



Review Article



Transradial versus Transfemoral Access for Intracranial Aneurysm Embolization: A Narrative Review of Safety, Feasibility, and Current Evidence

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Abstract

Endovascular embolization is a cornerstone treatment for intracranial aneurysms, and transfemoral access (TFA) has traditionally been the default vascular route. Transradial access (TRA) is increasingly used in neurointervention because it may reduce clinically important access-site complications, improve postprocedural comfort, and facilitate earlier ambulation. This narrative review aims to summarize direct and indirect evidence comparing TRA and TFA for intracranial aneurysm embolization, with attention to technical feasibility, access conversion, puncture-site complications, neurological events, radiation exposure, procedure duration, recovery, and cost considerations. Direct comparative evidence specific to aneurysm embolization remains limited and is mainly observational; some supporting data come from diagnostic cerebral angiography, mixed therapeutic neurointervention, and cardiovascular access literature. Available data suggest that TRA may be a safe and feasible option for selected patients when performed by experienced operators, particularly when radial anatomy is favorable and the intended device strategy is compatible with upper-extremity access. TFA remains essential for complex anatomy, large-bore device requirements, or insufficient TRA expertise. Access selection should therefore be individualized rather than based on a presumption of universal superiority. Well-designed multicenter studies are needed to define aneurysm-specific outcomes, long-term angiographic durability, patient-reported outcomes, and cost-effectiveness.

Introduction

Intracranial aneurysms are characterized by abnormal focal dilation of the intracranial arterial wall and affect approximately 3.2% of the general population worldwide.¹ Rupture results in aneurysmal subarachnoid hemorrhage,² which remains associated with substantial mortality and long-term morbidity.^{3,4} Over the past three decades, endovascular treatment has become a major therapeutic strategy for both ruptured and unruptured aneurysms, supported by landmark randomized and long-term follow-up

data.^{4,5} Coiling, flow diversion, stent assistance, balloon remodeling, and other adjunctive techniques have expanded the range of aneurysms that can be treated endovascularly, although risks such as incomplete occlusion, recurrence, intraoperative rupture, and thromboembolic events remain clinically important.⁶⁻⁹

For many years, transfemoral access (TFA) served as the default access route for neurointerventional procedures because the femoral artery provides a relatively large caliber and stable catheter support. However, femoral access is associated with puncture-site complications, including hematoma, pseudoaneurysm, and arteriovenous fistula.^{10,11} Retroperitoneal hemorrhage is less common but potentially serious,^{12,13} and femoral access generally requires a period of postprocedural immobilization.¹⁰ These disadvantages are especially relevant in elderly patients, patients receiving antithrombotic therapy, and patients with unfavorable groin anatomy.

Transradial access (TRA) was first established in cardiovascular intervention and has subsequently expanded into neurointerventional practice.¹⁴⁻¹⁸ Potential advantages include superficial

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compressibility of the radial artery, early ambulation, improved patient comfort, and reduced severe access-site bleeding. TRA introduces specific technical challenges, including smaller vessel caliber, radial artery spasm, and subclavian tortuosity.^{19,20} Transition to a radial-first practice also requires appropriate access selection and preservation of TFA proficiency.²¹ A learning curve and radial artery loops represent additional technical considerations.^{22,23} Ulnar artery access has been explored as an additional upper-extremity option,^{24,25} while distal radial access has also been evaluated in neurointerventional and cardiovascular practice.^{26,27} These approaches require careful patient selection and should not be generalized beyond the available evidence.

Evidence regarding TRA and TFA spans several levels of directness. Randomized evidence comparing access routes is currently available for diagnostic cerebral angiography, not for intracranial aneurysm embolization.¹⁹ Aneurysm-specific evidence remains sparse and primarily observational.^{28,29} Mixed neurointerventional studies provide useful access-safety and therapeutic feasibility context,^{20,30,31} while health-economic analyses provide additional information on recovery and resource use.³² These findings should not be treated as direct evidence for intracranial aneurysm embolization. Dedicated devices, including radial-specific guiding systems and large-bore support catheters, may expand the feasibility of TRA in selected complex procedures.^{28,33} This review therefore discusses TRA as a complementary access option for selected patients and experienced operators, while emphasizing that TFA remains necessary in many clinical scenarios (Table 1).^{19,20,28-32}

This narrative review aims to summarize current direct and indirect evidence comparing TRA and TFA for intracranial aneurysm embolization, with emphasis on technical feasibility, access-related complications, patient selection, device considerations, clinical outcomes, cost considerations, and remaining evidence gaps.

This review was informed by targeted searches of PubMed, Embase, the Cochrane Library, and Web of Science Core Collection, supplemented by manual review of relevant reference lists. Priority was given to studies addressing intracranial aneurysm embolization, neurointerventional access-route outcomes, and foundational cardiovascular access evidence where it clarified mechanisms or patient-centered outcomes. Selected foundational papers outside the main contemporary search window were retained when they provided important context. Because this is a narrative review rather than a systematic review, evidence was synthesized descriptively, with emphasis on study design, procedural context, and directness to intracranial aneurysm embolization. In keeping with this narrative design, no protocol registration, pre-defined eligibility criteria, or formal risk-of-bias assessment was undertaken; this descriptive approach distinguishes the present review from a systematic review or meta-analysis, a point readers should bear in mind when interpreting its conclusions.

Comparison of technical feasibility and procedure-related parameters

Technical success rate and access conversion rate

Technical success for TRA in intracranial aneurysm embolization is defined as successful vascular access and completion of the

planned embolization strategy. Direct randomized evidence comparing TRA and TFA specifically for aneurysm embolization is not currently available. The strongest randomized access-route evidence comes from Bhatia *et al.*,¹⁹ which evaluated diagnostic cerebral angiography and reported similar procedural success between TRA and TFA; this finding should be considered indirect for aneurysm treatment. A systematic review and meta-analysis has summarized the broader TRA evidence across cerebral angiography and neurointerventional procedures.²⁰ Therapeutic neurointerventional evidence, including aneurysm embolization, remains largely observational and is derived mainly from institutional cohorts and clinical series.^{28,29,31,34} TRA-to-TFA conversion remains necessary in a minority of neurointerventional cases.²¹ Radial artery spasm and anatomical variants are recognized technical barriers to TRA,^{10,23,26} while unfavorable proximal or target-vessel anatomy may contribute to access conversion.^{26,35} Vasodilator strategies and radial-specific guiding systems may help address some of these barriers.^{26,28} Ulnar artery access may serve as an alternative after TRA failure in selected cases.^{24,25} TRA has also been described for pediatric aneurysm coiling,³⁶ but this evidence is limited. Overall, available observational data suggest that TRA can achieve high technical success in selected aneurysm cases when anatomy, device requirements, and operator experience are favorable.

Procedure duration and radiation exposure

Procedure duration and radiation exposure are important indicators of procedural efficiency and safety. During early TRA adoption, fluoroscopy time may be longer than with TFA.³¹ Learning-curve data from diagnostic cerebral angiography indicate that technical efficiency improves with operator experience.²² Fluoroscopy and radiation-related findings should therefore be interpreted as context-dependent rather than intrinsic to either access route.^{19,22,31} Radiation exposure is influenced by operator proficiency, patient anatomy, procedural complexity, and imaging workflow.

Analysis of perioperative complication spectrum

Puncture site-related complications

Puncture-site complications are among the most clinically relevant differences between TRA and TFA. TFA complications include large hematomas, pseudoaneurysm, arteriovenous fistula, and rare but serious retroperitoneal hemorrhage.¹⁰⁻¹³ These risks are influenced by patient factors, anticoagulation, vessel depth, and the need for postprocedural immobilization. TRA-specific complications include radial artery spasm, forearm hematoma, and radial artery occlusion.^{18,20} Available data generally suggest that TRA is associated with fewer severe access-site bleeding complications, while TFA remains important when radial anatomy or device size is unsuitable.^{10,31}

Neurological complications and thromboembolic events

Neurological complications and thromboembolic events during aneurysm embolization are driven primarily by aneurysm morphology, device strategy, antithrombotic management, and operator technique. Available aneurysm-specific comparative data have not shown a clear difference in non-access-site complications

Table 1. Selected evidence informing TRA and TFA access selection for intracranial aneurysm embolization

Study / Source	Procedure context	Design	Evidence relevance	Key access-related finding	How it should be interpreted
Bhatia <i>et al.</i> ¹⁹	Diagnostic cerebral angiography	Randomized clinical trial	Diagnostic angiography; indirect background evidence	Reported similar procedural success for TRA and TFA in diagnostic angiography	Useful for access feasibility, but not direct evidence for aneurysm embolization
Rentiya <i>et al.</i> ²⁰	Cerebral angiography and mixed neurointerventional procedures	Systematic review and meta-analysis	Mixed neurointervention; indirect for aneurysm embolization	Supports overall feasibility of TRA across mixed neurointerventional practice	Heterogeneous source data; should not be read as aneurysm-specific proof
Hanaoka <i>et al.</i> ²⁸	Anterior circulation intracranial aneurysm coiling	Observational clinical series	Direct aneurysm embolization evidence	Radial-first aneurysm coiling with a radial-specific guiding sheath was reported feasible in selected patients	Non-randomized experience; patient anatomy and operator expertise are central
Fuga <i>et al.</i> ²⁹	Endovascular treatment of unruptured intracranial aneurysms	Comparative observational study	Direct aneurysm embolization evidence	Reported therapeutic efficacy and complication profiles for radial versus femoral access	Directly relevant, but still observational and potentially affected by selection bias
Catapano <i>et al.</i> ³¹	Mixed neuroendovascular procedures	Propensity-adjusted cohort	Therapeutic neurointervention; indirect for aneurysm embolization	Provides comparative access-site complication data after adjustment	Not aneurysm-specific; useful mainly for access-safety context
Khanna <i>et al.</i> ³⁰	Acute stroke interventions	Comparative cohort	Acute stroke intervention; indirect therapeutic evidence	Shows experience with TRA in therapeutic neurointervention outside aneurysm coiling	Clinical transferability to aneurysm embolization is limited
Catapano <i>et al.</i> ³²	Mixed neuroendovascular procedures	Propensity-adjusted cost analysis	Health-economic evidence; indirect	Suggests radial access may influence costs through access-site complications and recovery pathway	Cost conclusions are healthcare-system dependent and not aneurysm-specific

This table provides an illustrative summary of selected studies for a narrative review and is not a formal evidence synthesis. Evidence relevance indicates directness to intracranial aneurysm embolization. Cross-study comparisons should be interpreted cautiously because of heterogeneity in patient populations, operator experience, procedural context, and outcome definitions. TFA, transfemoral access; TRA, transradial access.

between TRA and TFA, but the evidence remains limited.²⁹ TRA requires navigation through the brachial and subclavian arteries and may create support challenges in some arch configurations; TFA may also involve aortic arch manipulation and carries its own vascular risks. Current evidence therefore supports cautious interpretation: access selection alone should not be assumed to determine neurological risk, and procedural planning should focus on patient anatomy, catheter stability, and embolization strategy.

Learning curve, anatomical indications, and device development

Learning curve and training challenges

TRA for neurointerventional procedures, including intracranial aneurysm embolization, is characterized by a distinct learning curve, requiring operators to develop proficiency in navigating complex vascular anatomy and in catheter manipulation techniques. Safe navigation of the full catheter pathway—from the radial artery through the brachial and subclavian arteries and the aortic arch to the internal carotid or vertebral artery—while accommodating individual anatomical variation is a core prerequisite for minimizing procedural complications.¹⁸

Available learning-curve data are derived mainly from diagnostic cerebral angiography. These studies indicate that technical efficiency improves with operator experience, although the

number of procedures required to achieve proficiency varies among operators and may be influenced by prior endovascular experience.²² These findings remain indirect for aneurysm embolization, which typically involves more complex device handling and intracranial navigation. During early TRA adoption, attention to fluoroscopy efficiency and radiation exposure remains important. A phased progression from simpler to more complex cases is a reasonable training approach, although the optimal training paradigm for aneurysm embolization has not been established.

Transition from TFA to TRA requires adaptation to upper-extremity and aortic arch anatomy, catheter formation, and device manipulation.¹⁸ Learning-curve data further indicate that technical efficiency improves with operator experience.²² Structured training and phased case selection may therefore facilitate the safe integration of TRA into aneurysm embolization practice.

Anatomical indications and patient selection

Patient selection for TRA in intracranial aneurysm embolization is a key determinant of procedural success, influenced by anatomical conditions and underlying disease status. Not all patients are suitable TRA candidates. The Allen test, with objective modifications such as the Barbeau test, may be used to assess palmar collateral circulation. However, the Allen test has limited predictive value for ischemic hand events and should not be used as an absolute determinant of TRA eligibility.¹⁸ Collateral-circulation assessment may instead be considered as one component of preprocedural evaluation. Other factors that may argue against TRA or require particular caution include prior radial artery harvest, severe upper-extremity vessel tortuosity or occlusion, and device requirements that are incompatible with radial access. However, with the development of small-diameter dedicated devices, the TRA-eligible population is gradually expanding.²⁸

Aortic arch and supra-aortic vessel morphology influence TRA feasibility. Acute target-vessel takeoff angles and other unfavorable proximal vascular features may increase technical difficulty,³⁵ whereas a bovine arch is not uniformly unfavorable and may facilitate catheterization of some left-sided targets.¹⁸ Access suitability should therefore be individualized according to the target vessel, laterality, and patient anatomy.

Notably, TRA may also provide access to posterior-circulation targets through the vertebral artery in selected cases; however, evidence specific to intracranial aneurysm embolization remains limited.³⁷

Therefore, comprehensive preoperative imaging evaluation of vascular anatomy is an essential prerequisite for optimal access selection. Clinical decision-making requires balanced consideration of procedural feasibility, device requirements, and individual patient benefit to maximize procedural success and minimize complications (Fig. 1).

Technological innovation of dedicated devices

Radial-specific guiding sheaths and large-bore support catheters may improve catheter support in selected procedures.^{28,33} Radial compression protocols are used to achieve hemostasis after TRA.¹⁰ Flow diversion and other adjunctive endovascular techniques have expanded treatment options for complex intracranial aneurysms.³⁸⁻⁴⁰ Complex aneurysm treatments may still require greater device support, so access-route compatibility should be assessed individually.³³ Device innovation should be viewed as

expanding options, not eliminating the need for TFA.

Clinical outcomes and health economic evaluation

Short-term and long-term clinical outcomes

Available observational comparative data suggest comparable procedural efficacy between TRA and TFA in selected unruptured aneurysm populations.²⁹ Patient-centered outcomes may favor TRA based on cardiovascular and mixed neurointerventional evidence.^{17,20} Hospital stay may be shorter in some mixed neuroendovascular cohorts.³² These advantages make TRA a practical option for selected patients, but they do not establish universal superiority over TFA.

Cost-effectiveness analysis

Cost comparisons between TRA and TFA should consider procedural costs, access-site complications, length of stay, and downstream resource use. In a propensity-adjusted study of mixed neuroendovascular procedures, TRA was associated with shorter hospital stay and lower hospital costs than TFA.³² Cardiovascular evidence has also reported favorable patient-centered and cost outcomes with radial access.¹⁷ However, these findings are indirect for intracranial aneurysm embolization, and firm aneurysm-specific cost-effectiveness conclusions cannot yet be drawn. Prospective aneurysm-specific economic evaluations incorporating complete cost data and long-term clinical outcomes within defined healthcare contexts are needed to clarify the cost impact of TRA in neurointerventional practice.

Limitations, controversies, and future perspectives

Limitations and controversies of existing evidence

The evidence base for comparing TRA and TFA in intracranial aneurysm embolization has substantial methodological limitations. No randomized trial has directly compared the two access routes specifically for aneurysm treatment; the available randomized evidence concerns diagnostic cerebral angiography.¹⁹ Most aneurysm-specific evidence is retrospective and single-center,^{28,29} making it susceptible to selection bias; anatomical factors are also known to affect TRA feasibility.³⁵ Operator experience is another major confounder, as TRA outcomes are often reported by centers with specific expertise. This review draws on three levels of evidence: direct aneurysm-embolization studies, indirect therapeutic neurointerventional evidence, and diagnostic/cardiovascular background evidence. Readers should interpret claims according to this hierarchy. Future multicenter studies should report standardized access conversion, puncture-site complications, radiation exposure, patient-reported outcomes, angiographic durability, and long-term neurological outcomes.

Future research directions and clinical practice recommendations

Future research should prioritize prospective multicenter studies with clearly defined safety endpoints, including severe access-site complications, symptomatic stroke, procedure conversion, and all-cause mortality. Secondary endpoints should include procedure duration, radiation exposure, patient comfort, length of stay, cost, aneurysm occlusion, retreatment, and functional outcome. Stand-

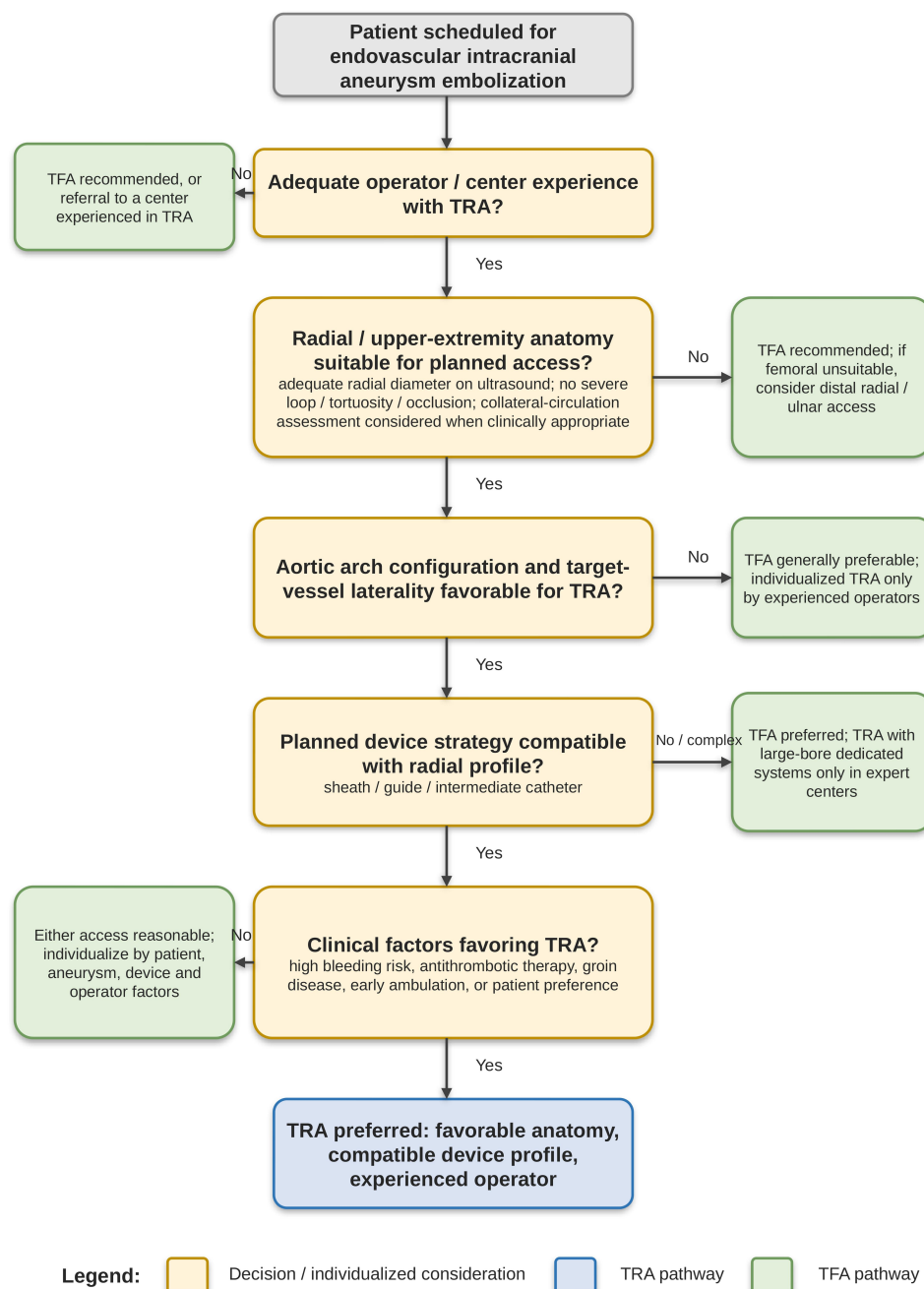


Fig. 1. Practical clinical decision algorithm for vascular access site selection in intracranial aneurysm embolization. The algorithm is a practical decision aid synthesized from current evidence and expert opinion; it is not a validated clinical decision rule. Final access selection should be individualized according to patient anatomy, target-vessel laterality, aneurysm and device requirements, operator experience, clinical urgency, and institutional resources. TFA, transfemoral access; TRA, transradial access.

ardized reporting of radial artery occlusion, spasm, pseudoaneurysm, and failed access attempts is needed. Practical clinical algorithms should incorporate operator experience, radial artery diameter, collateral-circulation assessment when clinically appropriate, arch anatomy, aneurysm complexity, and device-profile requirements. Until stronger evidence becomes available, TRA

should be selected through individualized and shared decision-making with patients; TFA should remain readily available when anatomy, urgency, or device requirements favor femoral access.

Conclusions

Current observational evidence suggests that TRA may be a safe and feasible option for selected patients undergoing intracranial aneurysm embolization in experienced centers. Potential advantages include fewer severe access-site bleeding complications, earlier ambulation, improved comfort, and shorter recovery pathways, particularly in patients with high bleeding risk or unfavorable femoral access. These advantages must be balanced against radial anatomy, device compatibility, aneurysm complexity, and operator experience. TFA remains an essential access route and should not be viewed as being replaced by TRA. Because the evidence base is limited by retrospective designs, indirect comparisons, and inconsistent outcome reporting, large prospective aneurysm-specific studies are needed before firm conclusions can be drawn regarding long-term efficacy, neurological outcomes, and cost-effectiveness.

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Conflict of interest

Dr. Waisang Poon has served as Editor-in-Chief of *Neurosurgical Subspecialties* since July 2024. The authors declare no other conflicts of interest.

Author contributions

Literature review, evidence summary (XY, WY), study conception and design (XY, WY, WH, CH, WP), interpretation of findings (WP), manuscript drafting, and critical revision (XY, WY, WH, CH, WP). All authors approved the final manuscript.

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