CT Angiography in Carotid Disease: Systematic Review with ☸SAIMSARA.

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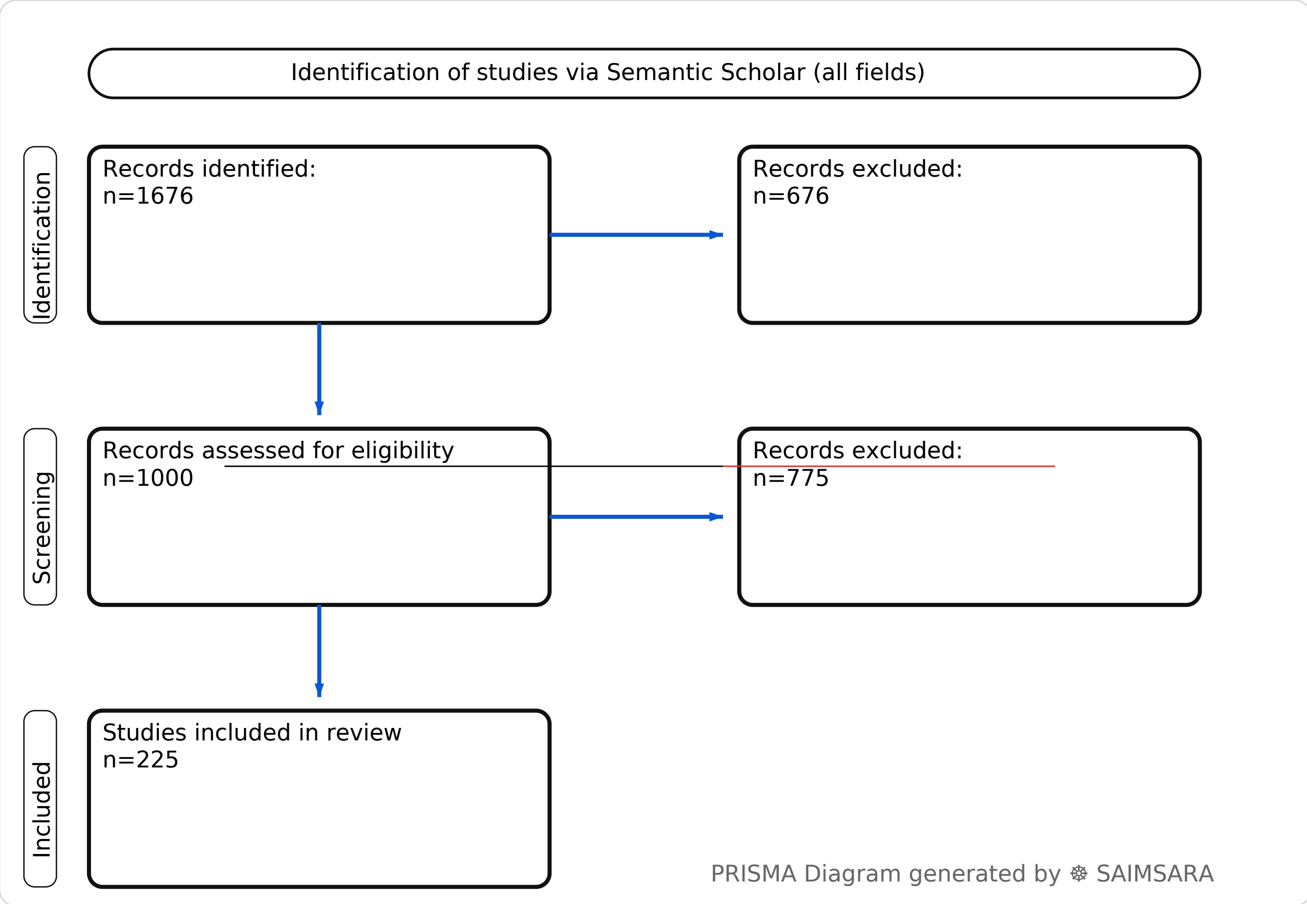
Abstract: Systematic review with multilayer AI research agent: keyword normalization, retrieval & structuring, and paper synthesis (see SAIMSARA About section for details). The review utilises 225 studies with 54037 total participants (naïve ΣN). The diagnostic accuracy of CT angiography for carotid artery disease, particularly stenosis, demonstrated a median of 90% (range: 85.7–94%) across several studies. This high accuracy underscores its critical role in the assessment of carotid pathologies, from common atherosclerotic stenosis to complex conditions like Moyamoya disease and vasculitis. However, the diverse study designs and heterogeneity in reporting metrics represent a significant limitation, impacting the certainty of broad generalizations. To advance clinical practice, future research should focus on standardizing CTA protocols for plaque characterization and conducting large-scale validation of AI-powered diagnostic tools to enhance efficiency and reduce variability.

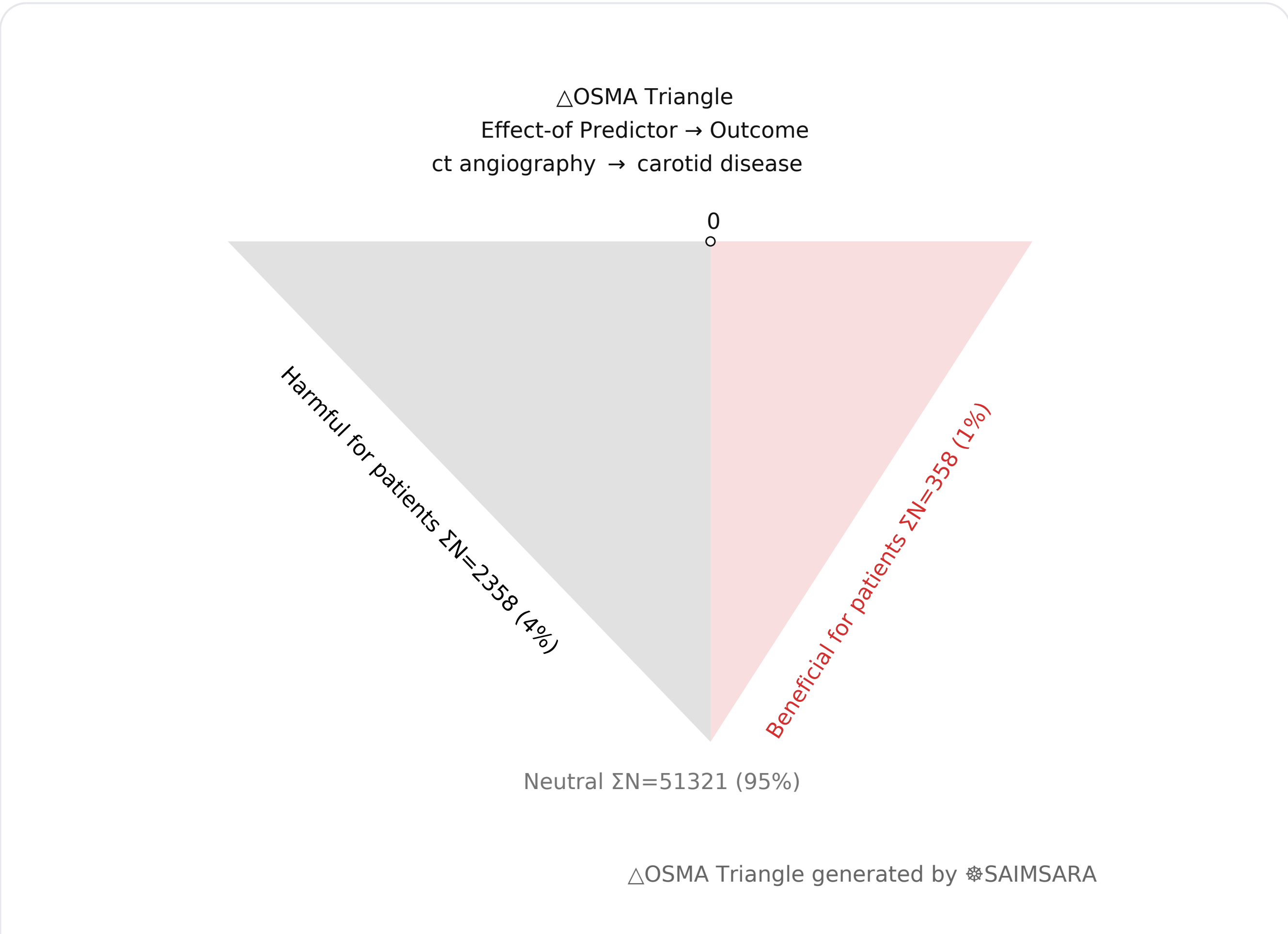
Keywords: Computed Tomography Angiography; Carotid Artery Disease; Carotid Stenosis; Atherosclerosis; Carotid Plaque; Diagnostic Imaging; Cerebrovascular Disease; Machine Learning; Vascular Imaging

Review Stats

- Generated: 2026-02-03 12:38:58 CET
- Plan: Pro (expanded craft tokens; source: Semantic Scholar)
- Source: Semantic Scholar
- Scope: All fields
- Keyword Gate: Fuzzy (≥60% of required terms, minimum 2 terms matched in title/abstract)
- Total Abstracts/Papers: 1676
- Downloaded Abstracts/Papers: 1000
- Included original Abstracts/Papers: 225
- Total study participants (naïve ΣN): 54037



Identification of studies via Semantic Scholar (all fields)
Identification
Records identified:
n=1676
Records excluded:
n=676
Screening
Records assessed for eligibility
n=1000
Records excluded:
n=775
Included
Studies included in review
n=225
PRISMA Diagram generated by ☸ SAIMSARA



△OSMA Triangle
Effect-of Predictor → Outcome
ct angiography → carotid disease
0
Harmful for patients ΣN=2358 (4%)
Beneficial for patients ΣN=358 (1%)
Neutral ΣN=51321 (95%)
△OSMA Triangle generated by ☸SAIMSARA

Outcome-Sentiment Meta-Analysis (OSMA): *(LLM-only)*

Frame: Effect-of Predictor → Outcome • *Source*: Semantic Scholar

Outcome: carotid disease Typical timepoints: 3-day, peri/post-op. Reported metrics: %, CI, p.

Common endpoints: Common endpoints: complications, occlusion, healing.

Predictor: ct angiography — exposure/predictor. Doses/units seen: 8 ml. Routes seen: oral. Typical comparator: risk score alone, real ct angiography, carotid calcification alone, conventional angiography in….

- **1) Beneficial for patients** — carotid disease with ct angiography — [17], [38], [47], [143] — ΣN=358
- **2) Harmful for patients** — carotid disease with ct angiography — [3], [6], [9], [11], [21], [45] — ΣN=2358
- **3) No clear effect** — carotid disease with ct angiography — [1], [2], [4], [5], [7], [8], [10], [12], [13], [14], [15], [16], [18], [19], [20], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [39], [40], [41], [42], [43], [44], [46], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92], [93], [94], [95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107], [108], [109], [110], [111], [112], [113], [114], [115], [116], [117], [118], [119], [120], [121], [122], [123], [124], [125], [126], [127], [128], [129], [130], [131], [132], [133], [134], [135], [136], [137], [138], [139], [140], [141], [142], [144], [145], [146], [147], [148], [149], [150], [151], [152], [153], [154], [155], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167], [168], [169], [170], [171], [172], [173], [174], [175], [176], [177], [178], [179], [180], [181], [182], [183], [184], [185], [186], [187], [188], [189], [190], [191], [192], [193], [194], [195], [196], [197], [198], [199], [200], [201], [202], [203], [204], [205], [206], [207], [208], [209], [210], [211], [212], [213], [214], [215], [216], [217], [218], [219], [220], [221], [222], [223], [224], [225] — ΣN=51321

1) Introduction

Carotid artery disease encompasses a spectrum of conditions, including stenosis, aneurysm, and dissection, which are significant contributors to cerebrovascular events such as stroke and transient ischemic attacks (TIAs). Accurate and timely diagnosis is crucial for effective patient management and risk stratification. Computed tomography angiography (CTA) has emerged as a cornerstone imaging modality, offering detailed anatomical and pathological insights into the carotid vasculature.

This paper synthesizes current research on the utility of CTA in the diagnosis, characterization, and management of carotid artery disease, drawing upon a diverse body of evidence ranging from diagnostic accuracy studies to investigations into plaque vulnerability and associations with systemic conditions.

2) Aim

Systematic review with multilayer AI research agent: keyword normalization, retrieval & structuring, and paper synthesis (see SAIMSARA About section for details).

3) Methods

Systematic review with multilayer AI research agent: keyword normalization, retrieval & structuring, and paper synthesis (see SAIMSARA About section for details).

- **Bias:** Qualitatively inferred from study design fields. The included studies predominantly comprise mixed (retrospective/prospective), cohort, and case series designs, with fewer randomized controlled trials (RCTs) or purely prospective studies, indicating a potential for selection bias and varying levels of evidence strength. Many studies lack specified directionality or follow-up, limiting the assessment of long-term outcomes and causal relationships.

4) Results

4.1 Study characteristics:

The included studies primarily consisted of mixed-design investigations (retrospective and prospective components), cohort studies, and case series, often focusing on specific patient populations such as those with carotid artery stenosis, acute ischemic stroke, transient ischemic attack, or conditions like Moyamoya disease and Takayasu arteritis. Sample sizes varied widely, from single case reports to large cohorts of over 1700 patients, with follow-up periods ranging from immediate post-procedure assessment to several years, though many studies did not specify follow-up duration.

4.2 Main numerical result aligned to the query:

The diagnostic accuracy of CT angiography for carotid artery disease, particularly stenosis, demonstrated a median of 90% (range: 85.7–94%) across several studies [1, 4, 146, 147]. For example, one machine learning approach leveraging craniocervical CTA achieved 90% accuracy in diagnosing carotid artery diseases [1], while a generative adversarial network-based model synthesizing CTA-like images showed 94% accuracy in an internal test set and 86% in an external validation set for aortic and carotid artery disease [4]. CTA also showed high accuracy in predicting the degree of stenosis in symptomatic carotid artery disease, reaching 91.4% [146] and 88.5% sensitivity with 85.7% specificity for severe stenosis [147].

4.3 Topic synthesis:

- **Diagnostic Efficacy and Modality Comparison:** CTA consistently demonstrates high diagnostic accuracy for carotid artery disease, with a median accuracy of 90% (range 85.7–94%) for stenosis [1, 4, 146, 147]. It shows good agreement with Doppler ultrasonography for high-grade stenosis (kappa = 0.63 [8], r = 0.76 [13]), often being more sensitive for severe stenosis and occlusion [23, 33]. While comparable to MRI for stenosis, MRI may offer higher diagnostic value for ulcerative plaques (MRI sensitivity 100%, specificity 91.44% vs. CTA sensitivity 78.79%, specificity 90% for ulcerative plaques) [104].
- **Plaque Characterization and Risk Stratification:** CTA aids in characterizing plaque morphology and composition, which is crucial for risk assessment. Expansive carotid remodeling is significantly greater in symptomatic patients than asymptomatic patients [27, 102], and CT-diagnosed non-alcoholic fatty liver disease (NAFLD) is strongly associated with symptomatic carotid plaque (OR 22.81, 95% CI 13.03–39.93) [11]. Dual-layer spectral-detector CTA parameters, such as higher attenuations in specific spectral datasets, may help distinguish symptomatic carotid plaques [17]. Radiomic features from CTA can also identify culprit lesions in cerebrovascular events more effectively than calcification alone [15].
- **Association with Systemic Vascular Disease:** Carotid artery disease detected by CTA is often associated with systemic atherosclerosis. A higher carotid plaque score is linked to significantly higher coronary artery calcium score (CACS) (411.3 ± 70.1 vs. 93.5 ± 31.8) and higher CAD-RADS classification in hypertensive patients [9]. Carotid plaque and intima-media thickness (IMT) show significant association with coronary calcification and coronary artery disease [7, 31, 33]. Physical activity, particularly moderate-to-vigorous physical activity (MVPA), is associated with a lower risk for significant atherosclerosis in both coronaries and carotids (OR 0.61–0.67 for CA, 0.72–0.79 for CarA) [36].
- **Specific Carotid Pathologies:** CTA is instrumental in diagnosing a wide range of carotid pathologies beyond typical stenosis, including aneurysms, dissections [1, 41, 60, 61, 149, 157], tortuosity, and hypoplasia [3, 14, 175]. It is diagnostic for fibromuscular dysplasia (FMD) with a typical "string-of-beads" sign [42, 63] and critical for diagnosing Moyamoya disease, revealing bilateral ICA stenosis with "puff of smoke" collateralization [12, 69, 72, 74, 77, 78, 81, 85, 99]. CTA also identifies vasculitis, such as Takayasu arteritis, showing diffuse wall thickening and occlusive disease [62, 96, 153, 161, 162, 169, 174, 188, 191, 219].
- **Technical Innovations and Optimization:** Advances in CTA include generative adversarial networks for synthesizing non-contrast CTA-like images with good diagnostic accuracy [4], AI-based automatic segmentation for 3D ultrasound reconstructions [10], and

ultra-low dose protocols that maintain image quality while significantly reducing radiation dose and contrast agent volume [28, 103, 108, 135]. Novel parameters from 3D plaque modeling, such as contact surface area (CSA) and flow lumen volume (FLV), show promise in predicting stroke risk compared to traditional stenosis measurements [55].

- **Clinical Impact and Surgical Planning:** CTA is recommended for precise preoperative assessment of critical occlusive carotid artery disease [5, 97], providing data for defining variants of stenosis, near-occlusion, and local occlusion. It identifies extracranial carotid and vertebral artery disease in patients with ruptured intracranial aneurysms, associating with unfavorable outcomes [3]. CTA also aids in evaluating postoperative changes in vascular perfusion territories after revascularization surgery in Moyamoya disease [12, 189].
- **Anatomical Variations and Collateral Circulation:** CTA effectively visualizes anatomical variations like Circle of Willis (CoW) variants, which are highly prevalent in patients undergoing carotid endarterectomy (97% prevalence) and are associated with brain ischemia [6, 46]. It can identify internal carotid artery stealing pathways in common carotid artery occlusive disease [16] and depicts variable dimensions and lengths of internal carotid arteries [14].

5) Discussion

5.1 Principal finding:

The central finding of this review is that CT angiography demonstrates a high diagnostic accuracy, with a median of 90% (range: 85.7–94%), in assessing carotid artery disease, particularly stenosis [1, 4, 146, 147]. This indicates its robust capability in identifying and characterizing various carotid pathologies.

5.2 Clinical implications:

- **Diagnostic Utility:** CTA is a highly accurate tool for diagnosing and characterizing carotid artery stenosis, occlusion, aneurysm, and dissection, often showing superior sensitivity for severe lesions compared to Doppler ultrasound [23, 33].
- **Risk Stratification:** CTA-derived plaque characteristics, such as remodeling ratio, composition, and spectral CT parameters, can help identify symptomatic and high-risk plaques, aiding in stroke risk prediction beyond simple luminal narrowing [11, 15, 17, 27, 55, 102].
- **Preoperative Planning:** CTA is essential for precise preoperative assessment of critical occlusive carotid artery disease, providing detailed anatomical information necessary for surgical or endovascular treatment decisions [5, 97].

- **Systemic Disease Link:** Detection of carotid disease via CTA should prompt consideration of co-existing coronary artery disease and other systemic atherosclerosis, as strong associations exist [7, 9, 31, 33].
- **Treatment Guidance:** CTA can guide endovascular therapies, identify large vessel occlusions for thrombectomy, and assess collateral circulation, which is critical in conditions like Moyamoya disease [12, 76, 80].

5.3 Research implications / key gaps:

- **Standardization of Plaque Characterization:** Further prospective studies are needed to standardize CTA-based plaque characterization methods (e.g., spectral CT parameters, 3D modeling) and validate their independent predictive value for stroke risk across diverse populations [15, 17, 55].
- **AI Integration and Validation:** Large-scale, multicenter prospective trials are required to validate the clinical utility and generalizability of AI-based CTA synthesis and segmentation models in routine practice, especially comparing their diagnostic accuracy and workflow impact against conventional CTA [1, 4, 10].
- **Long-term Outcomes of Non-Stenotic Disease:** More research is needed to understand the long-term clinical significance and optimal management strategies for non-stenotic carotid disease, particularly in patients with embolic stroke of undetermined source (ESUS) [21, 35, 53].
- **Radiation Dose Optimization:** Continued research into ultra-low dose CTA protocols is warranted to further minimize radiation exposure and contrast agent use without compromising diagnostic image quality, especially for screening or follow-up in younger or high-risk populations [28, 103, 108, 135].
- **Comparative Effectiveness with Advanced MRI:** Direct head-to-head prospective studies comparing CTA with advanced MRI techniques (e.g., black-blood CMR, contrast-enhanced MRA) are needed to establish optimal imaging algorithms for specific carotid pathologies and patient subgroups, particularly for plaque vulnerability and ulcerative plaques [51, 104, 121, 137].

5.4 Limitations:

- **Study Design Heterogeneity** — The prevalence of mixed, cohort, and case series designs limits the ability to establish strong causal inferences and introduces potential for selection bias.

- **Lack of Standardized Outcomes** — Variability in reported metrics (e.g., accuracy, sensitivity, correlation) and lack of consistent comparators across studies hinder direct quantitative synthesis.
- **Limited Long-term Follow-up** — Many studies lack long-term follow-up, making it difficult to assess the prognostic value of CTA findings over extended periods.
- **Population Specificity** — A significant number of studies focus on specific patient groups (e.g., stroke patients, Moyamoya disease), which may limit the generalizability of findings to broader populations.
- **Reporting Inconsistencies** — Significant heterogeneity in image acquisition, segmentation techniques, processing, and analysis between studies was noted, affecting comparability [30].

5.5 Future directions:

- **Standardized Plaque Imaging** — Develop and validate standardized CTA protocols for comprehensive plaque characterization, including composition and remodeling, across diverse patient cohorts.
- **AI-Powered Diagnostics** — Conduct large-scale prospective trials to integrate and validate AI-based models for automated CTA image synthesis, segmentation, and disease diagnosis in routine clinical workflows.
- **Non-Stenotic Plaque Risk** — Investigate the long-term natural history and optimal management of non-stenotic carotid plaques, particularly in cryptogenic stroke patients, using advanced CTA techniques.
- **Dose Reduction Strategies** — Further optimize ultra-low dose CTA protocols and spectral CT applications to minimize radiation and contrast exposure while maintaining diagnostic quality for carotid assessment.
- **Comparative Imaging Trials** — Perform head-to-head prospective studies comparing CTA with advanced MRI techniques for specific carotid pathologies, focusing on plaque vulnerability and clinical outcomes.

6) Conclusion

The diagnostic accuracy of CT angiography for carotid artery disease, particularly stenosis, demonstrated a median of 90% (range: 85.7–94%) across several studies [1, 4, 146, 147]. This high accuracy underscores its critical role in the assessment of carotid pathologies, from common atherosclerotic stenosis to complex conditions like Moyamoya disease and vasculitis. However, the diverse study designs and heterogeneity in reporting metrics represent a significant limitation, impacting the certainty of broad generalizations. To advance clinical practice, future research should focus on standardizing CTA protocols for plaque characterization and conducting large-scale validation of AI-powered diagnostic tools to enhance efficiency and reduce variability.

References

SAIMSARA Session Index — [session.json]

Figure 1. Publication-year distribution of included originals

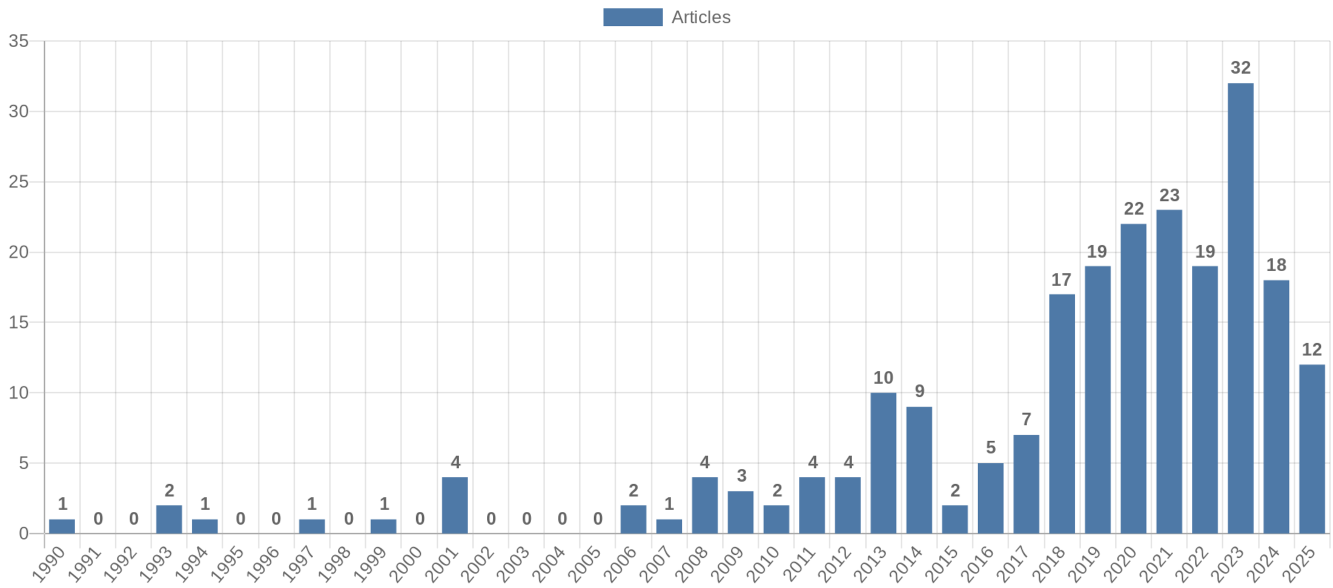


Figure 2. Study-design distribution of included originals

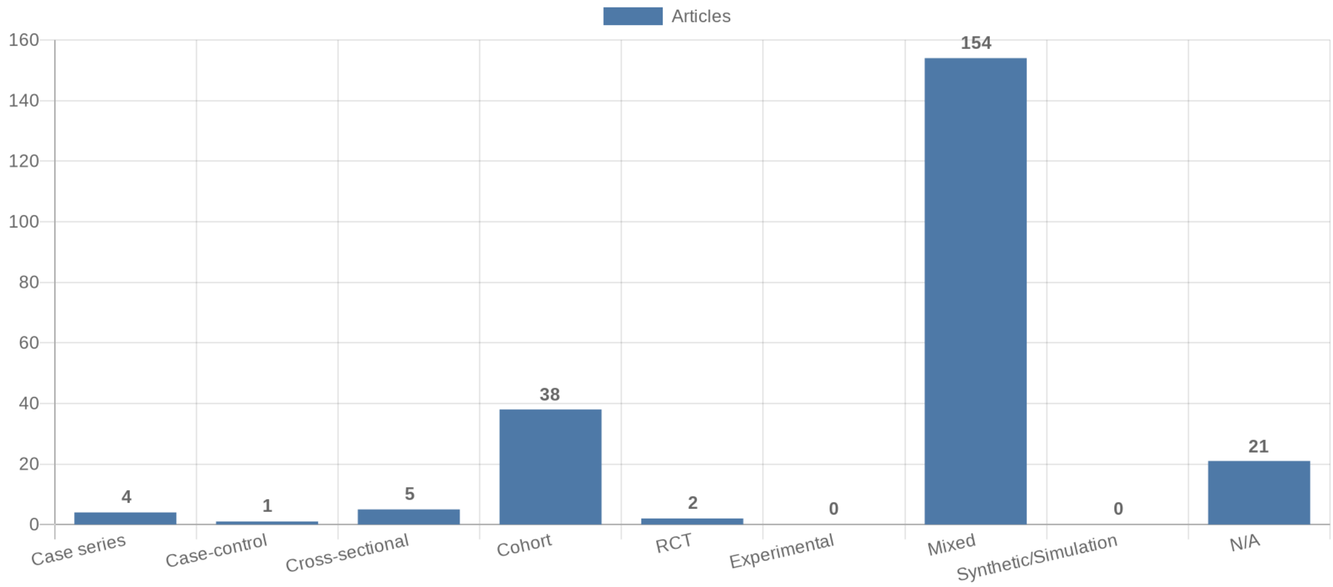


Figure 3. Study-type (directionality) distribution of included originals

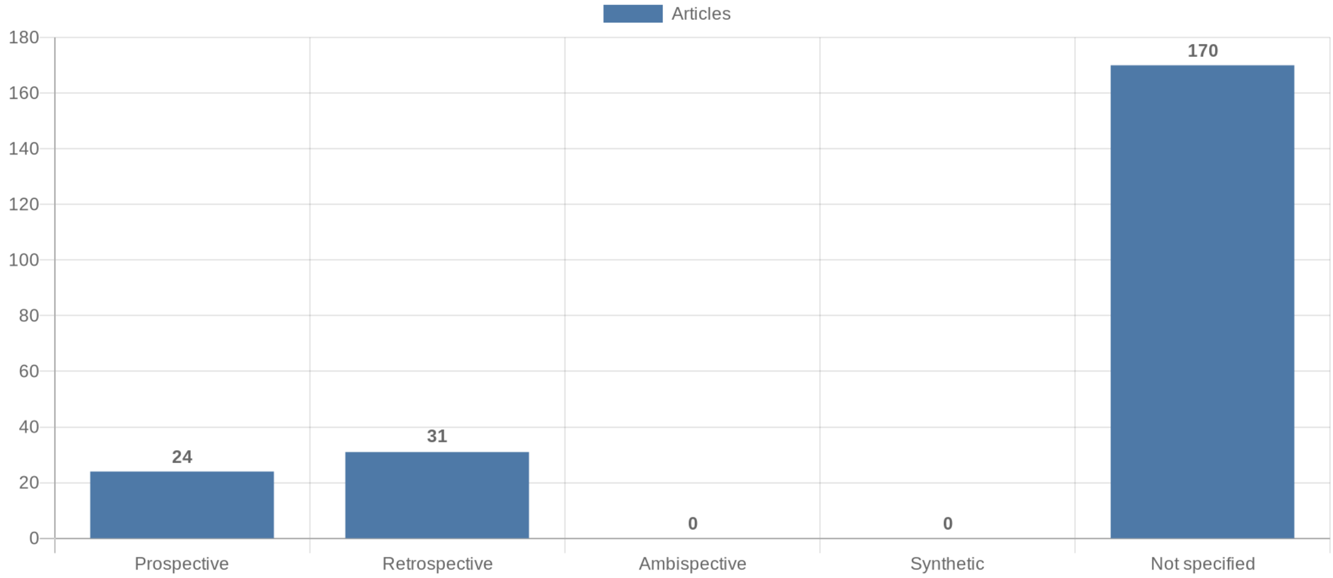


Figure 4. Main extracted research topics

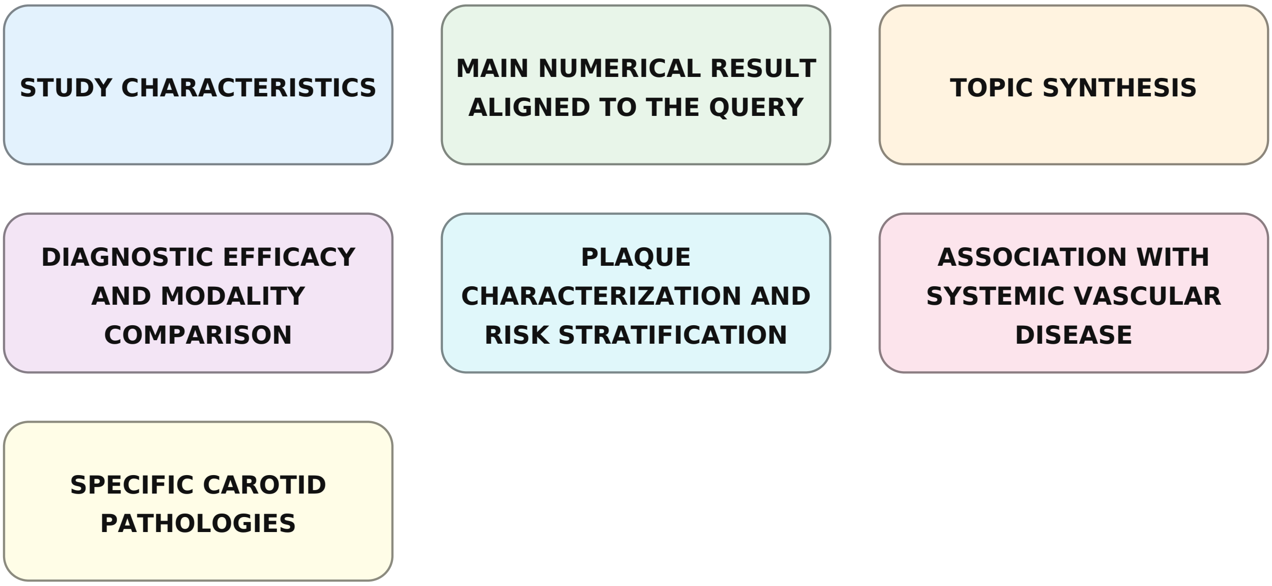
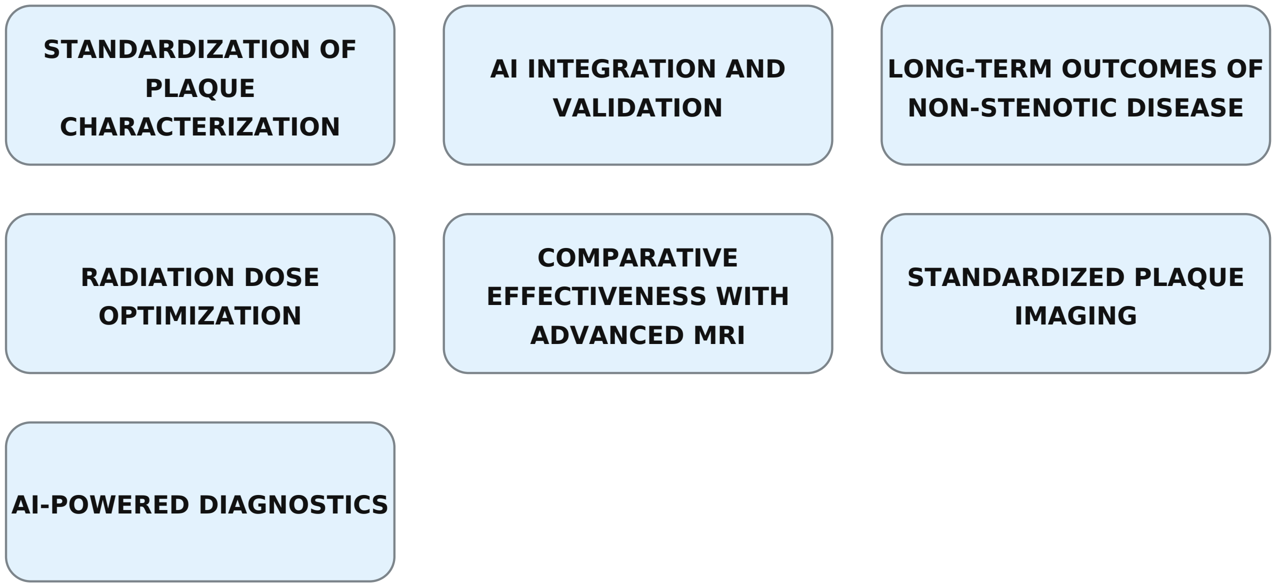


Figure 5. Limitations of current studies (topics)

Figure 6. Future research directions (topics)


STANDARDIZATION OF PLAQUE CHARACTERIZATION
AI INTEGRATION AND VALIDATION
LONG-TERM OUTCOMES OF NON-STENOTIC DISEASE
RADIATION DOSE OPTIMIZATION
COMPARATIVE EFFECTIVENESS WITH ADVANCED MRI
STANDARDIZED PLAQUE IMAGING
AI-POWERED DIAGNOSTICS