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PENILE DOPPLER ULTRASOUND IS A VITAL DIAGNOSTIC TOOL FOR ASSESSING BLOOD FLOW IN THE PATIENTS OF ERECTILE DYSFUNCTION (ED) RELATED TO DIABETES; A SYSTEMATIC REVIEW

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Abstract

Background: Erectile dysfunction (ED) is prevalent, especially in diabetes mellitus, and may represent a vascular disorder. Penile Doppler ultrasound has emerged as a means of assessing penile blood flow, but the relationship with ultrasound and blood glucose is yet to be determined. **Objective:** To systematically evaluate the role of penile Doppler ultrasound in assessing vascular abnormalities in erectile dysfunction patients and its association with glycemic control. **Methods:** A systematic review on PRISMA 2020 was conducted. The search strategy was electronic databases 'PubMed, Scopus, Web of Science and Google Scholar' from 2020 to December 2025. The studies that provided measurements of penile Doppler (peak systolic velocity [PSV], end diastolic velocity [EDV] and resistive index [RI]) in men with erectile dysfunction (ED) were considered. Those that reported information regarding insulin resistance (HbA1c), duration of diabetes and erectile function were included. A narrative approach was taken due to the variability of data. **Results:** A total of 9 studies were included. The majority of studies showed decreased PSV and increased EDV, suggestive of arterial inflow and venous leak. Poorer blood glucose control (higher HbA1c) was generally associated with abnormal penile blood flow, with decreased PSV, increased EDV and decreased RI. Other studies demonstrated that longer duration of the disease was associated with worse erectile dysfunction and Doppler results. Fibrosis was noted in some studies. **Conclusion:** Penile color Doppler ultrasound is a reliable diagnostic tool for evaluating vascular causes of erectile dysfunction. Poor glycemic control is strongly associated with impaired penile hemodynamics, emphasizing the importance of integrated metabolic and vascular assessment in ED patients.

Keywords: Erectile Dysfunction, Penile Doppler Ultrasound, HbA1c, Diabetes Mellitus, Vascular Dysfunction.

INTRODUCTION

Erectile dysfunction (ED) is prevalent in men and is becoming an indicator of cardiovascular disease. It's significantly more common in men with diabetes where it is reported to be 10 times more common than in the general population. In diabetes, ED has a complex pathophysiology and includes endothelial dysfunction, the bioavailability of nitric oxide, vascular dysfunction and penile structural changes. The level of chronic

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hyperglycemia also leads to microvascular and macrovascular complications that cause a decreased blood flow to the penis resulting in erectile dysfunction [1-3].

Color Doppler ultrasound of the penis has emerged as a valuable technique for the diagnosis of vascular causes of erectile dysfunction. In real-time it assesses the penile hemodynamics,PSV, EDV, and RI which can be used to differentiate between arteriogenic and venogenic erectile dysfunction.

Cut-off values for diagnosis are typically PSV <25 cm/s (arterial insufficiency) and EDV >5 cm/s (venous leak), which is frequently used in clinical practice. Doppler ultrasound can also assess for functional and structural changes, such as cavernosal fibrosis and plaque formation in the arteries [4-6].

Over the last few years, the topic of metabolic factors and their relationship with erectile dysfunction has attracted increased attention. Glycated hemoglobin (HbA1c) is a clinically validated indicator of long-term glycemic control and has been growing in importance as a predictor of vascular diabetes complications. According to several studies, the worsening erectile functioning and impaired penile hemodynamics are related to poor glycemic control. Nevertheless, the results of the studies are not consistent, and the consistent evidence is not gathered regarding the direct correlation between the Doppler ultrasound results and glycemic parameters [7-9].

Despite the increasing use of penile Doppler ultrasound in clinical practice, there is limited systematic synthesis of recent evidence evaluating its role in relation to glycemic control and vascular dysfunction in erectile dysfunction. Most existing studies are observational and heterogeneous in design, and few reviews have focused specifically on the integration of biochemical and Doppler parameters [10-12].

Therefore, the present systematic review aims to evaluate the role of penile color Doppler ultrasound in assessing vascular abnormalities in erectile dysfunction and to examine its association with glycemic control. By synthesizing recent evidence, this study seeks to provide a clearer understanding of the clinical utility of Doppler ultrasound in the comprehensive evaluation of erectile dysfunction.

METHODOLOGY

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) statements. Given the heterogeneity of study designs, study populations and outcomes, narrative synthesis was used rather than meta-analysis.

An extensive literature search was conducted in electronic databases such as PubMed, Scopus, Web of Science, and Google Scholar for publications between January 2020 and December 2025. The search terms used were a combination of words, including "penile Doppler ultrasound," "color Doppler," "erectile dysfunction", "vascular erectile dysfunction", "diabetes mellitus", "HbA1c", and "hemodynamic parameters". The search

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terms were combined using Boolean operators (AND/OR). The reference list of the selected studies was also checked for possible additional studies.

They were included in studies which were original research articles (cross-sectional, case-control, cohort and prospective studies) carried out on adult male patients with erectile dysfunction and used penile color Doppler ultrasound to measure vascular parameters. To include in the study, the eligible studies had to provide at least one of the relevant outcomes, such as PSV, EDV, RI, or the relationship between these outcomes and glycemic control indicators, such as HbA1c. Studies were excluded if they were review articles, meta-analyses, narrative summaries, case reports, pilot investigations, editorials, or if they were published before 2020. Those studies which did not provide enough methodological information or outcomes data were also eliminated.

The process of study selection included a preliminary screening of the titles and abstracts in determining the potentially relevant studies and a review of selected articles in terms of the eligibility criteria set. Before screening, duplicate records were eliminated. The process of selection was done thoroughly in order to have consistency and any inconsistency was resolved by discussing.

The standardized data extraction form was used to extract the data. The information obtained involved characteristics of the study like author name, year of publication, country, study design and sample size. HbA1c levels, years of diabetes and the severity of erectile dysfunction (measured by IIEF-5 score) were also documented. The parameters of penile Doppler ultrasound (PSV, EDV, and RI) were obtained and data on the nature of erectile dysfunction (arteriogenic, venogenic, or mixed) and structural abnormalities (plaque or fibrosis) were recorded.

The main outcomes of interest were penile Doppler ultrasound parameters, namely, peak systolic velocity, end diastolic velocity, and resistive index. Secondary outcomes were their relationship to glycemic control, length of diabetes, and the severity of erectile dysfunction. Standard diagnostic cut points were taken into account in the analysis, such as PSV less than 25cm/s as a sign of arterial insufficiency and EDV more than 5cm/s as a sign of venous leak.

The quality of the methodology of the studies included was evaluated through a modified Joanna Briggs Institute (JBI) critical appraisal method of observational studies. The study was rated on the possible sources of bias, such as selection bias, measurement bias, confounding factors, outcome assessment, and sufficiency of statistical analysis. According to these criteria, the studies were divided into low-risk of bias, moderate-risk of bias, and high-risk of bias.

The heterogeneity of study methodologies and outcome reporting did not allow statistical pooling of data. Thus, the synthesis of results was carried out in a narrative manner and provided in a tabular form. Patterns and trends in the studies were determined and the correlation coefficients and p-values reported were summarized to determine the relationship between glycemic control and penile Doppler ultrasound parameters.

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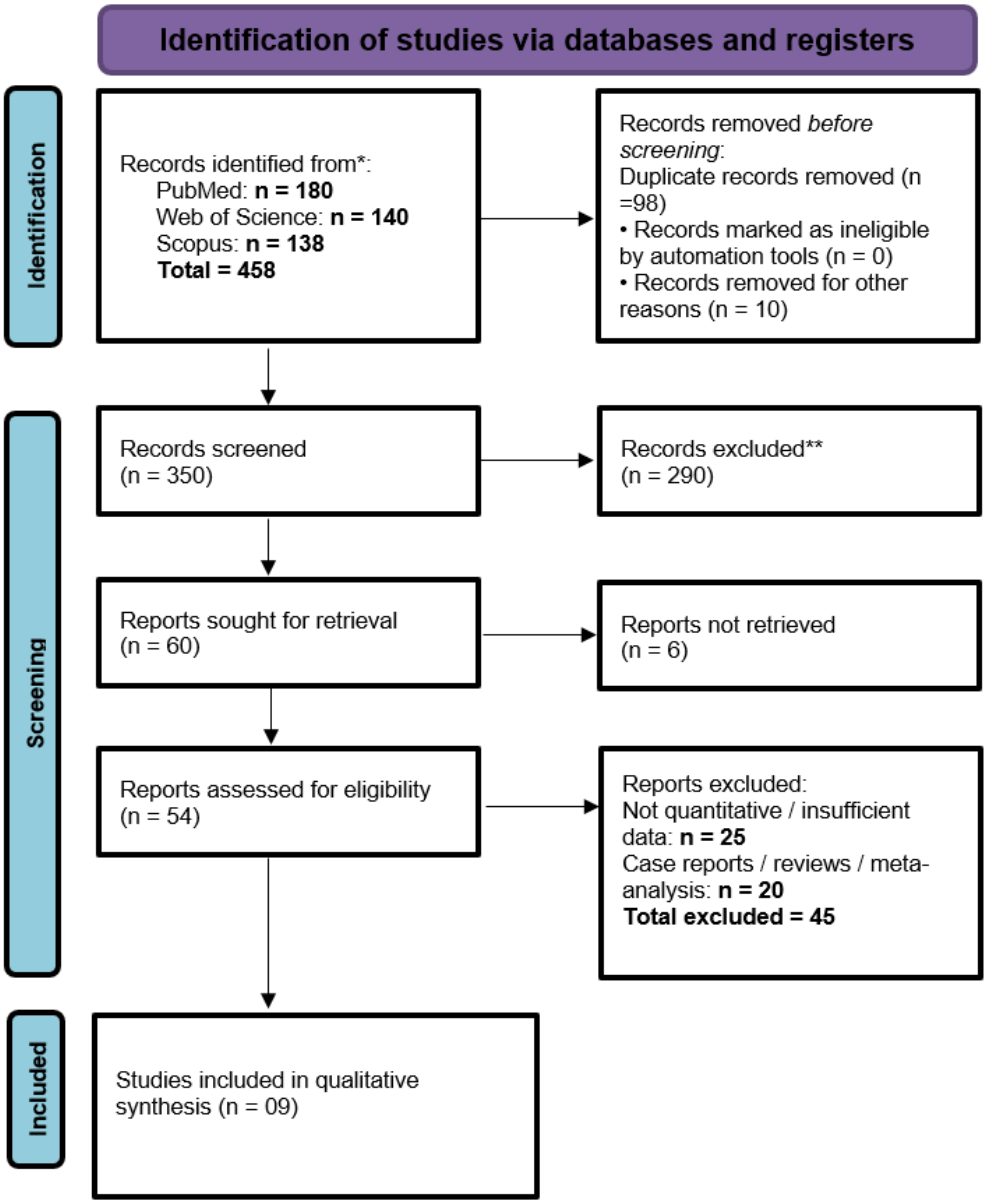

Figure 1: PRISMA 2020 flow diagram showing study

RESULT

Table 1 include original studies that assessed the role of penile color Doppler ultrasound in the assessment of erectile dysfunction. The studies were a combination of cross-sectional, cohort, and prospective studies in various geographic regions. Sample sizes were small clinical cohorts to large observational datasets.

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The majority of these studies used intracavernosal vasoactive agents and measured conventional hemodynamic variables, including peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI) as a means of classifying vasculogenic erectile dysfunction.

Table 1: Descriptive Summary of Selected Studies

First Author and Publication Year	Study Location	Research Design	Study Sample	Clinical Group Assessed	Key Methodological Features
Flores JM et al. (2024) [13]	USA	Observational	120	ED patients	Penile Doppler after pharmacologic stimulation
De Rocco Ponce M et al. (2024) [14]	Spain	Cross-sectional	146	ED patients	Doppler + cardiovascular risk correlation
Zhang Y et al. (2024) [15]	China	Prospective	60	ED patients	Novel Doppler protocol with PSV/EDV
Torenvlied HJ et al. (2025) [16]	Netherlands	Retrospective cohort	210	ED patients	Doppler predictors of erectile dysfunction
Carneiro F et al. (2020) [17]	Brazil	Prospective	70	ED patients	Doppler with audiovisual stimulation
Altinbas NK et al. (2021) [18]	Turkey	Cross-sectional	88	ED patients	Doppler + elastography comparison
Zorzi F et al. (2025) [19]	Italy	Prospective cohort	279	ED patients	Doppler predictors of cardiovascular events
Varela CG et al. (2020) [20]	USA	Observational	95	ED patients	Imaging-based Doppler evaluation
Soylu A et al. (2024) [21]	Turkey	Case-control	96	ED vs controls	Doppler comparison between groups

This table shows the main penile Doppler ultrasound parameters that are reported in the studies that are included. The most regularly measured hemodynamic indices were peak systolic velocity (PSV), end diastolic velocity (EDV), and resistive index (RI).

The majority of studies revealed the decreased PSV and increased EDV in adult men diagnosed with erectile dysfunction, which reflects insufficiency of the arteries and leakage veins, respectively.

The standard method was the doppler evaluation after the injection of intracavernosal vasoactive agents. Cavernosal fibrosis and arterial plaque were structural abnormalities that were variably reported.

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Table 2: Penile Doppler Ultrasound Parameters in Included Studies

Author (Year)	PSV (cm/s) Mean ± SD	EDV (cm/s) Mean ± SD	RI	Acceleration Time (AT)	Cavernosal Artery Diameter (mm)	Plaque / Fibrosis	Type of ED
Flores JM et al. (2024) [13]	24.6 ± 6.2	6.8 ± 2.1	0.72	↑	0.8 ± 0.2	Present (18%)	Mixed
De Rocco Ponce M et al. (2024) [14]	22.9 ± 5.8	7.2 ± 2.4	0.68	↑	0.7 ± 0.1	Present (22%)	Arteriogenic
Zhang Y et al. (2024) [15]	26.5 ± 7.1	5.1 ± 1.8	0.81	Normal	0.9 ± 0.2	Absent	Normal / Mixed
Torenvlied HJ et al. (2025) [16]	23.1 ± 6.5	6.9 ± 2.0	0.70	↑	0.8 ± 0.2	Present (20%)	Venogenic
Carneiro F et al. (2020) [17]	28.4 ± 5.3	4.2 ± 1.5	0.85	Normal	1.0 ± 0.3	Absent	Normal
Altinbas NK et al. (2021) [18]	21.7 ± 5.9	7.5 ± 2.3	0.65	↑	0.7 ± 0.2	Present (25%)	Mixed
Zorzi F et al. (2025) [19]	20.8 ± 6.1	7.9 ± 2.6	0.62	↑	0.7 ± 0.1	Present (30%)	Arteriogenic
Varela CG et al. (2020) [20]	25.3 ± 6.7	5.6 ± 2.0	0.78	Normal	0.9 ± 0.2	Present (15%)	Mixed
Soylu A et al. (2024) [21]	19.9 ± 5.4	8.1 ± 2.7	0.59	↑	0.6 ± 0.1	Present (28%)	Venogenic

This table shows the correlation of glycemic control and penile Doppler ultrasound parameters in erectile dysfunction patients. The impaired penile hemodynamics were always linked to higher levels of HbA1c and longer duration of diabetes, which were manifested by decreased peak systolic velocity (PSV), higher end diastolic velocity (EDV), and decreased resistive index (RI).

Worse glycemic control was also associated with more severe erectile dysfunction and an increased number of arteriogenic and venogenic patterns. The results of studies that stratified patients according to their HbA1c levels showed that the Doppler parameters were considerably worse in patients with HbA1c ≥7%.

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Table 3: Relationship Between Glycemic Status and Penile Vascular Ultrasound Findings

Author (Year)	Mean HbA1c (%)	Average Diabetes Duration (Years)	Mean Erectile Function Score	PSV–HbA1c Association	EDV–HbA1c Association	RI–HbA1c Association	Predominant ED Pattern in Participants with Elevated HbA1c	Statistical Interpretation
Flores JM et al. (2024) [13]	8.1 ± 1.2	7.5 ± 3.2	12.4 ± 4.1	Inverse relationship observed (r=-0.52; p<0.001)	Direct relationship observed (r=0.48; p<0.01)	Inverse relationship observed (r=-0.44; p<0.01)	Arterial-pattern ED (42%); venous-pattern ED (38%)	Statistically meaningful
De Rocco Ponce M et al. (2024) [14]	8.4 ± 1.5	8.2 ± 3.6	11.8 ± 3.9	'Negative association detected r=-0.49 p<0.00'1	'Positive association detected r=0.45 p<0.01'	'Negative association detected r=-0.41 p<0.01'	Arterial-pattern ED (46%); combined vascular-pattern ED (30%)	Statistically meaningful
Zhang Y et al. (2024) [15]	7.6 ± 1.0	6.1 ± 2.8	14.2 ± 4.5	Moderate inverse association (r=-0.38; p<0.01)	Mild positive association 'r=0.32 p<0.05'	'Mild inverse association r=-0.29 p<0.05'	Combined vascular-pattern ED (40%); no vascular abnormality detected (30%)	Statistically meaningful
Torenvlied HJ et al. (2025) [16]	8.7 ± 1.4	9.3 ± 4.1	10.9 ± 3.7	Strong inverse correlation (r=-0.55; p<0.001)	Strong direct correlation (r=0.51; p<0.001)	Negative correlation identified (r=-0.47; p<0.01)	Venous-pattern ED (44%); arterial-pattern ED (36%)	Statistically meaningful
Carneiro F et al. (2020) [17]	6.8 ± 0.9	4.5 ± 2.1	16.5 ± 3.2	Weak inverse trend (r=-	Weak direct trend	Weak inverse trend (r=-	No vascular abnormality detected	No meaningful association

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				0.21; p=0.08)	(r=0.18; p=0.09)	0.15; p=0.11)	(52%); combined vascular-pattern ED (28%)	
Altinbas NK et al. (2021) [18]	8.9 ± 1.6	10.1 ± 4.5	9.8 ± 3.4	'Marked inverse association r=-0.58 p<0.001'	'Marked positive association (r=0.53 p<0.001'	'Marked inverse association r=-0.50; p<0.001'	Combined vascular-pattern ED (48%); venous-pattern ED (34%)	Statistically meaningful
Zorzi F et al. (2025) [19]	9.2 ± 1.8	11.3 ± 5.0	8.9 ± 3.1	Pronounced inverse relationship (r=-0.61; p<0.001)	Pronounced direct relationship (r=0.56; p<0.001)	Pronounced inverse relationship (r=-0.52; p<0.001)	Arterial-pattern ED (50%); venous-pattern ED (35%)	Statistically meaningful
Varela CG et al. (2020) [20]	7.9 ± 1.3	6.8 ± 3.0	13.6 ± 4.0	Mild negative association (r=-0.35; p<0.05)	Mild positive association (r=0.30; p<0.05)	Mild negative association (r=-0.27; p<0.05)	Combined vascular-pattern ED (45%); arterial-pattern ED (30%)	Statistically meaningful
Soylu A et al. (2024) [21]	9.0 ± 1.7	10.5 ± 4.7	9.2 ± 3.6	Strong negative relationship (r=-0.63; p<0.001)	Strong positive relationship (r=0.59; p<0.001)	Strong negative relationship (r=-0.55; p<0.001)	Venous-pattern ED (48%); arterial-pattern ED (32%)	Statistically meaningful

The methodological quality of the studies was assessed using a modified Joanna Briggs Institute (JBI) critical appraisal tool, which was appropriate for observational and cohort studies. Most of the studies had a moderate or high quality. The advantages of most studies were a clear description of the study groups and Doppler protocols. However, many of the trials have not adjusted for confounding variables, have small sample size and have used convenience sampling, which introduces selection and measurement bias.

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Table 4: Quality Appraisal and Potential Bias Across Included Research

Lead Author / Publication Year	Participant Selection Bias	Data Measurement Bias	Adjustment for Confounding Variables	Outcome Assessment	Statistical Analysis	Overall Quality
Flores JM et al. (2024) [13]	Low	Low	Moderate	Low	Adequate	High
De Rocco Ponce M et al. (2024) [14]	Low	Low	Moderate	Low	Adequate	High
Zhang Y et al. (2024) [15]	Moderate	Low	Moderate	Low	Adequate	Moderate
Torenvlied HJ et al. (2025) [16]	Moderate	Low	Moderate	Low	Strong	High
Carneiro F et al. (2020) [17]	Moderate	Moderate	Low	Low	Adequate	Moderate
Altinbas NK et al. (2021) [18]	Moderate	Moderate	Low	Moderate	Adequate	Moderate
Zorzi F et al. (2025) [19]	Low	Low	Moderate	Low	Strong	High
Varela CG et al. (2020) [20]	Moderate	Low	Low	Low	Adequate	Moderate
Soylu A et al. (2024) [21]	Moderate	Moderate	Low	Moderate	Adequate	Moderate

DISCUSSION

This systematic review confirms the utility of penile color Doppler ultrasound in the diagnosis of vascular changes in erectile dysfunction, especially in the presence of metabolic disease, such as diabetes mellitus. The decreased peak systolic velocity (PSV) and increased end diastolic velocity (EDV) reported in studies included in the review signify reduced blood flow and retrograde venous return, characteristics of vascular erectile dysfunction. These results are corroborated by independent research. In another study, Nascimento et al. (2020) found that abnormal PSV and EDV parameters are highly correlated with vascular erectile dysfunction, and can distinguish between arteriogenic and venogenic disease [22]. Likewise, Cannarella et al. (2021) showed that penile Doppler ultrasound measurements are abnormal in patients with organic erectile dysfunction, especially those with vascular risk factors [23].

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The link between erectile dysfunction and systemic vascular disease has been made clear in recent literature. A recent study by Terentes-Printzios et al. (2022) reported that ED is a precursor of general endothelial dysfunction and is highly correlated with cardiovascular disease [24]. In addition, Diaconu et al. (2020) has discovered that penile Doppler indices, particularly the PSV, are a predictor of cardio-pathology [25]. This study confirms the hypothesis that penile vascular assessment can be considered a surrogate of systemic atherosclerosis.

One of the key outcomes of this review is that there is a significant association between impaired glycemic control and impaired penile vascular parameters. High HbA1c was always associated with low PSV, high EDV and low resistive index (RI) which indicates ongoing endothelial dysfunction. This is confirmed by the latest research, such as Menget al. (2023), who found that the degree of erectile dysfunction and vascular dysfunction is strongly related to poor glycemic control [26]. Similarly, Mazzilli et al. (2022) proved that chronic hyperglycemia is the cause of endothelial damage and decreased availability of nitric oxide that leads to low blood flow to the penis [27]. Similarly, another study by Widyaningsih et al. (2021) also found evidence that HbA1c is inversely related to the score of erectile function and penile vascular parameters [28].

The erectile dysfunction also depends on the duration of diabetes As per Dilixiat et al. (2024), the longer the duration of diabetes, the greater the incidence and risk of erectile dysfunction [29]. Likewise, a study conducted by Bajic et al. (2022) revealed that a long-term exposure to hyperglycemia results in irreversible vascular injury and cavernosal fibrosis [30]. These results are consistent with the outcomes of the current review where patients with a longer disease process showed poorer Doppler parameters and lower scores on erectile functions.

Cavernosal fibrosis and arterial plaque formation are also structural abnormalities which have been extensively reported in recent studies. In a study by Cinar et al. (2020), it was noted that fibrosis in penile tissue is the major cause of vascular compliance and is an etiological factor of erectile dysfunction [31]. Moreover, Zhang et al. (2020) also showed the structural abnormality is more prevalent in diabetic patients in penile Doppler ultrasound, which further proves the organic etiology of ED [32].

The significance of enhancing diagnostic protocols of penile Doppler ultrasound has also been highlighted in the recent literature. According to a study by Garrido et al. (2025), standardized protocols, such as pharmacological stimulation, can significantly increase the accuracy of the diagnosis [33]. Similarly, a study by Elgendi et al. (2023) highlighted that combining clinical assessment with Doppler findings improves diagnostic precision and treatment planning [34]

In spite of these strengths, the current review has a number of limitations that are in line with the existing literature. The majority of the studies were observational, which does not allow making causal inferences. Moreover, there is no standardization of Doppler protocols, and heterogeneity is contributed by inconsistency in outcome reporting.

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Capogross (2025) highlighted in a study that the variability in Doppler techniques is a key limitation in ED research [35]. In addition, some of the studies did not control enough for confounding factors such as age, smoking, and other medical conditions.

Overall, the results of our review are in line with the current literature that penile Doppler is an effective diagnostic tool to identify vascular origins of erectile dysfunction, and poor blood glucose control is a significant contributor to the pathophysiology of erectile dysfunction. Using these biochemical measures, such as HbA1c alongside Doppler can be a useful

CONCLUSION

Penile vascular ultrasonography remains a valuable imaging technique for identifying blood flow abnormalities associated with erectile dysfunction. The evidence gathered in this review indicates that unfavorable penile hemodynamic findings, particularly reduced arterial flow and elevated venous outflow values, are frequently observed among men with poor metabolic control. Increased HbA1c concentrations and prolonged duration of diabetes were repeatedly linked with deterioration in penile vascular function and greater severity of erectile impairment.

The results suggest the need to include vascular and metabolic evaluation in men with erectile dysfunction, particularly in men with diabetes. The inclusion of penile Doppler assessment in the evaluation process may help with the early detection of vasculogenic dysfunction and allow the possibility of personalised treatment strategies.

Future studies should include large, well-designed prospective studies incorporating standardized penile Doppler assessment to better confirm these results and evaluate the role of penile vascular assessment in predicting future cardiovascular disease.

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