Comparative Efficacy of Endovascular Versus Surgical Thrombectomy for Arteriovenous Graft Thrombosis in Hemodialysis Patients - A Systematic Review and Meta-Analysis

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Abstract

Background: End-stage kidney disease (ESKD) is a significant public health issue, necessitating hemodialysis as a primary renal replacement therapy. The long-term success of hemodialysis depends on maintaining functional vascular access, with arteriovenous grafts (AVGs) being widely utilized. Thrombosis remains a major complication leading to access failure, necessitating prompt and effective intervention. This systematic review and meta-analysis compare the efficacy of endovascular and surgical thrombectomy in managing thrombosed AVGs. Methods: A systematic search was conducted in Cochrane Library, EMBASE, and PubMed for studies published between 2015 and 2023. Studies comparing endovascular and surgical thrombectomy in hemodialysis patients were included. Statistical analyses were performed using Review Manager software, applying random-effects models where heterogeneity was significant ($I^2 > 50\%$). The primary outcomes assessed were technical failure, primary non-patency at one year, and secondary non-patency at one year. Results: Six retrospective cohort studies involving 1,520 participants were included. The analysis revealed no statistically significant difference in one-year primary non-patency between endovascular and surgical thrombectomy (OR: 0.58, 95% CI: 0.20–1.62, p = 0.29). Similarly, one-year secondary non-patency rates showed no significant difference (OR: 0.86, 95% CI: 0.64–1.16, p = 0.32). Technical failure rates were comparable between the two interventions. While surgical thrombectomy has traditionally been favored, recent advancements in endovascular techniques have led to equivalent patency outcomes. Conclusion: Endovascular and surgical thrombectomy demonstrate comparable efficacy in managing thrombosed AVGs in hemodialysis patients. Given the minimally invasive nature and technological advancements of endovascular techniques, they may offer a viable alternative to surgical thrombectomy. Further randomized controlled trials are needed to refine treatment strategies and optimize vascular access management.

Keywords: End-stage kidney disease, Hemodialysis vascular access, Arteriovenous graft thrombosis, Endovascular thrombectomy, Surgical thrombectomy

Significance | This study evaluates endovascular versus surgical thrombectomy in arteriovenous graft thrombosis, providing insights for optimizing hemodialysis vascular access management and patient outcomes.

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Introduction

End-stage kidney disease (ESKD) is a growing public health concern, affecting over 785,000 individuals in the United States as of 2018 (Gusev et al., 2021). The management of ESKD often

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requires renal replacement therapy, with hemodialysis being the most commonly employed modality. Hemodialysis relies on the establishment and maintenance of vascular access, which serves as the critical interface between the patient's circulatory system and the dialysis machine. The three principal types of vascular access used in hemodialysis are arteriovenous fistulas (AVFs), arteriovenous grafts (AVGs), and central venous catheters (CVCs) (Santoro et al., 2014; Etkin, Woo, & Guidry, 2023). While CVCs are generally reserved for short-term use due to their association with higher infection and thrombosis rates, AVFs and AVGs are preferred for long-term dialysis access (Drew et al., 2015). AVFs are surgically created by directly connecting an artery to a vein, whereas AVGs involve the use of a synthetic graft to bridge an artery and a vein. The establishment of a functional dialysis vascular access requires both a patent effluent vein and an intact feeding artery to ensure adequate blood flow for effective hemodialysis (Smith, Gohil, & Chetter, 2012).

The durability and long-term patency of AV access depend on several factors, including anatomical location, patient demographics (such as age, sex, and comorbidities), surgical expertise, and ongoing monitoring practices (Abularrage et al., 2004). Thrombosis remains a significant complication, often leading to vascular access failure and abandonment. Late thrombosis, which occurs after successful maturation of the access, is the primary reason for access failure. The pathophysiology of AV access thrombosis is frequently associated with underlying stenosis, which increases the risk of impaired blood flow, high venous pressures, and eventual occlusion (MacRae et al., 2016). Moreover, AV access thrombosis is strongly correlated with increased morbidity and mortality in hemodialysis patients, highlighting the urgency of effective management strategies (Girerd et al., 2019).

Early thrombosis, occurring before the access is ready for dialysis, is often indicative of immaturity and inadequate blood flow dynamics. Timely intervention is crucial to restoring access function and preventing the need for alternative vascular access options, such as CVCs, which are associated with higher risks of infection and cardiovascular complications (Hod et al., 2014). Various thrombectomy techniques have been developed to manage access thrombosis, but consensus regarding the most effective approach remains elusive. Current treatment strategies include both percutaneous (endovascular) and open surgical interventions. Surgical thrombectomy is a well-established approach that may necessitate additional procedures such as patch plasty, interposition graft placement, or anastomotic revision to ensure continued access functionality (Izagirre, 2012). Endovascular techniques, on the other hand, have gained traction due to their minimally invasive nature and high technical success rates. These include pharmacologic thrombolysis using agents such as alteplase and urokinase, pharmacomechanical thrombolysis, and mechanical thrombectomy, often supplemented with balloon angioplasty or stenting to address underlying stenosis (Comerota et al, 2018).

Historically, surgical thrombectomy has been considered the gold standard for thrombosed prosthetic grafts, yet long-term patency rates following surgical intervention have been suboptimal (Fonseca et al., 2019). Endovascular techniques have emerged as viable alternatives, demonstrating comparable, if not superior, outcomes in terms of procedural success and patency preservation (Koraen-Smith et al., 2018). However, randomized controlled trials evaluating these treatment modalities remain limited, and most available studies predate the widespread adoption of contemporary endovascular approaches (Lundström et al., 2022). Decision-making regarding thrombosis management is further influenced by institutional preferences, operator expertise, and resource availability (Almehmi et al., 2022).

Given the critical role of AV access in hemodialysis-dependent patients, optimizing thrombosis management strategies is essential to improving patient outcomes and reducing the burden of vascular access failure. This systematic review and meta-analysis aim to evaluate and compare the efficacy of endovascular and surgical interventions in the treatment of thrombosed AVGs, with the goal of informing clinical practice and guiding future research in this domain.

2. Methodology

2.1 Data Sources and Search Strategies

A comprehensive literature search was conducted independently by two researchers on January 20, 2023, using the Cochrane Library, EMBASE, and PubMed. A set of predefined keywords was employed to identify relevant studies comparing endovascular therapy and open surgery for thrombosed arteriovenous grafts in hemodialysis patients. The search query included the terms: ((Surgical) OR (Open Surgical)) OR ((Surgical Thrombectomy) OR (Open Surgical Thrombectomy)) AND ((Endovascular) OR (Endovascular Thrombectomy)) AND ((AV Shunt) OR (arteriovenous access) OR (Arteriovenous Hemodialysis)) AND ((Thrombosis) OR (thrombosed)). Additionally, a manual search was conducted to retrieve articles that met the eligibility criteria. Any discrepancies in study selection were resolved through consensus, with the involvement of a third author. The study adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. As illustrated in Figure 1, a total of six relevant studies were identified for inclusion.

The inclusion criteria for the studies were as follows: (1) the publication was written in English, and full-text access was available; (2) studies published between January 2015 and January 2023 were considered; (3) eligible study designs included cohort, case-control, case series, cross-sectional studies, and randomized

Table 1. Study characteristics

Author	Study Design	Sample size	Age	Result of the study	Discussion
Lundström, et al 2022	retrospective studies	A cohort consisting of 904 patients diagnosed with AV access thrombosis was examined, with 60% of the individuals being women.	Mean age 62 years	Following the endovascular intervention, it was seen that secondary patency rates were more favourable compared to surgical intervention. Specifically, at the 30-day mark, the secondary patency rate was 85% for endovascular intervention, whereas it was 77% for surgery. Similarly, at the 90-day mark, the secondary patency rate was 76% for endovascular intervention, but it was 69% for surgery. The surgical thrombectomy group exhibited higher adjusted odds of access abandonment within 90 days and 1 year, with odds ratios (OR) of 1.44 [95% confidence interval (CI): 1.05–1.97] and 1.25 (0.94–1.66), respectively. The results of the long-term examination exhibited consistency. No statistically significant disparities were observed in terms of the duration until the subsequent intervention or the rate of mortality. Additionally, the outcomes within different subgroups were found to be similar.	In the context of patients undergoing haemodialysis with AV access thrombosis, it was seen that endovascular intervention exhibited a little advantage in both the short and long term when compared to open surgery.
Koraen-Smith et al, 2018	retrospective studies	A total of 107 individuals underwent surgical thrombectomy, whereas 42 individuals received treatment with catheter-directed thrombolytic infusion.	Mean age 65 years	The effectiveness of surgical thrombectomy was found to be 60%, whereas thrombolysis had an efficacy rate of 73% (p=0.18). No severe problems or deaths were observed within a 30-day period following the surgery. A greater proportion of patients in the thrombolysis group underwent adjunctive procedures compared to the control group (65 out of 107 patients versus 37 out of 42 patients; p=0.002). Following open thrombectomy, there was an observed elevation in the likelihood of rethrombosis or a subsequent access-related event for both arteriovenous fistulas and arteriovenous grafts. Notably, arteriovenous fistulas demonstrated a comparatively lower risk than arteriovenous grafts. The average increase in risk between each treatment group was estimated to be 23.9% (95% confidence interval: 3.1–49).	Over the course of time, the administration of thrombolysis has demonstrated a decrease in the likelihood of a subsequent access-related incident for both arteriovenous fistulas (AVFs) and arteriovenous grafts (AVGs). The mean risk increment for a novel incidence among the therapy groups was 23.9%. As mentioned earlier, there was a higher frequency of adjunctive operations observed in the thrombolysis group, which emphasises the significance of improved visibility and the ability to address underlying causal lesions in order to sustain the patency of arteriovenous grafts (AVG) and arteriovenous fistulas (AVF).

Table 1. Continuous

Puangpunngam et al, 2019	retrospective studies	Seventy-four thrombosed dialysis grafts were included. Twenty-five and 49 grafts underwent endovascular therapy and open surgical thrombectomy, respectively	mean age of patients was 60.68±14.37 years	There were no statistically significant differences seen between the groups with respect to demographic characteristics, graft type, or the use of adjunct procedures. The operation demonstrated an effectiveness rate of 92% in the endovascular group and 98% in the thrombectomy group (p=0.262). The endovascular group exhibited a primary patency rate of 26% at the one-year mark, while the thrombectomy group demonstrated a rate of 33% (p=0.054). The secondary patency rate at one year was 82.6% in the endovascular group, whereas it was 56.2% in the thrombectomy group (p=0.122).	The arteriovenous graft (AVG) is the ideal choice for establishing a long-term hemodialysis access in individuals diagnosed with end-stage renal disease and a limited time frame before their first hemodialysis treatment. Nevertheless, it is important to note that access thrombosis is a frequently encountered complication in this patient population. The utilisation of endovascular therapy has become a global practise, serving as a viable substitute for open surgical thrombectomy in cases of thrombosed hemodialysis grafts. Initial studies revealed that open surgical thrombectomy exhibited superior efficacy compared to endovascular treatment.
Hongsakul et al, 2015	retrospective studies		mean ages were 55 ± 10 years	There were no statistically significant disparities observed between the pharmacomechanical thrombolysis group and the thrombectomy group with regard to procedural success rates (94% versus 93.8%, P = 0.15) or average patency durations (6.24 months against 6.30 months, P = 0.15). The primary and secondary patency rates for the group that underwent thrombolysis with angioplasty at the 12-month mark were found to be 28.0% ± 8.4% and 54.3% ± 7.8%, respectively. Statistical analysis revealed that there was no significant difference in these rates, as indicated by the p-values of 0.65 and 0.49, respectively. There were no notable problems associated with the operation.	Less frequent problems such as vein rupture, graft extravasation, and pseudoaneurysm development can be managed with an endovascular approach subsequent to thrombolysis.

Table 1. Continuous

Lambert et al, 2018	retrospective studies	A cumulative count of 155 access thrombectomies were executed.	Mean age were 61 years	Out of the 128 surgical thrombectomies performed, a total of 82 cases (64%) did not necessitate any supplementary treatment. Surgical revision was required in 43 cases (34%), while on-table balloon angioplasty was performed in 3 cases (2%). A balloon angioplasty procedure was performed subsequent to each of the 27 interventional thrombectomies. The utilisation of surgical revision (74%) or balloon angioplasty (87%) resulted in a significant increase in the success rate when compared to the absence of an adjuvant operation (38%; p<0.001). The thrombectomies of arteriovenous fistulas in the upper arm exhibited a greater incidence of primary failure (57%) compared to those performed in the forearm (40%) and arteriovenous grafts (33%; p=0.056). In comparison to surgical procedures, interventional treatment demonstrated superior assisted primary patency (p=0.02), with even more significant improvements observed following thrombectomy with further treatment (p=0.005). The patency rates were found to be similar across patients who underwent surgical revision and those who underwent balloon angioplasty of the access (p=0.15).	Thrombectomy as a standalone procedure exhibits a rather low success rate in approximately 66% of cases. This finding provides evidence in favour of the concept that the occurrence of dialysis access thrombosis might be attributed to the presence of stenosis inside the access. The selection of the preferred modality for thrombectomy is contingent upon the presence of local proficiency and resources, while also necessitating the implementation of proactive management strategies for an underlying stenosis. Thrombectomies accompanied with active stenosis treatment have demonstrated notable enhancements in results, as evidenced by a 40% aided primary patency rate seen over a three-year period.
Zhang et al, 2020	retrospective studies	Based on the thrombectomy approach, a total of 130 patients were allocated into two groups: an intervention group (N=65) receiving endovascular treatment, and a control group (N=65) receiving traditional hybrid treatment.	Age range of 30-84 years, with a mean of 57 years.	The study findings indicate that there was no statistically significant disparity observed in the procedural success rate between the intervention and control groups (P=0.55). There were no notable problems observed, although the control group saw two occurrences of vascular rupture, whereas the intervention group experienced three instances. The intervention group demonstrated significantly reduced procedure times compared to the control group (7414.21 min vs. 109.0519.20 min, respectively; P<0.05). During the 6-month follow-up period, there was no statistically significant disparity observed between the intervention and control groups in terms of the primary patency rate after the intervention (48.33% vs. 55.17%) or the secondary patency rate after the intervention (83.33% vs. 84.49%; P=0.79). The variables that were found to be significant predictors of primary patency after the intervention were dialysis clearance and 50% stenosis. The hazard ratio for dialysis clearance was 7.80 (95% confidence interval: 1.75-34.81; p=0.01), indicating a strong association. Similarly, the hazard ratio for 50% stenosis was 6.43 (95% confidence interval: 2.43-17.01; p<0.001), suggesting a significant relationship as well.	Hemodialysis access thrombosis is a commonly documented consequence of arteriovenous anastomosis, with an average occurrence rate of roughly two to three times per year. It is vital to promptly determine the appropriate course of action among endovascular, surgical, or mixed (hybrid) techniques to guarantee that patients attain a minimum of 50% initial patency within a span of 6 months.

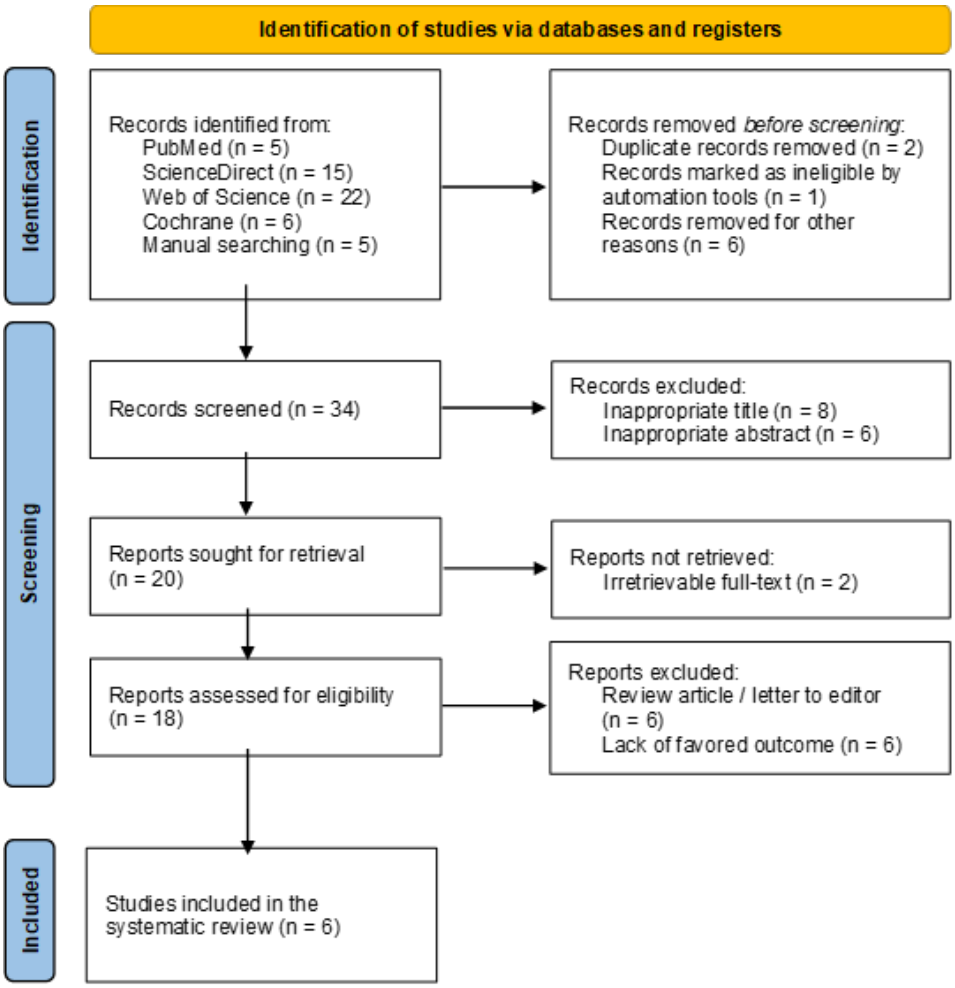

Figure 1. PRISMA flow diagram

controlled trials (RCTs); and (4) the study must involve either endovascular thrombectomy or open surgical thrombectomy.

2.2 Data Extraction

Data extraction was performed by collecting information on the author, year of publication, study design, sample size, results, and relevant discussions. Statistical analyses were carried out using Review Manager software. Given the heterogeneity among the studies, meta-analyses were conducted on three primary outcomes using random-effects models to calculate odds ratios (ORs) and 95% confidence intervals (CIs). For cases where statistical heterogeneity was moderate, dichotomous data regarding adjusted ORs were pooled using a fixed-effects meta-analysis. When the I^2 value exceeded 50%, a random-effects meta-analysis was applied. The key variables assessed included technical failure, primary non-patency at one year, and secondary non-patency at one year.

3. Results

A total of six retrospective cohort studies met the inclusion criteria, comprising 765 participants (50.3%) in the surgical thrombectomy group and 755 participants (49.6%) in the endovascular thrombectomy group. Many studies were excluded due to their publication date, as research on this topic has been limited in recent years. Table 1 provides an overview of the included studies.

The primary non-patency rate at one year did not show a statistically significant difference between endovascular and surgical thrombectomy. The odds ratio (OR) was 0.58 (95% CI: 0.20–1.62, p = 0.29), indicating no clear superiority of either intervention (Figure 3A). Similarly, the secondary non-patency rate at one year also demonstrated no significant difference between the two treatment modalities, with an OR of 0.86 (95% CI: 0.64–1.16, p = 0.32) (Figure 3B).

4. Discussion

4.1 Comparison of Endovascular and Surgical Thrombectomy in Hemodialysis Patients

Access thrombosis remains a significant complication among hemodialysis patients, and both open surgical thrombectomy and endovascular therapy are widely utilized for its management. Historically, open surgical thrombectomy has been regarded as the superior option due to its perceived higher success rate. For instance, a meta-analysis conducted by Green et al. (2002) involving seven randomized controlled trials reported that surgical thrombectomy had significantly better outcomes in terms of failure rate (RR: 1.90, 95% CI: 1.32–2.73, p = 0.0005) and 90-day patency rate (RR: 1.22, 95% CI: 1.05–1.40, p = 0.007) compared to endovascular therapy. However, more recent studies, such as those by Tordoir et al. (2009) and Hongsakul et al. (2015), have shown comparable outcomes between the two treatment methods.

Our findings align with more recent literature suggesting no significant differences in patency rates between surgical and endovascular thrombectomy over a one-year period. The absence of a significant disparity could be attributed to improvements in endovascular techniques, which now offer advantages such as reduced procedural time, minimal invasiveness, and the ability to simultaneously address both thrombosis and underlying stenosis (Almehmi et al., 2022; MacRae et al., 2016; Maleux, 2023).

4.2 Technical Failure and Procedural Success

The included studies also documented the proportion of technical failures. No statistically significant difference was observed between endovascular and surgical thrombectomy regarding technical failure. This contradicts some prior research, such as the analysis by Chan et al. (2019), which found that endovascular therapy had a significantly higher technical failure rate than surgical thrombectomy (RR: 1.58, 95% CI: 1.06–2.02, p = 0.03). Similarly, Fonseca et al. (2024) reported better primary patency at 30 days following surgical thrombectomy compared to mechanical thrombectomy.

Several factors may explain the variability in technical success across different studies. One key consideration is that graft thrombosis is often associated with outflow venous stenosis, primarily caused by venous neointimal hyperplasia. Effective management requires not only clot removal but also treatment of the underlying stenosis (MacRae et al., 2016). Open surgical thrombectomy typically involves a longer procedure due to additional steps such as graft incision, closure, and, in some cases, the need for general or regional anesthesia. Despite these factors, surgical thrombectomy has demonstrated comparable procedural success and primary graft patency rates when compared to endovascular techniques (Fonseca et al., 2024; Izagirre, 2012).

4.3 One-Year Primary Patency Rate

Our analysis found no significant difference in one-year primary patency between the two interventions. This is consistent with findings by Lundström et al. (2022), who reported that only 16% (n = 144) of patients maintained primary patency without intervention at one year. Their study also found that primary intervention-free patency favored endovascular therapy at 30 and 60 days, but by 90 days and 12 months, outcomes were comparable. Moreover, surgical thrombectomy was associated with a higher likelihood of access abandonment within the first 90 days (OR: 1.63, 95% CI: 1.11–2.33 at 30 days; OR: 1.44, 95% CI: 1.05–1.89 at 90 days).

Clinical practice guidelines generally favor arteriovenous fistulas over grafts due to their long-term patency advantages, although early failures remain a concern (Drew et al., 2015; Hod et al., 2014). Primary patency is typically defined as the duration between the initial intervention and the subsequent access-related event requiring re-intervention (Masud et al., 2018; Mo et al., 2024;

Takahashi, Harmsen, & Misra, 2020). Studies have emphasized the importance of timely intervention to optimize patency outcomes, as underlying stenosis is a major contributor to AV access thrombosis (MacRae et al., 2016). Endovascular therapy has been suggested as a superior approach in this regard due to its ability to detect stenosis through angiography and provide immediate correction (Malik et al., 2022).

4.4 One-Year Secondary Patency Rate

The current study found no statistically significant difference in the one-year secondary patency rate between surgical and endovascular thrombectomy. This finding is consistent with prior research. For instance, Lundström et al. (2022) observed better secondary patency outcomes with endovascular intervention over a five-year period. Generally, secondary patency—defined as the time until permanent access abandonment—was reported to be approximately 82% at one year and 73% at two years, with no substantial differences between arteriovenous grafts and fistulas (MacRae et al., 2016).

Similarly, Chan et al. (2019) found no significant difference in secondary non-patency rates between the two interventions at 30 days (RR: 1.04, 95% CI: 0.55–1.95, $p > 0.05$). Ko et al. (2018) also reported comparable secondary patency outcomes when evaluating hybrid versus surgical correction of arteriovenous graft occlusions. This suggests that while surgical thrombectomy remains a viable option, endovascular therapy provides a comparable long-term benefit, supporting its increasing use in clinical practice.

Several patient-related factors may play a role in secondary patency rates. The Virchow's triad of endothelial injury, stasis, and hypercoagulability is particularly relevant in patients with end-stage renal disease (ESRD), who often present with elevated C-reactive protein (CRP) levels, hyperhomocysteinemia, low serum albumin, and elevated lipoprotein levels, all of which contribute to increased thrombotic risk (Quencer & Oklu, 2017; Wu et al., 2023). These factors highlight the need for personalized treatment strategies based on patient-specific risk profiles.

4.5 Future Perspectives and Clinical Implications

Despite the findings of comparable outcomes between endovascular and surgical thrombectomy, several important considerations should guide clinical decision-making. Endovascular therapy offers the advantages of being minimally invasive and allowing multiple interventions over time, making it a suitable option for patients with significant comorbidities. Moreover, advancements in endovascular techniques, including newer thrombectomy devices and improved angioplasty methods, may further enhance the efficacy of this approach (Almehmi et al., 2022; MacRae et al., 2016; Maleux, 2023).

Current guidelines suggest that the choice of treatment should be based on institutional expertise and available resources. Given the evolving landscape of vascular access management, future research should focus on comparing novel endovascular techniques with surgical intervention in large-scale, prospective randomized controlled trials.

5. Conclusion

This systematic review and meta-analysis found no significant difference between endovascular and surgical thrombectomy in terms of one-year primary and secondary patency rates. While surgical thrombectomy has historically been regarded as the superior approach, advances in endovascular techniques have led to comparable long-term outcomes. Given the minimally invasive nature and growing success of endovascular therapy, it is increasingly becoming the preferred treatment option in many clinical settings. However, patient-specific factors, institutional expertise, and long-term follow-up studies should be considered when making treatment decisions. Further research is warranted to explore the role of novel endovascular interventions in optimizing vascular access patency in hemodialysis patients.

Author contributions

T.J. conceptualized and designed the study. N.K.S. conducted the experiments and collected data. D.H.L. performed the data analysis and interpretation. All authors contributed to drafting the manuscript, reviewed, and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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