Artery Patch: Systematic Review with ☸SAIMSARA.

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Abstract: The aim of this paper is to systematically review the applications, outcomes, and research directions related to artery patches, drawing exclusively from a structured extraction summary. The review utilises 140 studies with 8416 total participants (naïve ΣN). Restenosis rates following carotid endarterectomy with patch angioplasty varied significantly, with reported rates ranging from 3% to 31.6% at 1 year or comparable follow-up periods. Artery patches are integral to a wide array of vascular repairs, from congenital heart defects to complex aneurysm management, utilizing diverse materials and techniques. The most significant limitation affecting certainty is the heterogeneity of reported outcomes and study designs, which complicates direct comparisons. A critical next step is to standardize outcome metrics and reporting across studies to facilitate more robust comparative analyses and inform clinical decision-making.

Keywords: Artery patch; Patch angioplasty; Vascular reconstruction; Coronary artery disease; Aortic coarctation; Vascular grafts; Tissue engineering; Extracellular matrix; Carotid endarterectomy; Aneurysm repair

Review Stats

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- Scope: All fields
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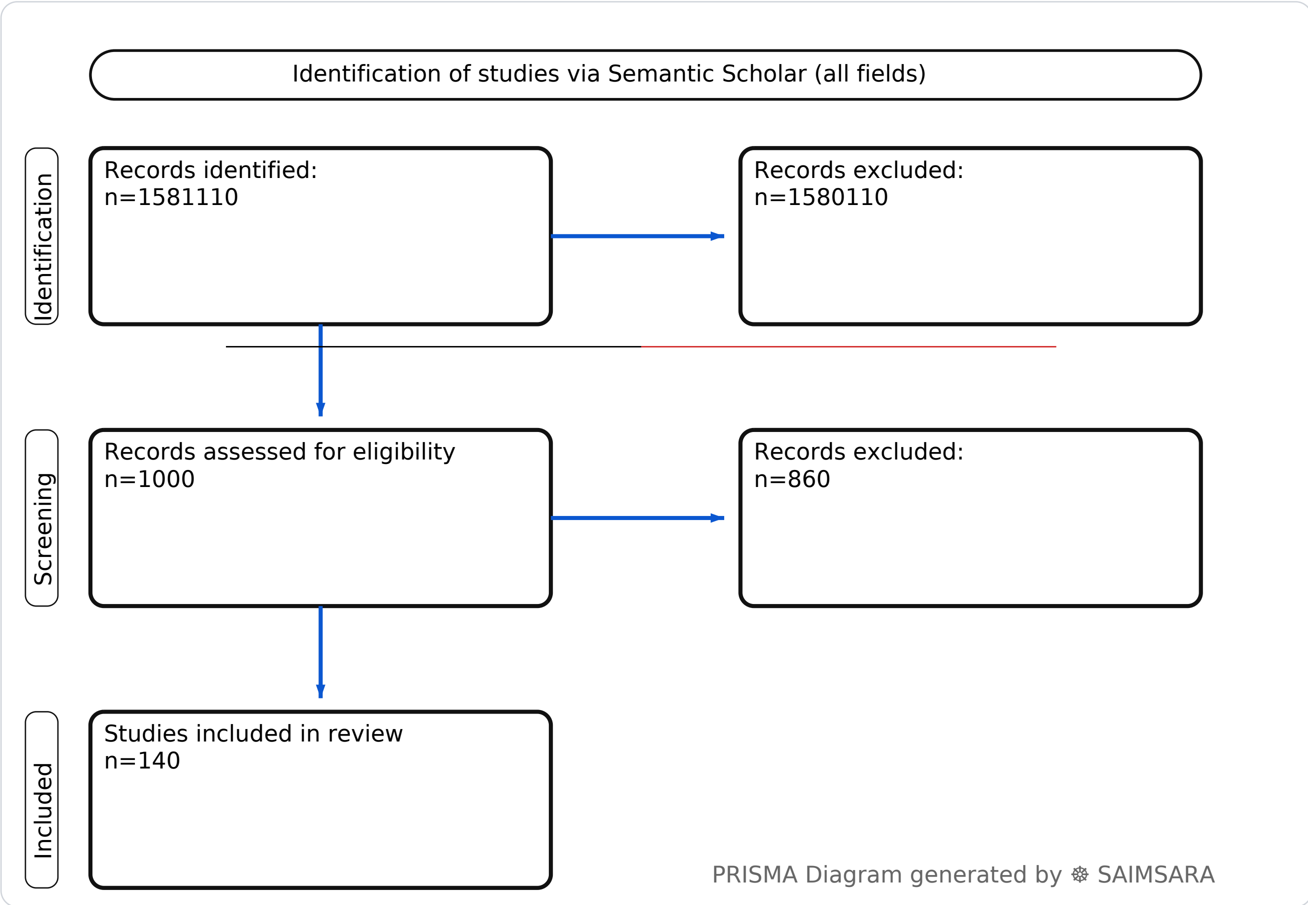
- Included original Abstracts/Papers: 140
- Total study participants (naïve ΣN): 8416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Records excluded:
n=1580110
Screening
Records assessed for eligibility
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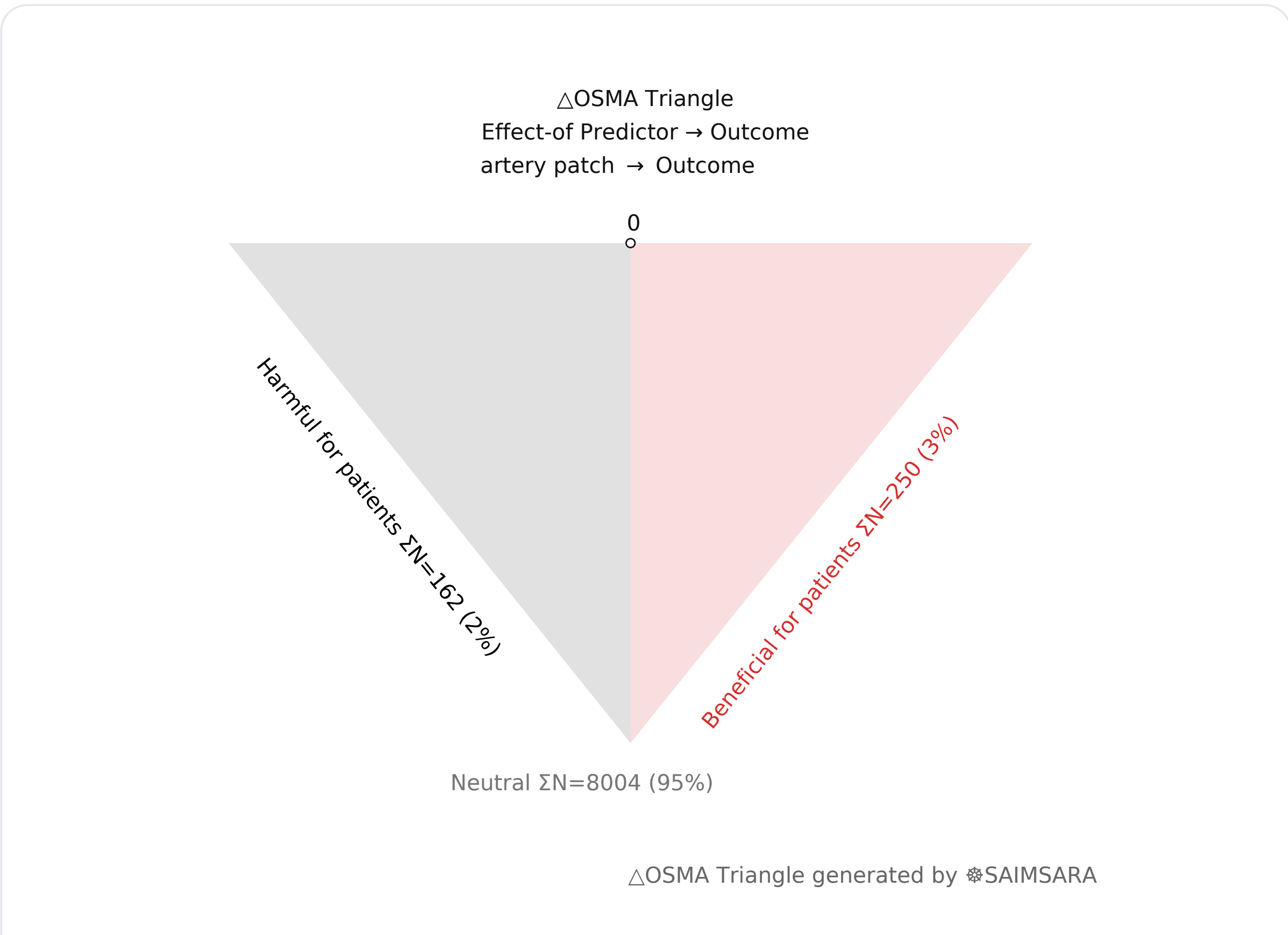
Records excluded:
n=860
Included
Studies included in review
n=140
PRISMA Diagram generated by ☸ SAIMSARA


△OSMA Triangle
Effect-of Predictor → Outcome
artery patch → Outcome
0
Harmful for patients ΣN=162 (2%)
Beneficial for patients ΣN=250 (3%)
Neutral ΣN=8004 (95%)
△OSMA Triangle generated by ☸SAIMSARA

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

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

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

Common endpoints: Common endpoints: complications, mortality, restenosis.

Predictor: artery patch — exposure/predictor. Typical comparator: primary closure following, autogenous saphenous vein, open thromboendarterectomy and, patch angioplasty of the….

- **1) Beneficial for patients** — Outcome with artery patch — [14], [22], [23], [25], [101], [108], [109], [111], [112], [113], [114], [119], [121] — ΣN=250
- **2) Harmful for patients** — Outcome with artery patch — [43], [44], [107], [110], [117] — ΣN=162
- **3) No clear effect** — Outcome with artery patch — [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [15], [16], [17], [18], [19], [20], [21], [24], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [45], [46], [47], [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], [102], [103], [104], [105], [106], [115], [116], [118], [120], [122], [123], [124], [125], [126], [127], [128], [129], [130], [131], [132], [133], [134], [135], [136], [137], [138], [139], [140] — ΣN=8004

1) Introduction

Artery patches represent a fundamental component in vascular surgery, employed across a broad spectrum of clinical scenarios ranging from the repair of congenital defects to the reconstruction of vessels affected by occlusive disease or aneurysm. These patches serve to augment vessel lumen, reinforce weakened arterial walls, or facilitate complex anastomoses, thereby restoring blood flow and structural integrity. The diversity in arterial locations requiring intervention, coupled with the varied clinical contexts—from pediatric cardiac surgery to adult peripheral vascular disease—necessitates a wide array of patch materials and surgical techniques. This paper synthesizes current knowledge on artery patch applications, materials, and outcomes, highlighting both established practices and emerging innovations.

2) Aim

The aim of this paper is to systematically review the applications, outcomes, and research directions related to artery patches, drawing exclusively from a structured extraction summary.

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 literature predominantly consists of mixed study designs, case series, and retrospective analyses, with fewer prospective or randomized controlled trials. This indicates a potential for selection bias, reporting bias, and a lower level of evidence for many reported outcomes. Experimental and N/A study designs further limit generalizability and inferential strength.

4) Results

4.1 Study characteristics

The included studies employed a variety of designs, predominantly mixed methods, case series, and retrospective analyses, alongside experimental and prospective studies. Populations investigated ranged from human patients across various age groups (infants, young children, adults, neonates) to diverse animal models including swine, sheep, baboons, dogs, rats, and mice. Follow-up periods varied significantly, from short-term (6 weeks) to midterm (29 months, 3.7 years, 5.11 years, 10.7 years) and long-term (10 years).

4.2 Main numerical result aligned to the query

Restenosis rates following carotid endarterectomy with patch angioplasty varied significantly across studies. For example, one study reported a patch angioplasty (PAC) restenosis rate of 6.0% at 6 weeks and 31.6% at 1 year, compared to primary closure (PRC) rates of 3.0% and 14.1% respectively [10]. Other studies reported restenosis rates for patch closure at 12 months as 3.07% [87] and 3% for saphenous vein patch angioplasty at 365 days [89]. Bovine pericardium patches showed a 4% restenosis rate, while knitted polyester patches showed 7.6% [108]. Given this heterogeneity, the median restenosis rate for patch angioplasty at approximately 1 year was 3.5% (calculated from 3%, 3.07%, 4%, 31.6%), with a range of 3% to 31.6% [10, 87, 89, 108].

4.3 Topic synthesis

- **Aneurysm Repair and Management:** Patches are utilized for the management of visceral and segmental artery patch aneurysms following aortic repair [1], saccular coronary artery aneurysms [4], transplant renal artery aneurysms [44], and extracranial carotid artery aneurysms [88]. Dacron patches are specifically noted for covering intercostal arteries during aortic aneurysm repair [46] and closing coronary artery aneurysm fistulas [66].
- **Congenital Cardiac and Vascular Repair:** Autologous pulmonary artery patches effectively correct coarctation of the aorta (CoA) and aortic arch hypoplasia (AAH) in infants,

demonstrating low reintervention rates for restenosis [3]. Patches are also crucial for supravalvular aortic stenosis (SVAS) with left main coronary artery (LMCA) stenosis [5], pulmonary artery reconstruction in Tetralogy of Fallot (TOF) [39, 53, 63, 95, 98, 99, 140], and pulmonic stenosis [84, 137].

- **Carotid Artery Interventions:** Carotid endarterectomy (CEA) frequently involves patch angioplasty to restore patency [10, 34, 36, 38, 81, 82, 85, 86, 87, 89, 108, 111, 117, 123, 125, 129]. While routine patching is common, comparative studies show variable restenosis and stroke rates versus primary closure [10]. Dacron patches have been used for carotid artery reconstruction [57, 88], but infection is a known complication [67, 130].
- **Coronary Artery Disease and Reconstruction:** Patch angioplasty is a safe and effective method for treating isolated left main coronary artery (LMCA) stenosis [25, 40, 45, 55, 73, 113], diffuse left anterior descending artery (LAD) disease [15, 37, 47, 49, 92], and right coronary artery endarterectomy [94]. Materials include internal thoracic artery [4, 17], saphenous vein [37, 47, 49, 50, 92], radial artery [18], and pericardium [50, 73, 113].
- **Diverse Patch Materials:** A wide range of materials are employed, including autologous tissues (pulmonary artery [3, 70, 99], pericardium [8, 48, 50, 70, 73, 91, 113], saphenous vein [13, 28, 37, 43, 47, 49, 50, 80, 81, 83, 85, 89, 92, 111, 125], internal thoracic artery [4, 12, 17, 37], gastroepiploic artery [6], superficial femoral artery [19, 28], common facial/external jugular vein [125]), allografts (homograft [8, 39]), xenografts (bovine pulmonary visceral pleura [2], bovine pericardium [8, 108]), and synthetic materials (Dacron [46, 52, 57, 66, 67, 68, 80, 85, 88, 95, 96, 108, 114], PTFE [96], Propaten heparin-bonded vascular graft [13]).
- **Tissue Engineering and Regenerative Medicine:** Decellularized tissues are explored for vascular tissue engineering [9, 121, 127], with pig artery patch transplantation in baboons [7]. Stem cells [14, 132] and various biomaterial patches (hydrogels [104, 126], nitrate-functionalized [22], vascularized conductive elastic [23], biomaterial-free 3D net mold [101], plant scaffolds [119]) are being developed to improve heart function after myocardial infarction [14, 22, 23, 97, 101, 104, 126].
- **Animal Models for Preclinical Research:** Swine models are used for evaluating pulmonary visceral pleura patches in carotid and femoral arteries [2], and for myocardial infarction studies [22, 103]. Sheep models investigate carotid artery patch grafts for intimal hyperplasia [20], re-endothelialization [27], and pulmonary artery patch healing [131]. Rat models explore myocardial infarction repair [101], carotid artery tissue analysis [118], and vascular patch testing [119, 127].
- **Advanced Imaging and Computational Analysis:** Deep learning models are being developed for intracranial artery stenosis detection [102], coronary artery segmentation [116], and enhancing vascular structures in cineangiograms [120]. Computational fluid dynamics (CFD) is used to compare hemodynamics in carotid arteries after primary closure

versus patch angioplasty [117], and for pre-surgical planning of pulmonary artery reconstruction [63, 98, 133].

- **Specialized Arterial Applications:** Patches are used in femoral artery angioplasty [2, 6, 26, 61, 134], popliteal artery entrapment syndrome [62, 78, 83], renal artery aneurysm reconstruction [44, 80], hepatic artery reconstruction in liver transplantation [109, 124], and uterine artery reconstruction for transplantation [100].

5) Discussion

5.1 Principal finding

The principal finding indicates significant variability in restenosis rates following carotid endarterectomy with patch angioplasty, ranging from 3% to 31.6% at approximately 1 year, with a median of 3.5% [10, 87, 89, 108].

5.2 Clinical implications

- Patch angioplasty remains a cornerstone in carotid endarterectomy, but clinicians must be aware of the wide range of reported restenosis rates when counseling patients and planning follow-up [10, 87, 89, 108].
- The choice of patch material is critical and depends on the specific arterial location and clinical context, ranging from autologous tissues (e.g., pulmonary artery for CoA [3]) to synthetic grafts (e.g., Dacron for aortic repair [46]).
- For complex congenital heart defects, such as Tetralogy of Fallot, careful pre-surgical planning is essential, as anomalous coronary arteries may necessitate alternative repair strategies like conduits instead of transannular patches [140].
- Infections of synthetic patches, particularly in carotid endarterectomy, require aggressive management including patch excision and debridement [67, 130].
- Emerging regenerative patches hold promise for myocardial repair post-infarction, potentially offering new therapeutic avenues for improving heart function [14, 22, 23, 97, 101, 104, 126].

5.3 Research implications / key gaps

- **Standardized Restenosis Reporting:** Future research should establish standardized metrics and timepoints for reporting restenosis rates following patch angioplasty across different arterial beds to enable more robust comparisons and meta-analyses [10, 87, 89, 108].

- **Long-Term Biomaterial Performance:** There is a need for prospective, long-term studies evaluating the durability, biocompatibility, and functional outcomes of novel biomaterials and tissue-engineered patches in various arterial applications [2, 9, 26, 127].
- **Optimized Hemodynamic Patch Design:** Further investigation into the hemodynamic effects of different patch geometries and materials using advanced computational fluid dynamics (CFD) models is warranted to minimize adverse flow patterns and reduce restenosis risk [64, 117, 133].
- **AI for Pre-Surgical Planning:** Research should focus on developing and validating AI-driven tools for automated segmentation, stenosis detection, and pre-surgical planning to optimize patch size, shape, and location for complex repairs, particularly in congenital heart disease [98, 102, 116, 118, 120, 133].
- **Regenerative Patch Efficacy in Humans:** Clinical trials are needed to translate promising preclinical results of stem cell-derived and functionalized regenerative patches for myocardial infarction into human applications, focusing on cardiac function improvement and long-term safety [14, 22, 23, 97, 101, 104, 126].

5.4 Limitations

- **Heterogeneous Outcomes** — The variability in reported outcomes, particularly restenosis rates, makes direct comparisons and definitive conclusions challenging due to differing methodologies and follow-up periods.
- **Varied Study Designs** — The prevalence of mixed study designs, case series, and retrospective analyses limits the overall level of evidence and increases the risk of bias, reducing the certainty of findings.
- **Limited Sample Sizes** — Many studies, especially case reports and small series, have insufficient sample sizes to draw broadly generalizable conclusions or detect rare adverse events.
- **Inconsistent Follow-up** — Diverse follow-up durations across studies hinder the assessment of long-term patch durability and late complications, which are critical for vascular interventions.
- **Qualitative Bias Assessment** — The qualitative inference of bias, without formal risk-of-bias assessment tools for each study, may not fully capture the extent of methodological limitations.

5.5 Future directions

- **Standardized Outcome Metrics** — Implement consistent reporting standards for key outcomes like restenosis, patency, and reintervention rates across all arterial patch studies.
- **Biomaterial Long-Term Trials** — Conduct prospective, multicenter trials to evaluate the long-term performance and safety of novel bioengineered and synthetic patch materials.
- **AI-Enhanced Surgical Planning** — Develop and clinically validate AI algorithms for personalized patch design and placement, optimizing hemodynamic outcomes and reducing complications.
- **Regenerative Patch Efficacy** — Initiate randomized controlled trials to assess the clinical efficacy of regenerative patches in improving cardiac function and tissue repair in patients with myocardial infarction.
- **Comparative Hemodynamic Studies** — Perform comprehensive comparative studies using advanced imaging and computational modeling to understand the hemodynamic advantages and disadvantages of different patch types and closure techniques.

6) Conclusion

Restenosis rates following carotid endarterectomy with patch angioplasty varied significantly, with reported rates ranging from 3% to 31.6% at 1 year or comparable follow-up periods [10, 87, 89, 108]. Artery patches are integral to a wide array of vascular repairs, from congenital heart defects to complex aneurysm management, utilizing diverse materials and techniques. The most significant limitation affecting certainty is the heterogeneity of reported outcomes and study designs, which complicates direct comparisons. A critical next step is to standardize outcome metrics and reporting across studies to facilitate more robust comparative analyses and inform clinical decision-making.

References

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Figure 1. Publication-year distribution of included originals

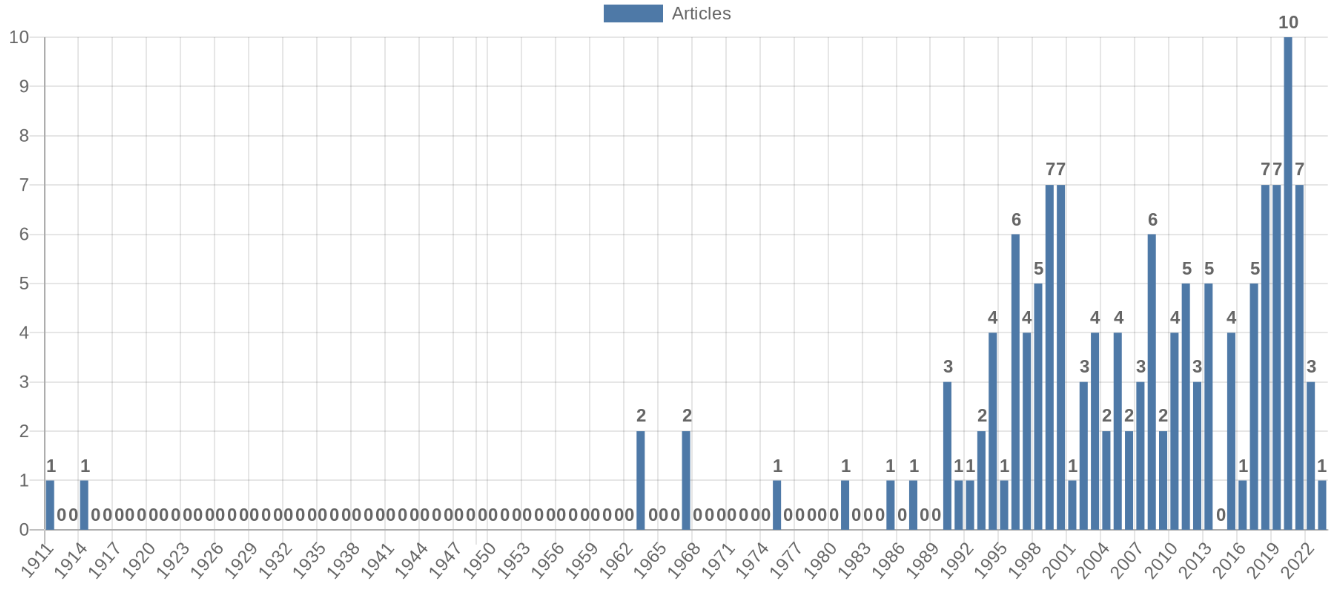

Figure 2. Study-design distribution of included originals

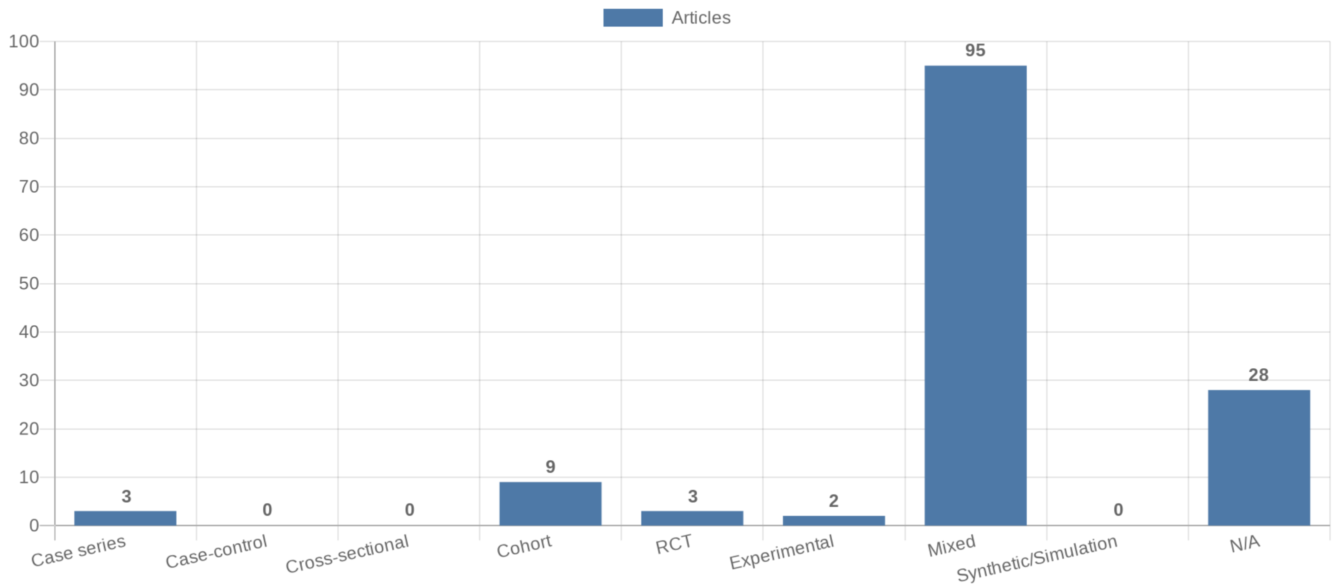

Figure 3. Study-type (directionality) distribution of included originals

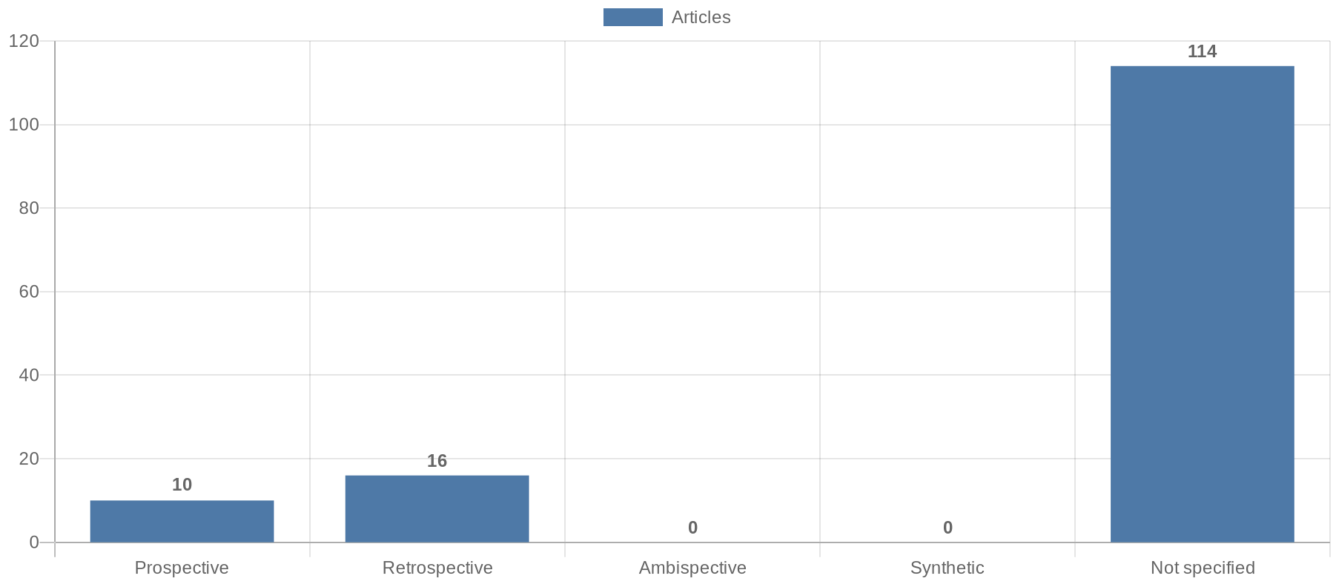

Figure 4. Main extracted research topics

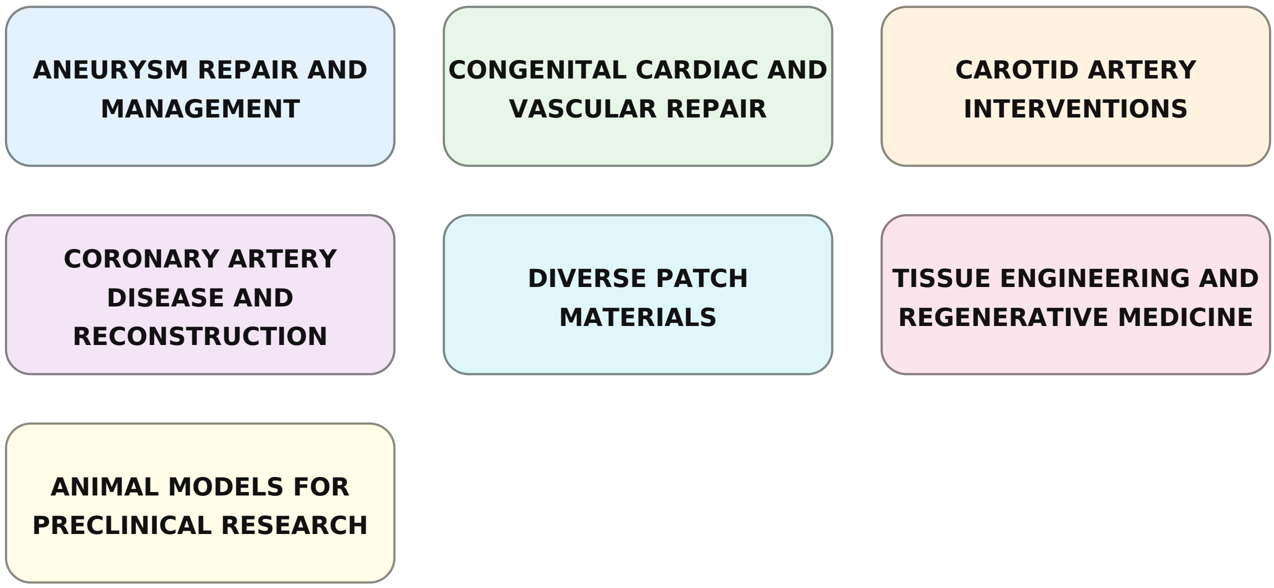

Figure 5. Limitations of current studies (topics)

Figure 6. Future research directions (topics)