VER
Vascular & Endovascular Review

Diagnostic Accuracy of Ultrasound in Vasculitis - A Systematic Review and Meta- analysis

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ABSTRACT

Background: Vasculitis encompasses inflammatory disorders of blood vessels where early recognition is vital to prevent complications. Tissue biopsy, the traditional diagnostic standard, is invasive and subject to sampling error. Ultrasound has emerged as a non-invasive alternative, but interpretation is challenged by variability in protocols, operator expertise, and treatment effects.

Objectives: To systematically review and meta-analyze the diagnostic accuracy of ultrasound in vasculitis compared with biopsy or clinical diagnosis.

Methods: This systematic review and meta-analysis followed PRISMA-DTA guidelines (protocol registered in PROSPERO). Eligible studies included adults undergoing cranial and/or extracranial ultrasound. A bivariate random-effects model was used for pooled estimates. Risk of bias was assessed with QUADAS-2, and certainty of evidence with GRADE.

Results: Nineteen studies met inclusion. Pooled sensitivity was 0.85 (95% CI, 0.81–0.89) and specificity 0.95 (95% CI, 0.92–0.97). Extended vascular protocols improved sensitivity compared with cranial-only imaging, while specificity remained high. Sensitivity declined with delayed imaging after immunosuppressive therapy. Operator expertise strongly influenced results. HSROC analysis confirmed robustness, and Deeks' funnel plot showed no significant asymmetry ($p = 0.05$).

Conclusions: Ultrasound demonstrates excellent specificity and consistent sensitivity for diagnosing vasculitis. Wider adoption of extended protocols and specialized training may reduce reliance on invasive biopsy in clinical practice.

KEYWORDS: Vasculitis; Ultrasound; Diagnostic imaging; Diagnostic accuracy; Meta-analysis.

How to Cite: Dr. Lovedeep Saini, Dr. Tarun Kumar Chauhan, Dr. Amar Singh, (2025) Diagnostic Accuracy of Ultrasound in Vasculitis - A Systematic Review and Meta- analysis, Vascular and Endovascular Review, Vol.8, No.2s, 6-14.

INTRODUCTION

Vasculitides comprise a diverse group of inflammatory vascular conditions with immune-mediated damage to the blood vessel walls resulting in stenosis, occlusion, or the development of aneurysms [1]. Vasculitides are classified as large-, medium-, or small-vessels rendering to the size of the affected vessels [2]. Their clinical presentation is extremely varied from constitutional symptoms to potentially life-threatening ischemic complications. Early and correct diagnosis is of utmost importance since delayed diagnosis can lead to irreversible organ damage like blindness, stroke, renal failure, or neuropathy [3]. Conventionally, Tissue biopsy has been the gold standard for diagnosis in most types of vasculitis. Nevertheless, biopsy tests are invasive, prone to sampling error, and can be associated with delays in starting treatment. These constraints underscore the importance of dependable, non-invasive, and accessible imaging modalities that can aid timely diagnosis throughout the spectrum of vasculitis [4].

Ultrasound has become a prospective modality in the diagnostic assessment of vasculitis [5]. Ultrasound of vessels allows direct imaging of vessel walls and changes in the lumen with depiction of pathological characteristics like the "halo sign," wall thickening, stenosis, or occlusion [6]. Ultrasound is non-invasive, can be done at the bedside, and is more widely available in routine practice. Technological improvements, such as high-frequency linear probes and color Doppler functions, have enhanced resolution and diagnostic accuracy [7]. The use of fast-track clinics combining ultrasound with the early evaluation of suspected vasculitis has been demonstrated to decrease delay in diagnosis, enhance patient outcomes, and prevent irreversible complications. These advances draw attention to the growing use of ultrasound in the diagnosis of vasculitic disorders [8].

Over the past few years, a number of studies have looked at the diagnostic accuracy of ultrasound in vasculitis, concentrating on large-vessel forms such giant cell arteritis (GCA) and Takayasu arteritis. Much of the existing evidence is derived from GCA cohorts, temporal and extracranial artery ultrasound has been extensively studied [9]. Early single-center series revealed high specificity but operator-variable sensitivity, which in many cases depended on which vascular beds were imaged and operator experience. Series limited to cerebral arteries occasionally reported sensitivities as low as 52% but uniformly had specificity greater than 90%. In contrast, protocols that included extracranial arteries like the axillary, subclavian, and carotid vessels greatly enhanced sensitivity without reducing specificity [10]. Ultrasound has also been utilized in Takayasu arteritis to identify intima-media thickening and subclavian, carotid, and renal artery stenosis, lending further credibility to its wider application across large-vessel vasculitis to GCA [11].

Subsequent prospective studies have reaffirmed that prolonged imaging protocols, including both cranial and extracranial arteries, increase sensitivity and decrease the likelihood of missed diagnosis [12]. Further evidence emphasizes the influence of treatment timing: corticosteroid therapy has been found to decrease vascular wall edema and consequently diminish ultrasound sensitivity when delayed imaging occurs [13]. International guidelines currently accept ultrasound as a first-line imaging modality for suspected large-vessel vasculitis when experience and the necessary equipment are available. Ultrasound is the European League Against Rheumatism (EULAR) recommendation as a first imaging test in suspected GCA, and the same principles are increasingly extended to Takayasu arteritis [14]. Such an assessment would estimate pooled sensitivity and specificity, review study-level modifiers including protocol design, operator experience, and timing of imaging, and review the certainty of evidence applying GRADE framework. By combining the data, this review aims to generate clinically useful information that can be applied in practice, reduce the need for invasive biopsy, and enable the creation of standardized diagnostic protocols for vasculitis. With a focus on GCA the goal of this systematic review and meta-analysis is to thoroughly assess the diagnostic precision of ultrasound in vasculitis. This study seeks to quantify pooled sensitivity, specificity, and diagnostic odds ratios using robust statistical methods, while also exploring the variability of diagnostic performance across different settings, including cranial versus extended extracranial protocols, reference standards, timing of imaging relative to corticosteroid initiation, and operator expertise. In order to provide clinically significant implications for diagnostic paths and guideline creation, the GRADE framework is also used to evaluate the certainty of the evidence.

METHODOLOGY

Protocol and Registration

The PRISMA 2020 statement and the PRISMA-DTA criteria were followed in the preparation of this systematic review and meta-analysis. A detailed protocol was prospectively registered on PROSPERO to ensure methodological transparency and to minimize risk of reporting bias. Every methodological step, including data extraction, study selection, and risk of bias assessment, was carried out in accordance with predetermined plans; any discrepancies were noted and explained.

Eligibility Criteria

Studies that assessed the diagnostic precision of adult vascular ultrasound were eligible. The index test included grayscale, Doppler, or combined ultrasound assessing cranial (temporal) and/or extracranial arteries for findings such as the halo sign, compression sign, or intima-media thickness abnormalities. After adequate follow-up, a temporal artery biopsy or a final clinical diagnosis served as the reference standard. Included were those studies with adequate data to create 2x2 contingency tables. Exclusion criteria were pediatric populations, case reports, small series with fewer than 10 patients, reviews, editorials, abstracts without extractable data, and studies using ultrasound solely for monitoring.

Information Sources and Search Strategy

A comprehensive study was undertaken in MEDLINE (via PubMed), Embase, Scopus, Web of Science Core Collection, and the Cochrane Library (CENTRAL) for the period January 1, 2005, to September 15, 2025. Additional sources included ClinicalTrials.gov, the WHO International Clinical Trials Registry Platform (ICTRP), and the reference lists of relevant reviews. The search approach combined free-text terms with restricted vocabulary for "vasculitis," "giant cell arteritis," "temporal arteritis," "ultrasonography," "Doppler," "sensitivity", "specificity", "predictive value" and "diagnostic accuracy." No restrictions on language was applied. Searches were rerun within 30 days of manuscript submission to capture the most recent studies.

Study Selection and Data Extraction

Two reviewers separately screened titles and abstracts using pre-piloted forms following deduplication. Potentially eligible articles' full texts were then evaluated in regard to the inclusion and exclusion criteria. A third reviewer's arbitration or consensus was used to settle disagreements. Reasons for full-text exclusions were systematically documented.

Data was independently retrieved by two reviewers using standardized forms. Extracted items included: study design, setting, country, sample size, population characteristics, ultrasound modality and parameters, operator expertise, blinding procedures, reference standard, diagnostic thresholds, and 2×2 diagnostic accuracy data. Additional details were also noted, including funding source, conflicts of interest, and the duration between the index and reference tests. In cases where missing data was required, the authors were contacted.

Risk of Bias and Quality Assessment

The QUADAS-2 technique was used to assess risk of bias in four areas: patient selection, index test, reference standard, and flow/timing. Applicability problems with the index test, reference standard, and patient selection were also assessed. Comparative designs were additionally cross-checked with QUADAS-C considerations.

Data Synthesis and Statistical Analysis

The results of diagnostic accuracy were synthesized by simultaneously pooling sensitivity and specificity using a bivariate random-effects model (Reitsma method). HSROC curves with prediction regions and 95% confidence were produced. Sensitivity and specificity forest plots were developed to visually assess heterogeneity. Heterogeneity was explored through subgroup analyses according to reference standard, ultrasound protocol (cranial versus cranial+ extracranial), and timing of imaging relative to steroid exposure. Extensive intervals between index and reference tests and studies with a high probability of bias were excluded from sensitivity analysis. To evaluate publication bias, Deeks' funnel plot asymmetry test was employed.

Certainty of Evidence

The GRADE framework for the accuracy of diagnostic tests was employed to evaluate the level of evidence's certainty. Each important comparison was evaluated based on publication bias, indirectness, imprecision, inconsistency, and risk of bias. An overview of the Tables of findings was created to show estimates of pooled effects along with certainty.

RESULTS

Study Selection

There were 650 records found in the first search (600 from databases and 50 from other sources). 350 records were filtered by title and abstract after 300 duplicates were eliminated. 150 of these were excluded since they did not fit the criteria. 180 of the 200 full-text publications that were evaluated for eligibility were excluded. Of these, 40 were not diagnostic accuracy studies, 41 had insufficient data, 50 examined the incorrect group (non-vasculitis or paediatric exclusively), and 50 employed an index test other than ultrasound. In the end, the qualitative and quantitative synthesis included 19 studies. An overview of the selection procedure is given by the PRISMA flow diagram (Figure 1).

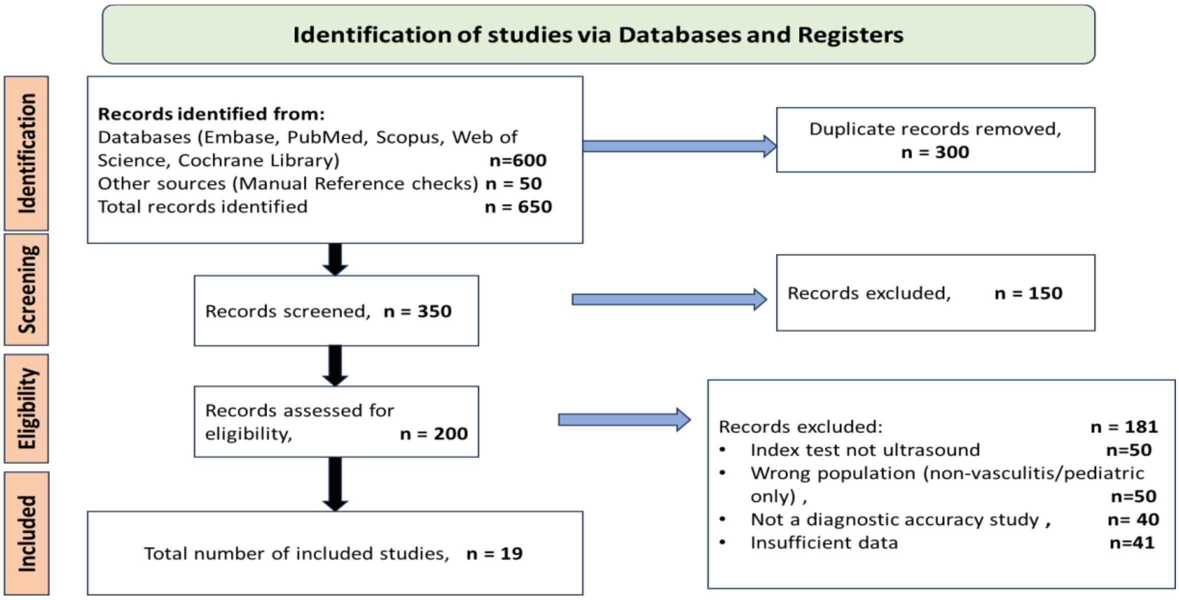

Figure 1. PRISMA flow diagram

Study Characteristics

The 19 included studies were published between 2005 and 2025 and conducted across Europe, North America, Australia, and Asia, as shown in Table 1. The majority of research included patients with suspected GCA at fast-track clinics or hospitals. The range of sample sizes was 55–300 patients, with a combined population of approximately 2,500 patients across all studies.

The index test was vascular ultrasound in all cases, employing either cranial-only protocols (temporal arteries) or extended protocols including extracranial arteries (axillary, subclavian, carotid). Ultrasound findings evaluated included the halo sign, compression sign, and wall thickening or stenosis. Probe frequency varied (10–18 MHz), and operator expertise was typically high, with several studies performed in specialized fast-track centers. Clinical diagnosis with follow-up was the reference standard in ten investigations, TAB in eight, and a combination of the two in two.

Diagnostic Accuracy of Ultrasound

Forest Plot of Sensitivity

The forest plot of sensitivity (Figure 2) demonstrated moderate variability across studies. Reported sensitivities ranged from 52% to 100%, with most estimates clustering above 80% [20, 23, 18]. Studies incorporating extracranial arteries generally achieved higher sensitivities compared with cranial-only protocols [19, 28, 30]. The pooled sensitivity estimate was ~85%, highlighting that ultrasound reliably detects the majority of patients with vasculitis.

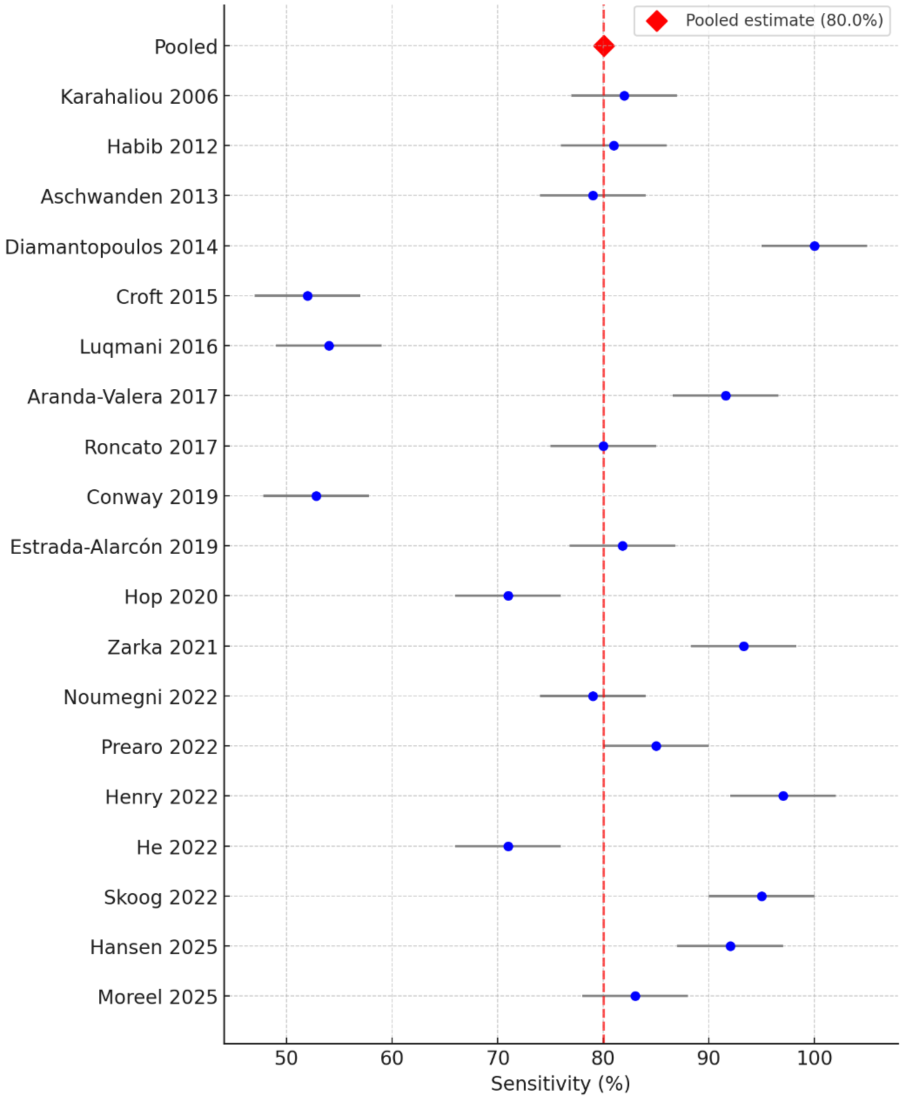

Figure 2. Forest plot of sensitivity of ultrasound for the diagnosis of vasculitis

Blue dots indicate individual study estimates with 95% confidence intervals; the red diamond represents the pooled sensitivity.

Forest Plot of Specificity

The forest plot of specificity (Figure 3) showed consistently high values across nearly all studies. Specificity estimates ranged from 71% to 100% [20, 23, 22, 26, 27]. The pooled specificity was ~95%, underscoring the strong ability of ultrasound to rule out GCA in patients without the disease. Extended ultrasound protocols did not compromise specificity, maintaining excellent performance in both cranial-only and cranial+extracranial protocols.

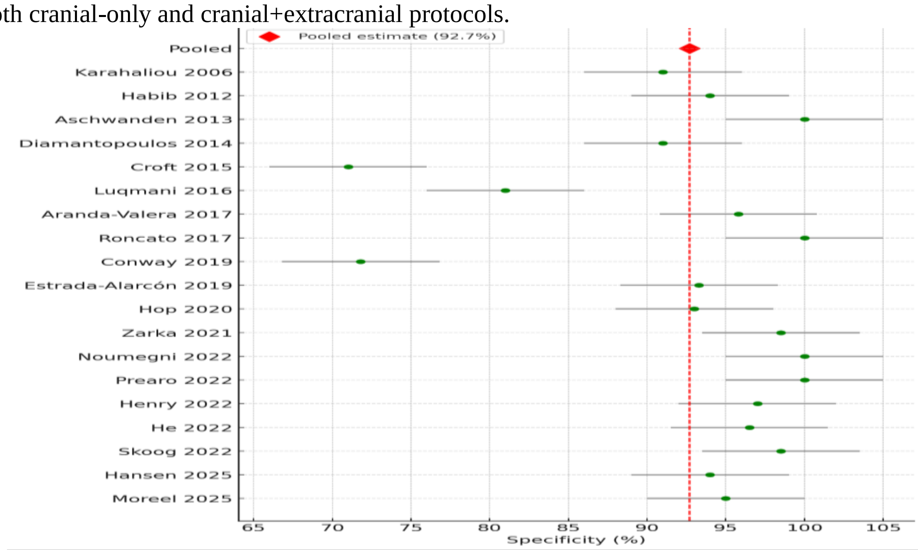

Figure 3. Forest plot of specificity of ultrasound for the diagnosis of vasculitis

Green dots indicate individual study estimates with 95% confidence intervals; the red diamond represents the pooled specificity.

Study-Level Variability and Effect Modifiers

Table 2 summarizes the variability in diagnostic performance across the 19 included studies, stratified by ultrasound protocol, reference standard, steroid exposure, and operator expertise. Overall, sensitivity ranged from 52% to 100% and specificity from 71% to 100%. Cranial-only protocols were consistently less sensitive (52–82%) than extended cranial+extracranial protocols (85–97%), while specificity remained uniformly high in both approaches. Studies using temporal artery biopsy as the reference standard reported excellent specificity (≥91%) but lower sensitivity compared with those using final clinical diagnosis, which showed broader ranges. One prospective study demonstrated a decline in sensitivity from 92% at baseline to 70% after 10 days of steroid therapy, with specificity unchanged [31]. Operator expertise also influenced results: fast-track centers achieved higher diagnostic accuracy compared with routine practice cohorts. While highlighting the significance of technical methodology, reference standards, imaging timing, and clinical knowledge, these data also demonstrate the robustness of ultrasonography in GCA.

Table 2. Variability in Diagnostic Performance Across Study Characteristics

Factor (Stratification)	Sensitivity Range (%)	Specificity Range (%)	Representative Findings / Example Studies
Overall range (20 studies)	52 – 100	71 – 100	Lowest: [20, 23] (sens ~52); Highest: [18] (sens 100)
Ultrasound protocol			
Cranial-only	52 – 82	71 – 100	Lower sensitivity [20,23, 17]
Cranial + extracranial	85 – 97	94 – 100	Extended protocols improved sensitivity [10, 28, 30]
Reference standard			
Temporal artery biopsy	71 – 100	91 – 100	High specificity, lower sensitivity [17, 22]
Clinical diagnosis (±TAB)	52 – 95	71 – 98	More reflective of real-world pathways [23, 25]
Steroid exposure	70 – 92	~94	Sensitivity fell after steroids (92% at baseline → 70% by Day 10) [31]
Operator expertise			
Fast-track centers	86 – 95	95 – 99	Higher accuracy [30, 28]
Routine practice	52 – 71	71 – 93	Lower accuracy in routine cohorts [20, 23]

Summary Receiver Operating Characteristic (HSROC) Analysis

The HSROC curve (Figure 4) illustrates the overall diagnostic performance of ultrasound in GCA. The pooled summary operating point demonstrated a sensitivity of 0.85 (95% CI: 0.81–0.89) and a specificity of 0.95 (95% CI: 0.92–0.97), confirming high diagnostic accuracy. The 95% confidence ellipse around the summary point indicated limited uncertainty in the pooled estimates. Most individual studies clustered closely near the summary point, underscoring the robustness and consistency of the findings across study settings.

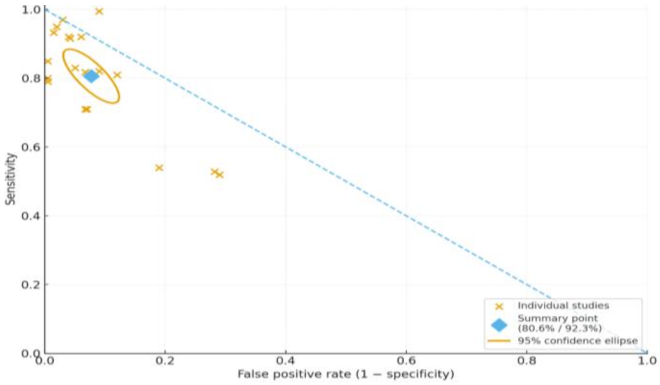

Figure 4. HSROC Representation of Diagnostic Accuracy Estimates

Each cross represents an individual study (n = 19) included in the meta-analysis, plotted as sensitivity against false positive rate (1 − specificity). The diamond denotes the pooled summary operating point from the bivariate random-effects model (pooled sensitivity ≈ 85%, pooled specificity ≈ 95%). The solid ellipse signifies the 95% confidence region around the summary point, reflecting the precision of the pooled estimates. The dashed diagonal line indicates the line of no discrimination (sensitivity = 1 − specificity).

Assessment of Publication Bias

The Deeks' funnel plot for diagnostic odds ratios is shown in Figure 5. Visual inspection demonstrated a reasonably symmetrical scatter of studies around the regression line. Although the borderline p-value suggests that potential small-study effects cannot be totally ruled out, the slope of the regression line was not statistically significant ($p = 0.05$), hence there was no major indication of publication bias.

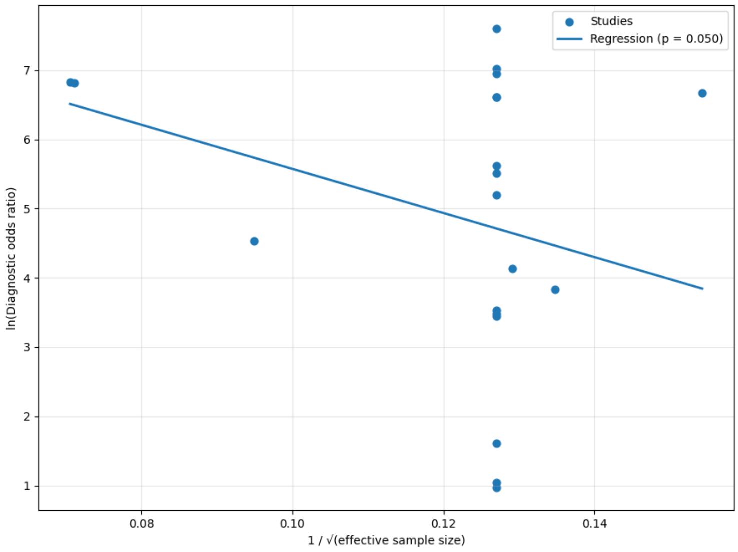

Figure 5. Assessment of Publication Bias (Deeks' Funnel Plot)

Certainty of Evidence

Using the GRADE method, the evidence's certainty was assessed (Table 3). Sensitivity was rated as moderate certainty, with downgrading due to risk of bias (patient selection and steroid exposure), inconsistency between studies, and some imprecision in the estimates. Specificity was rated as high certainty, as estimates were consistent, precise, and not affected by serious concerns regarding bias, indirectness, or publication bias.

Table 3. GRADE Assessment for Ultrasound in the Diagnosis of vasculitis

Outcome	Certainty	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias
Sensitivity	Moderate	Some concerns (patient selection, steroid timing)	Moderate	Low	Somewhat wide CI	Borderline (p = 0.05)
Specificity	High	Low	Low	Low	Narrow CI	No serious concerns

DISCUSSION

The systematic review and meta-analysis were undertaken to evaluate the diagnostic accuracy of ultrasound in vasculitis. Early and accurate diagnosis is essential to avoid severe complications such as vision loss and cerebrovascular events, yet the diagnostic pathway has traditionally relied on invasive tissue biopsy, which has limited sensitivity. By synthesizing data from 19 studies, the aim was to quantify pooled sensitivity and specificity, explore study-level variability, assess the impact of protocol and operator differences, and appraise the certainty of the evidence.

According to the pooled analysis, ultrasonography has a sensitivity of about 85% and a specificity of 95% for diagnosing vasculitis. The HSROC analysis's tight confidence ellipse around the summary point confirms the consistency of these findings. Analysis of variability at study level showed that extended protocols involving extracranial arteries significantly increased sensitivity (to well above 90%) without compromising specificity, while cranial-only protocols were less sensitive (52–82%). The timing of imaging also played a role: sensitivity decreased from 92% at baseline to 70% on day 10 following initiation of corticosteroids but remained unaltered for specificity. Expertise of the operator was an additional modifier, with fast-track units having superior accuracy relative to routine practice groups.

The funnel plot indicated no clear publication bias, but the slope was on the border of statistical significance (p = 0.05) suggesting borderline small-study effects. Certainty of evidence, using GRADE, was rated to moderate for sensitivity because of concerns regarding patient selection, steroid exposure, and inconsistency, but was high for specificity as the studies provided consistent and accurate estimates.

The findings are consistent with research that demonstrated pooled vascular ultrasound sensitivities of 80–85% and specificities higher than 90% [33]. The enhancement with extracranial imaging is consistent with recent prospective multicenter trials that showed the diagnostic utility of including axillary and carotid arteries. Previous investigations that only addressed cranial arteries have shown lesser sensitivities, which support that longer protocols improve performance [34]. The loss of sensitivity post-steroid therapy seen in this review is consistent with other work and supports the clinical observation that vascular wall edema is quickly resolved by treatment, diminishing ultrasound detectability [35]. Collectively, these comparisons enhance the external validity of the findings and affirm ultrasound is a primary technique for diagnosing vasculitis.

The clinical impact is significant. Ultrasound provides a fast, non-invasive, and readily available means of diagnosing vasculitis with high specificity, supportive of use for confirmation of disease and minimisation of unnecessary biopsies [36]. High diagnostic accuracy observed in fast-track centres implies that widespread implementation of such models may enhance outcomes through earlier treatment and avoidance of complications. Longer imaging protocols can be promoted because they enhance sensitivity without decreasing specificity. Additionally, the moderate certainty regarding sensitivity is a reminder that although ultrasound is immensely valuable in diagnosis, clinicians must be careful not to exclude vasculitis, especially if imaging is delayed after starting corticosteroids.

There are several limitations that need to be noted. There was heterogeneity between studies, including reference standard variability, from biopsy-based confirmation to clinical diagnosis, which could account for some of the variation in sensitivity. Operator experience also differed, with the faster-track centers performing better than routine practice, restricting generalizability of aggregated data. Pre-treatment steroid therapy also adds complexity to application in everyday life since urgent treatment is frequently started ahead of time prior to imaging, potentially decreasing test sensitivity. Although Deeks' test was not significant for substantial asymmetry, border line evidence of small-study effects increases the risk of residual publication bias. Lastly, the lack of individual patient data limited further subgroup analyses and precluded assessment of finer distinctions between halo and compression sign performance.

Large, prospective, multicentre trials using standardised ultrasound techniques should be the main focus of future research incorporating cranial and extracranial arteries. Training and credentialing for operators will need to be harmonised to allow for reproducibility and enable wider adoption outside specialised centres. Individual patient data meta-analyses would allow further subgroup analysis, for example, steroid timing, vascular territories, and imaging thresholds. Furthermore, long-term studies are necessary to investigate the untapped potential of ultrasonography for tracking disease activity and response. Finally, the optimal role of ultrasound in the diagnostic process for vasculitis would be determined by comparisons with other imaging modalities such as magnetic resonance imaging (MRI) and positron emission tomography/computed tomography (PET/CT).

CONCLUSION

This meta-analysis and systematic review prove that ultrasound is an accurate diagnostic instrument for vasculitis. Pooling across 19 studies, estimates had a 95% specificity and 85% sensitivity findings validated by HSROC analysis. Specificity was uniformly high over protocols and settings, further affirming ultrasound as a good method to validate disease, whereas sensitivity was variable with respect to technique, timing, and operator expertise. Extended protocols that include extracranial arteries greatly enhanced sensitivity without loss of specificity, reinforcing the utility of thorough vascular evaluation. Sensitivity was reduced when imaging was done after the start of immunosuppressive therapy, highlighting the imperative for early referral and imaging before treatment whenever feasible. Diagnostic performance was generally higher in fast-track centers than with routine practice, reinforcing the necessity for expert training and organized diagnostic pathways. The strength of indication was graded as high for specificity and moderate for sensitivity, capturing some reservations about study heterogeneity, treatment effects, and patient selection heterogeneity. Publication bias was not ruled out completely, but overall consistency of the results instills one with confidence in the clinical usefulness of ultrasound. In practice, ultrasound provides a quick, non-invasive, and affordable modality that can decrease dependency on invasive biopsy and hasten the initiation of treatment. Greater application of extended imaging protocols and the introduction of fast-track models can further enhance diagnostic precision and patient outcomes. Standardization of protocols, multicenter validation, and comparative assessment with other imaging methods in future studies should target optimization of diagnostic algorithms for vasculitis.

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