Carotid Web: Systematic Review with ☸SAIMSARA.

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Abstract: This paper aims to synthesize the current understanding of carotid webs, their characteristics, diagnostic approaches, pathophysiological mechanisms, and treatment outcomes, to identify key research gaps and inform future clinical practice. The review utilises 134 studies with 148725 total participants (naïve ΣN). Carotid webs are associated with a high risk of recurrent ischemic events under medical management alone, with reported recurrence rates varying widely, for example, from 17% within 2 years to 71.4% in a prospective series and 56%, and cumulative rates reaching 27.3% at 5 years. This high recurrence risk is particularly relevant for younger patients with cryptogenic stroke. The substantial heterogeneity in study designs and follow-up periods across the current literature most affects the certainty of definitive conclusions regarding optimal management. Therefore, a critical next step is to conduct large-scale, prospective comparative effectiveness trials to establish the best treatment strategies for symptomatic carotid webs.

Keywords: Carotid web; Ischemic stroke; Stroke recurrence; Thrombus formation; Carotid artery stenting; Carotid endarterectomy; CT angiography; Ultrasound imaging; Risk stratification; Geometric parameters

Review Stats

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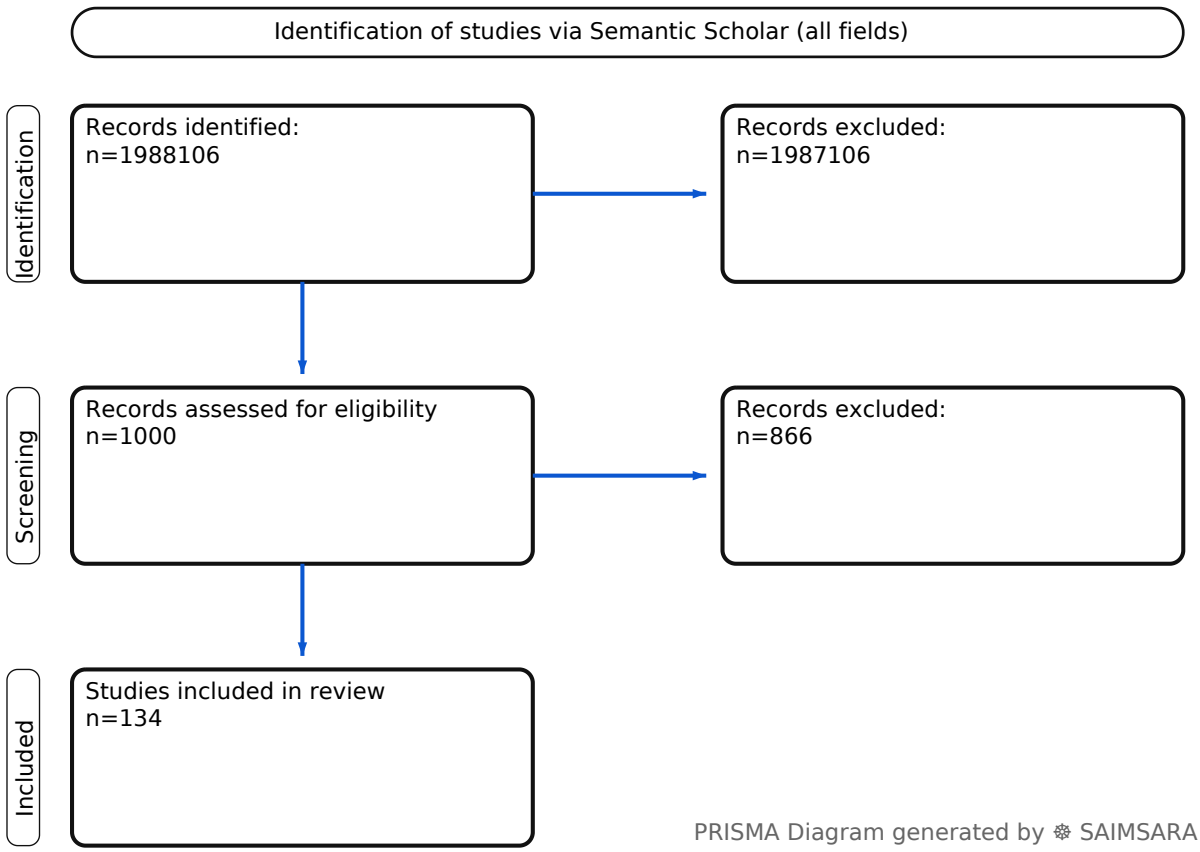
- Downloaded Abstracts/Papers: 1000
- Included original Abstracts/Papers: 134
- Total study participants (naïve ΣN): 148725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Records excluded:
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Screening
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Included
Studies included in review
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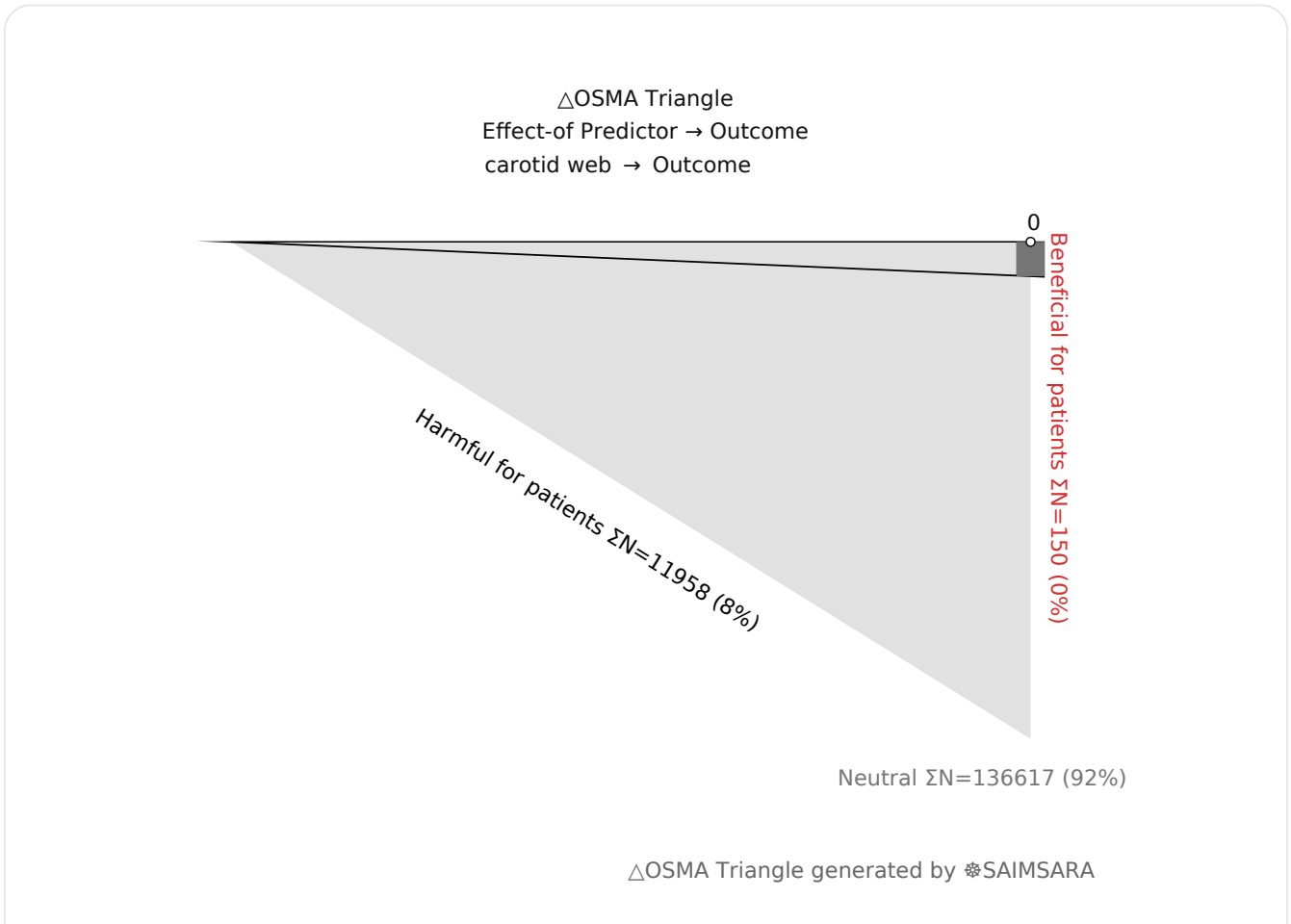
PRISMA Diagram generated by ☸ SAIMSARA


△OSMA Triangle
Effect-of Predictor → Outcome
carotid web → Outcome
0
Beneficial for patients ΣN=150 (0%)
Harmful for patients ΣN=11958 (8%)
Neutral ΣN=136617 (92%)
△OSMA Triangle generated by ☸SAIMSARA

Outcome-Sentiment Meta-Analysis (OSMA): *(LLM-only)*
Frame: Effect-of Predictor → Outcome • *Source*: Semantic Scholar
Outcome: Outcome Typical timepoints: 1-y, 3-y. Reported metrics: %, CI, p.
Common endpoints: Common endpoints: complications, occlusion, recurrence.
Predictor: carotid web — exposure/predictor. Doses/units seen: 0.17 ml. Routes seen: oral.
Typical comparator: asymptomatic caws, those without cw, stenting for carotid, conventional ultrasound….

- **1) Beneficial for patients** — Outcome with carotid web — [13], [14], [38], [45], [79], [80], [83] — ΣN=150
- **2) Harmful for patients** — Outcome with carotid web — [1], [2], [3], [4], [9], [11], [17], [19], [21], [24], [25], [27], [29], [32], [33], [43], [57], [60], [66], [74], [76], [78], [81], [90], [91], [100] — ΣN=11958
- **3) No clear effect** — Outcome with carotid web — [5], [6], [7], [8], [10], [12], [15], [16], [18], [20], [22], [23], [26], [28], [30], [31], [34], [35], [36], [37], [39], [40], [41], [42], [44], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [58], [59], [61], [62], [63], [64], [65], [67], [68], [69], [70], [71], [72], [73], [75], [77], [82], [84], [85], [86], [87], [88], [89], [92], [93], [94], [95], [96], [97], [98], [99], [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] — ΣN=136617

1) Introduction

Carotid webs (CWs), also known as intimal fibromuscular dysplasia, are increasingly recognized as a significant, yet often underdiagnosed, cause of ischemic stroke, particularly in younger patients and those with cryptogenic stroke [20, 21, 48, 51, 52, 55, 76, 90, 102, 103, 118]. These non-atherosclerotic fibrous bands typically arise along the posterior margin of the carotid bulb, causing mild luminal narrowing [106, 116]. Their presence is associated with disturbed flow patterns and the potential for thrombus formation, leading to acute ischemic events [2, 5, 31, 74, 75, 105]. The clinical challenge lies in their identification, risk stratification, and optimal management, given the substantial risk of recurrent stroke under medical therapy alone [11, 17, 81, 118].

2) Aim

This paper aims to synthesize the current understanding of carotid webs, their characteristics, diagnostic approaches, pathophysiological mechanisms, and treatment outcomes, to identify key

research gaps and inform future clinical practice.

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. Retrospective studies and case series, which constitute a significant portion of the literature, are inherently susceptible to selection bias and confounding, limiting the generalizability and causal inference of their findings. The lack of standardized diagnostic criteria and heterogeneous follow-up periods across studies also introduce variability and potential for detection bias.

4) Results

4.1 Study characteristics

The included studies predominantly employed mixed (retrospective and prospective components) or retrospective designs, alongside cohort studies, cross-sectional analyses, and numerous case series [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 49, 50, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 70, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 92, 93, 94, 95, 96, 97, 98, 99, 100, 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]. Populations primarily consisted of patients with symptomatic and asymptomatic carotid webs, often presenting with acute ischemic stroke (AIS) or transient ischemic attack (TIA), with some studies focusing on younger cohorts or cryptogenic stroke [1, 2, 3, 4, 7, 9, 10, 11, 16, 17, 19, 20, 21, 22, 24, 29, 32, 33, 34, 37, 39, 41, 43, 44, 45, 52, 55, 57, 59, 60, 61, 62, 70, 76, 77, 78, 79, 80, 81, 84, 102, 103, 111, 112, 118]. Follow-up periods varied widely, from short-term (e.g., 30 days [77], median 154 days [59]) to intermediate (e.g., 1 year [13, 45, 114, 115, 117], 2 years [3, 11]) and longer durations (e.g., 5 years [17], 12 years [70]).

4.2 Main numerical result aligned to the query

Carotid webs are associated with a high risk of recurrent ischemic events under medical management alone, with reported recurrence rates varying widely depending on the study population and follow-up duration. For instance, a prospective series reported 71.4% recurrent stroke [81], while other studies indicated recurrence rates of 56% [118] and 17% within 2 years compared to 3% in patients without CW [11]. Cumulative recurrence rates under medical treatment alone have been observed to reach 27.3% at 5 years [17].

4.3 Topic synthesis

- **High Stroke Recurrence Risk:** Carotid webs are associated with a substantial risk of early thrombus formation and recurrent ischemic stroke [2]. Symptomatic CWs show a significantly higher risk of recurrent stroke (e.g., 17% within 2 years vs. 3% without CW [11]; 27.3% at 5-year under medical treatment alone [17]; 56% recurrence rate [118]; 71.4% in a prospective series [81]). Delayed diagnosis increases recurrence risk 5-fold (aHR, 5.02) [3].
- **Morphological Risk Factors for Stroke:** Specific geometric parameters of CWs, such as angular measurements (e.g., CCA–web-pouch angle, ICA–web-pouch angle), are statistically associated with stroke status, with each additional high-risk angle increasing stroke odds by 9.47-fold [1, 33]. Symptomatic CWs tend to be longer, thicker, and larger in volume (e.g., mean length 3.2 mm vs 2.5 mm; median volume 15.0 mm^3 vs 10.6 mm^3) and oriented at more acute angles compared to asymptomatic ones [4, 19, 44, 57]. A web length of ≥3.4 mm was identified as an optimal threshold for stroke association [57].
- **Pathophysiological Mechanism of Stroke:** CWs create local hemodynamic disruption, characterized by flow stasis, larger recirculation zones, and increased wall shear stress, which stimulate thrombus formation [5, 31, 63, 74, 75, 105]. Thrombus formation within the CW is observed in a substantial proportion of patients (e.g., 17.4% [2]; 29.4% [16]). Embolized thrombi from CWs are histologically similar to other stroke thrombi [34, 35].
- **Diagnostic Modalities and Challenges:** CT angiography (CTA) and digital subtraction angiography (DSA) demonstrate comparable and superior performance to conventional ultrasound (US) in CW diagnosis [23, 82, 107]. Contrast-enhanced ultrasound (CEUS) may have higher accuracy for CW with thrombosis [16]. Optical coherence tomography (OCT) can corroborate diagnosis and identify microthrombi not seen on CTA/DSA [64, 84]. Delayed diagnosis is common, especially in minor strokes or without early CTA [3, 20]. A two-stage convolutional neural network (CNN) model shows high accuracy (92.2%) for CaW detection from CTA [6].
- **Patient Demographics and Associated Conditions:** CWs are frequently found in younger patients (e.g., mean age 49.8 years [17]; 41-59 years [16, 24, 32, 39, 43, 59, 76, 102, 112]), more commonly in females (e.g., 56.5% [17]; 74% [22]; 75% [23]), and in African American populations (e.g., 77.1% [19]; 86% [76]; 91% [59]), often with fewer traditional vascular risk factors [23]. The CW phenotype is uncommonly associated with classic fibromuscular dysplasia (FMD) changes (9% [22]), but CWs are significantly more frequent in patients with internal carotid artery dissection (ICAD) (57.6% vs 20% in VBAD and 21.8% in controls) [27, 134].
- **Treatment Strategies and Outcomes:** Carotid artery stenting (CAS) and carotid endarterectomy (CEA) appear to be safe and effective revascularization strategies for symptomatic CWs, showing low rates of recurrent stroke/TIA (e.g., 0% within 1 year for CAS

[13]; 0% in median 154 days for CEA [59]; 0% recurrence post-CEA [54, 62]) and in-stent restenosis compared to medical management alone [13, 14, 17, 25, 38, 45, 51, 54, 56, 58, 59, 62, 79, 108, 118]. Both endarterectomy and stenting diminish adverse hemodynamic effects [18]. Secondary invasive treatment is often considered in patients with absence of risk factors, milder stroke severity, and ipsilateral chronic cerebral infarction [10].

5) Discussion

5.1 Principal finding

The principal finding is that carotid webs are associated with a high risk of recurrent ischemic events under medical management alone, with reported recurrence rates varying widely, for example, from 17% within 2 years [11] to 71.4% in a prospective series [81] and 56% [118], and cumulative rates reaching 27.3% at 5 years [17]. This underscores the inadequacy of conservative approaches for symptomatic patients.

5.2 Clinical implications

- **Enhanced Diagnostic Vigilance:** Clinicians should consider carotid web as a potential stroke etiology, especially in younger patients, females, African Americans, and those with cryptogenic stroke, even in the absence of traditional vascular risk factors [16, 17, 21, 23, 52, 55, 76, 102, 112].
- **Optimized Imaging Protocols:** Early and comprehensive imaging with CT angiography (CTA) or digital subtraction angiography (DSA) is crucial for accurate diagnosis, as these modalities outperform conventional ultrasound [3, 23, 82]. Advanced techniques like contrast-enhanced ultrasound (CEUS) and optical coherence tomography (OCT) may further aid in detecting associated thrombus [16, 64].
- **Risk Stratification based on Morphology:** Geometric parameters such as web length, thickness, volume, and specific angular measurements can help stratify stroke risk and guide intervention decisions [1, 4, 19, 33, 57].
- **Consideration for Intervention:** Given the high recurrence rates with medical management, revascularization strategies like carotid artery stenting (CAS) or carotid endarterectomy (CEA) should be considered for symptomatic carotid webs, as they demonstrate safety and efficacy in preventing recurrence [13, 14, 17, 25, 38, 45, 51, 54, 56, 58, 59, 62, 79, 108, 118].
- **Routine Neurosonologic Monitoring:** Early and routine neurosonologic monitoring may be beneficial for detecting in-hospital re-thrombosis and enabling timely intervention, particularly in patients with acute presentations [2].

5.3 Research implications / key gaps

- **Comparative Efficacy of Interventions:** Further prospective, randomized controlled trials are needed to compare the long-term efficacy and safety of carotid artery stenting (CAS) versus carotid endarterectomy (CEA) versus optimized medical therapy for symptomatic carotid webs [101].
- **Standardized Diagnostic Criteria:** Research is required to establish universally accepted and standardized diagnostic criteria for carotid webs across different imaging modalities, potentially leveraging AI-driven segmentation and detection tools [6, 23, 107].
- **Natural History of Asymptomatic Carotid Webs:** Longitudinal prospective studies are necessary to determine the natural history and optimal management (medical vs. interventional) of incidentally discovered asymptomatic carotid webs [61].
- **Advanced Hemodynamic and Thrombogenic Modeling:** Further computational fluid dynamics (CFD) analysis coupled with histological validation is needed to fully elucidate the precise hemodynamic and thrombogenic mechanisms underlying carotid web-related stroke and to identify novel therapeutic targets [31, 74, 75, 105].
- **Biomarkers for Risk Prediction:** Investigation into novel biomarkers or imaging features that predict thrombus formation and stroke recurrence in carotid web patients could improve personalized risk assessment [1, 4, 19, 33, 57].

5.4 Limitations

- **Heterogeneous Study Designs** — The included literature comprises a mix of retrospective cohorts, case series, and mixed-design studies, limiting the ability to draw definitive causal conclusions or perform robust meta-analyses.
- **Variability in Diagnostic Approaches** — Different imaging modalities and diagnostic criteria were employed across studies, potentially affecting the reported prevalence and characteristics of carotid webs.
- **Lack of Standardized Follow-up** — Follow-up durations varied significantly, making direct comparisons of recurrence rates and long-term outcomes challenging.
- **Small Sample Sizes** — Many studies, particularly those on interventions or specific patient subgroups, involved small sample sizes, reducing statistical power and generalizability.
- **Limited Comparative Effectiveness Data** — There is a scarcity of direct comparative studies evaluating the long-term efficacy and safety of different treatment modalities (medical, stenting, endarterectomy).

5.5 Future directions

- **Standardized Diagnostic Protocols** — Develop and validate universal imaging protocols and diagnostic criteria for carotid webs to improve detection consistency.
- **Comparative Effectiveness Trials** — Conduct randomized controlled trials comparing medical management, carotid stenting, and carotid endarterectomy for symptomatic carotid webs.
- **Longitudinal Outcome Studies** — Establish large, prospective registries to track the natural history and long-term outcomes of both symptomatic and asymptomatic carotid webs.
- **Advanced Hemodynamic Modeling** — Utilize computational fluid dynamics to precisely quantify flow disturbances and thrombogenic risk associated with various carotid web morphologies.
- **AI-Enhanced Detection Tools** — Further develop and integrate convolutional neural networks and other AI tools for automated and highly accurate detection and characterization of carotid webs from routine imaging.

6) Conclusion

Carotid webs are associated with a high risk of recurrent ischemic events under medical management alone, with reported recurrence rates varying widely, for example, from 17% within 2 years [11] to 71.4% in a prospective series [81] and 56% [118], and cumulative rates reaching 27.3% at 5 years [17]. This high recurrence risk is particularly relevant for younger patients with cryptogenic stroke. The substantial heterogeneity in study designs and follow-up periods across the current literature most affects the certainty of definitive conclusions regarding optimal management. Therefore, a critical next step is to conduct large-scale, prospective comparative effectiveness trials to establish the best treatment strategies for symptomatic carotid webs.

References

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Figure 1. Publication-year distribution of included originals

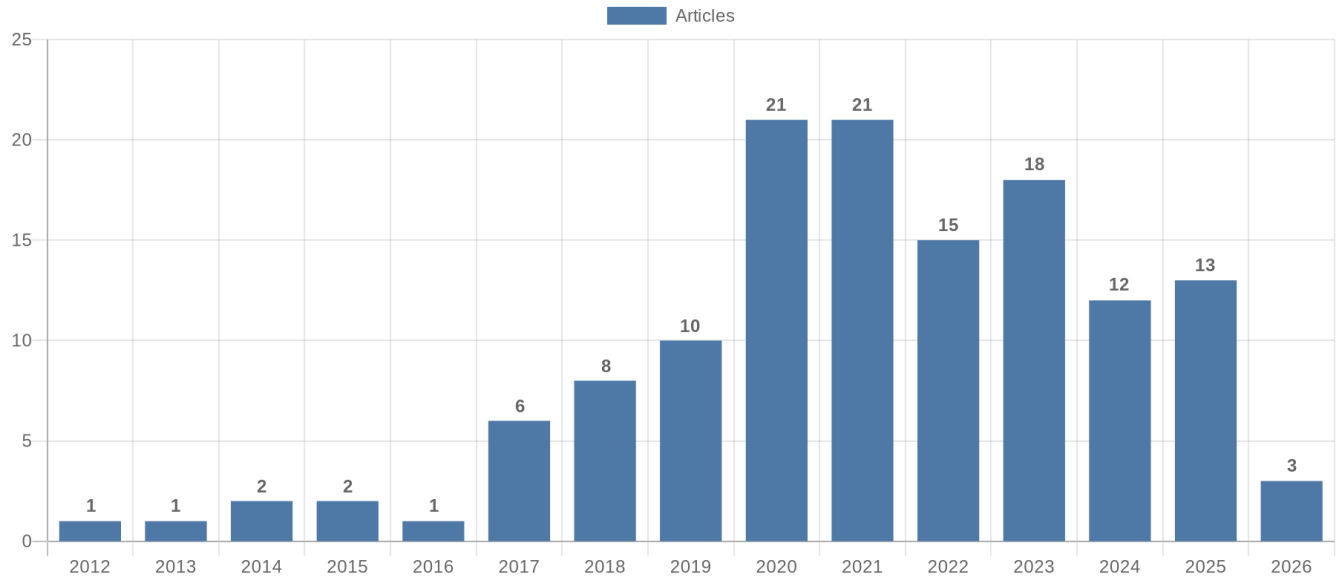

Figure 2. Study-design distribution of included originals

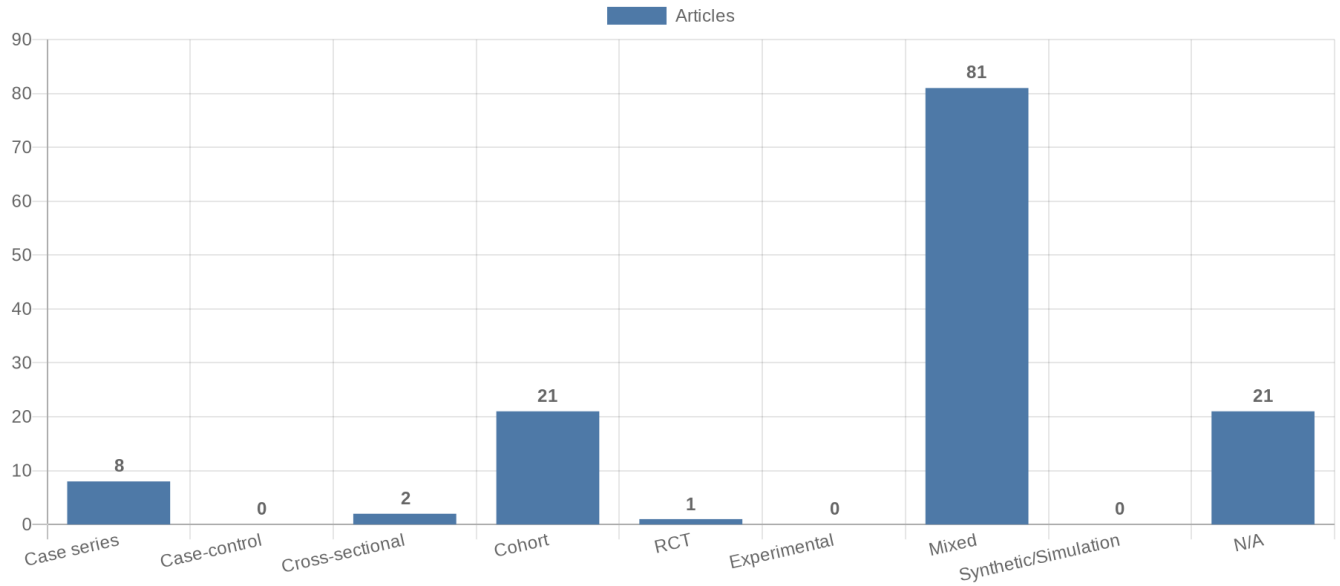

Figure 3. Study-type (directionality) distribution of included originals

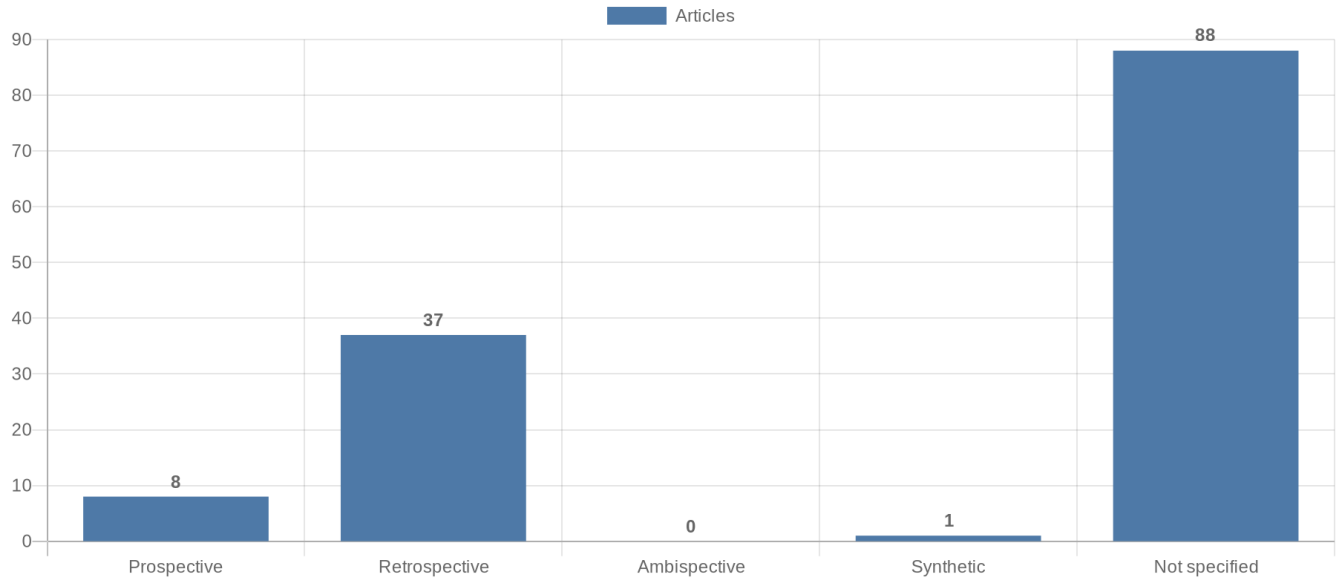

Figure 4. Main extracted research topics

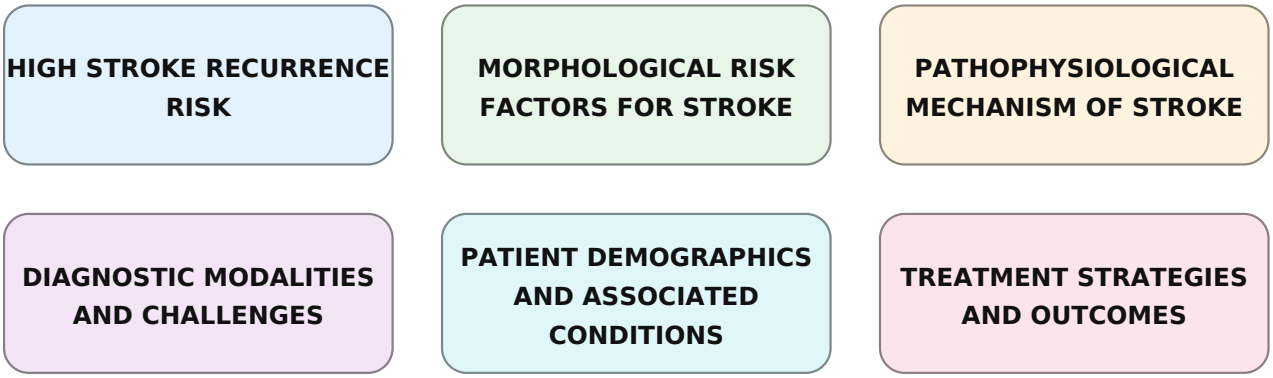

Figure 5. Limitations of current studies (topics)

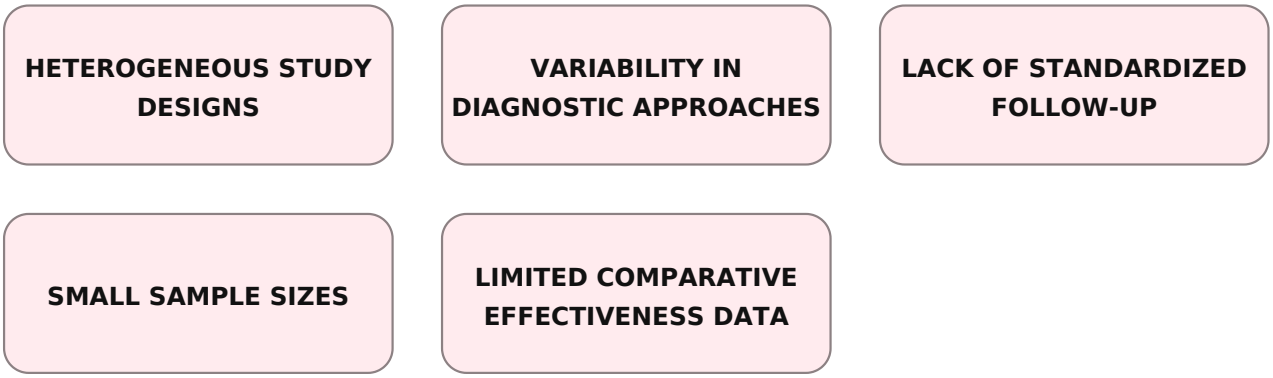

Figure 6. Future research directions (topics)