Crawford Classification Aneurysm: Systematic Review with ☸SAIMSARA.

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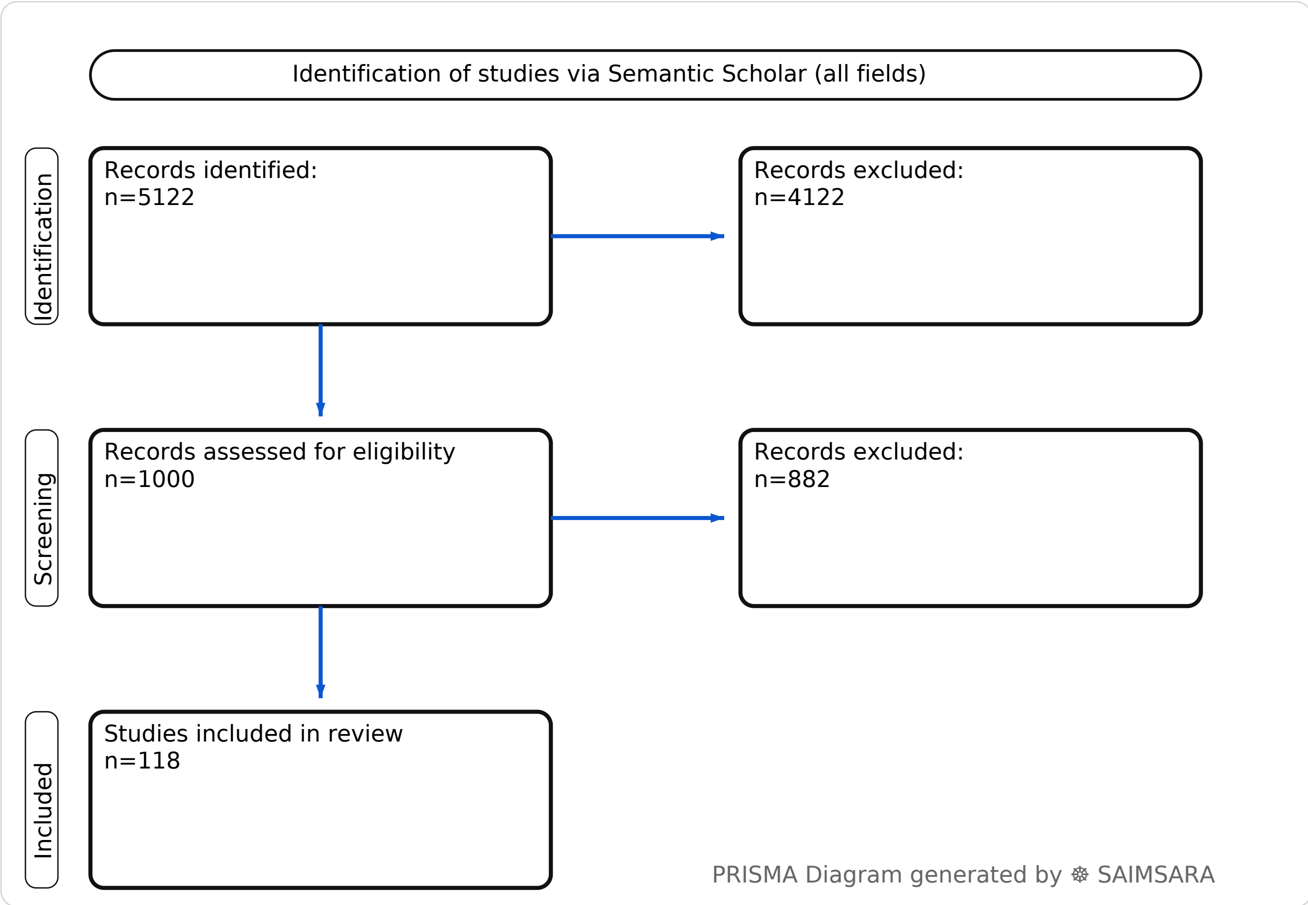
Abstract: This paper aims to synthesize current research themes related to aneurysm classification, with a particular focus on the Crawford classification for thoracoabdominal aortic aneurysms, and to identify associated clinical outcomes, emerging diagnostic tools, and therapeutic advancements. The review utilises 118 studies with 126287 total participants (naïve ΣN). For thoracoabdominal aortic aneurysm (TAAA) repair, the median 30-day or operative mortality rate across various studies was 9.6%, with a range from 0% to 64.7%. Spinal cord ischemia (SCI) or paraplegia rates in TAAA repair showed a median of 4.2%, ranging from 0% to 16.2%. These outcomes, assessed across diverse patient cohorts and treatment modalities, highlight the significant morbidity and mortality associated with TAAA, particularly influenced by the Crawford classification. The broad scope of aneurysm types and varied reporting of outcomes across studies represent the most significant limitation to certainty. Clinicians should integrate the Crawford classification with patient-specific risk factors to optimize treatment selection and implement robust spinal cord protection strategies in TAAA repair.

Keywords: Crawford classification; Thoracoabdominal aortic aneurysm; Aortic aneurysm; Aneurysm repair; Endovascular repair; Open surgical repair; Spinal cord ischemia; Postoperative mortality; Paraplegia; Aortic surgery

Review Stats

- Generated: 2026-02-13 00:02:15 CET
- Plan: Pro (expanded craft tokens; source: Semantic Scholar)
- Source: Semantic Scholar
- Scope: All fields
- Keyword Gate: Fuzzy (≥60% of required terms, minimum 2 terms matched in title/abstract)
- Total Abstracts/Papers: 5122
- Downloaded Abstracts/Papers: 1000
- Included original Abstracts/Papers: 118
- Total study participants (naïve ΣN): 126287



Identification of studies via Semantic Scholar (all fields)
Identification
Records identified:
n=5122
Records excluded:
n=4122
Screening
Records assessed for eligibility
n=1000
Records excluded:
n=882
Included
Studies included in review
n=118
PRISMA Diagram generated by ☸ SAIMSARA

△OSMA Triangle
Effect-of Predictor → Outcome
crawford classification aneurysm → Outcome
0
Harmful for patients ΣN=0 (0%)
Beneficial for patients ΣN=0 (0%)
Neutral ΣN=126287 (100%)
△OSMA Triangle generated by ☸SAIMSARA

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

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

Outcome: Outcome Typical timepoints: 30-day, peri/post-op. Reported metrics: %, CI, p.

Common endpoints: Common endpoints: occlusion, mortality, complications.

Predictor: crawford classification aneurysm — exposure/predictor. Routes seen: iv. Typical comparator: clinical factors and, younger patients, flow diverter stent treatment, types iii-v....

- **1) Beneficial for patients** — Outcome with crawford classification aneurysm — — — ΣN=0
- **2) Harmful for patients** — Outcome with crawford classification aneurysm — — — ΣN=0
- **3) No clear effect** — Outcome with crawford classification 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], [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], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107], [108], [109], [110], [111], [112], [113], [114], [115], [116], [117], [118] — ΣN=126287

1) Introduction

Aneurysms represent localized dilations of blood vessels, posing significant risks of rupture, hemorrhage, and end-organ ischemia. Accurate classification of aneurysms is crucial for guiding treatment strategies, predicting outcomes, and facilitating research. Among these, the Crawford classification system for thoracoabdominal aortic aneurysms (TAAAs) is a foundational anatomical scheme, categorizing aneurysms based on their longitudinal extent and involvement of visceral and renal arteries. This classification significantly impacts the complexity of surgical repair and associated morbidity and mortality. Beyond TAAAs, various other aneurysm types, particularly intracranial aneurysms, also rely on diverse classification systems to inform management and assess treatment efficacy.

2) Aim

This paper aims to synthesize current research themes related to aneurysm classification, with a particular focus on the Crawford classification for thoracoabdominal aortic aneurysms, and to identify associated clinical outcomes, emerging diagnostic tools, and therapeutic advancements.

3) Methods

Systematic review with multilayer AI research agent: keyword normalization, retrieval & structuring, and paper synthesis (see SAIMSARA About section for details).

- **Bias:** The included studies present a range of designs, predominantly retrospective and prospective cohort studies, with some mixed designs, case series, and randomized controlled trial protocols. This heterogeneity, coupled with varying sample sizes (from single cases to thousands), introduces potential for selection bias, confounding, and limited generalizability. The lack of consistent comparators and outcome definitions across studies further complicates direct comparisons and comprehensive synthesis.

4) Results

4.1 Study characteristics:

The studies primarily consisted of retrospective and prospective cohort designs, with several mixed-design studies and a few case series or experimental designs. Populations frequently included patients with thoracoabdominal aortic aneurysms (TAAA), but also encompassed various intracranial, cerebral, abdominal, and other peripheral aneurysms. Follow-up periods ranged from 30 days to 10 years, with many studies not specifying long-term follow-up.

4.2 Main numerical result aligned to the query:

For thoracoabdominal aortic aneurysm (TAAA) repair, the median 30-day or operative mortality rate across various studies was 9.6%, with a range from 0% [8] to 64.7% [44]. Spinal cord ischemia (SCI) or paraplegia rates in TAAA repair showed a median of 4.2%, ranging from 0% [1] to 16.2% [3]. These outcomes reflect diverse patient cohorts and treatment modalities, including open and endovascular approaches.

4.3 Topic synthesis:

- **Crawford Classification in TAAA Management:** The Crawford classification remains a critical framework for TAAA repair, with Type II TAAA often requiring the most extensive intervention and associated with higher postoperative morbidity and mortality [95]. Different types are frequently observed in patient cohorts, with Type III and Type IV TAAAs being common [1, 2, 5].
- **Outcomes of TAAA Repair (Mortality & SCI):** TAAA repair outcomes are highly variable, with operative mortality ranging from 0% [8] to 64.7% [44]. Emergency interventions are associated with significantly higher mortality (e.g., 43.1% [3]) compared to elective cases

(e.g., 4% [2]). Spinal cord ischemia (SCI) or paraplegia rates range from 0% [1] to 16.2% [3].

- **Endovascular vs. Open TAAA Repair:** Endovascular repair (ER) for TAAAs, including fenestrated and branched endografts, demonstrates acceptable outcomes, with reported 3% permanent paraplegia and 8% hospital mortality in high-risk patients [4], and pooled 30-day mortality of 6% and SCI of 8% [72]. Open repair (OR) of TAAA has shown operative mortality of 4% and paraplegia or paraparesis at discharge in 9% [2].
- **Spinal Cord Protection Strategies:** Minimally Invasive Staged Segmental Artery Coil Embolization (MISACE) is a promising spinal cord preconditioning strategy, with one cohort reporting 0% SCI at 30 days after ER [1] and a pooled postoperative SCI rate of 1.9% [23]. A randomized controlled trial is underway to further evaluate MIS^{2}ACE for paraplegia prevention [41].
- **Risk Factors and Patient Characteristics in TAAA:** Advanced age, extensive reconstructive surgery, and ruptured aneurysms are significant factors increasing mortality in TAAA repair [7]. Women with TAAA tend to present with more extensive pathology (Crawford types I, II, or III) and challenging iliac accesses, leading to lower technical success rates in F/BEVAR [37].
- **Intracranial Aneurysm Classification and Rupture Risk:** Various classification systems, such as the Raymond-Roy Occlusion Classification, are widely used for intracranial aneurysms to assess post-treatment occlusion [12, 14, 57, 67, 68]. Machine learning models are increasingly deployed to predict rupture status based on morphological, hemodynamic, and transcriptomic features, achieving high accuracies (e.g., 95.2% [39], 92.6% [48]) [11, 13, 34, 42, 45, 46, 48, 77, 85, 101].
- **Endovascular Treatment for Intracranial Aneurysms:** Endovascular coiling and flow diversion techniques are effective, with reported adequate occlusion rates (e.g., 78.0% at 12 months with LUNA AES [29], 83.3% complete occlusion with Pipeline Embolization Device [18]). Aneurysm diameter and the modified Raymond-Roy occlusion classification are identified as independent risk factors for recurrence after coiling [12].
- **Emerging Classification Systems and Diagnostic Tools:** New classification systems are being proposed for various aneurysm types, including abdominal aortic aneurysms (histopathological [10], juxtarenal [35]), cerebral aneurysms (A1 segment [16], ACoA [17], superior hypophyseal artery [51, 52]), and others [58, 89, 109]. Advanced imaging techniques and artificial intelligence are being developed for aneurysm detection, classification, and rupture risk assessment, demonstrating high accuracy (e.g., 0.953 accuracy for 3D ResNet in AAA classification [25], 89 ± 3% accuracy for Endoleak recognition [38]) [26, 47, 53, 74].
- **Complications and Reinterventions:** Reintervention rates after endovascular abdominal aortic aneurysm repair can be substantial, with 15% at 3 years and 33% at 10 years [24]. Nuisance bleeding is a common complication in patients with cerebral aneurysms treated

with Pipeline embolization devices (27%) [28].

5) Discussion

5.1 Principal finding:

The Crawford classification for thoracoabdominal aortic aneurysms (TAAAs) is fundamental for guiding treatment and risk assessment, with median 30-day or operative mortality rates ranging from 0% [8] to 64.7% [44] and spinal cord ischemia/paraplegia rates from 0% [1] to 16.2% [3] across various repair modalities.

5.2 Clinical implications:

- **Personalized Risk Assessment:** The Crawford classification, combined with patient-specific factors like age, rupture status, and extent of disease, is crucial for stratifying risk and informing patient selection for open versus endovascular TAAA repair [7, 37].
- **Optimizing Treatment Modality:** Different Crawford TAAA types, particularly Type II, are associated with higher morbidity and mortality, necessitating careful consideration of treatment approaches, including advanced endovascular techniques or open repair with spinal cord protection strategies [95, 1].
- **Enhanced Spinal Cord Protection:** Strategies like Minimally Invasive Staged Segmental Artery Coil Embolization (MISACE) should be considered for TAAA repair, especially in high-risk patients, to mitigate spinal cord ischemia [1, 23].
- **Long-term Monitoring:** Given the significant reintervention rates after endovascular abdominal aortic aneurysm repair (up to 33% at 10 years), long-term surveillance is essential for all aneurysm patients, regardless of initial treatment [24].
- **Gender-Specific Considerations:** Clinicians should be aware that women with TAAA may present with more extensive pathology and challenging anatomy, potentially influencing technical success rates in complex endovascular repairs [37].

5.3 Research implications / key gaps:

- **Comparative Efficacy by Crawford Type:** Future research should conduct large-scale, prospective comparative studies to precisely evaluate the long-term efficacy and safety of open versus endovascular TAAA repair, specifically stratified by each Crawford classification type [2, 4].
- **Standardized SCI Reporting:** There is a need for a consensus on standardized definitions and reporting of spinal cord ischemia (SCI) and paraplegia outcomes in TAAA repair to

enable more robust meta-analyses and inter-study comparisons [1, 3].

- **Advanced Predictive Analytics for TAAA:** Develop and validate machine learning models integrating clinical, imaging, and genetic data to predict TAAA rupture risk and post-operative complications, similar to advancements seen in intracranial aneurysms [39, 48].
- **Optimal Spinal Cord Preconditioning Protocols:** Further randomized controlled trials are needed to define the optimal protocols, patient selection criteria, and long-term benefits of spinal cord preconditioning strategies like MIS²ACE across all TAAA Crawford types [41, 23].
- **Impact of Novel Classification Systems:** Research should investigate the clinical utility and impact on patient outcomes of newly proposed classification systems for various aneurysm types (e.g., cerebral, abdominal, renal) beyond their initial descriptive value [10, 16, 17, 35, 51, 52].

5.4 Limitations:

- **Heterogeneous Study Designs** — The included studies encompass a wide range of designs, from small case series to large retrospective cohorts, limiting direct comparability and synthesis of outcomes.
- **Variability in Outcome Reporting** — Metrics for complications like spinal cord injury and mortality are reported with different definitions and timepoints, hindering a precise meta-analysis.
- **Limited Direct Comparative Evidence** — Few studies directly compare different treatment modalities (e.g., open vs. endovascular) or specific Crawford types within the same study with consistent methodology.
- **Broad Aneurysm Scope** — While the Crawford classification is specific to TAAA, the search results included a broad range of aneurysm types and classification systems, diluting the focus on the primary query.
- **Lack of Long-Term Follow-up Consistency** — Follow-up durations vary significantly across studies, making it difficult to assess long-term efficacy and safety profiles consistently.

5.5 Future directions:

- **Comparative Effectiveness Research** — Conduct large, prospective comparative studies (e.g., RCTs) evaluating outcomes of different TAAA repair modalities stratified by Crawford classification.

- **Standardized Outcome Reporting** — Develop and adopt standardized definitions and reporting metrics for TAAA complications (e.g., SCI, mortality) to enable more robust meta-analyses.
- **Advanced Predictive Modeling** — Integrate machine learning with clinical and imaging data to develop highly accurate, patient-specific risk prediction models for TAAA rupture and post-operative complications.
- **Longitudinal Registry Studies** — Establish and maintain comprehensive, long-term registries for TAAA patients to track outcomes, reinterventions, and quality of life over extended periods.
- **Role of Preconditioning Strategies** — Further investigate the efficacy and optimal protocols for spinal cord preconditioning strategies like MISACE in preventing SCI across all Crawford TAAA types.

6) Conclusion

For thoracoabdominal aortic aneurysm (TAAA) repair, the median 30-day or operative mortality rate across various studies was 9.6%, with a range from 0% [8] to 64.7% [44]. Spinal cord ischemia (SCI) or paraplegia rates in TAAA repair showed a median of 4.2%, ranging from 0% [1] to 16.2% [3]. These outcomes, assessed across diverse patient cohorts and treatment modalities, highlight the significant morbidity and mortality associated with TAAA, particularly influenced by the Crawford classification. The broad scope of aneurysm types and varied reporting of outcomes across studies represent the most significant limitation to certainty. Clinicians should integrate the Crawford classification with patient-specific risk factors to optimize treatment selection and implement robust spinal cord protection strategies in TAAA repair.

References

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Figure 1. Publication-year distribution of included originals

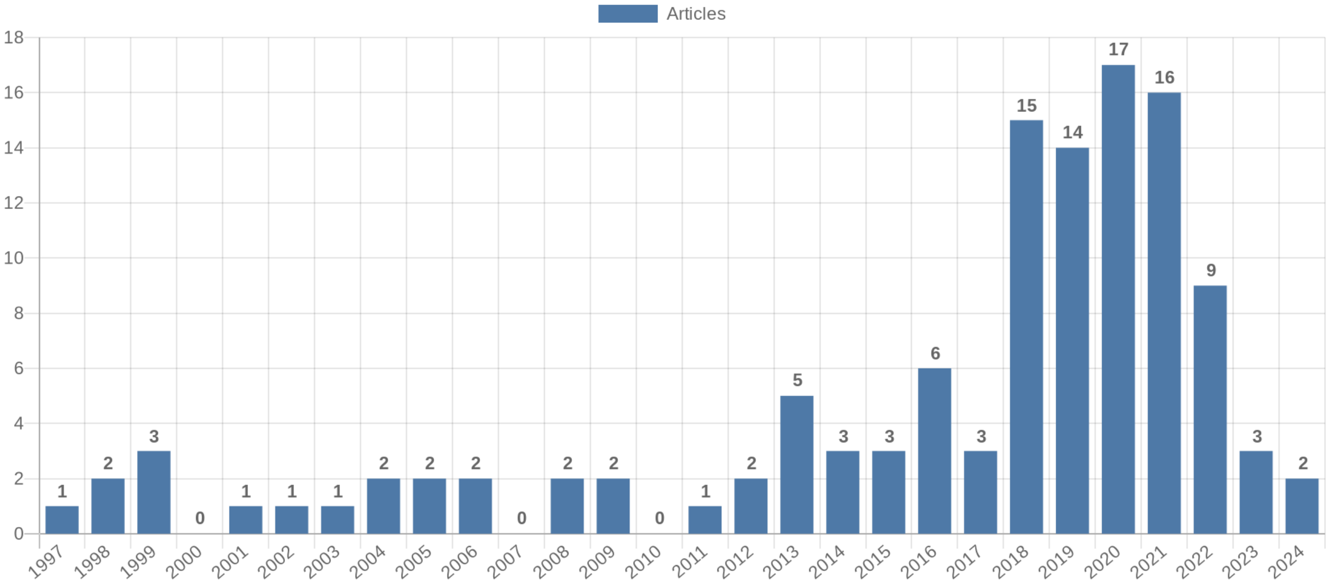

Figure 2. Study-design distribution of included originals

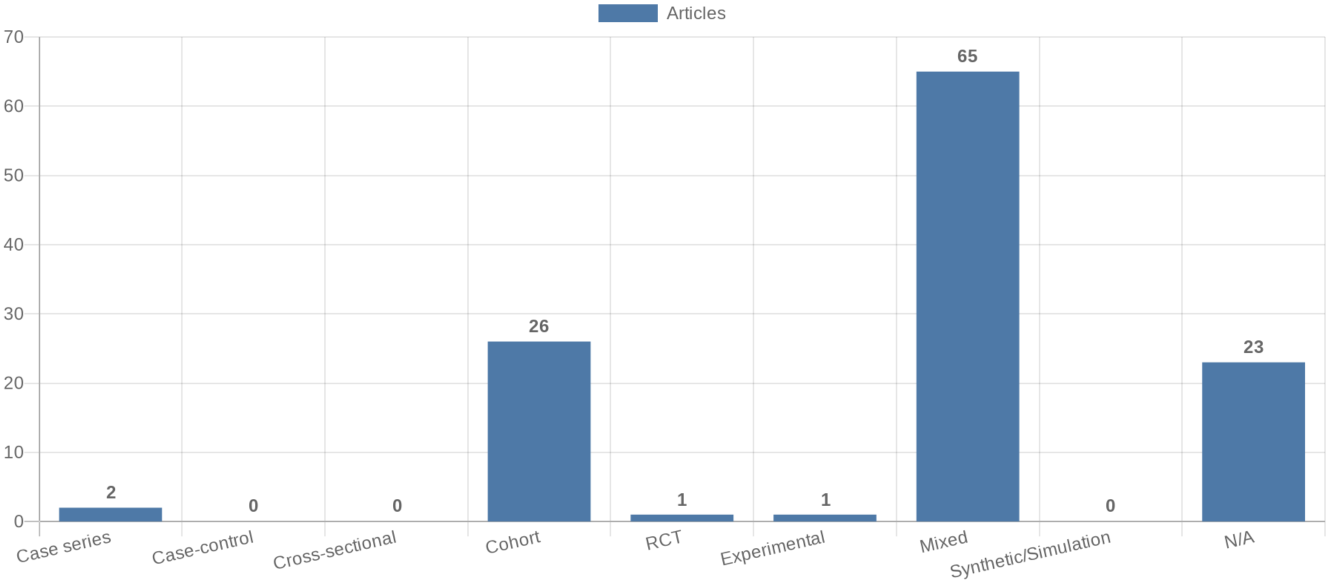

Figure 3. Study-type (directionality) distribution of included originals

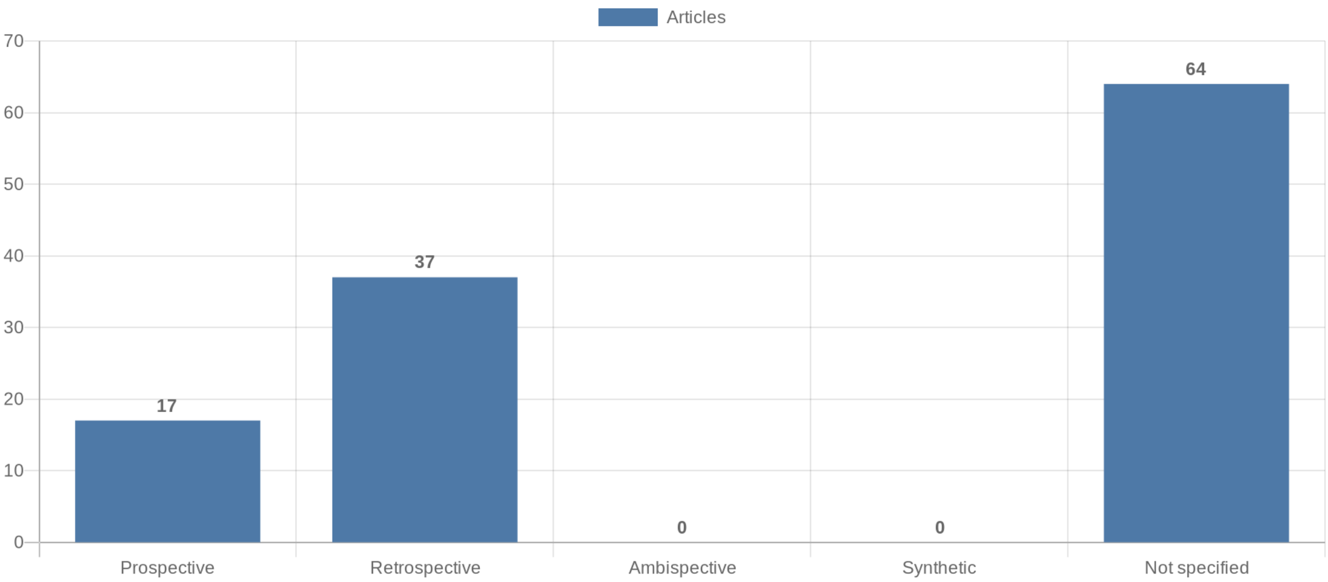

Figure 4. Main extracted research topics

- CRAWFORD CLASSIFICATION IN TAAA MANAGEMENT
- OUTCOMES OF TAAA REPAIR MORTALITY & SCI
- ENDOVASCULAR VS. OPEN TAAA REPAIR
- SPINAL CORD PROTECTION STRATEGIES
- RISK FACTORS AND PATIENT CHARACTERISTICS IN TAAA
- INTRACRANIAL ANEURYSM CLASSIFICATION AND RUPTURE RISK
- ENDOVASCULAR TREATMENT FOR INTRACRANIAL ANEURYSMS

Figure 5. Limitations of current studies (topics)

- HETEROGENEOUS STUDY DESIGNS
- VARIABILITY IN OUTCOME REPORTING
- LIMITED DIRECT COMPARATIVE EVIDENCE
- BROAD ANEURYSM SCOPE
- LACK OF LONG-TERM FOLLOW-UP CONSISTENCY

Figure 6. Future research directions (topics)

- COMPARATIVE EFFICACY BY CRAWFORD TYPE
- STANDARDIZED SCI REPORTING
- ADVANCED PREDICTIVE ANALYTICS FOR TAAA
- OPTIMAL SPINAL CORD PRECONDITIONING PROTOCOLS
- IMPACT OF NOVEL CLASSIFICATION SYSTEMS