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

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Abstract: The study aims to systematically review the role of computed tomography in the diagnosis, assessment, monitoring, and management of abdominal aortic aneurysms, synthesizing key findings and identifying emerging research directions. The review utilises 260 studies with 42115 total participants (naïve ΣN). Artificial intelligence for opportunistic screening of abdominal aortic aneurysms in CT scans demonstrated a median diagnostic accuracy of 87.83%, with a range from 85.6% to 95.3%. This high accuracy suggests a promising role for automated CT analysis in improving early AAA detection in diverse clinical settings. However, the methodological heterogeneity across studies, particularly in CT acquisition and measurement protocols, remains a significant limitation affecting the certainty and generalizability of findings. A concrete next step for clinicians is to explore the integration of AI-powered opportunistic screening tools into routine CT workflows to enhance early detection and patient care.

Keywords: Abdominal Aortic Aneurysm; Computed Tomography; CT Angiography; Deep Learning; Image Segmentation; Aneurysm Rupture; Aneurysm Progression; Radiomics Analysis; Body Composition; EVAR Surveillance

Review Stats

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- Source: Semantic Scholar
- Scope: All fields
- Keyword Gate: Fuzzy (≥60% of required terms, minimum 2 terms matched in title/abstract)
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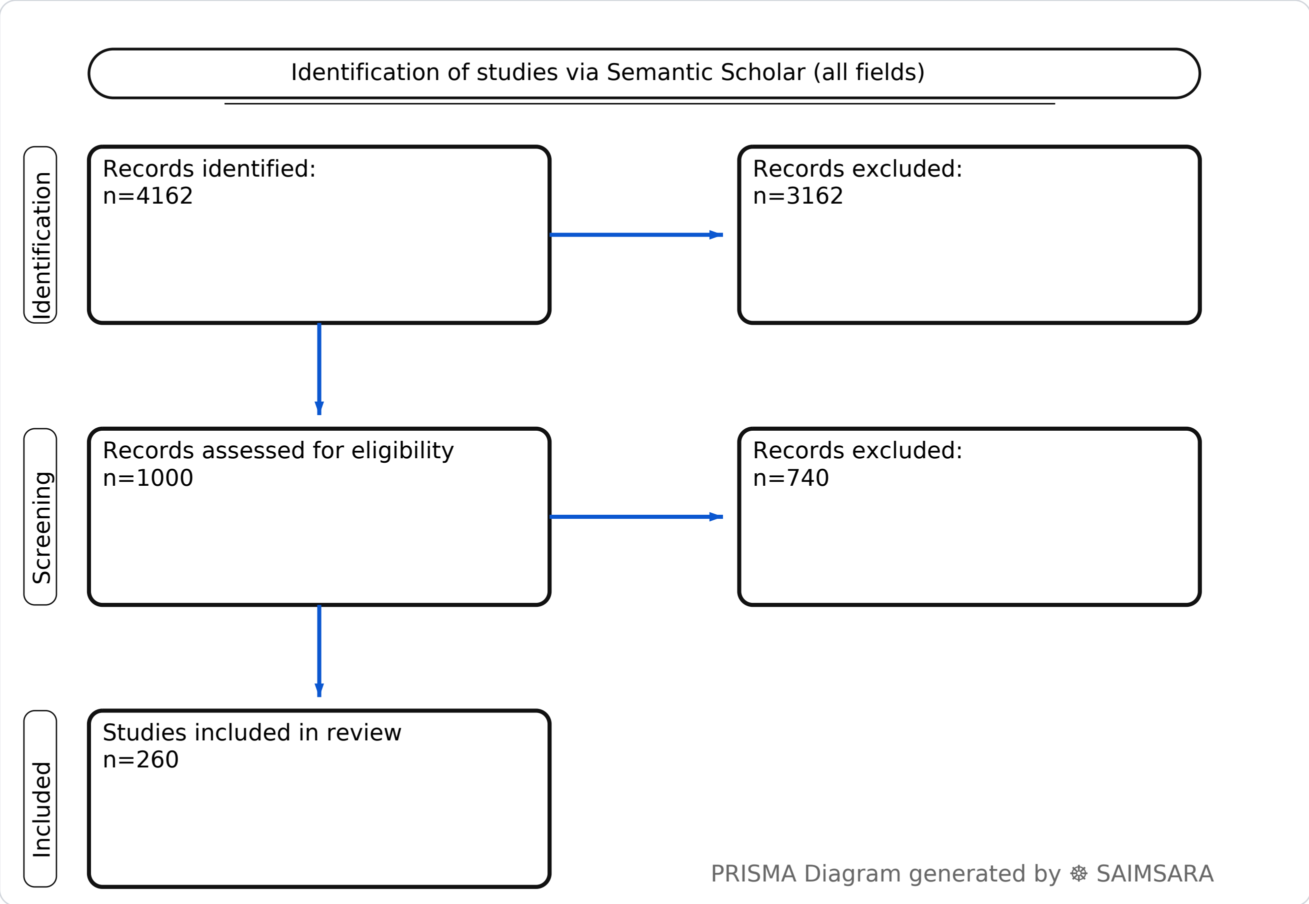
- Included original Abstracts/Papers: 260
- Total study participants (naïve ΣN): 42115



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Records excluded:
n=3162
Screening
Records assessed for eligibility
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Records excluded:
n=740
Included
Studies included in review
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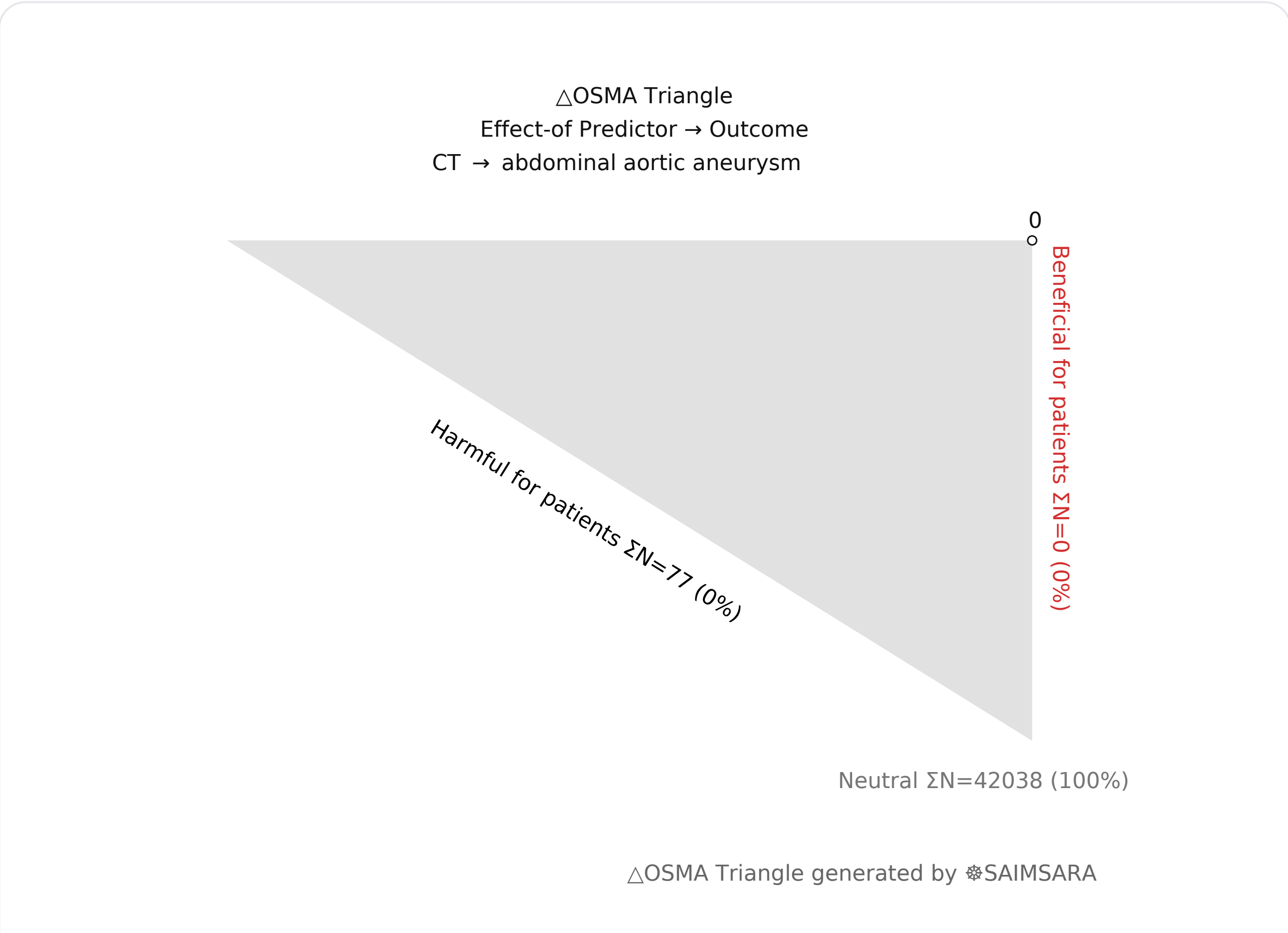
PRISMA Diagram generated by ☸ SAIMSARA



△OSMA Triangle
Effect-of Predictor → Outcome
CT → abdominal aortic aneurysm
0
Beneficial for patients ΣN=0 (0%)
Harmful for patients ΣN=77 (0%)
Neutral ΣN=42038 (100%)
△OSMA Triangle generated by ☸SAIMSARA

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

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

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

Common endpoints: Common endpoints: complications, mortality, survival.

Predictor: CT — procedure/intervention. Routes seen: intravenous. Typical comparator: multiplanar reformation, clinical factors and, saline controls, physician-controlled manual….

- **1) Beneficial for patients** — abdominal aortic aneurysm with CT — — — ΣN=0
- **2) Harmful for patients** — abdominal aortic aneurysm with CT — [98] — ΣN=77
- **3) No clear effect** — abdominal aortic aneurysm with CT — [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], [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], [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], [232], [233], [234], [235], [236], [237], [238], [239], [240], [241], [242], [243], [244], [245], [246], [247], [248], [249], [250], [251], [252], [253], [254], [255], [256], [257], [258], [259], [260] — ΣN=42038

1) Introduction

Abdominal aortic aneurysm (AAA) represents a critical vascular pathology characterized by localized dilatation of the abdominal aorta. Computed tomography (CT) imaging has emerged as an indispensable tool in the comprehensive management of AAA, spanning from initial detection and diagnostic assessment to pre-operative planning, monitoring of disease progression, and post-intervention surveillance. This paper synthesizes current research on the multifaceted applications of CT in the context of AAA, highlighting advancements in imaging techniques, computational analysis, and artificial intelligence (AI) integration.

2) Aim

The study aims to systematically review the role of computed tomography in the diagnosis, assessment, monitoring, and management of abdominal aortic aneurysms, synthesizing key findings and identifying emerging research directions.

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. Many studies lacked specified design or directionality, and sample sizes were often not reported, suggesting potential for selection bias and limited generalizability. The prevalence of mixed study designs and retrospective cohorts further indicates a qualitative bias towards observational data over interventional evidence.

4) Results

4.1 Study characteristics

The structured extraction summarized 260 studies, predominantly mixed designs and cohort studies, with some randomized controlled trials (RCTs) and case reports. Populations varied from patients undergoing elective AAA intervention to those with small or ruptured AAAs, as well as mouse models and phantom studies. Follow-up periods, when specified, ranged from 12 months to 3.3 years.

4.2 Main numerical result aligned to the query

Artificial intelligence (AI) for opportunistic screening of abdominal aortic aneurysms in CT scans demonstrated a median accuracy of 87.83% [5, 7, 70, 207], with a range from 85.6% to 95.3% [5, 7]. Specifically, one systematic review reported a mean sensitivity of 95% (95% CI 100–87%), mean specificity of 96.6% (95% CI 100–75.7%), and mean accuracy of 95.2% (95% CI 100–54.5%) for AI-based opportunistic screening [5].

4.3 Topic synthesis

- **AI for AAA Detection and Segmentation:** Deep learning methods, including convolutional neural networks (CNNs) and U-Net architectures, achieve high accuracy (e.g., 95.3% [7], 87.83% [70], 86% [207]) and Dice score coefficients (e.g., 91.03% [12]) for automated AAA detection, segmentation, and opportunistic screening from CT images [5, 6, 7, 9, 12, 14, 25, 41, 49, 59, 61, 80, 93, 120, 132, 144, 152, 193, 197, 207, 208, 213, 256].

- **AAA Growth Rate Prediction:** Combined analysis of lumen volume and wall shear stress from CT was superior to maximal diameter alone in predicting 1-year AAA enlargement, especially in aneurysms smaller than 50 mm [10]. Machine learning models predicted high versus low growth rates with AUCs up to 81.2% [29], with diameter-diameter ratio, tortuosity, and intraluminal thrombus thickness as important factors [29]. Intraluminal thrombus (ILT) and baseline diameter were independent predictors of AAA growth rate, with AAAs containing ILT growing significantly faster (median 1.9-fold faster in small AAAs) [101]. Most small AAAs showed linear growth (70%) with a median annual rate of 0.17 cm/y [32].
- **AAA Rupture Risk Assessment:** CT analysis of aortic calcifications [3], peak wall rupture index (HR=1.05 per % increase) [58], and periaortic adipose tissue CT attenuation [23] are used to predict AAA rupture. High peak wall stress (PWS) showed an inconsistent association with greater odds of rupture in large AAAs [106].
- **Post-EVAR Surveillance and Complication Detection:** CT texture analysis (accuracy 85.17-87.23%) [11] and diameter measurements from CT scans [38, 72] predict aneurysm progression and sac enlargement after endovascular aneurysm repair (EVAR). CT angiography is crucial for detecting endoleaks [71, 73, 74, 82, 83, 91, 110, 164, 174, 226].
- **Pre-operative Planning and Device Suitability:** CT provides detailed anatomical information for pre-operative assessment [89, 116, 122, 131, 143, 247, 251, 253], including neck morphology (statistical shape models) [30], iliac artery tortuosity [179, 241], and stent-graft suitability [76, 77, 85, 88, 159, 161, 162, 245, 246].
- **Hemodynamics and Biomechanics:** Computational fluid dynamics (CFD) analysis using CT images reveals changes in blood flow, wall shear stress (WSS), and oscillatory shear index (OSI) associated with AAA growth [22, 37, 47, 51, 60, 97, 99, 138, 173] and rupture risk [68, 99, 106, 114, 128, 175, 178].
- **Inflammation and Tissue Characterization:** CT-derived body composition [1], periaortic adipose tissue attenuation index (PAAI) [98, 210], and 18F-FDG PET/CT uptake [13, 17, 84, 86, 102, 104, 105, 137, 139, 166, 168, 191, 218, 220, 233] are used to assess inflammation, cellular activity, and tissue alterations in AAA.
- **CT Technique Optimization and Comparison:** Studies explore dose reduction strategies (e.g., dual-energy CT angiography, virtual monochromatic imaging) [21, 36, 74, 174], contrast inhomogeneity [28], and optimal bolus timing for endoleak detection [82, 110]. CT is compared with ultrasound [4, 18, 69, 79, 117, 118, 180, 181, 202, 216] and MRI [35, 67, 76, 180, 215, 243] for various assessments.
- **Opportunistic Screening and Incidental Findings:** CT scans performed for other indications can opportunistically detect AAAs [5, 55, 142, 169, 192, 213, 227, 254, 258].

Simple renal cyst (SRC) and bovine aortic arch (BAA) were associated with increased prevalence of AAA [192].

- **3D Modeling and Phantoms:** Patient-specific 3D models reconstructed from CT data are used for hemodynamic studies [46, 47, 60, 173], surgical planning [193, 238], and creating physical phantoms for experimental evaluation and training [31, 56, 145, 157, 161, 214, 257].

5) Discussion

5.1 Principal finding

The integration of artificial intelligence into computed tomography protocols for opportunistic screening of abdominal aortic aneurysms demonstrates a median diagnostic accuracy of 87.83% [5, 7, 70, 207], indicating a high potential for automated and efficient detection.

5.2 Clinical implications

- **Enhanced Screening:** High diagnostic accuracy of AI in CT scans [5, 7, 70, 207] supports the implementation of opportunistic AAA screening during routine CT examinations, potentially improving early detection.
- **Improved Risk Stratification:** Advanced CT analysis, including radiomics [2], aortic calcifications [3], and periaortic adipose tissue attenuation [23, 98, 210], offers superior prediction of AAA progression and rupture risk compared to maximal diameter alone [10, 58, 68].
- **Optimized Surveillance:** For small AAAs, linear growth modeling suggests CT follow-up every 2 years for those <4.25 cm [32]. Post-EVAR, CT texture analysis [11] and sophisticated endoleak detection techniques [91, 174] enhance monitoring efficacy.
- **Personalized Treatment Planning:** Detailed 3D CT reconstructions enable patient-specific assessment of neck morphology [30], tortuosity [241], and stent-graft suitability [116, 162, 245], leading to more precise endovascular repair planning.
- **Reduced Radiation Exposure:** Emerging techniques like dual-energy CT [21, 36] and spectral photon-counting CT [174] aim to reduce iodine dose and radiation exposure while maintaining diagnostic accuracy for follow-up.

5.3 Research implications / key gaps

- **Standardized Measurement Protocols** — Develop and validate uniform CT acquisition and measurement protocols to reduce inter- and intraobserver variability across institutions

[4, 8, 77, 147, 149, 228].

- **Prospective AI Validation** — Conduct large-scale prospective randomized trials to validate the clinical utility and cost-effectiveness of AI-driven opportunistic AAA screening in diverse populations [5, 7, 49, 213].
- **Longitudinal Hemodynamic Studies** — Investigate the long-term predictive power of patient-specific hemodynamic parameters (e.g., wall shear stress, oscillatory shear index) derived from serial CT data on AAA growth and rupture in larger cohorts [10, 22, 37, 47, 51, 70, 99, 173].
- **Biomarker Integration** — Explore the integration of CT-derived tissue characteristics (e.g., inflammation, calcification, body composition) with genetic and serological biomarkers to develop more comprehensive AAA risk prediction models [1, 3, 13, 17, 23, 33, 84, 86, 96, 98, 102, 104, 105, 137, 139, 166, 168, 191, 210, 218, 220, 233].
- **Comparative Effectiveness of Follow-up** — Systematically compare the long-term outcomes and cost-effectiveness of CT-based surveillance strategies against other modalities (e.g., ultrasound, MRI) for different AAA sizes and post-EVAR scenarios [4, 18, 69, 79, 117, 118, 180, 181, 202, 215, 216].

5.4 Limitations

- **Methodological Heterogeneity** — Many studies lacked specified design or directionality, and employed diverse methodologies and outcome metrics, limiting direct comparability and meta-analysis.
- **Variability in CT Acquisition** — Differences in CT scanner technology, contrast protocols, and image reconstruction techniques across studies introduce variability in measurements and analyses.
- **Limited Large-Scale Prospective Data** — A substantial portion of the evidence relies on retrospective analyses or smaller cohort studies, which may not fully capture long-term outcomes or generalizability to broader patient populations.
- **Focus on Diameter** — Despite evidence suggesting its limitations, maximal diameter remains a primary measurement, potentially overlooking other critical biomechanical and biological factors influencing AAA progression and rupture.
- **AI Generalizability Concerns** — While AI models show high accuracy in specific datasets, their generalizability to diverse patient populations and imaging protocols from different institutions requires further robust validation.

5.5 Future directions

- **Standardized Imaging Protocols** — Develop and implement consensus guidelines for CT acquisition and measurement in AAA to enhance reproducibility and comparability across studies.
- **Prospective AI Trials** — Conduct large-scale, multicenter prospective trials to validate AI algorithms for AAA detection, segmentation, and risk prediction in real-world clinical settings.
- **Integrated Risk Models** — Develop and test comprehensive predictive models that integrate CT-derived anatomical, hemodynamic, and tissue characteristics with clinical and genetic data.
- **Advanced Imaging Biomarkers** — Explore novel CT-based imaging biomarkers, such as periaortic fat attenuation and calcification patterns, for their independent and combined predictive value in AAA management.
- **Personalized Follow-up Strategies** — Design studies to evaluate adaptive, patient-specific CT surveillance protocols based on individual AAA risk profiles, leveraging AI and advanced biomechanical modeling.

6) Conclusion

Artificial intelligence for opportunistic screening of abdominal aortic aneurysms in CT scans demonstrated a median diagnostic accuracy of 87.83% [5, 7, 70, 207], with a range from 85.6% to 95.3% [5, 7]. This high accuracy suggests a promising role for automated CT analysis in improving early AAA detection in diverse clinical settings. However, the methodological heterogeneity across studies, particularly in CT acquisition and measurement protocols, remains a significant limitation affecting the certainty and generalizability of findings. A concrete next step for clinicians is to explore the integration of AI-powered opportunistic screening tools into routine CT workflows to enhance early detection and patient care.

References

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Figure 1. Publication-year distribution of included originals

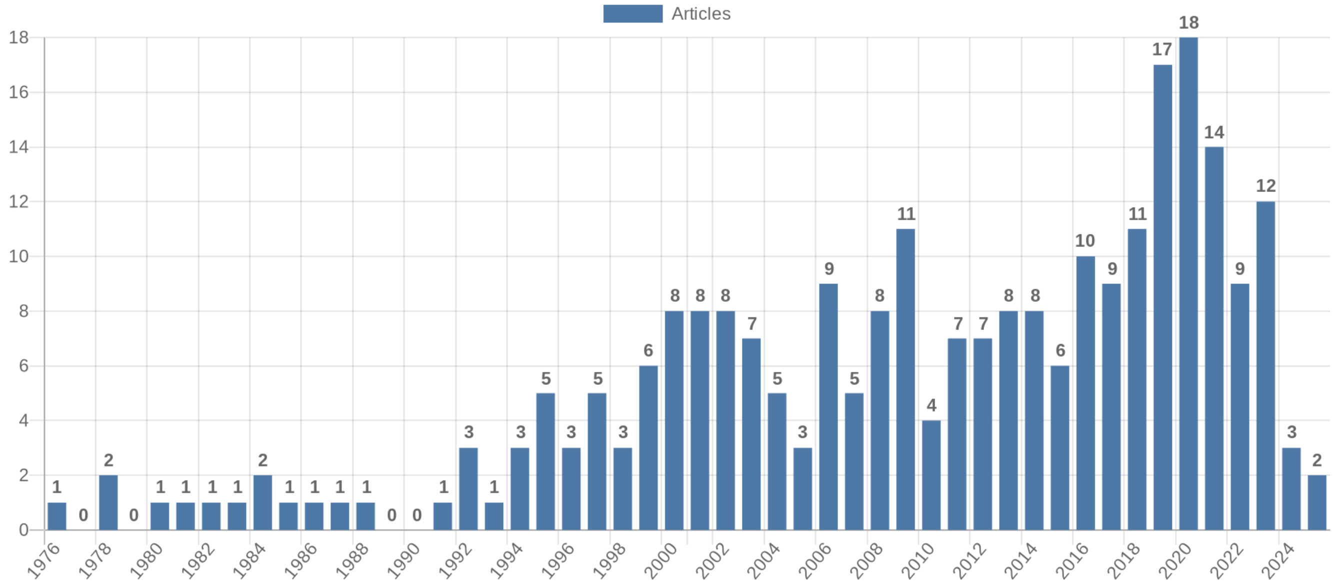

Figure 2. Study-design distribution of included originals

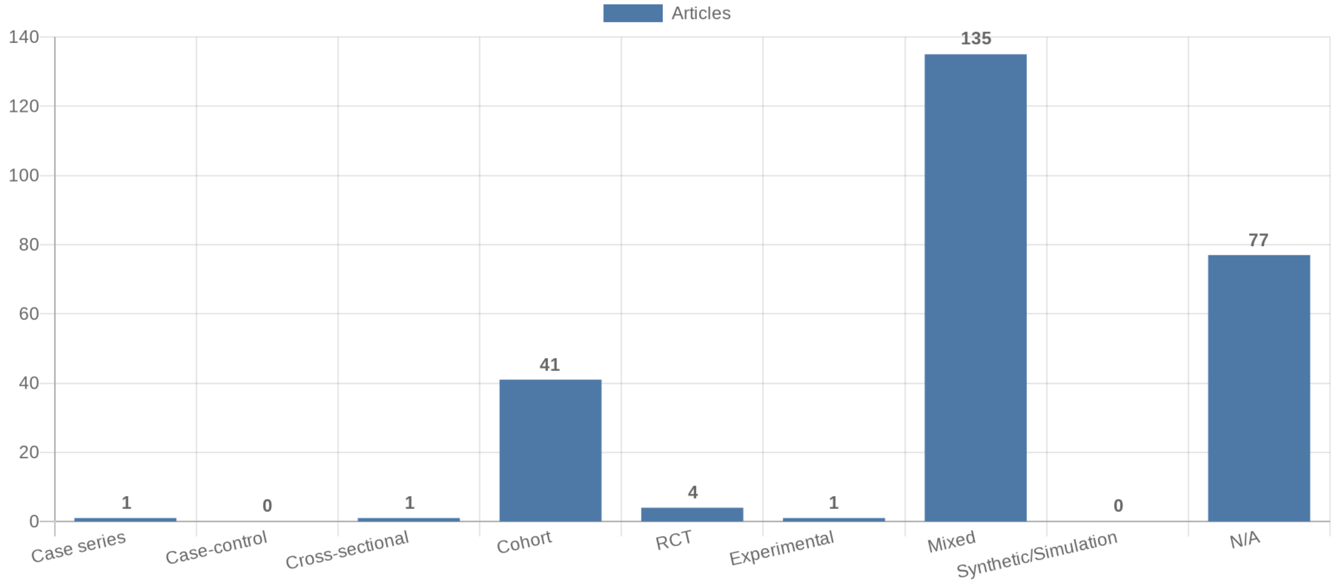

Figure 3. Study-type (directionality) distribution of included originals

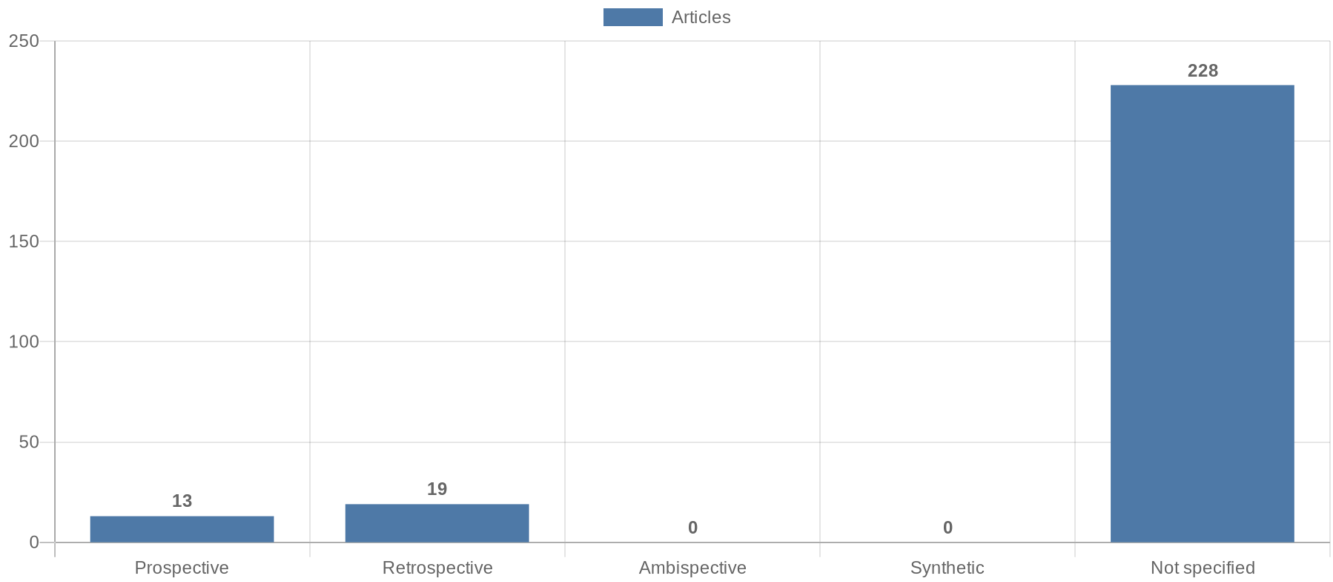

Figure 4. Main extracted research topics

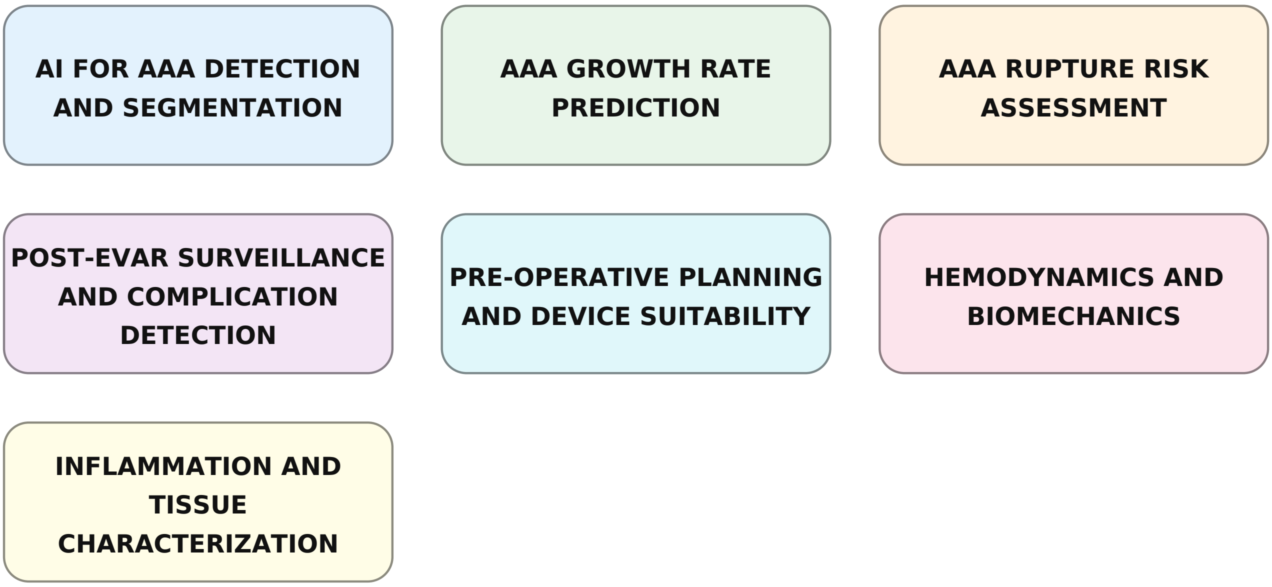

Figure 5. Limitations of current studies (topics)

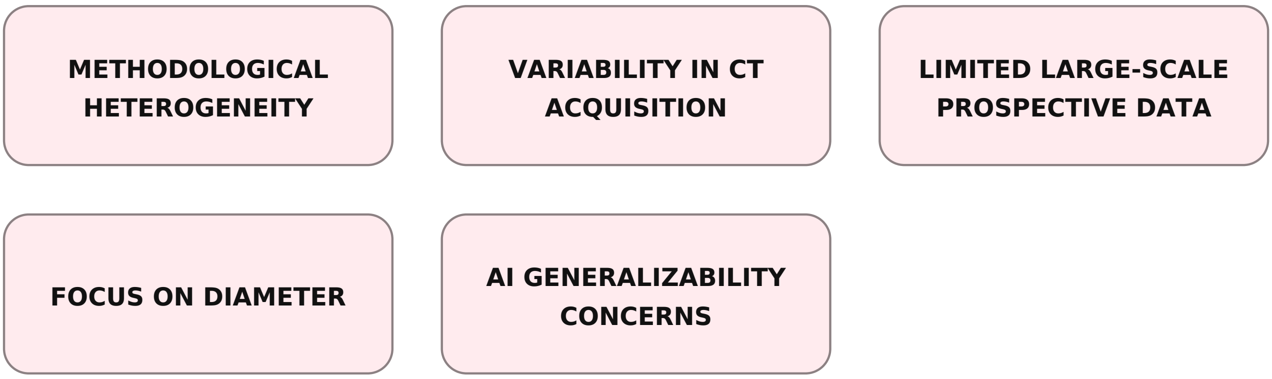

Figure 6. Future research directions (topics)