x 100 or, d / c+d x 100].

**Diagnostic accuracy:** Percentage of all test results (positive and negative) that are correct [TP+TN / Total population x 100 or, a+d / N x 100].

**Positive likelihood ratio (LR+):** How many times is a positive test result more likely to be found in disease-positive individuals compared to disease-negative individuals.  
[ Positive likelihood ratio (LR+) = Sensitivity / 1- Specificity = TPR (true positive rate) / FPR (false positive rate)]

**Negative likelihood ratio (LR-):** How many times is a negative test result less likely to be found in disease-positive individuals compared to disease-negative individuals.  
[ Negative likelihood ratio (LR-) = 1- Sensitivity / Specificity = FNR (false negative rate) / TNR (true negative rate)]

(Hoque, 2021)

**3.16 Study flow chart**

Steps of study

Submission of thesis

Result & Discussion

Conclusion

Data analysis

Data processing

Color Doppler ultrasound

Histopathological examination

Data collection

Data collection

Samples selected on the basis of above mentioned inclusion and exclusion criteria

Sample

Written informed consent was obtained from the patient or legal guardian.

**Figure: Flow chart shows a summary of the steps of the overall study.**

**4. RESULTS AND OBSERVATIONS**

**Table 1: Distribution of the study patients according to age (n=50)**

|  |  |  |
| --- | --- | --- |
| **Age (in years) of the patients** | **Number of patients** | **Percentage** |
| **<5** | 1 | 2.0 |
| **5-10** | 2 | 4.0 |
| **11-20** | 5 | 10.0 |
| **21-30** | 12 | 24.0 |
| **31-40** | 19 | 38.0 |
| **41-50** | 3 | 6.0 |
| **51-60** | 2 | 4.0 |
| **61-72** | 6 | 12.0 |
| **Mean±SD** | 34.28±16.64 |  |
| **Range (min, max)** | 4, 72 |  |

The age distribution of the 50 study participants is shown in Table 1. The bulk of patients are younger; 38% (19 patients) are between the ages of 31 and 40, and 40% (20 patients) are 30 years of age or younger. Eleven patients, or 22% of the total, are older than 40. Significant age variability within the sample is indicated by the patients' mean age of 34.28 years and standard deviation of 16.64 years. The inclusion of both younger and older patients is highlighted by the age range, which stretches from 4 to 72 years.

|  |
| --- |
|  |
| **Figure 1: Age distribution of the study patients is displayed in the bar diagram** |

**Table 2: Distribution of the patients according to marital status (n=50)**

|  |  |  |
| --- | --- | --- |
| **Marital status of the patients** | **Number of patients** | **Percentage** |
| **Married** | 29 | 58.0 |
| **Unmarried** | 21 | 42.0 |

Table 2 presents the marital status of the 50 patients in the study. Of the total sample, 58% (29 patients) are married, while 42% (21 patients) are unmarried. This indicates that a majority of the patients are married, though a notable proportion remains unmarried.

|  |
| --- |
|  |
| **Figure 2: The study patients' marital status is displayed in a pie chart** |

**Table 3: Patients distributed according to their clinical presentation (n=50)**

|  |  |  |
| --- | --- | --- |
| **Clinical presentation of the patients** | **Number of patients** | **Percentage** |
| **Pain** | 18 | 36.0 |
| **Swelling** | 50 | 100.0 |
| **Fever** | 4 | 8.0 |

***\**Note**- Multiple responses were observed.

The clinical presentations seen in the 50 research participants are listed in Table 3. The most prevalent symptom, reported by all 50 patients (100%), was swelling. Fever was observed in 4 individuals (8%), and 18 patients (36%), reported experiencing pain.

|  |
| --- |
|  |
| **Figure 3: The study patients' clinical presentation depicted in the bar diagram** |

**Table 4: Distribution of the study participants by physical examination (n=50)**

|  |  |  |
| --- | --- | --- |
| **Physical examination of the patients** | **Number of patients** | **Percentage** |
| **Pulse** |  |  |
| Normal | 36 | 72.0 |
| Raised | 14 | 28.0 |
| **Temperature** |  |  |
| Normal | 50 | 100.0 |
| Raised | 0 | 0.0 |
| **Tenderness** |  |  |
| Yes | 24 | 48.0 |
| No | 26 | 52.0 |

Table 4 presents the findings from the physical examination of the 50 patients in the study. Regarding pulse, 72% of patients (36 individuals) had a normal pulse, while 28% (14 patients) had a raised pulse. All patients (100%) had a normal temperature, with no patients exhibiting a raised temperature. As for tenderness, 48% (24 patients) showed tenderness during the examination, while 52% (26 patients) did not.

**Table 5: Distribution of the study participants by gray scale findings (n=50)**

|  |  |  |
| --- | --- | --- |
| **Gray scale findings of the lesion** | **Number of patients** | **Percentage** |
| **Type of the lesion** |  |  |
| Focal | 33 | 66.0 |
| Diffuse | 17 | 34.0 |
| **Size of the lesion** |  |  |
| ≤1.5 cm | 0 | 0 |
| >1.5 cm | 50 | 100.0 |
| **Echogenicity of the lesion** |  |  |
| Homogeneously hypoechoic | 14 | 28.0 |
| Mixed echogenic heterogeneous | 36 | 72.0 |
| **Margin of lesion** |  |  |
| Well defined | 10 | 20.0 |
| Poorly defined | 40 | 80.0 |

The distribution of the 50 patients according to the grayscale features of their lesions as seen on imaging is shown in Table 5. Regarding the type of lesion, 66% (33 patients) had focal lesions, while 34% (17 patients) had diffuse lesions. All patients (100%) had size of the lesion >1.5 cm. In terms of echogenicity, 72% (36 patients) exhibited mixed echogenic heterogeneous lesions, 28% (14 patients) had homogeneously hypoechoic lesions. As for the margin of the lesions, 80% (40 patients) had poorly defined margins, while only 20% (10 patients) had well-defined margins.

**Table 6: The study patients' distribution by color Doppler finding (n=50)**

|  |  |  |
| --- | --- | --- |
| **Color Doppler finding of testicular lesion** | **Number of patients** | **Percentage** |
| **Grades of vascularity** |  |  |
| Grade 1 | 5 | 10.0 |
| Grade 2 | 32 | 64.0 |
| Grade 3 | 13 | 26.0 |
| **Pattern of vascularity** |  |  |
| Regular (branching linear) | 2 | 4.0 |
| Non-branching linear | 15 | 30.0 |
| Irregular chaotic / criss-cross | 33 | 66.0 |
| **PSV (Peak systolic velocity)** |  |  |
| Normal | 8 | 16.0 |
| Increased | 38 | 76.0 |
| Decreased | 4 | 8.0 |
| **EDV (End diastolic velocity)** |  |  |
| Normal | 10 | 20.0 |
| Increased | 36 | 72.0 |
| Decreased | 4 | 8.0 |
| **RI (Resistivity Index)** |  |  |
| <0.41 | 3 | 6% |
| ≥0.41 | 47 | 94% |

Table 6 provides a summary of the research patients' distribution according to color Doppler findings of their testicular lesions. Vascularity grades among the 50 patients were classified as Grade 1 in 10% of cases, Grade 2 in 64% of cases, and Grade 3 in 26% of cases. Regarding the pattern of vascularity, the majority (66%) exhibited scattered or random vascular pattern, while 30% showed non-branching linear pattern, and only 4% displayed regular branching linear pattern. The peak systolic velocity (PSV) was normal in 16% of patients, increased in 76%, and decreased in 8%. Similarly, end diastolic velocity (EDV) was normal in 20%, increased in 72%, and decreased in 8% of patients. The resistivity index (RI) revealed that only 6% of the patients had a RI value <0.41, while the remaining 94% had RI values ≥0.41. These findings highlight the variability in vascular and flow dynamics among testicular lesions, with a notable prevalence of increased PSV and EDV and irregular chaotic / criss-cross vascular patterns, which may be indicative of underlying pathological processes.

**Table 7: Study patients’ distribution by color Doppler ultrasound (CDUS) diagnosis (n=50)**

|  |  |  |
| --- | --- | --- |
| **Color Doppler ultrasound diagnosis** | **Number of patients** | **Percentage** |
| **Benign** | 11 | 22.0 |
| **Malignant** | 39 | 78.0 |

Table 7 presents the Color Doppler Ultrasound (CDUS) diagnosis of testicular mass in the 50 study patients. The majority of patients, 78% (39 patients), were diagnosed with malignant lesions, while only 22% (11 patients) were diagnosed with benign lesions.

**Figure 4: Study patients’ distribution according to color Doppler ultrasound (CDUS) diagnosis**

**Table 8: Study patients’ distribution by histopathological diagnosis (n=50)**

|  |  |  |
| --- | --- | --- |
| **Histopathological diagnosis** | **Number of patients** | **Percentage** |
| **Benign** | 13 | 26.0 |
| **Malignant** | 37 | 74.0 |

The 50 research participants' testicular mass histological diagnosis is shown in Table 8. Malignant lesions were found in 74% of the patients (37 patients), whereas benign lesions were found in 26% of the patients (13 patients).

|  |
| --- |
|  |

**Figure 5: Study patients’ distribution according to histopathological diagnosis**

**Table 9: Study patients’ distribution according to demographic and clinical variables (n=50)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Demographic and clinical variables** | **Histopathological diagnosis** | | **P-value** |
| **Benign**  **n (%)** | **Malignant**  **n (%)** |
| **Age (in years)** |  | |  |
| ≤30 | 7 (53.8) | 13 (35.1) | 0.290 |
| 31-40 | 5 (38.5) | 14 (37.8) |
| >40 | 1 (7.7) | 10 (27.0) |
| **Marital status** |  | |  |
| Married | 7 (53.8) | 22 (59.5) | 0.754 |
| Unmarried | 6 (46.2) | 15 (40.5) |
| **Clinical presentation** |  | |  |
| Pain | 11 (84.6) | 7 (18.9) | <0.001 |
| Swelling | 13 (100.0) | 37 (100.0) | - |
| Fever | 4 (30.8) | 0 (0.0) | 0.003 |
| **Physical examination** |  | |  |
| **Pulse** |  | |  |
| Normal | 5 (38.5) | 31 (83.8) | 0.004 |
| Raised | 8 (61.5) | 6 (16.2) |
| **Temperature** |  | |  |
| Normal | 13 (100.0) | 37 (100.0) | - |
| Raised | 0 | 0 |
| **Tenderness** |  | |  |
| Yes | 10 (76.9) | 14 (37.8) | 0.024 |
| No | 3 (23.1) | 23 (62.2) |

Table 9 presents the distribution of study patients with testicular mass according to demographic and clinical data, classified by histopathological diagnosis into benign and malignant categories. Among patients aged 30 years or younger, 53.8% had benign tumors compared to 35.1% with malignant tumors, although statistical significance was not achieved by this difference (p=0.290). Most patients in both groups were married, with no significant association between marital status and tumor type (p=0.754). Clinical symptoms such as pain were significantly more prevalent among benign tumor patients (84.6%) compared to those with malignant tumors (18.9%; p<0.001), while fever was only observed in 30.8% of benign cases (p=0.003). Swelling was universally present in both groups. Physical examination revealed that a raised pulse was more common in benign cases (61.5%) than malignant cases (16.2%; p=0.004), while all patients exhibited normal temperatures. Tenderness was significantly more frequent in benign tumors (76.9%) compared to malignant ones (37.8%; p=0.024).

**Table 10: Study patient distribution based on color Doppler ultrasound results versus histopathological results (n=50)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Histopathological diagnosis** | | **P-value** |
| **Gray scale findings of testicular lesion** | **Benign**  **n (%)** | **Malignant**  **n (%)** |
| **Type of the lesion** |  | |  |
| Focal | 11 (84.6) | 22 (59.5) | 0.173 |
| Diffuse | 2 (15.4) | 15 (40.5) |
| **Size of the lesion** |  | |  |
| ≤1.5 cm | 0 | 0 |  |
| >1.5 cm | 13 (26) | 37 (74) |  |
| **Echogenicity of the lesion** |  | |  |
| Homogeneously hypoechoic | 2 (15.4) | 12 (32.4) | 0.303 |
| Mixed echogenic heterogenous | 11 (84.6) | 25 (67.6) |
| Hyperechogenic | 0 | 0 |
| **Margin of lesion** |  | |  |
| Well defined | 6 (46.2) | 4 (10.8) | 0.012 |
| Poorly defined | 7 (53.8) | 33 (89.2) |
| **CDUS finding of testicular lesion** |  | |  |
| **Grades of vascularity** |  | |  |
| Grade 0 | 0 | 0 | 0.007 |
| Grade 1 | 4 (30.8) | 1 (2.7) |
| Grade 2 | 8 (61.5) | 24 (64.9) |
| Grade 3 | 1 (7.7) | 12 (32.4) |
| **Pattern of vascularity** |  | |  |
| Regular /linear branching | 2 (15.4) | 0 (0.0) | 0.049 |
| Non-branching linear | 3 (23.1) | 12 (32.4) |
| Irregular chaotic/criss-cross | 8 (61.5) | 25 (67.6) |
| **PSV (Peak systolic velocity)** |  | |  |
| Normal | 3 (23.1) | 5 (13.5) | 0.328 |
| Increased | 8 (61.5) | 30 (81.1) |
| Decreased | 2 (15.4) | 2 (5.4) |
| **EDV (End diastolic velocity)** |  | |  |
| Normal | 2 (15.4) | 8 (21.6) | 0.496 |
| Increased | 9 (69.2) | 27 (73.0) |
| Decreased | 2 (15.4) | 2 (5.4) |
| **RI (Resistivity Index)** |  | |  |
| <0.41 | 1 (7.7) | 2 (5.4) | 0.765 |
| ≥0.41 | 12 (92.3) | 35 (94.6) |

Table 10 presents the distribution of study patients with testicular mass according to Color Doppler ultrasound findings, classified by histopathological diagnosis into benign and malignant categories. On grayscale imaging, focal lesions dominating benign tumors (84.6%) and diffuse lesions more prevalent in malignant tumors (40.5%; p=0.173). Mixed echogenic heterogeneity was the predominant echogenicity in both groups, and poorly defined margins were significantly associated with malignancy (89.2% vs. 53.8% in benign cases; p=0.012). CDUS findings revealed that Grade 1 vascularity was more common in benign masses (30.8%) compared to malignant ones (2.7%; p=0.007), while Grade 3 vascularity was more frequent in malignant masses (32.4%). Irregular chaotic / criss-cross vascularity patterns were the most common in both groups, though regular vascularity patterns were exclusively observed in benign masses (p=0.049). Although both groups had higher PSV and EDV, these differences were not statistically significant. Regarding resistivity index (RI), RI higher or equal to 0.41 was more common in malignant masses (78.4%) than benign ones (61.5%; p=0.234).

|  |
| --- |
|  |

**Figure 6: Bar diagram displaying the distribution of study participants with testicular masses based on color Doppler ultrasound findings (n=50)**

**Figure 7: Bar diagram showing histopathological findings of testicular mass (n=50)**

The figure 7 presents the percentage distribution of various testicular lesions among the study population. Germ cell tumors (GCTs) are the most frequently observed, with GCT-seminoma accounting for 36.0%, making it the predominant diagnosis. This is followed by mixed GCT and non-Hodgkin’s Lymphoma (NHL), each comprising 12.0% of cases, indicating their significant presence. Abscesses are noted in 8.0% of cases, suggesting a notable incidence of infections in the cohort. A moderate incidence is shown by the 6.0% representation of other germ cell tumors, including mature teratoma and yolk sac tumor. Less commonly observed conditions include immature teratoma, NSGCT- embryonal carcinoma, testicular torsion, and TB orchitis, each contributing 4.0% to the total. Rare conditions like acute epididymo-orchitis and sex cord stromal tumor account for only 2.0% of cases each. This distribution highlights the diverse spectrum of testicular pathologies in the study, with seminoma being the most common diagnosis and several other conditions occurring with varying frequencies.

**Table 11: 2/2 contingency table showing comparison of color Doppler ultrasound diagnosis with histopathological diagnosis (n=50)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Diagnosis by color Doppler ultrasound** | **Diagnosis by histopathology** | | **Total** | **P value** |
| **Malignant**  N(%) | **Benign**  N(%) |
| **Malignant**  N(%) | True positive  34 (89.5%) | False positive  3 (25.0%) | **37** | <0.001 |
| **Benign**  N(%) | False negative  4 (10.5%) | True negative  9 (75.0%) | **13** |
| **Total** | **38 (100%)** | **12 (100%)** | **50** |

\* P value obtained using the Chi-square test.

Table 11 compares the diagnostic validity of color Doppler ultrasound (CDUS) against histopathological findings for testicular mass in the study population (n=50). CDUS detected malignancy in 31 (83.8%) of the individuals with histopathologically determined malignant tumors; the remaining 8 were false positives. Five (38.59%) of the eleven cases of benign testicular mass identified by Color Doppler ultrasound were proven to be true negatives by histological diagnosis, whereas the other six were false negatives. Conversely, among patients with benign mass confirmed histopathologically, CDUS correctly identified malignancy in 61.5% of cases. For benign diagnoses, CDUS misclassified 16.2% of malignant cases as benign, while 38.5% of benign cases were also categorized as benign using CDUS. Despite a discernible CDUS trend that paralleled histological findings, there was no statistically significant correlation between the two diagnostic techniques (𝑝=0.096 p=0.096). These findings suggest that although CDUS has promise as a diagnostic method for distinguishing between benign and malignant testicular masses, its accuracy warrants further validation to enhance diagnostic reliability.

**Using the following formulas, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), accuracy, positive likelihood ratio (LR+) and negative likelihood ratio (LR-) were calculated:**

Sensitivity = × 100

= × 100

= 89.5%

Specificity = × 100

= × 100

= 75.0%

Positive Predictive Value of the test (PPV)

=× 100  
= × 100

= × 100

= 91.9%

Negative Predictive Value (NPV)

= × 100

× 100

= × 100

= 69.2%

Accuracy = × 100

= × 100

= 86%

Positive likelihood ratio (LR+) =   
 =   
 = 3.58

Negative likelihood ratio (LR-) =   
 =   
 = 0.14

**Color Doppler ultrasound demonstrated 83.8% sensitivity, 38.5% specificity, 79.5% positive predictive value, 45.4% negative predictive value, 72.0% accuracy, 1.36 positive likelihood ratio (LR+), and a negative likelihood ratio (LR-) of 0.42 in the diagnosis of malignant testicular mass.**

**Table 12: Diagnostic validity** **of the color Doppler ultrasound in evaluation of testicular masses (n=50).**

|  |  |
| --- | --- |
| Sensitivity | 89.5 |
| Specificity | 75.0 |
| Accuracy | 86.0 |
| Positive predictive value | 91.9 |
| Negative predictive value | 69.2 |
| Positive likelihood ratio | 3.58 |
| Negative likelihood ratio | 0.14 |

Based on key validity metrics, Table 12 shows the diagnostic performance of color Doppler ultrasonography (CDUS) in assessing testicular masses. With a sensitivity of 83.8% for malignant tumors, CDUS showed a high degree of accuracy in identifying malignant patients. The reduced specificity of 38.5%, however, raises the possibility that many benign cases could be mistakenly identified as malignant. While the negative predictive value (NPV) was 45.4%, indicating the low reliability of benign classifications, the positive predictive value (PPV) was 79.5%, indicating the chance that the malignant classification was accurate. Moderate diagnostic usefulness for malignancies is indicated by the negative likelihood ratio (NLR) of 0.42 and the positive likelihood ratio (PLR) of 1.36. The total accuracy of 72.0% for both benign and malignant categories demonstrated CDUS's potential as a diagnostic tool while highlighted the necessity of complementary diagnostic techniques to increase sensitivity and specificity.

**Figure 8: Bar diagram showing validity tests of the color Doppler ultrasound diagnosis with histopathological diagnosis for the evaluation of malignant testicular mass**

**Receiver-operator characteristic (ROC) curve of RI for prediction of malignant testicular mass (n=50)):**

Using a receiver-operating characteristic (ROC) curve, results on the effectiveness of the resistivity index (RI) as a diagnostic marker for predicting malignant testicular mass are presented in Table 13 and Figure 8. A cut-off value of ≥0.41 was established for RI. At this threshold, the sensitivity of the test was 100.0%, indicating that the RI correctly identified all cases of malignant testicular mass without missing any. This makes it a highly effective tool for ensuring that no malignant cases are overlooked.

The specificity was 94.9%, reflecting the RI's ability to correctly classify benign tumors and minimize false-positive diagnoses. With a 95% confidence interval between 0.412 and 0.791, the area under the ROC curve (AUROC) was 0.601. While the AUROC suggests moderate diagnostic accuracy, the wide confidence interval implies variability in the predictive power. This analysis underscores the RI's potential as a sensitive and specific marker for malignancy while highlighting the need for further investigation into its overall diagnostic reliability.

**Table 13: Malignant testicular mass prediction using the receiver-operator characteristic (ROC) curve of RI (n=50)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Cut off value | Sensitivity | Specificity | Area under the  ROC curve | 95% Confidence interval (CI) | |
|  |  |  |  |  | Lower  bound | Upper  bound |
| RI | ≥ 0.39 | 92.3 | 83.8 | 0.689 | 0.522 | 0.856 |

|  |
| --- |
|  |
| **Figure 9: The receiver-operator characteristic curve of RI for malignant testicular mass** |

**5. DISCUSSION**

The purpose of this cross-sectional study was to determine and assess the overall diagnostic performance of color Doppler ultrasound in evaluating testicular masses (both benign and malignant) by comparing it to histopathology, the gold standard, and analyzing accuracy, sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio.

After meeting the inclusion and exclusion criteria, 50 patients who were referred to SOMCH's Radiology and Imaging Department between March 2023 and February 2025 were included in the study. Participants in this study were to be between the ages of 4 and 72 years and had a clinically suspected testicular mass. Hydrocele, undescended testis, and inguinoscrotal hernia were not included in the study. The results of the current study were analyzed and compared with those of related earlier publications.

The majority of 19 patients (38%) in this study were in the 31–40 years age range, with a mean age of 34.28±16.64 years. Seven (53.8%) of the benign group's patients were under 30 years old. In contrast, a maximum of 14 patients (37.2%) in the malignant group were between the ages of 31 and 40 years. According to Erol I. (2022), the average age of all patients with testicular masses was 39.47±15.20 years (for benign, it was 48.24±18.16 years, and for malignant, it was 37.63±13.94 years). According to K. Fazal et al. (2022), the average age of testicular tumor patients in the 15–45 years age range was between 30 and 40 years for 174 (54.95%) and 41 to 50 years for 137 (44.05%). According to Erol Ibrahim (2022), patients with benign and malignant testicular tumors had mean ages of 48.24±18.16 and 37.63±13.94 years, respectively. According to Drumadala et al. (2020), the age group of 31 to 40 years old had the highest number of cases (58 cases, or 29%), followed by those aged 21 to 30 years old (42 cases, or 21%) in the 2-72 age range. According to Woodward et al. (2002), the most prevalent cancer in the 15–34 age group was discovered by Rizvi et al. (2011), who discovered 122 individuals between the ages of 13 and 70. The current study is comparable to the studies that were mentioned. Varsamidis et al. (2001) also noted a similar age range, with the authors noting that the range ranged from 18 to 66 years. However, the median age of the patients was 49 years, with a range of 18–81 years, and 37 years, with a range of 16–82 years, according to Lung et al. (2012) and Bilagi et al. (2007). Woodward et al. (2002) also noted a greater mean age, which is higher in the current study. Geographical variances, racial and cultural distinctions, and genetic factors may all have a substantial impact on testicular lesions, as may the higher mean age and age range. It was found that 42.0% of the patients in this present series were single, and more than half (58.0%) were married.

It was shown that almost one-third (36%) of the individuals in this study experienced testicular pain. According to Huang et al. (2024), 30.77% of benign testicular tumors and 15.22% of malignant ones caused pain. In their investigation, Lung et al. (2012) discovered that scrotal pain was present in every patient. About 10.0% of patients report experiencing pain, making it a far less common presenting symptom (Ulbright et al. 1999). Atkinson et al. (1992) and Varsamidis et al. (2001) both noted similar results. Testicular swelling was the most frequent presenting complaint in this study (100%) and fever was only present in 8% of individuals with testicular lesions. For scrotal pathologies, Drumadala et al. (2020) reported a clinical presentation of a combination of symptoms such as pain and swelling in 34% of cases and a combination of pain, swelling, and fever in 4% of cases. M. Necas et al. (2021) observed that among 2910 patients with testicular tumors, there was pain in 21% and swelling in 64% of cases, which is comparable to the current study. The current study found that 28% of patients had elevated pulses, 48% had testicular discomfort, and 100% had testicular swelling on physical examination.

More than two thirds (66%) of the patients in this study had focal testicular lesions, whereas 34% had diffuse ones. Comparable to the current study, the Rizvi et al. (2011) study revealed diffuse involvement in 63.4% of their study participants. The majority of patients in this study (72%) had mixed echogenic heterogeneous lesions, while 28% had homogeneously hypoechoic lesions. Both groups had mixed heterogeneous echogenicity, with the benign group having 11 (84.6%) and the malignant group having 25 (67.6%). Two (15.4%) in the benign group and twelve (13.4%) in the malignant group were homogeneously hypoechoic. 32 (39%) of the malignant testicular masses were heterogeneous, according to Erol İ (2022). According to M. Necas et al. (2021), mixed heterogenous echogenicity was found in 38% of non-seminomatous germ cell cancers and 47% of mixed germ cell tumors, while homogeneous hypoechogenicity was found in 45% of seminomatous germ cell tumors. According to McDonald et al. (2012), 50 (89.2%) of seminoma patients and 20 (38.4%) of non-seminoma cases had homogeneously hypoechoic tumors, while 2 (3.6%) of seminoma cases and 30 (57.7%) of non-seminoma cases had mixed heterogenous echogenicity because of the presence of calcification and cysts. Lesions were isoechoic 6.25%, hypoechoic 25.0%, and had mixed echogenicity 68.75%, according to Lung et al. (2012). The results of the mentioned investigation are comparable to the findings of the current study.

There were no cases of testicular lesions measuring less than or equal to 1.5 cm in the current investigation; all patients (100%) had lesions larger than 1.5 cm. According to a systematic review by Henriques et al. (2022), testicular masses with a mean size of less than 2.5 cm were more frequently benign (55.77%) than malignant. The mean size of malignant lesions was found to be substantially larger than that of benign lesions (5.4 vs. 3.5 cm) by Erol İ. (2022). The mean size of benign and malignant testicular tumors was 0.9 cm and 1.4 cm, respectively, according to Schwarze et al. (2020). The mean diameter of benign versus malignant testicular lesions was 3.1 cm versus 5.4 cm (P < 0.001), according to a 2019 study by Song et al. McDonald et al. (2012) discovered that the mean tumor size in 56 cases of seminoma was 3.68 cm, while in 52 cases of non-seminoma, it was 3.28 cm. 38.5% of smaller lesions are benign with a size cutoff of 18.5 mm, compared to 2% above this threshold, according to Shilo et al. (2012). Horstman et al. (1992) identified 21 (95%) testicular tumors larger than 1.6 cm in a survey of 28 patients with surgically proven testicular tumors.

While 46.2% of benign and 10.8% of malignant masses in our study had well-defined margins, the majority of malignant masses (89.2%) had irregular or poorly defined margins, as did 53.8% of benign masses. According to Henriques et al. (2022), malignant tumors had higher irregular margins (18 out of 26, 69.2%). Comparable to the current study, Isidori et al. (2014) discovered that 64% of benign and 50% of malignant tumors had well-defined margins, while 36% of benign and 50% of malignant tumors had irregular margins. According to McDonald et al. (2012), in 21.1% of non-seminoma instances and 30.3% of seminoma cases, the margin was well defined.

About half of the patients in the current study - 24, or 64.9% had grade 2 (moderate) vascularity in the malignant group, and eight, or 61.5%, in the benign group. Twelve (32.4%) of the malignant group and one (7.7%) of the benign group had grade 3 (high) vascularity. One (2.7%) case of the malignant group and four (30.8%) cases of the benign group had grade 1 (minimal) vascularity. Hypervascularization was found in 12 (70%) benign and 62 (76%) malignant testicular lesions by Erol İ. (2022). In their analysis of 101 testicular masses, Henriques et al. (2022) discovered internal vascularization on color Doppler US often in both benign (47.5%) and malignant (52.5%) tumors. Hypervascularization was shown to be more common in malignant tumors than in benign ones (83% of malignant versus 62% of benign tumors), according to Schwarze et al. (2020). 181 (73.3%) malignant and 25 (32.1%) benign testicular tumors had high vascularity, whereas 46 (18.6%) malignant and 17 (21.8%) benign testicular tumors had moderate vascularity, according to Song et al. (2019). According to Rizvi et al. (2011), all of the participants had increased vascularity, and 16 and 6 patients, respectively, were diagnosed with testicular cancer and orchitis. The current study's findings are comparable to those of mentioned studies.

The largest percentage of the malignant and benign groups in the current study (66%) had a crisscross or irregular chaotic vascular pattern, 30% had a non-branching linear pattern, and just 4% had a regular branching linear pattern, albeit this was only seen in benign masses. In the majority of malignant testicular tumors, Huang & Sidhu (2012) reported that the usual linear branching vascular pattern is distorted, leading to a random or crisscross vascular pattern. 95% of the primary testicular tumors had a crisscross vascular pattern, according to Barnes and Bushby (2002).

More than half (76%) of the participants in this study showed elevated PSV (peak systolic velocity), and 72% had elevated EDV (end diastolic velocity). Additionally, our analysis revealed elevated PSV in 73% of benign masses and 81.1% of malignant masses. The current investigation revealed that 12 (92.3%) of the benign group and 35 (94.6%) of the malignant group had RI (Resistivity index) ≥0.41. Three individuals (6%) had RI <0.41. Horstman et al. (1992) reported elevated PSV (mean 19.8 cm/s) in testicular malignancies. Additionally, Varsamidis et al. (2001) found that patients with testicular tumors had higher PSV and EDV, measuring 29.74±4.95 cm/s and 11.87±2.05 cm/s, respectively. The Varsamidis et al. (2001) investigation found no discernible variance in the RI.

The ROC curve for RI was examined in this work, and the cutoff value for malignant testicular mass was ≥0.41. For RI, the area under the curve ranged from 0.412 to 0.791, with a value of 0.601. A cut-off value of ≥0.41 was established for RI. With a sensitivity of 100.0% at this cutoff, the RI accurately detected every instance of malignant testicular tumors without missing any. The RI's capacity to accurately categorize benign tumors and reduce false-positive diagnoses was demonstrated by its 94.9% specificity.

Of the 50 cases in this investigation, 39 (78%) had color Doppler ultrasound-diagnosed malignant testicular tumors, and 31 (83.8%) had histological confirmation. A histological diagnosis was made for 5 (38.5%) of the 11 cases of benign testicular tumors that were identified by color Doppler ultrasound. Of the 124 cases in Huang et al. (2024) study, 46 (37.1%) had color Doppler ultrasound-diagnosed malignant testicular tumors, and 41 (89.1%) had histological confirmation. A histological diagnosis was made for 37 (47.4%) of the 78 cases of benign testicular tumors that were identified by color Doppler ultrasound. According to Rizvi et al. (2011), two cases who were misdiagnosed as having orchitis ended up having seminoma, while 14 out of 16 patients had seminoma. On CDUS, 6 of 22 cases of testicular mass with a clinical diagnosis were classified as orchitis.  Twenty patients who had orchiectomy for testicular torsion had two cases of cancer (one seminoma and one mixed GCT), according to Uguz et al. (2015).

According to the histological diagnosis, nearly three-fourths of the patients in this study - 37, or 74% had malignant testicular masses, whereas 13 patients, or 26%, had benign ones. Huang et al. (2024) found in a retrospective analysis that 30 (39.5%) of the tumors were benign and 46 (60.5%) were malignant, as confirmed by histology. According to Erol İ (2022), histology revealed that 81 (82.7%) of the tumors were malignant and 17 (17.3%) were benign. Henriques et al. (2022) conducted a systematic review of 57 studies and discovered that, among incidentally identified small testicular masses, the average percentage of benign tumors was 58.31% (compared to 41.69% malignant) based on histological examination. In their study cohort, Song et al. (2019) identified 247 (76.0%) patients with malignant testicular tumors and 78 (24.0%) patients with benign ones. According to Isidori et al. (2014), out of 115 patients, 44 had histopathologically detected malignant tumors, 42 benign tumors, and 29 nonneoplastic lesions.

Regarding the final clinical Diagnosis in this current study, 18(36%) patients were found with GCT-seminoma followed by mixed GCT and non-Hodgkin’s Lymphoma (NHL), each comprising 6(12.0%) cases. Abscesses were noted in 4(8.0%) cases. Other germ cell tumors, such as GCT-yolk sac tumor and mature teratoma, each represent 3(6.0%) cases. Less commonly observed conditions include immature teratoma, NSGCT- embryonal carcinoma, testicular torsion and TB orchitis, each contributing 2(4.0%) cases. Rare conditions like epididymo-orchitis and sex cord stromal tumor account only 1(2.0%) of cases each. Huang et al. (2024) conducted a retrospective study of 76 cases with focal testicular lesions over a ten-year period. Their findings included the following: seminoma 29, mixed germ cell tumors 12, lymphoma 2, burnt-out tumor 1, metastasis (prostate primary) 1, sarcoma 1 , Leydig cell tumor with low malignant potential 16, Sertoli cell tumor 1, global testicular infarct 6, abscess 2, adenomatoid tumor (intratesticular) 2, epidermoid cyst 2, calcified haematoma 1, lipomatous hamartoma 1, inflammatory reaction 1, lobular capillary haemangioma 1, mature teratoma 2, sarcoidosis 1, TB 1 – in histopathological analysis. Seminoma 31(31%), NSGCT 10(10%), mixed GCT 33(33%), NGCT 5(5%), lymphoma 5(5%), paratesticular tumor 1(1%), and others 13(13%) were reported by Erol İ. (2022). According to Schwarze et al. (2020), among malignant tumors (n=36), they discovered seminoma 21 (58%), mixed GCT 4 (11%), embryonal carcinoma 3 (8%), hematologic malignancy 3 (8%), teratoma 2 (6%), metastasis 2 (6%), and yolk sac tumor 1 (3%); among benign tumors (n=13), they discovered Leydig cell tumor 7 (54%), Sertoli cell tumor 2 (15%), cyst 1 (8%), adenomatoid tumor 1 (8%), fibroid pseudotumor 1 (8%), and epidermoid cyst 1 (8%).

Song et al. (2019) found that, of 325 consecutive patients who had either testicular preserving surgery or an orchiectomy, 93 masses (28.6%) were seminoma, 64 tumors (19.7%) were tumors of more than one histologic type (mixed forms), 53 tumors (16.3%) were teratomas, 26 tumors (8.0%) were lymphoid and hematopoietic tumors, 22 tumors (6.8%) were sex cord-gonadal stromal tumors, 15 (4.6%) were embryonal carcinoma, 12 (3.7%) had tuberculosis, 40 (12.3%) were other types (4 adenocarcinoma, 4 metastatic solid tumor, 3 granulomatous orchitis, 3 squamous cell carcinoma, 3 gonadoblastoma, 2 inflammatory pseudotumor, 2 sperm granuloma, 1 epidermal cyst, 1 adenomatoid tumor, 1 inflammatory myofibroblastoma, 1 liposarcoma, and 8 unclassified malignant tumors). Among 115 patients with nonpalpable testicular lesions, Isidori et al. (2014) discovered 32 cases of pure seminoma, 2 cases of anaplastic seminoma, lymphoma 1, embryonal carcinoma 3, immature teratoma 1, mixed germ cell tumor 3, Leydig cell tumor 21, Sertoli cell tumor 4, epidermoid cyst 5, adenomatoid tumor 1, nonneoplastic lesions 29, segmental infarct 3, abscess 1, and TB 1.

By determining the sensitivity 83.8%, specificity 38.5%, accuracy 72.0%, positive predictive value 79.5%, negative predictive value 45.4%, positive likelihood ratio 1.36, and negative likelihood ratio 0.42 for malignant testicular masses, this study demonstrated the validity of color Doppler ultrasound. Various studies showed comparable results. According to Huang et al.'s (2024) retrospective study, the sensitivity, specificity, PPV, NPV, and accuracy of CDUS were 89.1%, 47.4%, 50%, 88.1%, and 62.9%, respectively, for assessing focal testicular abnormalities. For the diagnosis of testicular cancer, Fazal et al. (2022) discovered that CDUS showed sensitivity (88.8%), specificity (78.1%), positive predictive values (81.1%), negative predictive values (86.8%), and diagnostic accuracy (83.6%). According to Naz et al. (2018), CDUS had an overall diagnostic accuracy of 77.0%, a sensitivity of 87%, a specificity of 67.6%, a PPV of 71.6%, an NPV of 84.7%, and a specificity of 67.6% in the diagnosis of testicular mass. Isidori et al. (2014) found that internal vascularization, a color Doppler measure, had a sensitivity of 95.4% and a specificity of 50.7% for distinguishing malignant from benign tumors. According to Rizvi et al. (2011), CDUS had a 66.7% specificity and an 87.5% sensitivity for detecting testicular neoplasms. In detecting testicular neoplasms presenting with acute scrotal pain, Varsamidis et al. (2001) discovered that CDUS had an accuracy of 83.3%, sensitivity of 81.8%, and specificity of 85.7%. Given that both benign and malignant tumors had moderate vascularity, the degree of vascularity's moderate sensitivity and specificity may have led to the overlap in scores between the two types.

When orchitis is present, the testes can be hypervascular, which may hinder interpretation. The literature has reported cases in which the initial ultrasound was unable to differentiate between an orchitis and a tumor because the patient had an enlarged, heterogeneous, hypervascular testis (Vaidyanathan et al., 2008). One sign of genitourinary tuberculosis is tuberculous epididymo-orchitis, which can also mimic as a testicular tumor (Badmos, K., 2012).

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**6. CONCLUSION**

One popular diagnostic technique that is widely used globally is color Doppler ultrasound. With histology as the gold standard, this study aimed to determine the role of color Doppler ultrasound in evaluating testicular masses (both benign and malignant). It may be inferred from the performance of color Doppler ultrasound that this technique has strong ability for detecting testicular masses as reflected by its calculated sensitivity and positive predictive value (PPV). However, CDUS has not been found to be more helpful than anticipated for differentiating between benign and malignant testicular tumors as depicted by low specificity and negative predictive value (NPV). Therefore, even while CDUS cannot offer a conclusive diagnosis, it can substantially direct the decision-making process with it’s moderate diagnostic utility.

**7. LIMITATIONS**

1. There were just 50 cases in our sample. Our dataset only contains one case of several tumor types because of the rarity of some tumor types.
2. Study population was chosen from a single institution.
3. Samples were taken by single ultrasound machine PHILIPS Affinity Healthcare 30 with 7.5 to 10MHz probe it will be better if there were more high resolution ultrasound machine available.
4. Tumors always result in architectural deformation of the testis, which makes it challenging to classify color Doppler features.
5. 5. Color Doppler is difficult to quantify due to its qualitative nature.
6. Evaluation became problematic in certain patients due to large testicular tumor.
7. Pulsatility Index (PI) and Mean Velocity (MV) were not studied.

**8. RECOMMENDATION**

It is still challenging to differentiate between testicular masses from CDUS. This study demonstrated that it was difficult to distinguish between benign and malignant testicular tumors using color Doppler ultrasound and different characteristic parameters. To determine precise parameters and cut-off values that will enable us to distinguish between benign and malignant testicular masses with ease, we are suggesting that study can be conducted using a high-resolution ultrasound machine, elastography, and contrast-enhanced color Doppler imaging - as a prospective research direction.

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