Abdominal Aortic Aneurysm and Survival: Systematic Review with ☸SAIMSARA.

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Abstract: The aim of this paper is to systematically review and synthesize the available evidence on factors influencing survival in patients with abdominal aortic aneurysms, encompassing various treatment modalities, patient demographics, and clinical contexts. The review utilises 344 studies with 329232 total participants (naïve ΣN). For elective repair of intact abdominal aortic aneurysms, the median 30-day mortality rate for open surgical repair was 2.95%, while for endovascular aneurysm repair, it was 1.1%. For ruptured AAAs, EVAR offered a lower median 30-day mortality of 16.5% compared to 35% for OSR. While these findings suggest an early survival advantage for EVAR, particularly in ruptured cases, the generalizability is limited by the diverse study designs and patient populations. The most significant limitation affecting certainty is the prevalence of retrospective cohort studies, which are prone to selection and confounding biases. A concrete next step is to conduct large-scale, long-term randomized controlled trials to definitively compare EVAR and OAR across various patient subgroups, focusing on both early and late survival and quality of life.

Keywords: Abdominal aortic aneurysm; AAA repair; Patient survival; Endovascular aneurysm repair; Open aneurysm repair; Statin therapy; Socioeconomic factors; Elderly patients; Cancer comorbidity; Prognostic factors

Review Stats

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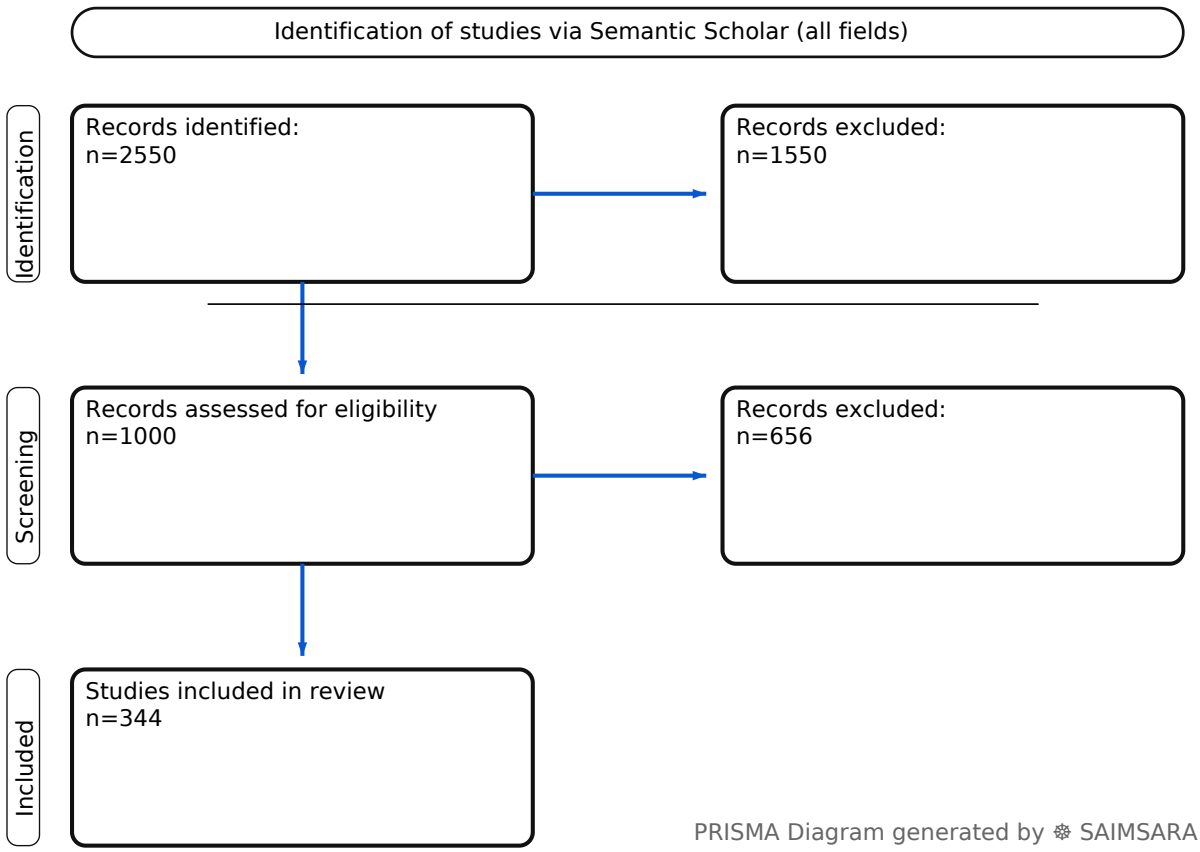
- Included original Abstracts/Papers: 344
- Total study participants (naïve ΣN): 329232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Records excluded:
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Studies included in review
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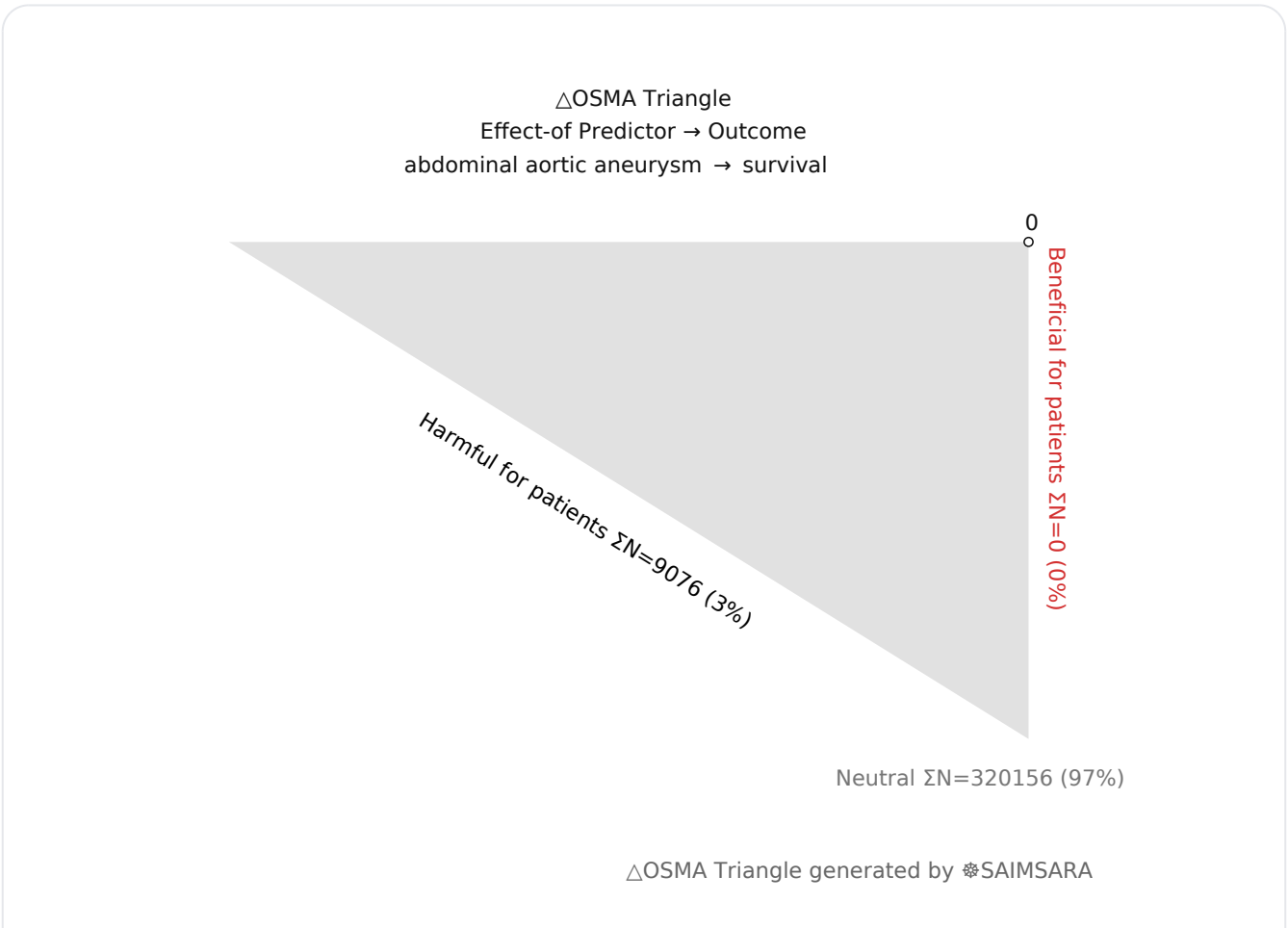
PRISMA Diagram generated by ☸ SAIMSARA


△OSMA Triangle
Effect-of Predictor → Outcome
abdominal aortic aneurysm → survival
0
Beneficial for patients ΣN=0 (0%)
Harmful for patients ΣN=9076 (3%)
Neutral ΣN=320156 (97%)
△OSMA Triangle generated by ☸SAIMSARA

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

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

Outcome: survival Typical timepoints: 5-y, peri/post-op. Reported metrics: %, CI, p.

Common endpoints: Common endpoints: survival, mortality, recurrence.

Predictor: abdominal aortic aneurysm — exposure/predictor. Doses/units seen: 11 ml. Routes seen: intravenous, subcutaneous. Typical comparator: patients without cancer, statin or no treatment groups, open aneurysm repair, 52% for or. elderly patients....

- **1) Beneficial for patients** — survival with abdominal aortic aneurysm — — — ΣN=0
- **2) Harmful for patients** — survival with abdominal aortic aneurysm — [39], [62], [75], [77], [88], [232], [239], [258] — ΣN=9076
- **3) No clear effect** — survival with abdominal aortic aneurysm — [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], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [76], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [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], [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], [226], [227], [228], [229], [230], [231], [233], [234], [235], [236], [237], [238], [240], [241], [242], [243], [244], [245], [246], [247], [248], [249], [250], [251], [252], [253], [254], [255], [256], [257], [259], [260], [261], [262], [263], [264], [265], [266], [267], [268], [269], [270], [271], [272], [273], [274], [275], [276], [277], [278], [279], [280], [281], [282], [283], [284], [285], [286], [287], [288], [289], [290], [291], [292], [293], [294], [295], [296], [297], [298], [299], [300], [301], [302], [303], [304], [305], [306], [307], [308], [309], [310], [311], [312], [313], [314], [315], [316], [317], [318], [319], [320], [321], [322], [323], [324], [325], [326], [327], [328], [329], [330], [331], [332], [333], [334], [335], [336], [337], [338], [339], [340], [341], [342], [343], [344] — ΣN=320156

1) Introduction

Abdominal aortic aneurysm (AAA) represents a significant cardiovascular pathology associated with substantial morbidity and mortality, particularly upon rupture. Advances in surgical techniques, including open aneurysm repair (OAR) and endovascular aneurysm repair (EVAR), alongside improved perioperative management, have continuously reshaped patient outcomes. Understanding the multifaceted factors influencing survival across different patient cohorts, aneurysm characteristics, and treatment strategies is crucial for optimizing clinical decision-making and patient care. This paper synthesizes current research on AAA and its impact on survival, drawing from a comprehensive body of evidence.

2) Aim

The aim of this paper is to systematically review and synthesize the available evidence on factors influencing survival in patients with abdominal aortic aneurysms, encompassing various treatment modalities, patient demographics, and clinical contexts.

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 majority of studies are retrospective cohort or mixed designs, introducing potential selection and confounding biases. Randomized controlled trials (RCTs) are fewer but provide higher certainty evidence. Animal and synthetic models offer mechanistic insights but limited direct clinical applicability.

4) Results

4.1 Study characteristics:

The evidence base comprises a diverse range of study designs, predominantly retrospective cohort studies and mixed designs, with several randomized controlled trials and experimental animal models. Populations studied include patients undergoing elective or emergency repair of intact, ruptured, infrarenal, juxtarenal, and complex AAAs, as well as specific subgroups such as octogenarians, nonagenarians, and those with comorbidities like cancer or chronic kidney disease. Follow-up periods vary widely, from 30-day perioperative outcomes to long-term assessments spanning up to 25 years.

4.2 Main numerical result aligned to the query:

For elective repair of intact abdominal aortic aneurysms, the median 30-day mortality rate for open surgical repair (OSR) was 2.95% (range: 1.9% [56] to 5.3% [225]), while for endovascular aneurysm repair (EVAR), it was 1.1% (range: 0% [80] to 2.7% [116]). In cases of ruptured AAA, the median 30-day mortality for EVAR was 16.5% (range: 8.7% [42] to 42.8% [80]), significantly lower than for OSR, which had a median of 35% (range: 24.2% [39] to 57.1% [42]).

4.3 Topic synthesis:

- **Treatment Modality Comparison (EVAR vs. OAR) and Survival:**
- EVAR offers an early survival benefit over OSR for intact AAAs, but this benefit may diminish or reverse in the long term, with EVAR showing higher long-term mortality and reintervention rates after 1-4 years [172, 210].
- For ruptured AAAs (rAAA), EVAR is associated with lower 30-day mortality and improved short-term survival compared to OSR [42, 94, 99, 164, 250, 254, 261, 343]. However, long-term survival may be similar between modalities [128, 254].
- Survival is comparable for open surgical repair and fenestrated EVAR (fEVAR) for juxtarenal AAAs [29].
- Hybrid thoracoabdominal aortic aneurysm (TAAA) repair shows acceptable long-term outcomes, with 5-year overall survival of 61-69% [12, 281].
- Open repair for non-ruptured AAAs may show higher 5-year survival (75.3%) compared to EVAR (50.0%) in some cohorts [68].
- Overall survival rates after EVAR for AAA range from 92% at 24 months [52] to 54% at 5 years [59], and 35.3% at 10 years for intact AAA [98].
- **Patient-Specific Risk Factors for Survival:**
- **Age:** Elderly patients (octogenarians, nonagenarians) undergoing EVAR have reduced immediate postoperative mortality compared to OAR, but similar long-term mortality [96, 106, 236, 237, 247]. However, 3- and 5-year survival rates are significantly lower in elderly patients (≥75 years) undergoing elective EVAR (3-year: 74.6% for 75-84 years, 51.9% for ≥85 years; 5-year: 64.2% for 75-84 years, 39.7% for ≥85 years) [10]. Octogenarians undergoing elective EVAR have very low 3- to 5-year survival (32-51%) [324].
- **Sex:** Women have significantly lower survival than men up to 8 years following rAAA repair [45, 253] and after elective OAR (9-year survival: 43.8% for women vs. 55.0% for men) [28]. Female patients undergoing complex endovascular aortic repair have higher in-hospital death and lower long-term survival [341].
- **Comorbidities:**
- Preoperative sarcopenia and malnutrition correlate with poor long-term survival after EVAR [4, 92]. Low skeletal muscle index (SMI) and subcutaneous fat index (SFI) are associated

with poorer long-term survival (5-year mortality: 55% vs 28% in low vs high SMI) [321].

- Late-stage intra-abdominal malignancies lead to significantly poorer prognosis after synchronous AAA repair (2-year mortality: Stage IV 69%) [11]. Cancer patients have significantly less favorable outcomes (9-year survival: 27.0% with cancer vs 55.4% without) [53].
- Chronic obstructive pulmonary disease (COPD) is a significant predictor of mortality after OAR [56, 84].
- Acute kidney injury (AKI) is a significant risk factor for reduced postoperative survival [26, 37, 213, 260].
- Cardiorespiratory fitness is impaired in AAA patients, and lower peak oxygen uptake is associated with increased postoperative mortality [14, 139, 291].
- Coronary artery disease (CAD) and peripheral arterial disease (PAD) are highly prevalent in AAA patients [101, 132].
- Diabetes mellitus (DM) does not significantly affect total or cardiovascular mortality after elective EVAR [93].
- Hyperlipidemia is associated with decreased death risk in aneurysm patients [333].
- **Inflammatory Markers:** High preoperative C-reactive protein (CRP) [115], higher neutrophil-to-lymphocyte ratio (NLR) (>2.77, HR 0.833 for survival) [20], and lower hemoglobin-to-red cell distribution width ratio (HRR) [20] are associated with lower long-term survival. An elevated triglyceride-glucose (TyG) index predicts increased postoperative mortality [234]. A CONUT score ≥4 is an independent risk factor for midterm mortality [229].
- **Aneurysm Characteristics:** AAA diameter prior to EVAR was not associated with overall survival [3], but AAA size ≥5.6 cm was associated with increased 3-year mortality risk (HR 1.59) after EVAR for intact AAA [88]. Aortic neck angle-length index >4.8 increases intraoperative complications but not 5-year survival [240]. Aortoiliac calcification correlates with 5-year survival [19], and higher calcium burden (Agatston score) is associated with significantly lesser survival after EVAR [230]. Shrinking AAA sac after EVAR is associated with better long-term survival [49], and sac regression is a prognostic factor for survival [287, 325].
- **Blood-related factors:** Red blood cell transfusions are dose-dependently associated with increased short- and long-term mortality (HR 1.54) [76, 90]. Anemia is associated with decreased long-term survival after EVAR [137, 171]. Initial ED coagulation profile does not predict rAAA survival [100]. Postoperative coagulopathy and larger crystalloid infusion volumes are associated with poorer survival after rAAA EVAR [40].
- **Pharmacological Interventions:**
- Postoperative statin treatment markedly improved long-term survival after AAA repair (HR 1.43) [1, 27, 209], with no additional benefit from high-intensity therapy [1]. Statin use is a predictor of mortality in ML models [86].

- PCSK9 inhibitors show the highest freedom from all-cause mortality in AAA patients compared to statins or no treatment [13].
- Experimental studies suggest therapeutic potential for HDAC inhibitors [104], miR-126a-5p overexpression [71], hydralazine [238], and MMP-12 inhibition [262] in reducing AAA formation and improving survival in mouse models.
- GPVI blockade attenuated aneurysm progression and increased survival in murine models [278].
- **Surgical Factors Affecting Survival:**
- Increasing surgeon volume correlates with patient survival following OAR [16]. Hospital volume was not associated with adjusted long-term mortality for juxtarenal OAR [222].
- Cross-clamp location affects short-term survival in OAR [22].
- EVAR with specific endografts (Endologix AFX® [59], Gore Excluder [52], INCRAFT [275], Fenestrated Anaconda™ [287, 325]) demonstrates acceptable survival rates.
- Open conversion for aortic endograft infections is associated with high early mortality (30-day: 31%) and poor mid-term survival (5-year: 30%) [130].
- Compliance with instructions for use (IFU) for EVAR may be linked to reintervention risk but not necessarily survival [161, 165, 168].
- **Ruptured AAA (rAAA) Specifics:**
- Treatment choice and survival after rAAA are critical considerations [5].
- Emergency EVAR for rAAA can be performed with acceptable short-term outcomes, but long-term mortality is substantial (5-year mortality: 61.7%) [83].
- Improved trends in patient survival and decreased major complications after emergency rAAA repair have been reported [44].
- Long-term survival after rAAA repair has improved over time in Sweden [255].
- Delay to treatment impacts survival in rAAA [127, 154].
- Early decompressive laparotomy may improve survival in abdominal compartment syndrome after rAAA surgery [265].
- Mycotic AAA repair with biological grafts shows good overall survival (5-year: 71%) [187].
- **Predictive Models and Risk Scores:**
- Various models predict survival after AAA repair, including the Glasgow Aneurysm Score [124], SOFA and SAPS II scores for in-hospital mortality in rAAA [167], and machine learning models for 3-year survival after EVAR [86, 87].
- External validation of survival prediction models has been performed [30, 32, 41, 55].
- A risk score showed good discrimination for survival after EVAR, indicating low-risk patients benefit [33].
- **Socioeconomic and Geographic Disparities:**
- Socioeconomic disparities affect repair rates and survival, with men from deprived areas having higher mortality [2, 17, 34, 51].

- Regional variation in 30-day mortality and 5-year survival for suprarenal aneurysm repair exists [221].
- AAA screening has improved long-term survival for men aged 65-79 in Sweden [228, 259, 307].
- **Experimental/Preclinical Research:**
- Mouse models investigate mechanisms of AAA formation and potential therapeutic targets, including TFEB activation [60], PCSK9 inhibition [61], chronic intermittent hypoxia [64], miR-24 [108], APLN loss [239], ADSC-exos miR-17-5p [241], and gingival fibroblasts [263].
- **Concomitant Malignancy:**
- Patients with AAA have a significantly higher prevalence of cancers and increased risk of cancer-related death [232]. Two-stage procedures for concomitant AAA and malignancy may offer better short-term results [231].

5) Discussion

5.1 Principal finding:

The central finding is that for elective repair of intact abdominal aortic aneurysms, the median 30-day mortality rate for open surgical repair was 2.95%, while for endovascular aneurysm repair, it was 1.1% [56, 80, 116, 140, 177, 225, 226, 233, 324, 343]. For ruptured AAAs, EVAR offered a lower median 30-day mortality of 16.5% compared to 35% for OSR [39, 42, 43, 66, 80, 83, 188].

5.2 Clinical implications:

- **Treatment Choice:** For ruptured AAAs, EVAR should be considered the first-line treatment in centers with expertise due to its early survival benefit [42, 94, 99, 206].
- **Elderly Patient Management:** While EVAR reduces immediate postoperative mortality in octogenarians, long-term survival remains a concern, necessitating careful patient selection and realistic expectations [10, 236, 324].
- **Pharmacological Optimization:** Postoperative statin therapy significantly improves long-term survival after AAA repair, highlighting the importance of medical management [1, 27, 209].
- **Risk Factor Assessment:** Preoperative assessment for malnutrition, sarcopenia, and inflammatory markers (NLR, HRR, CRP, TyG index, CONUT score) can identify high-risk patients for targeted interventions [4, 20, 92, 115, 229, 234].
- **Socioeconomic Considerations:** Awareness of socioeconomic disparities in access to care and survival outcomes is crucial for equitable healthcare delivery [2, 17, 34, 51].

5.3 Research implications / key gaps:

- **Long-Term EVAR Outcomes:** Further RCTs comparing long-term (beyond 10 years) all-cause and aneurysm-related mortality between EVAR and OAR for intact AAAs are needed to clarify the durability of EVAR benefits [172, 210, 279, 284].
- **Personalized Risk Stratification:** Develop and validate advanced predictive models, including machine learning, incorporating a broader range of clinical, imaging, and biological markers (e.g., genetic, inflammatory, nutritional) to guide individualized treatment decisions [86, 87, 204].
- **Pharmacological Adjuncts:** Conduct prospective trials on novel pharmacological agents (e.g., PCSK9 inhibitors, TFEB activators, HDAC inhibitors, MMP-12 inhibitors) to prevent AAA progression or improve postoperative survival [13, 60, 61, 104, 262].
- **Ruptured AAA Management:** Investigate the optimal management strategy for ruptured AAAs in hemodynamically unstable patients or those with challenging anatomy, particularly in low-resource settings [24, 206].
- **Sex-Specific Outcomes:** Further research is needed to understand the biological and systemic factors contributing to poorer survival outcomes in women after AAA repair, especially for ruptured cases [28, 45, 253, 341].

5.4 Limitations:

- **Heterogeneous Study Designs** — The reliance on diverse study designs, particularly retrospective cohorts, introduces variability and potential biases in reported outcomes.
- **Inconsistent Follow-up Periods** — Varied follow-up durations across studies make direct comparisons of long-term survival challenging.
- **Lack of Standardized Metrics** — Different reporting metrics for survival and mortality hinder direct quantitative synthesis.
- **Limited RCT Evidence** — The scarcity of large-scale, long-term randomized controlled trials for many comparisons limits definitive conclusions.
- **Geographic and Population Specificity** — Many studies are specific to certain countries or populations, limiting generalizability.

5.5 Future directions:

- **Standardize Outcome Reporting** — Standardize reporting of survival and mortality outcomes.
- **Prospective Cohort Studies** — Conduct large, multinational prospective cohort studies.

- **Comparative Effectiveness Research** — Perform comparative effectiveness research on treatment strategies.
- **Biomarker Discovery and Validation** — Identify and validate novel biomarkers for risk prediction.
- **Implement AI-Driven Tools** — Implement AI-driven tools for personalized risk assessment.

6) Conclusion

For elective repair of intact abdominal aortic aneurysms, the median 30-day mortality rate for open surgical repair was 2.95%, while for endovascular aneurysm repair, it was 1.1% [56, 80, 116, 140, 177, 225, 226, 233, 324, 343]. For ruptured AAAs, EVAR offered a lower median 30-day mortality of 16.5% compared to 35% for OSR [39, 42, 43, 66, 80, 83, 188]. While these findings suggest an early survival advantage for EVAR, particularly in ruptured cases, the generalizability is limited by the diverse study designs and patient populations. The most significant limitation affecting certainty is the prevalence of retrospective cohort studies, which are prone to selection and confounding biases. A concrete next step is to conduct large-scale, long-term randomized controlled trials to definitively compare EVAR and OAR across various patient subgroups, focusing on both early and late survival and quality of life.

References

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Figure 1. Publication-year distribution of included originals

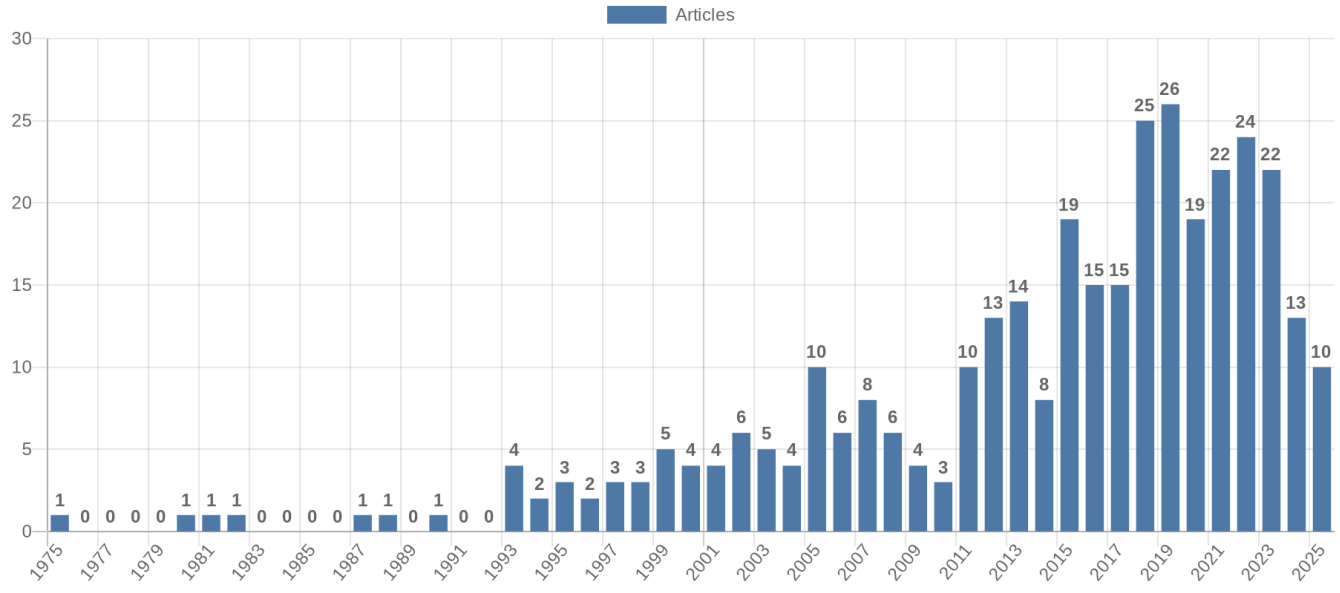

Figure 2. Study-design distribution of included originals

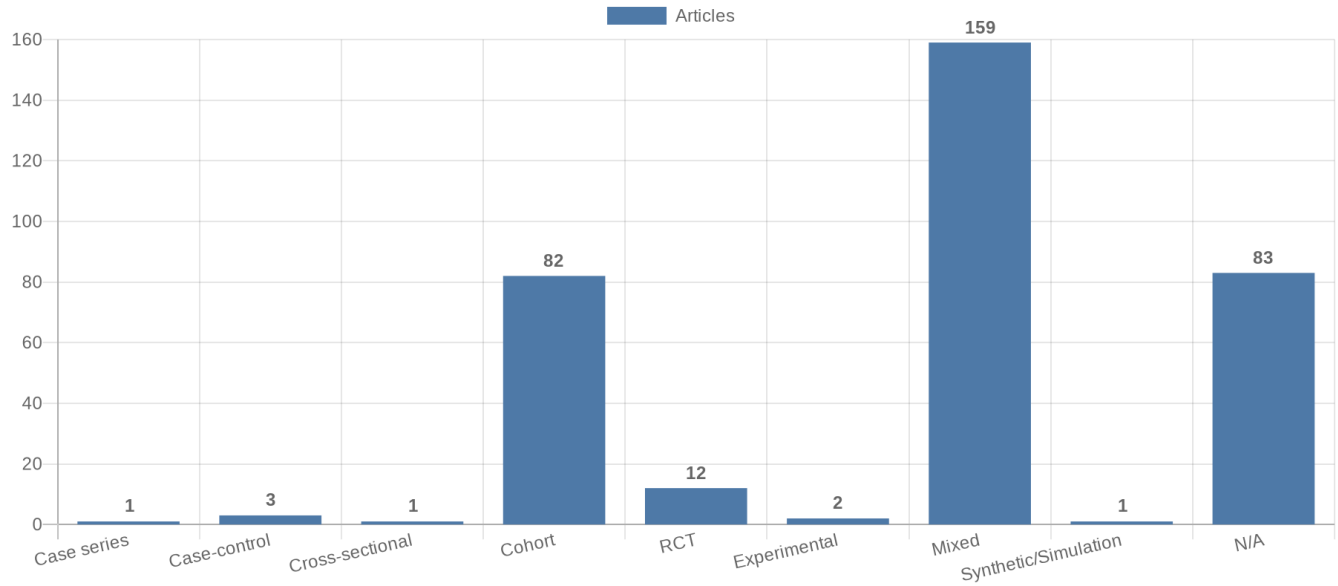

Figure 3. Study-type (directionality) distribution of included originals

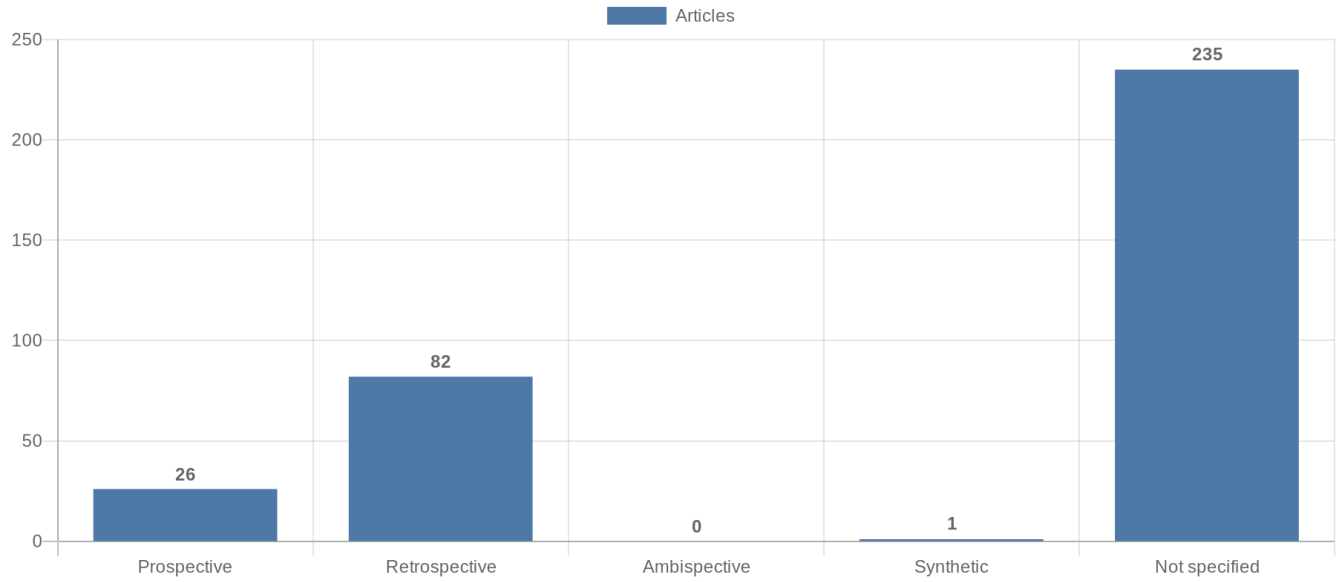

Figure 4. Main extracted research topics

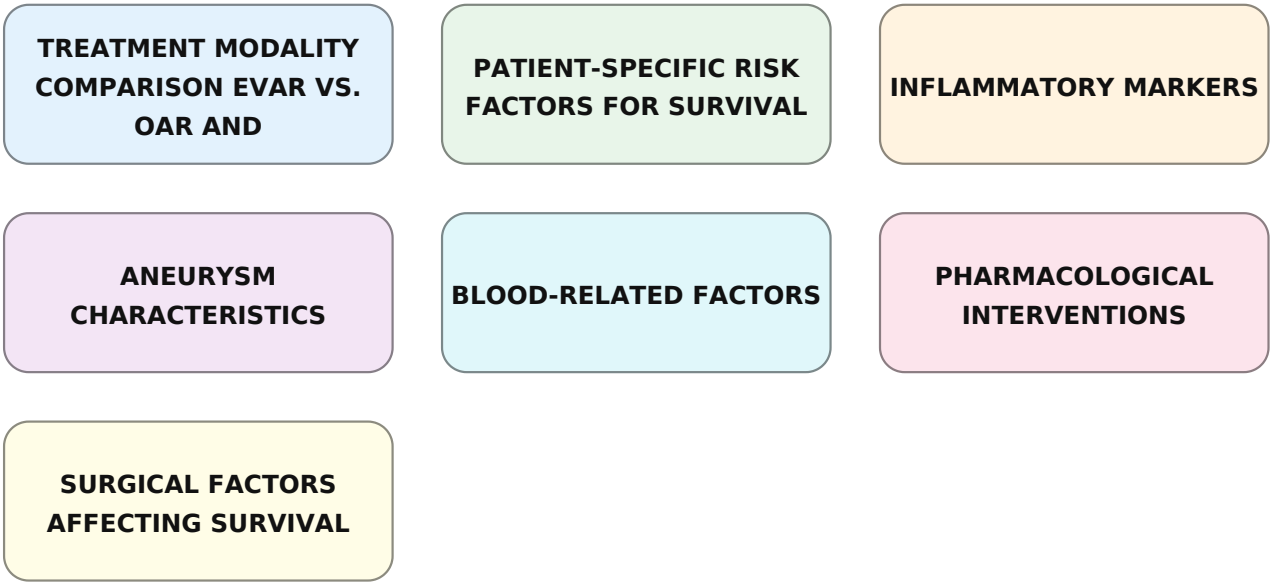

Figure 5. Limitations of current studies (topics)

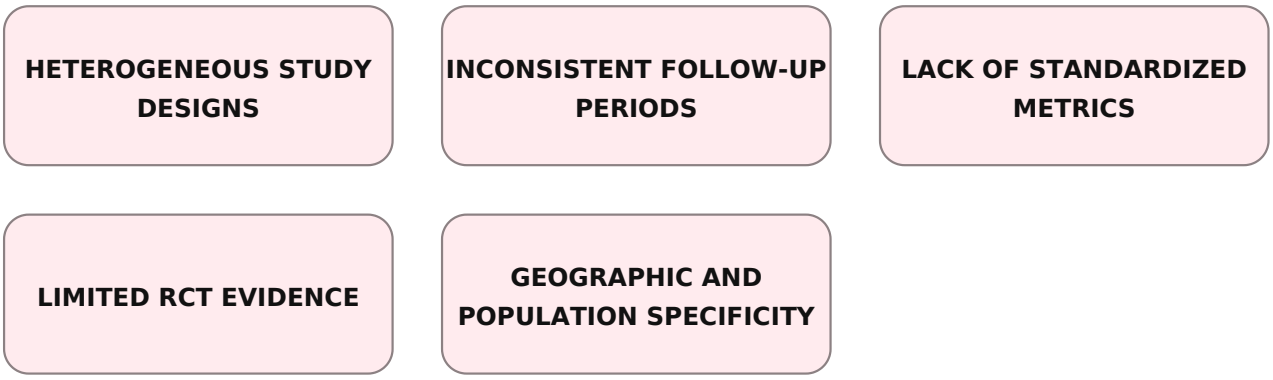

Figure 6. Future research directions (topics)