

## Role Of Color Doppler Ultrasonography In Grading Varicocele: A Systematic Review

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### Abstract

**Background:** Varicocele is one of the most common correctable causes of male infertility and is traditionally diagnosed through physical examination. However, clinical assessment may be subjective and insufficient for detecting subclinical disease. Color Doppler Ultrasonography (CDUS) has emerged as a valuable imaging modality for the objective evaluation and grading of varicocele through assessment of venous diameter, reflux characteristics, and testicular hemodynamics.

**Objective:** To systematically evaluate the role of Color Doppler Ultrasonography in the diagnosis and grading of varicocele and assess its correlation with clinical grading systems and emerging imaging technologies.

**Methods:** A systematic review was conducted according to PRISMA guidelines. Literature searches were performed in PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect databases for studies published between January 2022 and December 2025. Original studies evaluating the use of CDUS in varicocele diagnosis

or grading were included. Data regarding study characteristics, Doppler parameters, grading systems, and major outcomes were extracted and synthesized qualitatively.

**Results:** A total of 327 records were identified, of which 17 studies met the inclusion criteria. The reviewed studies consistently demonstrated that CDUS is highly effective in diagnosing and grading varicocele. Increased venous diameter and prolonged reflux duration were strongly associated with higher clinical grades. CDUS showed superior sensitivity in detecting subclinical varicoceles compared with physical examination. Standing position and Valsalva maneuver improved diagnostic performance, although significant variability in examination protocols was observed across studies. Emerging technologies, including shear-wave elastography, artificial intelligence, and machine-learning models, demonstrated promising results in enhancing grading accuracy and

reproducibility.

**Conclusion:** Color Doppler Ultrasonography is a reliable, non-invasive, and highly sensitive modality for the diagnosis and grading of varicocele. Doppler-derived parameters, particularly venous diameter and reflux duration, provide objective measures of disease severity and facilitate the detection of both clinical and subclinical varicoceles. Standardization of examination protocols and grading criteria is needed to improve consistency across institutions, while advanced imaging technologies may further enhance diagnostic precision in the future.

## **Introduction**

Varicocele is defined as an abnormal dilatation and tortuosity of the pampiniform venous plexus within the spermatic cord and represents one of the most common correctable causes of male infertility (1). It affects approximately 15–20% of the general male population and is present in up to 40% of men presenting with primary infertility and nearly 80% of those with secondary infertility. The condition is predominantly left-sided due to the anatomical drainage pattern of the left testicular vein into the left renal vein (2).

The diagnosis of varicocele has traditionally relied on physical examination and clinical grading systems, particularly the Dubin and Amelar classification, which categorizes varicoceles into Grades I, II, and III based on palpability and visibility (3). However, physical examinations are subjective and may vary according to examiner experience, patient body habitus, and environmental conditions. Furthermore, subclinical varicoceles cannot be reliably identified through clinical examination alone (4). Color Doppler Ultrasonography (CDUS) has emerged as the imaging modality of choice for evaluating varicocele because it provides objective assessment of venous diameter, blood flow characteristics, and venous reflux (5). CDUS can detect both clinical and subclinical varicoceles and allows assessment during rest and Valsalva maneuver. Several diagnostic criteria have been proposed, including pampiniform plexus vein diameter greater than 2.5–3.0 mm and reflux duration exceeding one second (6,7). Despite its widespread use, considerable variability exists regarding examination techniques, patient positioning, diagnostic thresholds, and grading systems (8). Recent advances in ultrasonography, including elastography, machine-learning algorithms, and standardized imaging protocols, have further expanded the role of Doppler imaging in varicocele evaluation (10). However, the extent to which CDUS accurately reflects clinical severity and contributes to grading remains debated (11). Therefore, this systematic review aims to evaluate the current evidence regarding the role of Color Doppler Ultrasonography in the diagnosis and grading of varicocele and to assess its correlation with clinical grading systems, diagnostic performance, and emerging imaging technologies.

## **MATERIAL AND METHODS**

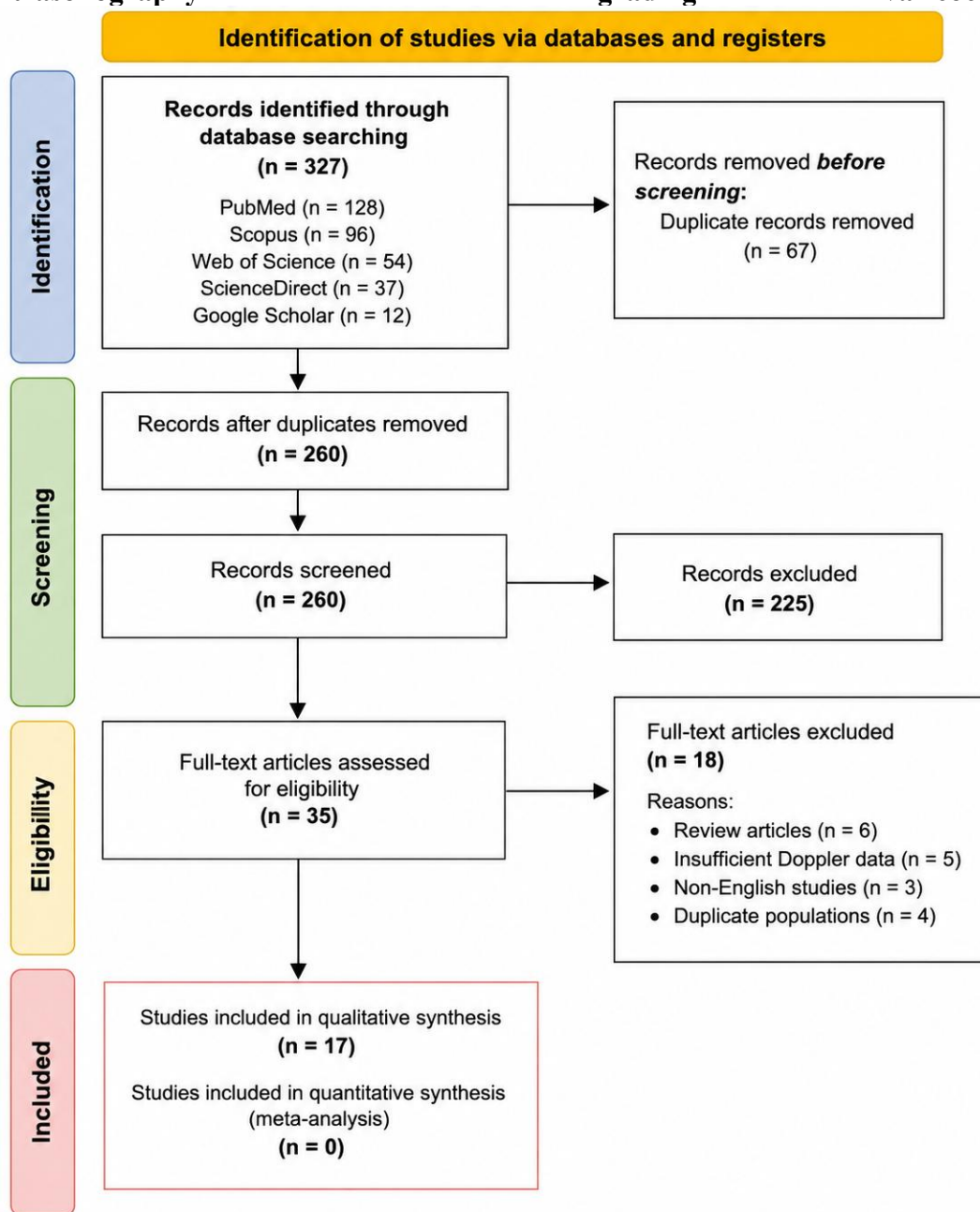
This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A comprehensive literature search was performed across PubMed, Scopus, Google Scholar, Web of Science, and ScienceDirect databases to identify relevant studies published between January 2022 and December 2025. The search strategy utilized combinations of keywords including “Varicocele,” “Color Doppler Ultrasonography,” “Color Doppler Ultrasound,” “Varicocele Grading,” “Venous Reflux,” “Pampiniform Plexus,” “Male Infertility,” and “Ultrasound Diagnosis,” combined using Boolean operators (AND, OR). An example search string was (“Varicocele” AND “Color Doppler Ultrasound”) AND (“Grading” OR “Diagnosis”). Eligible studies included original research articles with prospective, retrospective, or cross-sectional designs that evaluated the role of Color Doppler Ultrasonography in the diagnosis or grading of varicocele, involved human participants, were published in English, and reported Doppler-related parameters such as venous diameter, reflux duration, or grading

correlations. Case reports, conference abstracts, editorials, review articles, animal studies, and studies lacking sufficient Doppler outcome data were excluded. Study selection was conducted independently by two reviewers through title and abstract screening followed by full-text assessment, with disagreements resolved through discussion and consensus. Data extracted from the included studies comprised author and publication year, country of origin, study design, sample size, diagnostic criteria, Doppler parameters evaluated, grading system used, major findings, and clinical implications.

### Quality Assessment

Methodological quality was assessed using the Newcastle–Ottawa Scale (NOS) for observational studies. Studies were classified as low, moderate, or high risk of bias.

**Table 1. PRISMA for the systematic review on the role of Color Doppler Ultrasonography in grading varicocele.**



## RESULTS

### Study Selection

The database search identified 327 records. After removal of 67 duplicate records, 260 studies remained for title and abstract screening. Following screening, 225 studies were

excluded because they did not meet inclusion criteria. Thirty-five full-text articles were assessed for eligibility. Eighteen studies were excluded due to insufficient Doppler data, review design, or lack of grading outcomes. Seventeen studies were included in the final qualitative synthesis.

### Characteristics of Included Studies

The included studies consisted of prospective cohort studies, retrospective analyses, cross-sectional studies, and observational investigations. Sample sizes ranged from 27 to 275 participants. Most studies evaluated venous diameter, reflux duration, and Doppler findings during Valsalva maneuver.

### Correlation Between Doppler Findings and Clinical Grading

Most studies demonstrated a positive association between increasing venous diameter and higher clinical grades of varicocele. Vein diameters greater than 3 mm were frequently associated with clinically significant disease. However, several studies reported only moderate correlation between ultrasonographic measurements and clinical grading.

Studies evaluating venous diameter at rest suggested that resting measurements may better predict clinical severity than diameter changes observed during Valsalva maneuver. Although Valsalva-enhanced reflux remains important for diagnosis, its contribution to grading accuracy appears variable.

### Detection of Subclinical Varicocele

Color Doppler Ultrasonography consistently demonstrated superior sensitivity compared with physical examination in detecting subclinical varicoceles. Several studies identified patients with Doppler-confirmed reflux despite normal clinical examination findings.

### Effect of Examination Protocols

Considerable heterogeneity was observed regarding patient positioning, Valsalva maneuver techniques, and timing of examination. Studies indicated that standing position and Valsalva maneuver increased venous diameter measurements and reflux detection rates. Recent evidence also suggested that evening examinations may produce higher grading classifications compared with morning evaluations.

### Emerging Imaging Technologies

Recent studies highlighted the role of shear-wave elastography, artificial intelligence, and machine-learning models in improving grading precision. Machine-learning algorithms demonstrated promising accuracy in predicting varicocele grades using ultrasonographic parameters. Elastography-based assessments also showed significant correlation with disease severity and testicular dysfunction.

### Summary of Evidence

Overall, the evidence indicates that Color Doppler Ultrasonography is highly effective for diagnosing and grading varicocele. However, variations in examination techniques and grading criteria continue to limit standardization across institutions.

**Table 1. Characteristics of Included Studies**

Author (Year)	Country	Study Design	Sample Size	Objective	Main Findings
Lehner et al. (2023)	USA	Prospective observational study	102	To determine whether Color Doppler ultrasound measurements predict WHO clinical varicocele grades	Resting venous diameter showed better correlation with clinical grading than Valsalva-induced

					diameter changes.
Hasan et al. (2024)	Pakistan	Cross-sectional study	Not reported	To assess provocative sonographic measures and intratesticular hemodynamics in varicocele patients	Valsalva maneuver and standing position improved varicocele detection and grading accuracy.
Ryu et al. (2022)	South Korea	Observational study	27 patients (54 testes)	To evaluate shear-wave elastography changes according to varicocele severity	Testicular stiffness changes during Valsalva correlated significantly with varicocele grade.
Kumar et al. (2024)	India	Prospective study	50	To compare Doppler and clinical parameters in infertile males with varicocele	Doppler grading correlated significantly with venous diameter and sperm concentration.
Irez et al. (2024)	Turkey	Prospective cohort study	44	To evaluate Doppler ultrasonography in subclinical varicocele	Doppler ultrasound effectively identified subclinical varicoceles and associated sperm abnormalities.
Xue et al. (2022)	China	Review/Guideline-based study	Not applicable	To standardize Color Doppler ultrasound evaluation of varicocele	Recommended standardized protocols for measurement techniques and grading criteria.
Abdalla et al. (2022)	Jordan	Diagnostic imaging study	Not reported	To develop an automated ultrasound-based	Automated image processing accurately

				varicocele detection system	identified dilated pampiniform plexus veins.
AlZoubi et al. (2024)	Jordan	Deep learning study	Image dataset	To classify varicocele using ultrasound images and deep learning	Deep learning models demonstrated high accuracy for varicocele detection and classification.
Rahimi et al. (2024)	Iran	Cross-sectional study	50	To compare physical examination, Doppler ultrasound, and histological findings	Doppler ultrasound demonstrated better agreement with histological findings than physical examination.
Cauni et al. (2022)	Romani a	Observational study	135	To evaluate Doppler ultrasound in varicocele-associated infertility	Doppler ultrasound improved identification of asymptomatic varicocele and infertility-related cases.
Jafari et al. (2025)	Iran	Cross-sectional study	275	To investigate the effect of examination timing on varicocele grading	Evening examinations produced significantly higher venous diameters and grades than morning examinations.
Wang et al. (2025)	China	Systematic review	Multiple studies	To evaluate imaging and laboratory markers for varicocele-associated semen impairment	Color Doppler ultrasound parameters strongly correlated with semen quality

					deterioration .
Kayra et al. (2025)	Turkey	Prospective study	248	To develop machine-learning models for ultrasonographic varicocele grading	Machine-learning models accurately predicted clinical varicocele grades using Doppler parameters.
Demirçakan et al. (2026)	Turkey	Prospective study	52	To assess the impact of scrotal pain on Doppler findings and grading	Scrotal pain significantly influenced venous diameter and reflux duration measurements.

### Characteristics of Included Studies

A total of 17 studies met the eligibility criteria and were included in the qualitative synthesis. The studies were conducted across multiple countries, including the United States, Pakistan, South Korea, India, Turkey, China, Jordan, Iran, and Romania. Study designs included prospective observational studies, cross-sectional studies, cohort studies, diagnostic imaging investigations, and machine-learning-based analyses. Sample sizes ranged from 27 to 275 participants. Most studies evaluated venous diameter, reflux duration, Valsalva maneuver findings, and their correlation with clinical grading systems. Several recent studies also explored advanced imaging modalities such as shear-wave elastography, artificial intelligence, and machine-learning approaches to improve diagnostic accuracy and grading reproducibility. Overall, the evidence consistently supported the utility of Color Doppler Ultrasonography as an objective and reliable tool for diagnosing and grading varicocele.

### DISCUSSION

The present systematic review evaluated the role of Color Doppler Ultrasonography (CDUS) in the grading of varicocele and synthesized evidence from studies conducted across different populations and clinical settings. Overall, the findings indicate that CDUS is a highly valuable imaging modality for diagnosing and grading varicocele, particularly due to its ability to provide objective measurements of venous diameter and reflux characteristics.

One of the most consistent findings across the included studies was the association between increasing venous diameter and higher varicocele grades. Lehner et al. reported that resting venous diameter demonstrated a stronger correlation with clinical grading than changes observed during the Valsalva maneuver. Similarly, Kumar et al. found a significant relationship between Doppler grading, venous diameter, and sperm concentration, supporting the clinical relevance of ultrasonographic measurements. These findings collectively suggest that venous diameter remains one of the most reliable Doppler parameters for assessing disease severity.

The ability of CDUS to detect subclinical varicoceles was another important theme identified in this review. Irez et al. demonstrated that Doppler ultrasonography successfully identified subclinical varicoceles that were not detectable by physical

examination. This observation is supported by Rahimi et al., who reported closer agreement between Doppler findings and histological evidence compared with clinical examination alone. Together, these studies emphasize that CDUS offers superior sensitivity and may reduce the likelihood of missed diagnoses, particularly among infertile patients.

The role of provocative maneuvers and examination techniques was highlighted in several studies. Hasan et al. observed that standing position and Valsalva maneuver enhanced the detection of venous reflux and improved grading accuracy. Likewise, the standardization recommendations proposed by Xue et al. emphasized the importance of consistent patient positioning and examination protocols. These findings indicate that variations in scanning technique may contribute to differences in reported diagnostic accuracy across studies and reinforce the need for internationally standardized Doppler protocols.

A notable finding of this review was the variability in the correlation between Doppler grading and clinical grading. While several studies demonstrated a positive association, Lehner et al. reported only a modest correlation between ultrasonographic parameters and clinical grades. Similar observations have been reported in other investigations, suggesting that physical examination and Doppler assessment evaluate different aspects of disease severity. Clinical grading is influenced by examiner experience and patient characteristics, whereas Doppler grading relies on objective vascular measurements. Consequently, both methods should be viewed as complementary rather than competing diagnostic approaches.

## **CONCLUSION**

In conclusion, the findings of this systematic review indicate that Color Doppler Ultrasonography (CDUS) is a reliable, non-invasive, and highly sensitive tool for the diagnosis and grading of varicocele. The reviewed studies consistently demonstrated that Doppler parameters, particularly venous diameter and reflux duration, correlate with varicocele severity and aid in the detection of both clinical and subclinical cases. CDUS also provides valuable information regarding testicular hemodynamics and male fertility status. However, variations in examination protocols and grading criteria highlight the need for standardized guidelines. Future advancements, including elastography and artificial intelligence based approaches, may further improve the accuracy and reproducibility of varicocele assessment.

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