Popliteal Artery Entrapment: Systematic Review with ☸SAIMSARA.

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Abstract: This paper aims to synthesize the current understanding of Popliteal Artery Entrapment Syndrome, encompassing its prevalence, diagnostic methodologies, treatment strategies, and associated clinical outcomes, based on a structured extraction of scientific literature. The review utilises 154 studies with 1545 total participants (naïve ΣN). Long-term surgical treatment for popliteal artery entrapment syndrome (PAES), including myotomy with or without arterial reconstruction, demonstrates excellent patency, with one study reporting a 15-year primary patency of 98%. This robust outcome primarily reflects experience in specialized centers treating symptomatic patients, often young and active individuals. The most significant limitation affecting certainty across the broader understanding of PAES is the heterogeneous study designs, predominantly comprising case reports and small retrospective series. Clinicians should maintain a high index of suspicion for PAES in young, active patients presenting with exertional lower extremity pain, and consider dynamic imaging for definitive diagnosis.

Keywords: Popliteal Artery Entrapment Syndrome; Vascular claudication; Surgical treatment; Arterial reconstruction; Dynamic ultrasound; CT angiography; Functional entrapment; Anatomical variations; Athletes; Acute limb ischemia

Review Stats

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- Scope: All fields
- Keyword Gate: Fuzzy (≥60% of required terms, minimum 2 terms matched in title/abstract)
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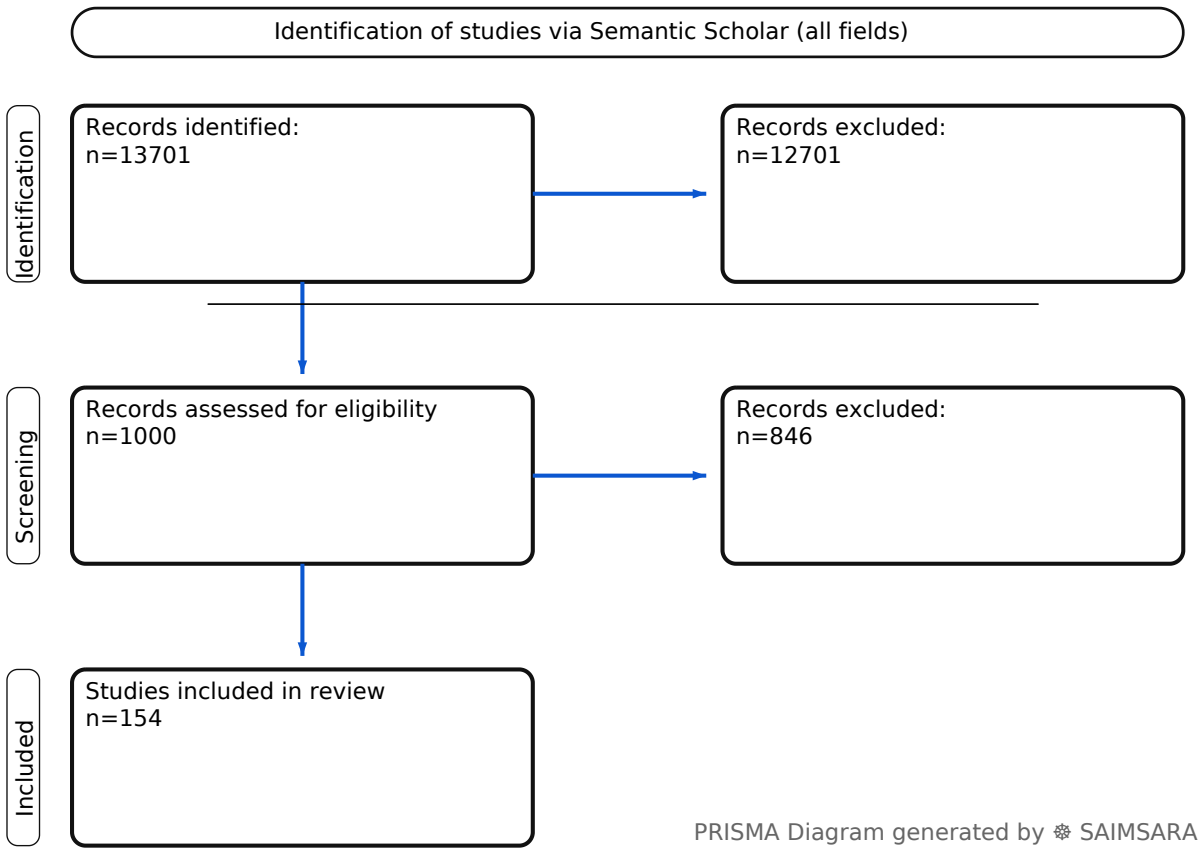
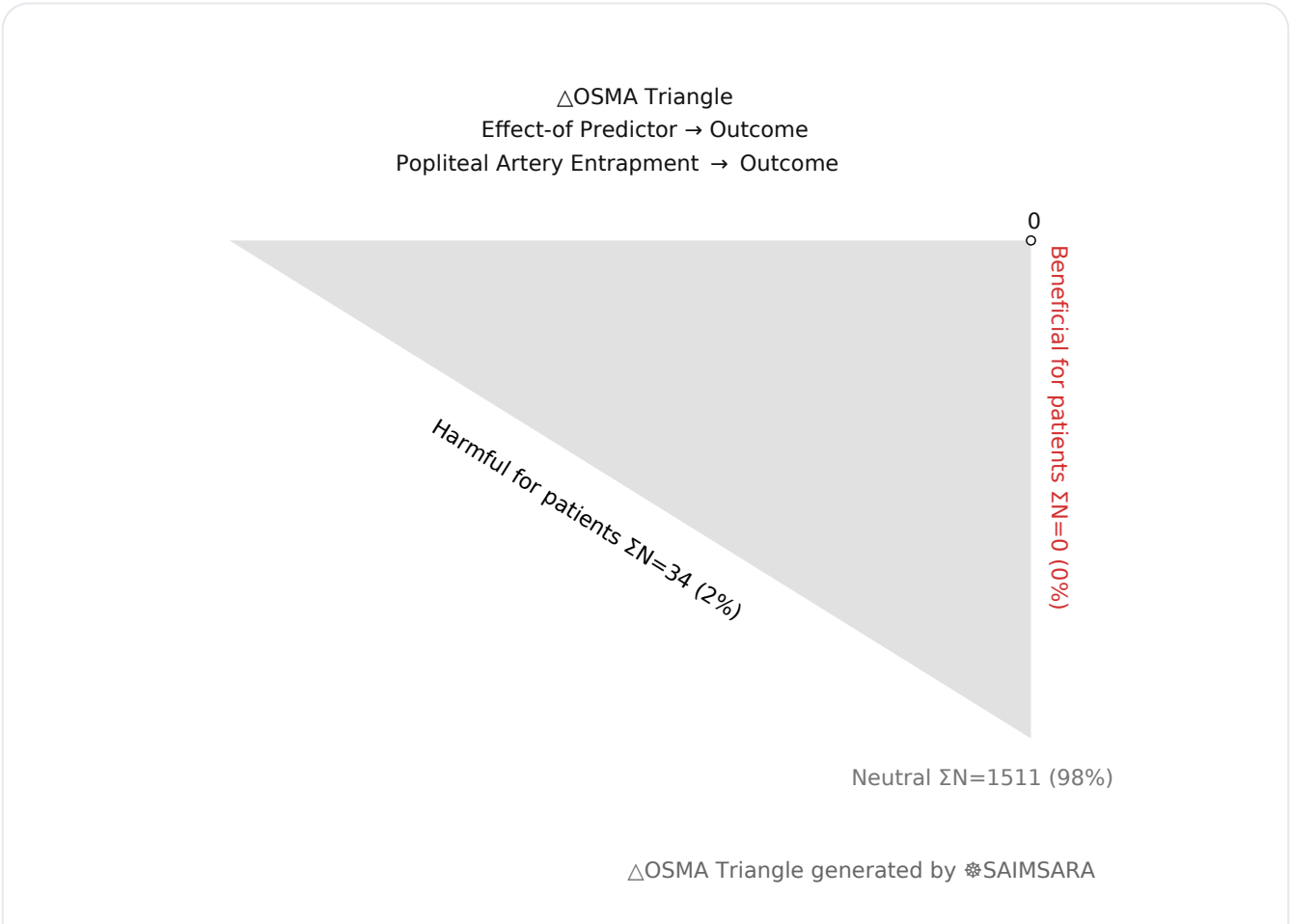
- Downloaded Abstracts/Papers: 1000
- Included original Abstracts/Papers: 154
- Total study participants (naïve ΣN): 1545


Identification of studies via Semantic Scholar (all fields)
Identification
Records identified:
n=13701
Records excluded:
n=12701
Screening
Records assessed for eligibility
n=1000
Records excluded:
n=846
Included
Studies included in review
n=154
PRISMA Diagram generated by ☸ SAIMSARA


△OSMA Triangle
Effect-of Predictor → Outcome
Popliteal Artery Entrapment → Outcome
0
Beneficial for patients ΣN=0 (0%)
Harmful for patients ΣN=34 (2%)
Neutral ΣN=1511 (98%)
△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, 15-y. Reported metrics: %, p.
Common endpoints: Common endpoints: occlusion, functional, complications.
Predictor: Popliteal Artery Entrapment — exposure/predictor. Typical comparator: non-dancer athletes, digital subtraction, balloon angioplasty for the, extramuscular grafts….

- **1) Beneficial for patients** — Outcome with Popliteal Artery Entrapment — — — ΣN=0
- **2) Harmful for patients** — Outcome with Popliteal Artery Entrapment — [60], [152], [153], [154] — ΣN=34
- **3) No clear effect** — Outcome with Popliteal Artery Entrapment — [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [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], [143], [144], [145], [146], [147], [148], [149], [150], [151] — ΣN=1511

1) Introduction

Popliteal Artery Entrapment Syndrome (PAES) is a condition characterized by the abnormal compression of the popliteal artery, often leading to exertional lower extremity pain, such as intermittent claudication, particularly in young, active individuals and athletes [3, 4, 8, 10, 38, 53, 81, 85, 86, 99, 102, 104, 105, 106, 111, 112, 123, 136]. This compression can be anatomical, due to aberrant muscle or tendon insertions, or functional, where normal muscle contraction causes compression [2, 13, 22, 25, 82, 103, 101, 149]. Diagnosis can be challenging due to its rarity, varied presentation, and potential for confusion with other lower limb injuries or conditions like chronic exertional compartment syndrome (CECS) or cystic adventitial disease [24, 61, 99, 106, 108, 110]. Early diagnosis and appropriate treatment are crucial for preventing long-term complications, including arterial occlusion, aneurysm formation, or limb ischemia [23, 40, 52, 60, 74, 78, 94, 152].

2) Aim

This paper aims to synthesize the current understanding of Popliteal Artery Entrapment Syndrome, encompassing its prevalence, diagnostic methodologies, treatment strategies, and associated clinical outcomes, based on a structured extraction of scientific literature.

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 literature reviewed predominantly consists of mixed study designs, including numerous case reports and small retrospective series, which inherently carry a higher risk of publication bias and limited generalizability compared to larger prospective or randomized controlled trials. The lack of specified directionality in many studies further limits the ability to assess potential biases.

4) Results

4.1 Study characteristics

The reviewed literature comprises a diverse range of study designs, including numerous case reports detailing unique presentations in athletes, military personnel, and young individuals [2, 3, 4, 5, 8, 9, 10, 11, 23, 35, 36, 37, 58, 63, 68, 69, 73, 76, 77, 78, 79, 81, 84, 85, 89, 90, 91, 94, 107, 108, 111, 112, 132, 141, 145, 146]. Retrospective studies analyze patient cohorts treated for PAES or related conditions, providing insights into surgical outcomes and diagnostic prevalence over periods ranging from 15 months to 15 years [1, 7, 13, 15, 22, 29, 31, 42, 44, 75, 118, 124, 153]. Prospective studies and randomized controlled trials (RCTs) are less common but address specific interventions like atherectomy or stent placement for popliteal artery lesions [14, 74, 114, 116, 119, 122]. Anatomical studies on cadavers also contribute to understanding popliteal artery variations [27, 93, 113].

4.2 Main numerical result aligned to the query

No single comparable numeric outcome exists across the diverse studies regarding the primary patency or success rates of interventions specifically for popliteal artery entrapment syndrome (PAES) due to varying definitions, follow-up durations, and patient populations. However, long-term surgical outcomes for PAES, including myotomy with or without arterial reconstruction, demonstrate good patency, with one study reporting a 15-year primary patency of 98% and freedom from target lesion revascularization of 92.4% in a cohort of 47 patients [1]. Another study on surgical treatment for PAES (49 limbs in 38 patients) reported all patients cured of their symptoms at a median follow-up of 34 months [42]. For acute popliteal artery occlusion, which can be caused by entrapment, intra-arterial thrombolysis showed a technical success of 90% and clinical success of 87% at 30 days [74].

4.3 Topic synthesis

- **Surgical Treatment Outcomes:** Long-term results of surgical treatment for PAES, including myotomy with or without arterial reconstruction using venous bypass, demonstrate good patency at 15 years (98% primary patency, 92.4% freedom from target lesion revascularization) [1]. Popliteal artery release alone or with vein bypass is the treatment of choice, with all patients cured of symptoms at 34 months median follow-up in one cohort [42]. Surgical myomectomy and popliteal bypass with interposition of vein graft can result in complete symptom resolution for Type II PAES [4]. Surgical intervention is often necessary for anatomical abnormalities [103].
- **Diagnostic Modalities:** Dynamic ultrasound is useful for demonstrating popliteal artery compression, observed in 38% of symptomatic knees in clinically suspected PAES without anatomic abnormality [15]. It also showed abnormalities in 83% (25/30 legs) of patients with popliteal vascular entrapment syndrome (PVES), with provocative maneuvers being helpful [75]. CT angiography (CTA) is crucial for diagnosis, especially post-traumatic [3, 32, 34, 39, 40, 41, 48, 54, 68]. MRI and MR angiography (MRA) are effective for evaluating PAES, including stress MR imaging and dynamic MRA [41, 43, 45, 51, 59, 88, 76]. Intravascular ultrasound (IVUS) is also useful for diagnosis [17, 28]. The ankle brachial index (ABI) is reduced in PAES (median ABI = 0.87, IQR = 0.6–1.0) but does not correlate with syndrome type [12].
- **Patient Demographics & Risk Factors:** PAES is frequently seen in young athletes, active-duty service members, and highly active individuals, often presenting as exertional lower extremity pain or intermittent claudication [2, 8, 10, 23, 38, 53, 81, 85, 86, 99, 102, 104, 105, 106, 111]. It can occur bilaterally [6, 8, 11, 36, 80]. Rare cases include presentation in a young girl [37] or a 16-year-old female with comorbidities [112]. Genetic involvement is suggested by cases in siblings [9].
- **Anatomical Variations & Types:** PAES results from compression by surrounding musculature, with various types described [4, 13, 14, 22, 76, 101, 113, 149]. Common anomalies include Type II GNM (gastrocnemius muscle) anomaly (51.4%) and aberrant plantaris muscle (28.6%) [13, 22]. The plantaris muscle has variations that may cause PAES [101]. Abnormal origin of the medial head of the gastrocnemius can lead to entrapment [76].
- **Differential Diagnosis & Associated Conditions:** PAES symptoms can mimic chronic exertional compartment syndrome (CECS), with a radiological prevalence of PAE in CECS subjects being 51.6% [7, 58, 97, 99, 100, 106, 153]. It must also be distinguished from cystic adventitial disease (CAD) and fibromuscular dysplasia [25, 51, 91, 92, 99, 108, 110, 128]. Other differential diagnoses include stress fractures and medial tibial stress syndrome [100]. PAES can be associated with peripheral thromboembolism [60].

- **Non-Surgical Treatments:** Ultrasound-guided dry needling to the medial head of the gastrocnemius has been used as a novel treatment for functional PAES [2]. Botulinum toxin is explored as a potential treatment for functional PAES [21]. Nonsurgical treatment of cystic adventitial disease caused by functional PAES has been reported [25].
- **Vascular Pathology & Complications:** PAES can lead to various vascular pathologies including stenosis, occlusion (19/26 symptomatic legs in one study) [13], aneurysm formation (2 limbs in a PVES study) [75], and acute limb ischemia [23, 74]. Histopathologic examination reveals abnormalities in the adventitia and media of the popliteal arteries [49]. Popliteal artery FMD (flow-mediated dilation) is impaired post-prolonged leg bending [115, 151].
- **Popliteal Artery Injuries & Interventions:** Popliteal artery injuries can occur due to blunt trauma (50% of injuries in one trauma center) [124], knee dislocation [5, 122], or fractures of the tibia and fibula [141, 142]. Surgical repair of popliteal artery injuries is critical for limb salvage [120, 129]. Atherectomy and stent placement are options for obstructive lesions, with atherectomy showing favorable outcomes at 1 year (75% primary patency) [114, 116, 119, 135].
- **Popliteal Vein Entrapment:** Entrapment can also affect the popliteal vein, caused by structures like the third head of the gastrocnemius muscle [84, 143, 145, 146].

5) Discussion

5.1 Principal finding

Long-term surgical treatment for popliteal artery entrapment syndrome (PAES), including myotomy with or without arterial reconstruction, demonstrates excellent patency, with one study reporting a 15-year primary patency of 98% [1].

5.2 Clinical implications

- PAES should be on the differential diagnosis for exertional lower extremity pain, especially in young, active individuals and athletes, even without traditional vascular risk factors [8, 81, 99, 102, 104, 105, 106, 112].
- Dynamic imaging modalities, such as duplex ultrasound with provocative maneuvers, CT angiography, and MR angiography, are critical for accurate diagnosis and identifying the specific anatomical entrapment type [3, 15, 17, 20, 28, 32, 34, 39, 41, 43, 45, 48, 51, 54, 59, 65, 68, 75, 88, 140].
- Surgical intervention, often involving myotomy with or without arterial reconstruction, is the primary effective treatment for anatomical PAES, demonstrating high long-term patency and symptom resolution [1, 4, 42, 44, 46, 47, 70, 103].

- Non-surgical approaches, such as dry needling or botulinum toxin, may be considered for functional PAES, but their long-term efficacy and indications require further clarification [2, 21].
- Early diagnosis and treatment are important to prevent progressive arterial damage, such as occlusion, aneurysm formation, or acute limb ischemia, which can lead to severe complications [23, 52, 60, 74, 78, 94, 152].

5.3 Research implications / key gaps

- **Comparative Treatment Efficacy** — Future studies should compare the long-term efficacy and recurrence rates of non-surgical treatments (e.g., dry needling, botulinum toxin) versus surgical interventions for functional PAES [2, 21].
- **Standardized Diagnostic Criteria** — Research is needed to develop standardized, evidence-based diagnostic criteria for PAES, particularly for functional entrapment, to reduce misdiagnosis and ensure timely intervention [15, 24, 75, 82].
- **Genetic Predisposition** — Further investigation into the genetic basis of PAES, potentially through family-based studies, could elucidate predisposing factors and inform screening strategies [9].
- **Athlete-Specific Outcomes** — Prospective cohort studies are needed to evaluate the long-term career and functional outcomes of athletes treated for PAES, considering specific sports and levels of activity [38, 53, 102, 103, 104, 105, 106].
- **Impact of Endothelial Dysfunction** — Studies should explore the clinical significance of impaired popliteal artery endothelial function in PAES patients and its potential role in disease progression or treatment response [115, 151].

5.4 Limitations

- **Heterogeneous Study Designs** — The reliance on numerous case reports and small retrospective studies limits the generalizability and strength of evidence for prevalence, optimal diagnosis, and treatment.
- **Lack of Standardized Outcomes** — Inconsistent reporting of outcomes, follow-up durations, and patient populations across studies prevents robust quantitative synthesis of treatment efficacy or complication rates.
- **Diagnostic Variability** — The diverse array of diagnostic modalities and criteria used in different studies introduces variability, making it difficult to compare diagnostic accuracy and establish a gold standard.

- **Focus on Symptomatic Cases** — Most studies focus on symptomatic individuals, potentially underestimating the true prevalence of anatomical variations or subclinical entrapment in asymptomatic populations [109].
- **Limited Long-Term Data** — While some studies report long-term surgical patency, comprehensive long-term follow-up data for all treatment types and patient subgroups, especially non-surgical, is sparse.

5.5 Future directions

- **Prospective Cohort Studies** — Conduct large, multicenter prospective cohort studies to evaluate the natural history of PAES and the long-term outcomes of various treatment modalities.
- **Standardized Imaging Protocols** — Develop and validate standardized dynamic imaging protocols (e.g., Duplex US, CTA, MRA) for consistent and accurate diagnosis of PAES types.
- **Registry Development** — Establish an international PAES patient registry to collect comprehensive data on demographics, clinical presentation, diagnostic findings, treatments, and long-term outcomes.
- **Biomarker Identification** — Investigate potential biomarkers for early detection of arterial damage or to predict treatment response in PAES patients.
- **Patient-Reported Outcomes** — Incorporate standardized patient-reported outcome measures (PROMs) to better understand the impact of PAES and its treatments on quality of life and functional status.

6) Conclusion

Long-term surgical treatment for popliteal artery entrapment syndrome (PAES), including myotomy with or without arterial reconstruction, demonstrates excellent patency, with one study reporting a 15-year primary patency of 98% [1]. This robust outcome primarily reflects experience in specialized centers treating symptomatic patients, often young and active individuals. The most significant limitation affecting certainty across the broader understanding of PAES is the heterogeneous study designs, predominantly comprising case reports and small retrospective series. Clinicians should maintain a high index of suspicion for PAES in young, active patients presenting with exertional lower extremity pain, and consider dynamic imaging for definitive diagnosis.

References

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Figure 1. Publication-year distribution of included originals

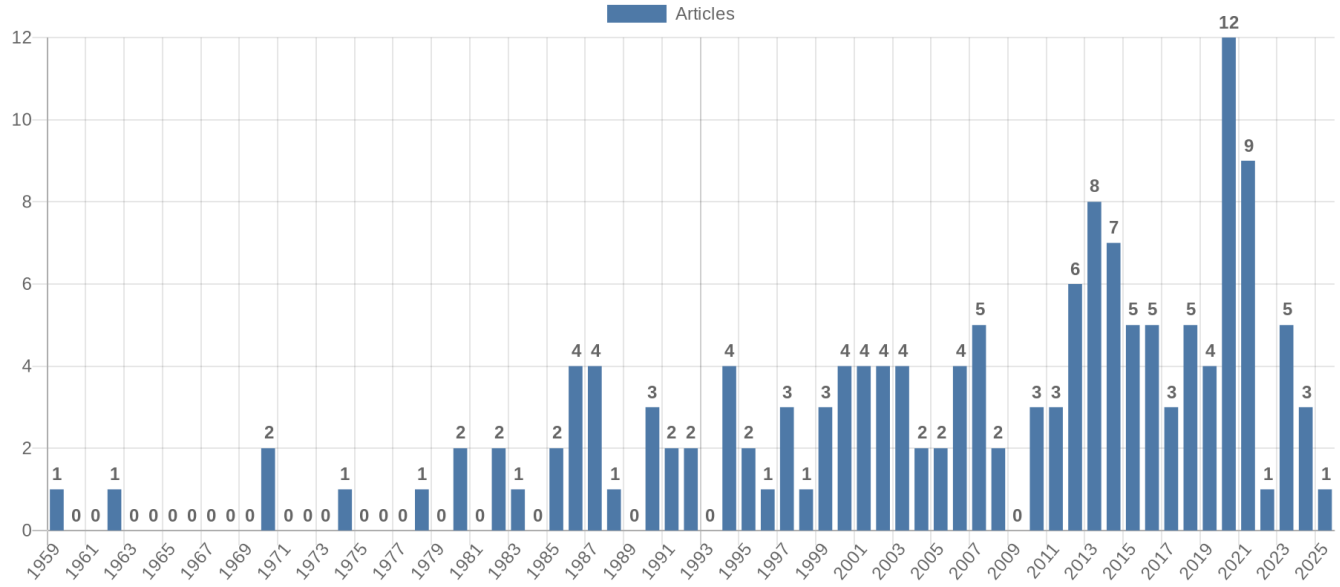

Figure 2. Study-design distribution of included originals

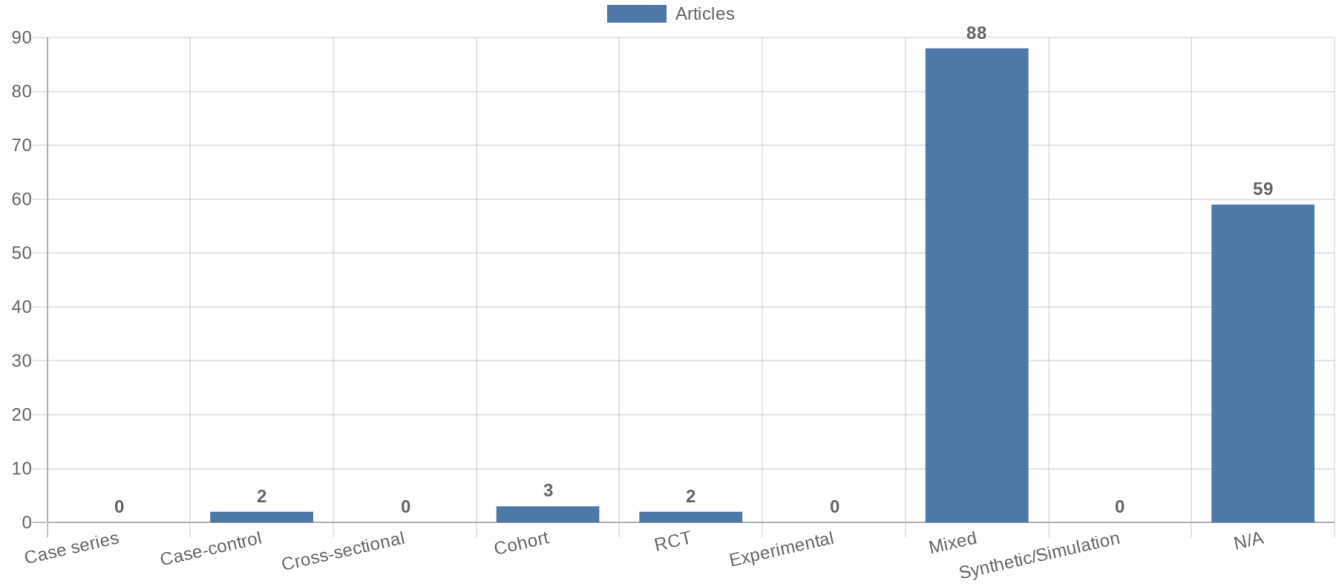

Figure 3. Study-type (directionality) distribution of included originals

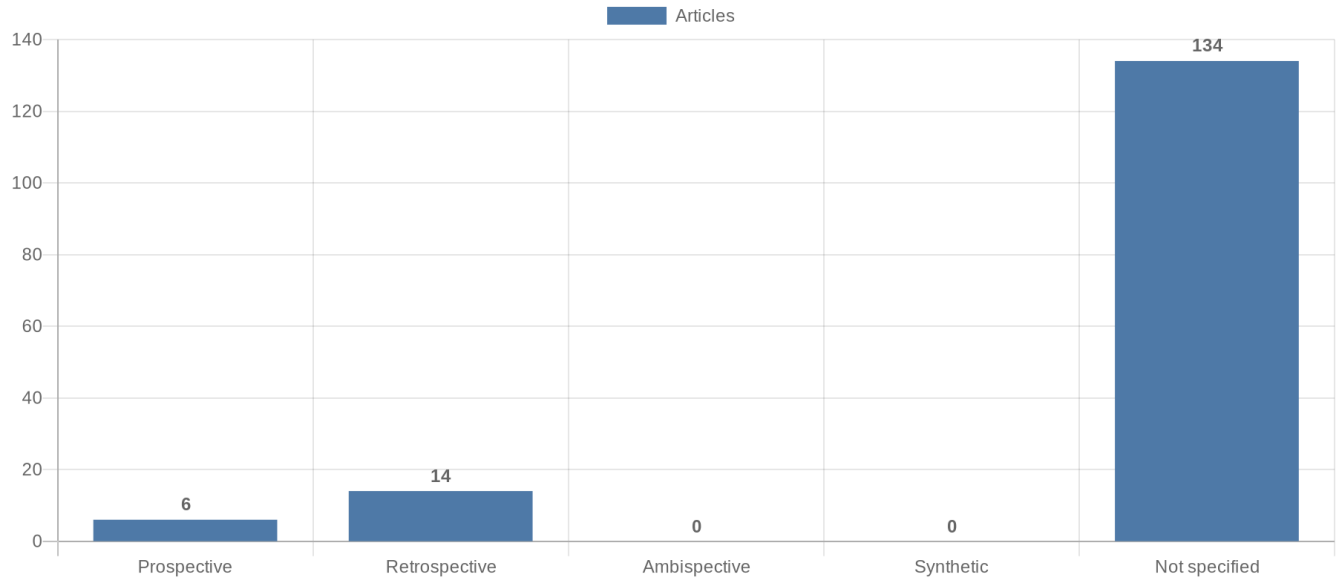

Figure 4. Main extracted research topics

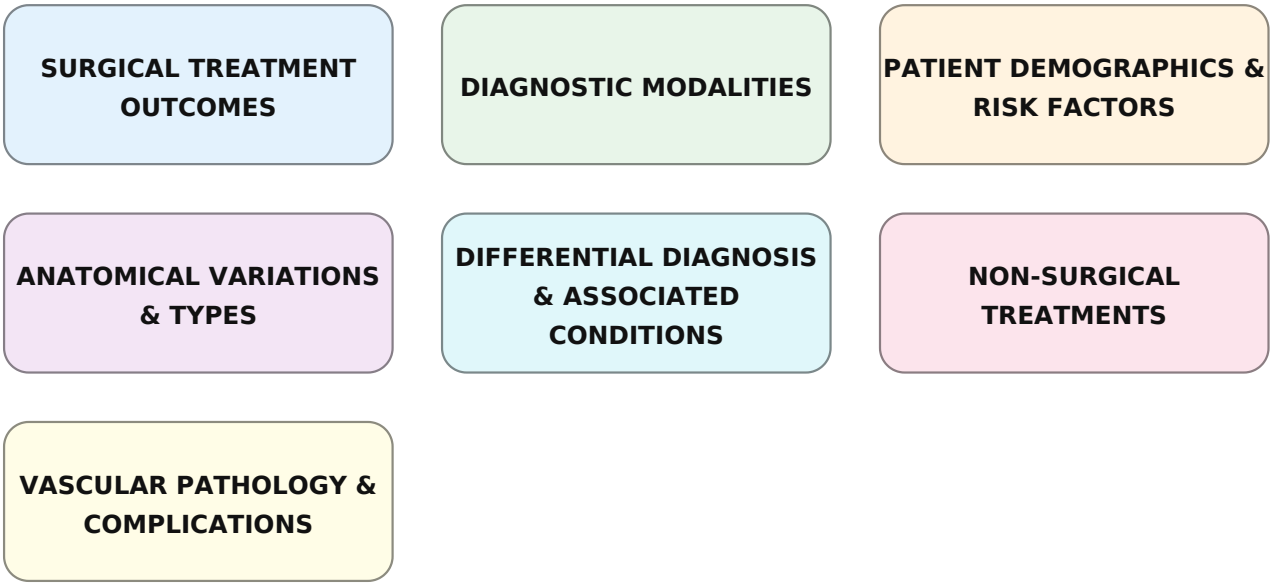

Figure 5. Limitations of current studies (topics)

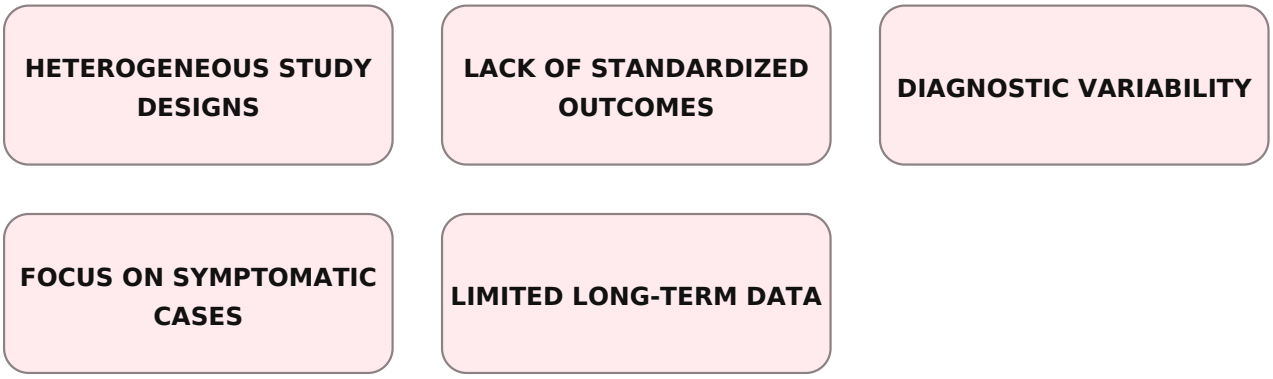

Figure 6. Future research directions (topics)

COMPARATIVE TREATMENT EFFICACY

STANDARDIZED DIAGNOSTIC CRITERIA

GENETIC PREDISPOSITION

ATHLETE-SPECIFIC OUTCOMES

IMPACT OF ENDOTHELIAL DYSFUNCTION

PROSPECTIVE COHORT STUDIES

STANDARDIZED IMAGING PROTOCOLS