Aspiration Thrombectomy: Systematic Review with ☸SAIMSARA.

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Abstract: This paper aims to synthesize current evidence on the efficacy, safety, and procedural aspects of aspiration thrombectomy across various clinical indications, identifying key outcomes, influencing factors, and areas for future research. The review utilises 355 studies with 122918 total participants (naïve ΣN). Aspiration thrombectomy in acute ischemic stroke (AIS) demonstrates a high rate of successful recanalization, with a median of 89.3% (ranging from 50% to 100%) across various studies. This efficacy extends to non-stroke indications like pulmonary embolism and deep vein thrombosis. However, the heterogeneity of study designs, particularly the prevalence of retrospective and mixed studies, limits the certainty and generalizability of findings. Future research should focus on large-scale randomized controlled trials with standardized outcome reporting to refine treatment protocols and optimize patient selection. Clinicians should consider the benefits of larger bore catheters and combined techniques, while remaining vigilant for potential complications.

Keywords: Aspiration Thrombectomy; Acute Ischemic Stroke; Large Vessel Occlusion

Review Stats

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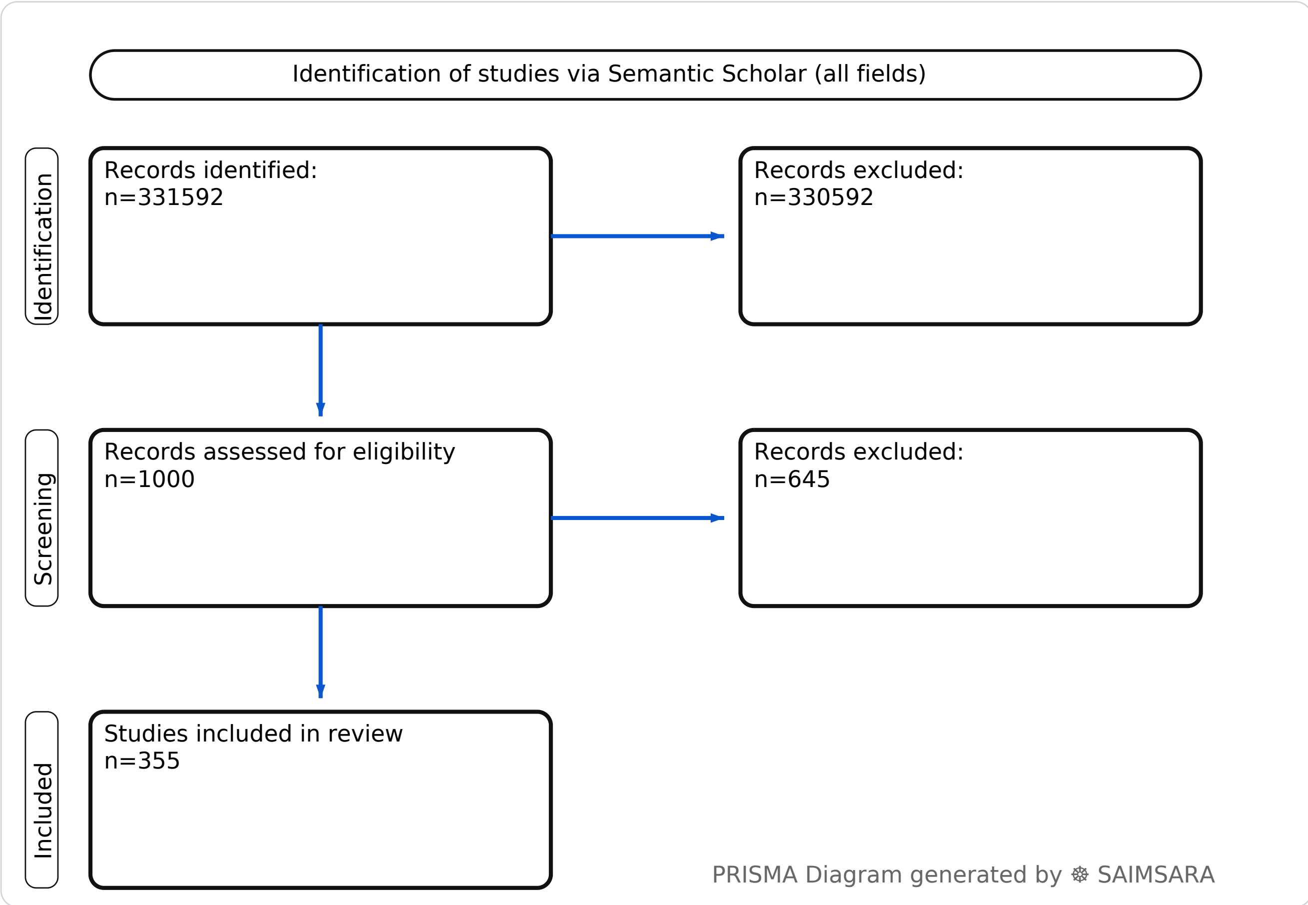
- Total study participants (naïve ΣN): 122918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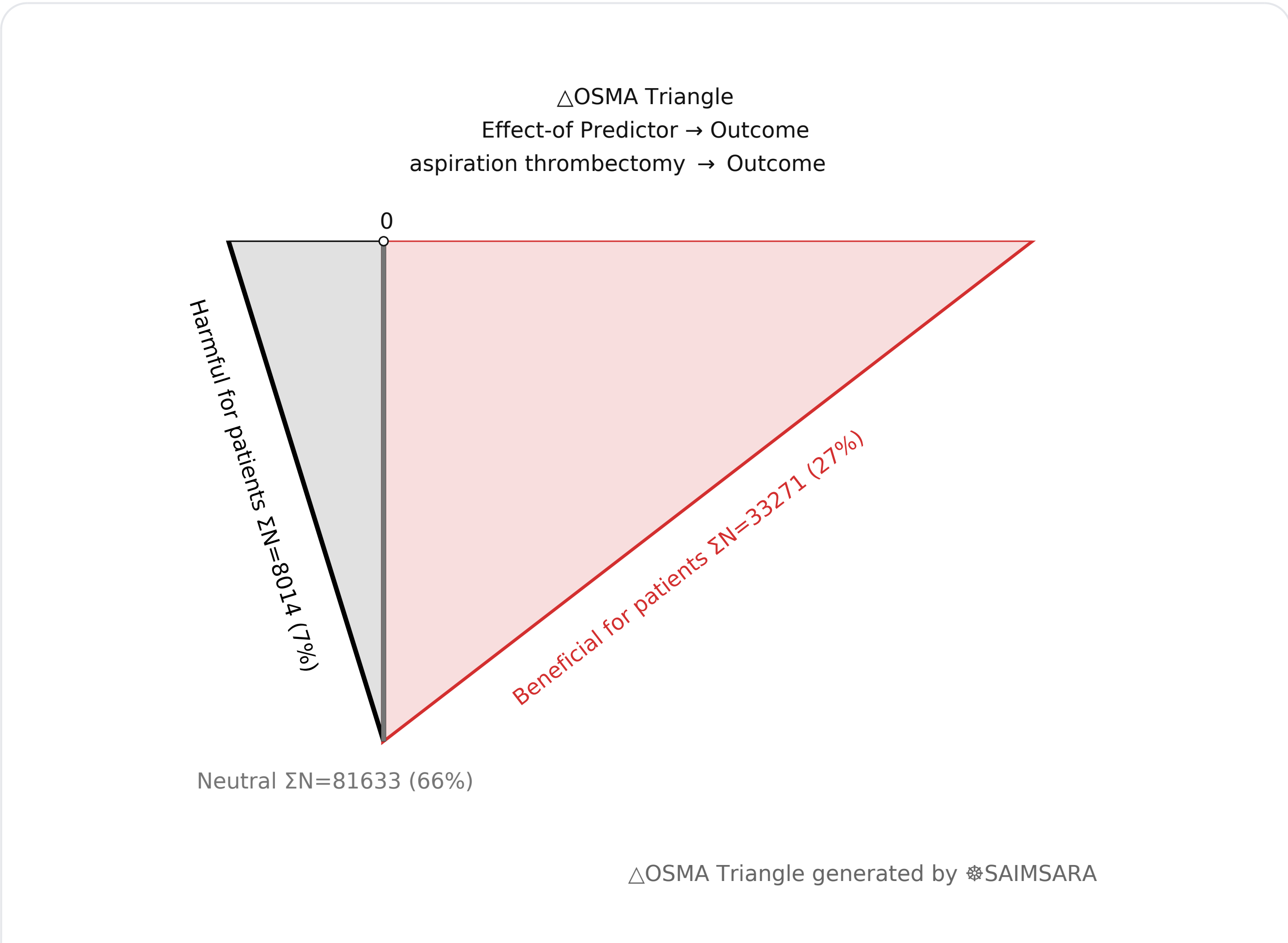
△OSMA Triangle
Effect-of Predictor → Outcome
aspiration thrombectomy → Outcome
0
Harmful for patients ΣN=8014 (7%)
Beneficial for patients ΣN=33271 (27%)
Neutral ΣN=81633 (66%)
△OSMA Triangle generated by ☸SAIMSARA

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

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

Outcome: Outcome Typical timepoints: 90-day, 3-mo. Reported metrics: %, CI, p.

Common endpoints: Common endpoints: complications, occlusion, functional.

Predictor: aspiration thrombectomy — exposure/predictor. Doses/units seen: 60 ml. Routes seen: intravenous, iv. Typical comparator: static aspiration, stent retriever thrombectomy, more proximal guide catheter, stent retriever-based….

- **1) Beneficial for patients** — Outcome with aspiration thrombectomy — [1], [4], [5], [6], [9], [10], [11], [12], [13], [14], [15], [16], [18], [20], [21], [22], [23], [24], [51], [52], [53], [54], [55], [56], [57], [59], [61], [64], [65], [67], [72], [73], [74], [75], [78], [79], [80], [85], [88], [91], [95], [96], [99], [100], [102], [103], [104], [105], [107], [109], [110], [111], [112], [114], [116], [117], [118], [119], [120], [121], [124], [125], [129], [145], [147], [149], [150], [226], [227], [228], [231], [232], [233], [235], [237], [238], [239], [240], [241], [243], [244], [245], [246], [247], [248], [250], [251], [252], [253], [255], [256], [257], [258], [259], [260], [261], [262], [263], [264], [265], [266], [267], [268], [269], [271], [272], [273], [274], [286], [287], [291], [296], [298], [336], [339], [342], [347], [348], [350], [354], [355] — ΣN=33271
- **2) Harmful for patients** — Outcome with aspiration thrombectomy — [19], [25], [58], [66], [87], [90], [127], [148], [242], [283], [288], [293], [294], [297], [299], [352] — ΣN=8014
- **3) No clear effect** — Outcome with aspiration thrombectomy — [2], [3], [7], [8], [17], [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], [60], [62], [63], [68], [69], [70], [71], [76], [77], [81], [82], [83], [84], [86], [89], [92], [93], [94], [97], [98], [101], [106], [108], [113], [115], [122], [123], [126], [128], [130], [131], [132], [133], [134], [135], [136], [137], [138], [139], [140], [141], [142], [143], [144], [146], [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], [229], [230], [234], [236], [249], [254], [270], [275], [276], [277], [278], [279], [280], [281], [282], [284], [285], [289], [290], [292], [295], [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], [337],

[338], [340], [341], [343], [344], [345], [346], [349], [351], [353] — ΣN=81633

1) Introduction

Aspiration thrombectomy (AT) is a minimally invasive endovascular procedure used to remove blood clots from occluded vessels. Initially developed for acute ischemic stroke (AIS), its application has expanded to various thrombotic conditions including pulmonary embolism (PE), acute myocardial infarction (AMI), deep vein thrombosis (DVT), and acute limb ischemia (ALI). This technique involves the use of specialized catheters to apply suction directly to the thrombus, aiming for rapid and effective recanalization. The evolution of AT devices and techniques, including advancements in catheter design, aspiration methods, and combined approaches with stent retrievers, continues to shape its efficacy and safety profile across diverse patient populations and anatomical locations.

2) Aim

This paper aims to synthesize current evidence on the efficacy, safety, and procedural aspects of aspiration thrombectomy across various clinical indications, identifying key outcomes, influencing factors, and areas for future research.

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. Retrospective cohort studies and mixed designs are prevalent, introducing potential selection and confounding biases. The inclusion of experimental and *in vitro* studies indicates a focus on technical feasibility and device development, which may not directly translate to clinical outcomes. Randomized controlled trials (RCTs) are present but represent a smaller proportion of the evidence, suggesting a need for higher-level evidence in certain areas.

4) Results

4.1 Study characteristics: The included studies comprise a diverse range of designs, predominantly mixed (combining retrospective and prospective elements or different data types) [1, 5, 7, 9, 10, 11, 12, 14, 17, 18, 19, 22, 23, 25, 26, 29, 30, 32, 33, 34, 35, 37, 38, 39, 40, 41, 42, 44, 45, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 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, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 119, 121, 122, 123, 124, 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, 156, 158, 161, 162, 163, 164, 166, 167, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 191, 192, 193, 194, 195, 196, 197, 198, 200, 201, 202, 203, 204, 205, 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, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 261, 262, 263, 264, 265, 266, 267, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 282, 283, 284, 287, 288, 290, 291, 295, 296, 297, 298, 299, 300, 301, 302, 303, 305, 306, 307, 309, 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, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355], cohort [4, 6, 13, 15, 16, 20, 21, 24, 36, 37, 38, 40, 41, 44, 45, 46, 47, 49, 50, 53, 54, 55, 58, 59, 66, 67, 74, 75, 79, 80, 85, 86, 87, 90, 95, 96, 97, 99, 100, 101, 102, 103, 104, 105, 108, 109, 110, 111, 113, 114, 115, 116, 119, 120, 121, 123, 125, 126, 127, 129, 132, 133, 134, 135, 139, 141, 142, 147, 148, 149, 152, 153, 154, 155, 156, 158, 161, 162, 163, 165, 166, 168, 183, 188, 189, 190, 191, 192, 196, 197, 198, 200, 201, 204, 205, 206, 207, 208, 209, 210, 212, 213, 214, 216, 217, 219, 220, 222, 223, 226, 227, 230, 231, 233, 237, 239, 240, 241, 242, 243, 244, 245, 247, 250, 251, 252, 255, 256, 257, 258, 259, 260, 262, 263, 265, 266, 267, 268, 270, 274, 280, 285, 286, 287, 290, 291, 293, 294, 295, 296, 301, 302, 303, 304, 305, 307, 308, 311, 312, 313, 315, 318, 320, 323, 325, 326, 32
32, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355]. Randomized controlled trials (RCTs) [2, 3, 28, 51, 56, 63, 118, 130, 131, 138, 151, 159, 160, 169, 201, 205, 233, 234, 268, 275, 279, 281, 285, 288, 289, 310] and experimental/synthetic/simulation studies [8, 22, 27, 31, 140, 167, 172, 173, 174, 175, 176, 181, 184, 187, 193, 194, 195, 199, 211, 218, 224, 228, 236, 238, 249, 264, 269, 282, 283, 284, 306, 314, 319, 329, 345] are also included. Populations studied range from acute ischemic stroke (AIS) patients with large vessel occlusions (LVOs) [3, 10, 18, 32, 33, 36, 38, 40, 42, 44, 47, 50, 55, 56, 58, 59, 75, 78, 80, 85, 87, 90, 95, 96, 97, 99, 100, 102, 104, 105, 108, 109, 111, 112, 113, 114, 116, 118, 119, 120, 121, 125, 127, 129, 139, 141, 142, 147, 148, 150, 153, 154, 155, 158, 162, 163, 165, 183, 185, 188, 189, 191, 192, 197, 198, 200, 201, 203, 204, 205, 206, 207, 208, 209, 210, 212, 213, 214, 216, 217, 219, 220, 221, 222, 223, 226, 227, 230, 232, 233, 234, 237, 238, 239, 240, 241, 242, 243, 244, 245, 247, 251, 252, 253, 256, 257, 259, 260, 262, 263, 268, 270, 274, 275, 280, 285, 286, 287, 292, 294, 295, 302, 303, 304, 305, 307, 308, 311, 312, 313, 315, 318, 320, 321, 323, 324, 325, 326, 327, 328, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 355] and distal/medium vessel occlusions (DMVOs/MeVOs) [1, 9, 16, 21, 23, 49, 53, 67, 110, 115, 123, 126, 145, 149, 156, 158, 161, 163, 183, 187, 189, 192, 200, 202, 255, 301, 337, 318, 321] to pulmonary embolism (PE) [4, 13, 29, 30, 43, 48, 57, 68, 82, 128, 235, 265, 266, 297], acute myocardial infarction (AMI)/STEMI [11, 28, 46, 51, 62, 63, 66, 130, 136, 138, 143, 151, 152, 157, 168, 178, 180, 182, 229, 279, 281, 288, 289, 299, 310, 317,

330, 352, 354], deep vein thrombosis (DVT) [34, 52, 61, 69, 89, 106, 131, 137, 166, 171, 250, 266, 291], and acute limb ischemia (ALI) [25, 83, 91, 146, 164, 231, 248]. Follow-up periods vary widely, from immediate post-procedure or discharge to 30 days, 90 days, or even several years.

4.2 Main numerical result aligned to the query:

Across studies focusing on acute ischemic stroke (AIS) and reporting successful recanalization (defined as modified Thrombolysis in Cerebral Infarction (mTICI) 2b-3 or 2c-3), the median rate was 89.3% [80], with a range from 50% [53] to 100% [111, 185, 263, 287, 301]. For first-pass effect (FPE), also in AIS, the median rate was 53% [12, 188], ranging from 11.8% [213] to 100% [107, 194]. Good functional outcome (modified Rankin Scale (mRS) ≤2) at 90 days in AIS patients showed a median of 50.6% [2], with a range from 17.7% [213] to 96.8% [301]. For pulmonary embolism (PE), technical success rates were high, with a reported 96.9% [4] and 100% [266] in different studies. In acute limb ischemia (ALI), primary technical success was 90.8% [164], but amputation-free survival was worse with aspiration mechanical thrombectomy (88.4% vs 95.3%) [25].

4.3 Topic synthesis:

- **Aspiration Thrombectomy Efficacy in Stroke:** High successful recanalization rates (median 89.3%, range 50-100%) and first-pass effect (median 53%, range 11.8-100%) are consistently reported across various vessel occlusions, including LVOs, DMVOs, and MeVOs [1, 9, 12, 18, 20, 42, 49, 50, 55, 74, 79, 80, 99, 102, 103, 111, 114, 121, 129, 145, 149, 156, 185, 188, 194, 213, 214, 219, 227, 237, 241, 257, 259, 287, 301, 302, 304, 315, 318, 351].
- **Catheter Design and Technique Optimization:** Larger aspiration catheter inner diameters (e.g., 0.088-inch, Catalyst 7, ACE 68/71) are associated with higher first-pass effect rates and faster procedural times [19, 26, 107, 120, 145, 153, 193, 194, 203, 210, 216, 241, 243, 264, 298, 313, 318]. Techniques like the "plunger technique" [5, 17], manual cyclic aspiration [5], adaptive pulsatile aspiration [22], and longer dwell times [117] are explored for improved clot ingestion.
- **Comparison with Stent Retriever Thrombectomy:** Aspiration thrombectomy (AT) often shows comparable functional outcomes to stent retriever (SR) thrombectomy in AIS [2, 15, 36, 45, 67, 99, 113, 118, 123, 125, 183, 197, 205, 214, 268, 274, 285, 293], with some studies indicating shorter procedure times and fewer passes for AT [20, 38, 41, 45, 79, 99, 102, 104, 111, 114, 119, 208, 213, 214, 216, 219, 241, 243, 256, 257]. However, SR-first may have higher first-device recanalization in some contexts [36, 58, 285].
- **Adjunctive Therapies and Combined Approaches:** Combining AT with stent retrievers (SR+CA or similar) can improve first-pass effect (FPE) and successful reperfusion rates, especially in DMVOs [56, 116, 158, 163, 188, 191, 200, 202, 210, 217, 230, 238, 239, 247, 256, 269, 321, 342, 345, 348] and for specific clot characteristics [81, 169, 192, 223, 228,

238, 349]. Balloon guide catheters (BGC) further enhance outcomes by reducing passes and shortening times [44, 47, 75, 198, 239, 240, 256, 269, 341].

- **Factors Influencing Outcomes:** Clot characteristics (perviousness, composition, length, phenotype) and vessel anatomy (tortuosity, diameter, catheter-to-vessel ratio) significantly impact AT success [37, 70, 86, 94, 109, 154, 155, 187, 190, 195, 207, 212, 223, 224, 244, 249, 252, 284, 293, 295, 298, 300, 306, 314, 325, 339, 340, 349, 352]. Intracranial atherosclerotic disease (ICAS) can lead to less successful immediate reperfusion and more vessel injury with contact aspiration [108, 222, 293].
- **Safety Profile and Complications:** While generally safe, AT carries risks including symptomatic intracranial hemorrhage (sICH) (median 2.8% [67], range 0-19.64% [18, 97]) [2, 13, 15, 19, 20, 46, 48, 49, 53, 56, 62, 66, 74, 75, 79, 90, 97, 116, 129, 148, 158, 163, 188, 189, 192, 196, 197, 199, 200, 201, 225, 233, 242, 251, 254, 281, 294, 297, 299, 310, 336, 337, 340], distal embolization [38, 56, 58, 66, 195, 200, 242, 282, 284, 298, 339, 352], and vessel perforation [199, 297, 337]. In non-stroke settings, amputation-free survival can be worse [25].
- **Applications Beyond Stroke:** AT is effectively used in pulmonary embolism (PE) for hemodynamic improvement and clot removal [4, 13, 29, 30, 48, 235, 265, 266], acute myocardial infarction (AMI) for thrombus removal and microvascular function [11, 28, 51, 130, 354], deep vein thrombosis (DVT) for clot clearance and symptom relief [34, 52, 61, 166, 250, 291], and acute limb ischemia (ALI) for rapid revascularization [91, 164, 248].

5) Discussion

5.1 Principal finding: Aspiration thrombectomy (AT) in acute ischemic stroke (AIS) demonstrates a high rate of successful recanalization, with a median of 89.3% (ranging from 50% to 100%) across various studies [80], indicating its robust technical efficacy in restoring blood flow.

5.2 Clinical implications:

- **Device Selection Guidance:** Larger bore aspiration catheters (e.g., 0.088-inch, ACE 68/71, Catalyst 7) are associated with higher first-pass effect rates and faster procedures, suggesting a preference for these devices when anatomically feasible [19, 107, 153, 210, 216, 241, 243, 313].
- **First-Line Strategy Considerations:** While AT often achieves comparable functional outcomes to stent retriever (SR) thrombectomy, it may offer advantages in terms of shorter procedure times and fewer passes [20, 38, 41, 45, 79, 99, 102, 104, 111, 114, 119, 208, 213, 214, 216, 219, 241, 243, 256, 257]. This could influence initial treatment choices in acute stroke.

- **Combined Techniques for Complex Cases:** For challenging occlusions, particularly in distal or medium vessels, or those with specific clot characteristics, combining AT with stent retrievers and/or balloon guide catheters (BGCs) can enhance recanalization rates and first-pass success [56, 116, 158, 163, 188, 191, 200, 210, 217, 230, 238, 239, 247, 256, 269, 342, 345, 348].
- **Risk Mitigation for Hemorrhage:** The direct aspiration first pass technique (ADAPT) has been identified as a negative predictor of symptomatic intracranial hemorrhage (sICH) in some contexts [336], suggesting a potentially safer profile compared to other techniques in specific patient groups.
- **Expanding Indications:** AT is a viable and effective treatment for various non-stroke thrombotic conditions, including pulmonary embolism, deep vein thrombosis, and acute limb ischemia, offering hemodynamic improvements and clot removal, especially when thrombolysis is contraindicated [4, 13, 29, 30, 48, 91, 164, 235, 250, 265, 266, 291].

5.3 Research implications / key gaps:

- **Optimal Catheter-to-Vessel Ratio:** Further prospective studies are needed to define precise optimal catheter-to-vessel ratio cutoffs for various anatomical locations and clot types to maximize first-pass success and minimize complications [252, 249, 212].
- **Comparative Effectiveness in DMVOs/MeVOs:** Large-scale RCTs are needed to definitively compare aspiration-first versus stent retriever-first or combined techniques for distal and medium vessel occlusions, particularly concerning long-term functional outcomes and safety [1, 9, 16, 21, 23, 49, 53, 67, 110, 115, 123, 149, 156, 161, 183, 189, 192, 200, 301].
- **Impact of Clot Characteristics on Strategy:** Prospective studies should investigate how detailed pre-procedural imaging of clot composition (e.g., fibrin/platelet content, perviousness) and thrombus phenotype can guide the selection of aspiration-only, stent retriever-only, or combined thrombectomy strategies to optimize outcomes [37, 86, 109, 154, 207, 223, 224, 300, 314, 339, 349, 352].
- **Long-Term Outcomes in Non-Stroke Indications:** More long-term follow-up data (beyond 90 days) are required for non-stroke applications like PE, DVT, and ALI to assess sustained benefits, recurrence rates, and quality of life, especially for newer devices and techniques [4, 11, 13, 25, 28, 46, 52, 61, 62, 66, 91, 131, 152, 164, 231, 248, 250, 258, 266, 291, 296, 331, 332, 334, 354].
- **Role of IV Alteplase with Aspiration:** Further investigation is warranted into the potential adverse effects of prior intravenous alteplase administration on the efficacy of aspiration thrombectomy, particularly in specific stroke patient subgroups, to refine treatment

protocols [90, 201, 233, 261, 310].

5.4 Limitations:

- **Heterogeneity of Study Designs:** The prevalence of retrospective cohort and mixed studies limits the certainty and generalizability of findings compared to prospective randomized controlled trials.
- **Variability in Outcome Definitions:** Different definitions for "successful recanalization" (e.g., TICI 2b, 2c, 3) and "good functional outcome" (e.g., mRS ≤2, ≤3) across studies make direct comparisons challenging.
- **Device-Specific Reporting:** Many studies focus on specific devices or techniques, making it difficult to draw broad conclusions about aspiration thrombectomy as a whole, as performance can vary significantly between catheters.
- **Lack of Standardized Protocols:** Procedural nuances like aspiration pressure, dwell time, and adjunctive techniques (e.g., BGC use) are not uniformly reported or standardized, potentially influencing outcomes.
- **Limited Long-Term Follow-up:** While 90-day outcomes are common for stroke, longer-term data, especially for non-stroke indications, are often sparse, limiting understanding of sustained efficacy and safety.

5.5 Future directions:

- **Standardized Outcome Reporting:** Develop and implement universal definitions for technical and clinical success endpoints in thrombectomy studies.
- **Comparative Device Trials:** Conduct head-to-head randomized controlled trials comparing newer generation aspiration catheters against established devices across various vessel sizes and clot types.
- **Advanced Imaging Integration:** Integrate advanced pre-procedural imaging (e.g., clot composition, vessel tortuosity) into prospective trials to guide individualized thrombectomy strategies.
- **Longitudinal Registry Development:** Establish comprehensive, international registries with long-term follow-up for all thrombectomy indications to track real-world effectiveness and safety.
- **AI-Driven Procedural Optimization:** Utilize computational models and AI to predict optimal catheter selection, aspiration parameters, and adjunctive techniques based on patient-specific anatomy and clot characteristics [167, 181].

6) Conclusion

Aspiration thrombectomy in acute ischemic stroke (AIS) demonstrates a high rate of successful recanalization, with a median of 89.3% (ranging from 50% to 100%) across various studies [80]. This efficacy extends to non-stroke indications like pulmonary embolism and deep vein thrombosis. However, the heterogeneity of study designs, particularly the prevalence of retrospective and mixed studies, limits the certainty and generalizability of findings. Future research should focus on large-scale randomized controlled trials with standardized outcome reporting to refine treatment protocols and optimize patient selection. Clinicians should consider the benefits of larger bore catheters and combined techniques, while remaining vigilant for potential complications.

References

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Figure 1. Publication-year distribution of included originals

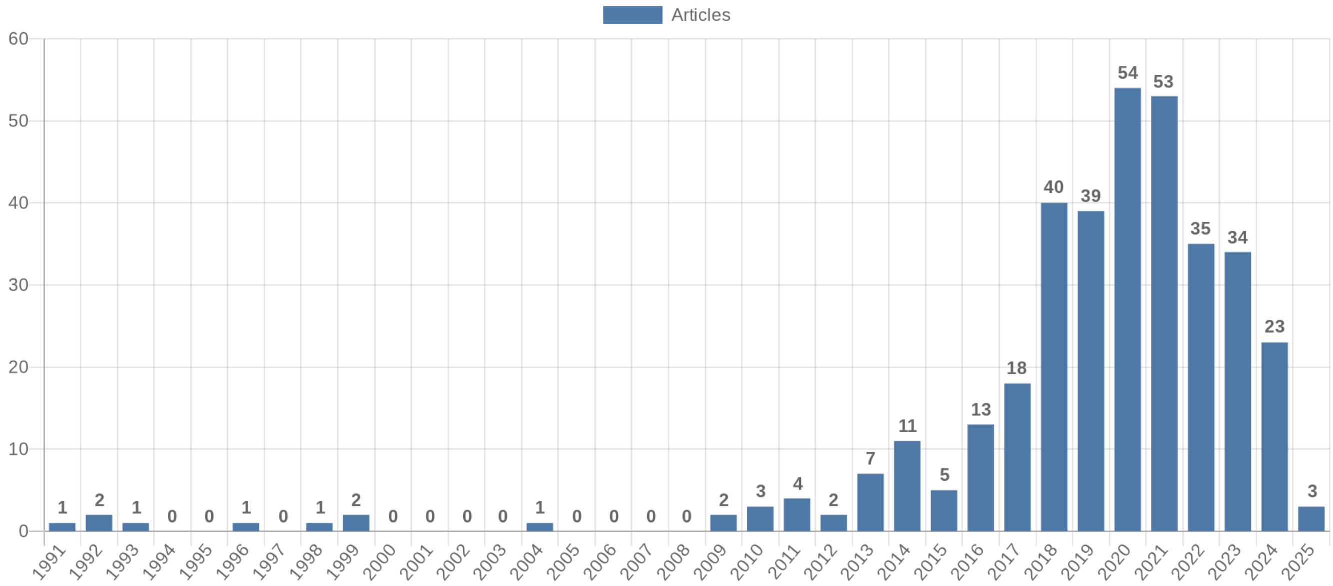

Figure 2. Study-design distribution of included originals

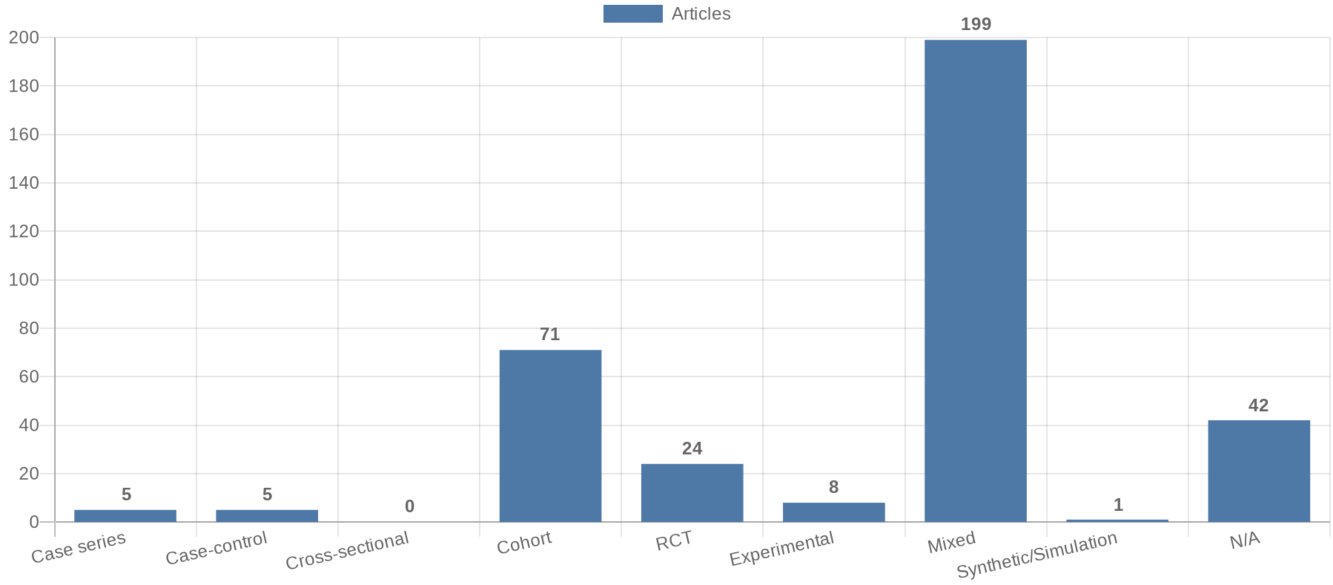

Figure 3. Study-type (directionality) distribution of included originals

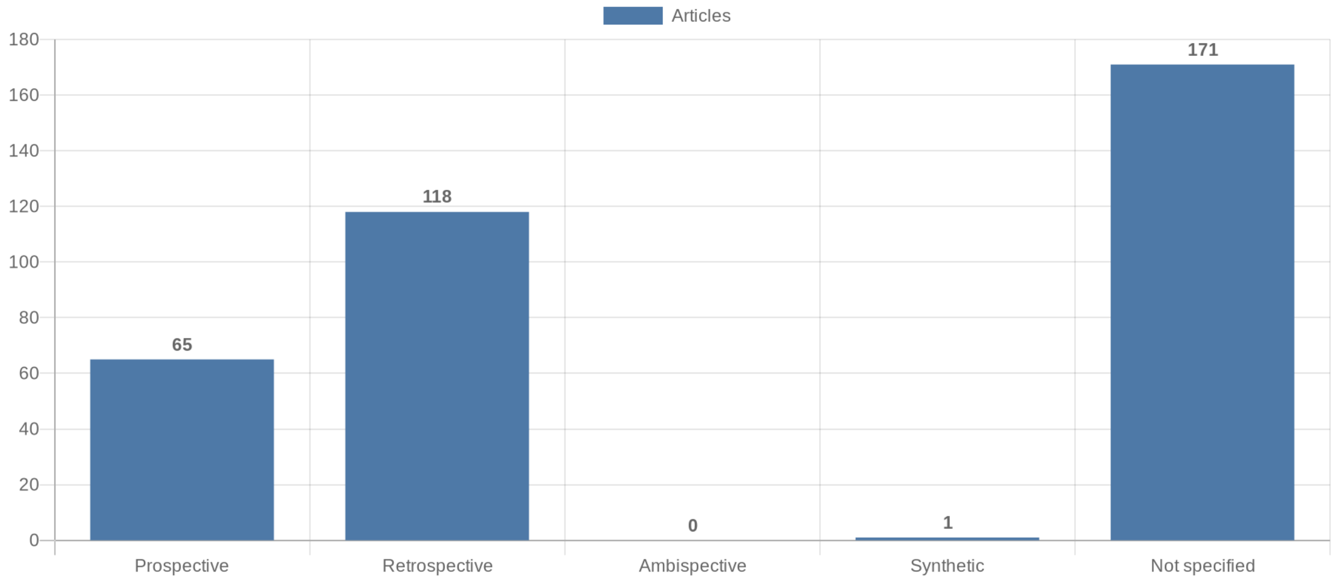

Figure 4. Main extracted research topics

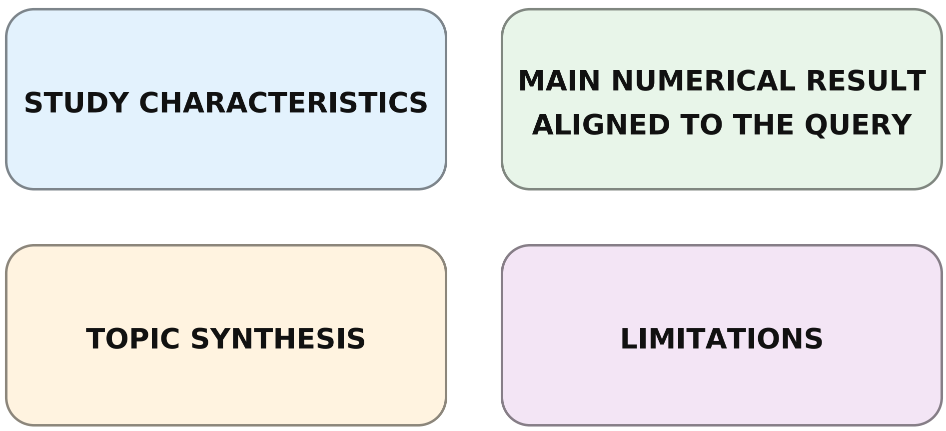

Figure 5. Limitations of current studies (topics)

HETEROGENEITY OF STUDY DESIGNS

VARIABILITY IN OUTCOME DEFINITIONS

DEVICE-SPECIFIC REPORTING

LACK OF STANDARDIZED PROTOCOLS

LIMITED LONG-TERM FOLLOW-UP

Figure 6. Future research directions (topics)

OPTIMAL CATHETER-TO-VESSEL RATIO

COMPARATIVE EFFECTIVENESS IN DMVOS/MEVOS

IMPACT OF CLOT CHARACTERISTICS ON STRATEGY

LONG-TERM OUTCOMES IN NON-STROKE INDICATIONS

ROLE OF IV ALTEPLASE WITH ASPIRATION

STANDARDIZED OUTCOME REPORTING

COMPARATIVE DEVICE TRIALS