INPLASY

Perioperative and long-term outcomes after pediatric moyamoya revascularization: a protocol for a systematic review and meta-analysis

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ADMINISTRATIVE INFORMATION

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Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 10 September 2026 and was last updated on 10 September 2026.

INTRODUCTION

Review question / Objective This review addresses the following question, framed using the PICOS structure.

Population (P): Children and adolescents younger than 18 years with moyamoya angiopathy, including both idiopathic moyamoya disease (MMD) and moyamoya syndrome (MMS) secondary to conditions such as sickle cell disease, Down syndrome, neurofibromatosis type 1, or prior cranial irradiation.

Intervention (I): Surgical cerebral revascularization, comprising indirect procedures (encephaloduroarteriosynangiosis [EDAS], pial synangiosis, encephalomyosynangiosis, encephaloduroarteriomyosynangiosis, multiple burr holes), direct procedures (superficial temporal artery to middle cerebral artery [STA-MCA] bypass), and combined direct plus indirect techniques.

Comparator (C): None. This is a single-arm proportional meta-analysis in which pooled event proportions are estimated within the revascularized population rather than against a separate comparator arm.

Outcomes (O): Pooled proportions of good functional outcome (as defined by each included study), perioperative stroke, long-term stroke, long-term intracranial hemorrhage, and perioperative mortality.

Study design (S): Observational studies (retrospective and prospective cohort studies and case series) reporting extractable patient-level numerator and denominator data for at least one prespecified endpoint.

Objective: To quantify (1) the risk of perioperative ischemic events following surgical revascularization in pediatric moyamoya, and (2) the frequency of long-term stroke and intracranial hemorrhage after surgery, using standardized pooling methods, patient-level denominators, and

prespecified outcome windows, in order to generate clinically interpretable benchmarks for the preoperative risk counseling of children and their families.

Rationale Moyamoya angiopathy is a progressive cerebrovascular disorder characterized by stenosis or occlusion of the terminal internal carotid arteries and the proximal branches of the circle of Willis, accompanied by the development of fragile basal collateral networks. In children it most commonly presents with ischemic stroke or transient ischemic attack, and recurrent hypoperfusion contributes to cognitive decline and long-term disability. Surgical revascularization – indirect, direct, or combined – is the standard treatment for symptomatic or hemodynamically compromised children, aiming to augment cerebral perfusion and prevent recurrent ischemic events.

Despite widespread surgical adoption, the pediatric evidence base consists predominantly of single-center observational cohorts characterized by heterogeneous outcome definitions, variable follow-up durations, and differing denominators (patient-, hemisphere-, or procedure-based reporting). Perioperative ischemic complications occur in a meaningful minority of patients, with identified risk factors including posterior circulation involvement, preoperative infarction burden, and disease severity, and reported rates vary substantially between series. These factors limit the precision with which clinicians can counsel families about the early risks and the long-term durability of surgery. Previous syntheses demonstrate overall benefit but reveal substantial between-study heterogeneity, particularly regarding short-term ischemic events and long-term durability across surgical strategies.

A systematic review with single-arm meta-analysis, using standardized pooling methods, strictly patient-level denominators, prespecified outcome windows, and explicit handling of overlapping institutional cohorts, is therefore needed to establish clinically interpretable benchmarks for perioperative risk and long-term event rates after pediatric moyamoya revascularization.

Condition being studied Moyamoya angiopathy is a chronic, progressive, occlusive cerebrovascular disease characterized by bilateral stenosis or occlusion of the terminal portions of the internal carotid arteries and the proximal anterior and middle cerebral arteries, with compensatory development of an abnormal network of fragile basal collateral vessels that produce the characteristic "puff of smoke" appearance on angiography. Angiographic severity is conventionally staged using the Suzuki grading system (grades I to VI).

The condition is termed moyamoya disease (MMD) when it is idiopathic, and moyamoya syndrome (MMS) when it occurs in association with a predisposing condition such as sickle cell disease, Down syndrome, neurofibromatosis type 1, or prior cranial irradiation. These subtypes carry distinct baseline risk profiles.

In the pediatric population, moyamoya most commonly presents with ischemic stroke or transient ischemic attack, rather than with the hemorrhagic presentation more typical of adults. Recurrent cerebral hypoperfusion in children is associated with progressive neurological deficit, cognitive decline, epilepsy, and long-term disability, and the disease follows a progressive course in the majority of affected children if untreated. Surgical cerebral revascularization is the standard of care for symptomatic or hemodynamically compromised children, but it carries a defined perioperative ischemic risk that must be weighed against the long-term stroke prevention it is intended to confer. It is that trade-off, in the pediatric population specifically, that this review seeks to quantify.

METHODS

Search strategy Databases and registers were searched from inception to 22 March 2026: PubMed/MEDLINE, Embase, Web of Science Core Collection, Scopus, Cochrane CENTRAL, CINAHL, ClinicalTrials.gov, and the WHO ICTRP. No language or date restrictions were applied. The search combined three concept blocks: moyamoya AND pediatric population AND surgical revascularization/bypass.

PubMed/MEDLINE strategy:
#1 "Moyamoya Disease"[Mesh] OR moyamoya[tiab] OR "moya moya"[tiab]
#2 "Child"[Mesh] OR "Infant"[Mesh] OR "Adolescent"[Mesh] OR pediatric*[tiab] OR paediatric*[tiab] OR child*[tiab] OR infant*[tiab] OR adolescen*[tiab] OR juvenile[tiab] OR youth[tiab] OR "school age"[tiab]
#3 "Cerebral Revascularization"[Mesh] OR "Anastomosis, Surgical"[Mesh] OR revascular*[tiab] OR bypass[tiab] OR synangiosis[tiab] OR EDAS[tiab] OR EDAMS[tiab] OR encephaloduroarteriosynangiosis[tiab] OR encephalomyosynangiosis[tiab] OR encephaloduroarteriomyosynangiosis[tiab] OR "pial synangiosis"[tiab] OR "STA-MCA"[tiab] OR

"indirect bypass"[tiab] OR "direct bypass"[tiab] OR "combined bypass"[tiab] OR anastomosis[tiab] OR "burr hole"[tiab]
#4 #1 AND #2 AND #3

The strategy was translated to each platform's syntax, preserving the three concept blocks. Embase used Emtree terms 'moyamoya disease'/exp, 'child'/exp and 'cerebral revascularization'/exp together with the free-text terms in :ti,ab. Web of Science Core Collection used TS=(moyamoya AND (pediatric OR paediatric OR child* OR juvenile OR adolescen*) AND (revascular* OR bypass OR synangiosis OR EDAS OR "STA-MCA")). Scopus used TITLE-ABS-KEY with the same three blocks. Cochrane CENTRAL used moyamoya AND (child* OR p?ediatric) AND (revascular* OR bypass OR synangiosis) in Title/Abstract/Keyword. CINAHL used (MH "Moyamoya Disease") plus the free-text blocks in TI/AB. ClinicalTrials.gov and the WHO ICTRP were searched by condition "moyamoya" with the age filter "Child" and screened for surgical and revascularization studies.

Reference lists of all included studies and of relevant reviews were hand-searched for additional eligible reports. Records from all sources were de-duplicated before screening. The search identified 5,142 records from databases and 42 records from registers; the flow of records through screening and eligibility assessment is reported in the PRISMA 2020 flow diagram.

Participant or population Children and adolescents younger than 18 years with angiographically confirmed moyamoya angiopathy who underwent surgical cerebral revascularization. Both idiopathic moyamoya disease (MMD) and moyamoya syndrome (MMS) - moyamoya occurring in association with a predisposing condition such as sickle cell disease, Down syndrome, neurofibromatosis type 1, or prior cranial irradiation - are eligible, and both unilateral and bilateral disease are included. No restriction is applied on the basis of Suzuki grade at presentation, clinical presentation (ischemic stroke, transient ischemic attack, hemorrhage, seizure, headache, or incidental detection), sex, ethnicity, or geographic region. Studies of mixed pediatric and adult cohorts are eligible only where outcomes for patients younger than 18 years are separately extractable; where pediatric and adult outcomes cannot be separated, the study is excluded from the primary analysis and considered only within a mixed-age sensitivity analysis. All denominators are patient-based; cohorts reported exclusively at the hemisphere or procedure level, without extractable patient-level denominators, are not eligible.

Intervention Surgical cerebral revascularization for pediatric moyamoya, in any of its forms: indirect revascularization (encephaloduroarteriosynangiosis [EDAS], pial synangiosis, encephalomyosynangiosis [EMS], encephaloduroarteriomyosynangiosis [EDAMS], omental transposition, and multiple burr holes); direct revascularization (superficial temporal artery to middle cerebral artery [STA-MCA] bypass and other direct anastomoses); and combined direct plus indirect procedures. Unilateral, bilateral, staged, and single-stage operations are all eligible. No restriction is applied on the basis of surgeon, institution, perioperative management protocol, or era of surgery.

Comparator Not applicable. This is a single-arm proportional meta-analysis: pooled event proportions are estimated within the revascularized pediatric population, and no comparator arm (non-operated or alternative procedure) is required for study eligibility. Where included studies do report non-revascularized or alternative-technique comparison groups, only the revascularized arm contributes to the pooled proportions. Comparison between bypass types (indirect versus direct or combined) is prespecified as a subgroup analysis rather than as a review-level comparator.

Study designs to be included Observational studies reporting outcomes after surgical revascularization for pediatric moyamoya: retrospective and prospective cohort studies, comparative cohorts, and single-arm case series with extractable patient-level numerator and denominator data for at least one prespecified endpoint. Randomized trials were eligible but none were identified. Case reports, editorials, narrative reviews, conference abstracts without extractable data, and studies reporting only hemisphere- or procedure-based denominators were excluded.

Eligibility criteria INCLUSION CRITERIA: (1) studies of patients with moyamoya angiopathy (moyamoya disease or moyamoya syndrome) who underwent surgical cerebral revascularization; (2) pediatric patients under 18 years, or mixed-age cohorts in which pediatric outcomes are separately extractable; (3) reporting of at least one prespecified endpoint - good functional outcome, perioperative stroke, long-term stroke, long-term intracranial hemorrhage, or perioperative mortality - with an extractable numerator and a patient-level denominator; (4) observational cohort studies or case series, retrospective or prospective; (5) any

language and any publication year. EXCLUSION CRITERIA: (1) studies in which pediatric and adult outcomes cannot be separated; (2) studies in which moyamoya-specific outcomes cannot be separated from those of other cerebrovascular diagnoses; (3) studies in which outcome data are not extractable as a numerator and denominator; (4) studies in which follow-up outcomes cannot be attributed specifically to the revascularized cohort; (5) studies reporting outcomes exclusively per hemisphere or per procedure without extractable patient-level denominators; (6) case reports, editorials, letters, narrative reviews, and conference abstracts lacking extractable data. OVERLAPPING COHORTS: potentially overlapping cohorts from the same institution are identified by overlapping enrollment periods, shared authorship, and institutional affiliation; where overlap is confirmed, only the study with the larger sample size or the longer follow-up is retained, so that no patient contributes more than once to any pooled estimate. BILATERAL OPERATIONS: for studies reporting bilateral procedures, patient-level denominators are retained and event counts are not double-counted per hemisphere. STUDY QUALITY is not used as an eligibility criterion: given the rarity of pediatric moyamoya and the predominance of retrospective single-arm surgical series, studies are not excluded on the basis of Newcastle-Ottawa Scale score alone; all eligible cohorts are retained to avoid discarding potentially informative outcome data, and risk-of-bias ratings are used instead to contextualize the pooled estimates and the observed heterogeneity.

Information sources Electronic bibliographic databases: PubMed/MEDLINE, Embase, Web of Science Core Collection, Scopus, the Cochrane Central Register of Controlled Trials (CENTRAL), and CINAHL, each searched from inception to 22 March 2026.

Trial registers: ClinicalTrials.gov and the World Health Organization International Clinical Trials Registry Platform (WHO ICTRP), searched by condition "moyamoya" with the age filter "Child" and screened for surgical and revascularization studies.

Other sources: reference lists of all included studies and of relevant narrative and systematic reviews were hand-searched for additional eligible reports. Grey literature in the form of conference abstracts was screened but included only where sufficient numerator and denominator data were extractable. Corresponding authors were to be contacted where outcome data appeared extractable but were incompletely reported.

No language, date, or geographic restrictions were applied to any source. Records retrieved from all sources were exported into a single reference library and de-duplicated prior to screening; the number of records identified, screened, excluded, and included at each stage is reported in the PRISMA 2020 flow diagram.

Main outcome(s) All main outcomes are expressed as pooled proportions (events divided by total patients) with 95% confidence intervals.

1. Good functional outcome – the proportion of children judged to have a good functional result at last available follow-up, as defined by each included study (most commonly a modified Rankin Scale score of 0-2, an equivalent pediatric functional scale, or the study's own explicit definition of a good or excellent outcome). Study-specific definitions are tabulated rather than harmonized, and the pooled estimate is interpreted descriptively.

2. Perioperative stroke – the proportion of patients sustaining a new ischemic or hemorrhagic stroke within the perioperative window as defined by each study, conventionally within 30 days of, or during the same admission as, the revascularization procedure.

3. Long-term stroke – the proportion of patients sustaining any new stroke beyond the perioperative window during the study's stated follow-up period.

4. Long-term intracranial hemorrhage – the proportion of patients sustaining intracranial hemorrhage beyond the perioperative window, reported where available.

5. Perioperative mortality – the proportion of patients who died within the perioperative window.

Effect measure: pooled proportion, estimated with a random-effects inverse-variance model after Freeman-Tukey double arcsine transformation. Heterogeneity is quantified with I-squared and tau-squared, and prediction intervals are reported for every endpoint contributed by at least three studies. Outcomes with zero events across all contributing studies are summarized descriptively rather than pooled.

Additional outcome(s) Descriptive and contextual outcomes, tabulated rather than pooled where data are too sparse or too heterogeneously defined for meta-analysis:

– Distribution of revascularization technique (indirect, direct, combined) across the included cohorts.
– Distribution of diagnosis (moyamoya disease versus moyamoya syndrome) and, where reported, the specific predisposing condition in syndromic cases.
– Suzuki grade at presentation, where reported.
– Duration of follow-up.
– Study-level risk of bias (Newcastle-Ottawa Scale) and the GRADE certainty rating for each pooled endpoint.

In addition, a secondary institutional cohort analysis is conducted alongside the review as a contextual, non-pooled component. In that analysis the longitudinal angiographic outcome is the change in Suzuki grade between presentation and most recent follow-up in a single-institution retrospective pediatric cohort, compared between revascularized and non-revascularized children. This institutional analysis contributes to no pooled estimate in the meta-analysis and does not replicate the clinical endpoints listed above; it is reported separately as mechanistic context for the surgical benefit suggested by the pooled clinical outcomes.

Data management Records retrieved from all databases and registers were exported into a single reference management library, where duplicates were identified and removed before screening. Two reviewers independently screened titles and abstracts against the eligibility criteria, and then independently assessed the full text of every record passing that stage. Disagreements at either stage were resolved by discussion and consensus, with a third author available for adjudication.

Data were extracted independently by the same two reviewers using a standardized, piloted extraction form. Extracted variables included first author, publication year, country, study design, enrollment period, sample size, age range and mean or median age, sex distribution, diagnosis (moyamoya disease versus moyamoya syndrome, and the predisposing condition where applicable), Suzuki grade at presentation, revascularization technique (indirect, direct, or combined), laterality and staging of surgery, duration of follow-up, the numerator and patient-level denominator for each prespecified endpoint, each study's own definition of that endpoint, and the Newcastle-Ottawa Scale domain scores.

Extracted data were reconciled between reviewers and discrepancies resolved by consensus with reference to the source article. The reconciled dataset was held in a single spreadsheet and imported into the analysis software for pooling; the extraction form and the analytic dataset are retained by the corresponding author. Study flow at each stage of identification, screening, eligibility assessment, and inclusion is documented in a PRISMA 2020 flow diagram.

Quality assessment / Risk of bias analysis Risk of bias was assessed at the study level using the Newcastle-Ottawa Scale (NOS) for observational cohort studies, which evaluates three domains: Selection (0-4 stars), Comparability (0-2 stars), and Outcome (0-3 stars), for a total score of 0-9. Two reviewers independently scored each included study, and disagreements were resolved by consensus.

Overall study quality was categorized a priori as low risk of bias (NOS 7-9), moderate risk (NOS 5-6), or high risk (NOS 4 or below). For single-arm surgical series without a non-exposed comparison group, the Comparability domain is not applicable and was scored as zero; consequently, lower totals in such studies may reflect inherent design limitations rather than deficiencies in conduct or reporting, and NOS totals are interpreted with that caveat.

Given the rarity of pediatric moyamoya and the predominance of retrospective single-arm surgical series, studies were not excluded on the basis of NOS score alone. All eligible cohorts were retained in order to avoid discarding potentially informative outcome data, and risk-of-bias ratings were used instead to contextualize the pooled estimates and to help explain between-study heterogeneity.

The certainty of the evidence for each pooled outcome was graded using the GRADE approach across the domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias, with evidence from observational studies starting at low certainty. A GRADE summary-of-findings table is reported.

Small-study effects and potential publication bias were examined for any outcome contributed by at least ten studies, using funnel plots together with Egger's regression test and Peters' test.

Strategy of data synthesis All meta-analytic calculations were performed in IBM SPSS Statistics version 31.0.1.0.

Proportions were pooled using a random-effects inverse-variance model applied to Freeman-Tukey

double arcsine transformed proportions, with back-transformation of the pooled estimate and its confidence limits to the proportion scale. Between-study variance (tau-squared) was estimated by restricted maximum likelihood (REML), and the Hartung-Knapp adjustment was applied to the confidence interval of every pooled estimate. No continuity correction was applied, because the Freeman-Tukey transformation accommodates zero-event cells directly.

All denominators are patient-based. Studies reporting exclusively hemisphere- or procedure-based data without extractable patient-level denominators were excluded. For studies reporting bilateral operations, patient-level denominators were retained and event counts were not double-counted per hemisphere. Potentially overlapping cohorts from the same institution were identified by overlapping enrollment periods, shared authorship, and institutional affiliation; where overlap was confirmed, only the study with the larger sample or the longer follow-up contributed to the pooled estimate.

Statistical heterogeneity was quantified using I-squared and tau-squared, and interpreted alongside the point estimate rather than as a threshold for pooling. Prediction intervals were calculated and reported for every endpoint with at least three contributing studies, in order to convey the expected range of true proportions in a new setting. Outcomes for which no events occurred in any contributing study, such as perioperative mortality, were summarized descriptively rather than pooled.

Results are presented as forest plots for each endpoint, together with a table of study characteristics, a risk-of-bias figure, and a GRADE summary-of-findings table. Where heterogeneity was substantial, the pooled estimate is interpreted descriptively, and the prediction interval rather than the confidence interval alone is emphasized in the interpretation. Small-study effects were assessed by funnel plot with Egger's and Peters' tests for endpoints with at least ten contributing studies.

Subgroup analysis Three subgroup analyses were prespecified:

1. Revascularization technique – indirect procedures versus direct or combined procedures.
2. Diagnosis – moyamoya disease (idiopathic) versus moyamoya syndrome (secondary to sickle cell disease, Down syndrome, neurofibromatosis type 1, prior cranial irradiation, or another predisposing condition).
3. Study quality – Newcastle-Ottawa Scale total score of 7 or above versus below 7.

Each subgroup analysis was to be conducted for every endpoint with a sufficient number of contributing studies, using the same random-effects Freeman-Tukey model as the primary analysis, with between-subgroup differences assessed by a test of subgroup interaction.

These subgroup analyses were prespecified but could not be executed, because subgroup-level event counts and denominators were not reported with sufficient consistency across the included studies: most cohorts reported outcomes for mixed technique groups or mixed diagnostic groups without a separable numerator and denominator for each subgroup. The inability to execute the prespecified subgroup analyses is reported explicitly as a limitation of the review, and the resulting clinical heterogeneity is acknowledged as a probable contributor to the observed statistical heterogeneity, particularly for the good functional outcome endpoint.

Sensitivity analysis The following sensitivity analyses were planned:

1. Mixed-age cohorts – studies in which pediatric outcomes could be extracted only approximately, or cohorts spanning both pediatric and adult patients, were excluded from the primary analysis; their effect on the pooled estimates is examined in a mixed-age sensitivity analysis reported as a supplementary table.

2. Overlapping cohorts – where institutional cohorts were judged to overlap and only the larger or longer-followed study was retained, the pooled estimate was recalculated substituting the alternative study, to confirm that the choice did not materially alter the result.

3. Leave-one-out analysis – each pooled estimate was recalculated with each contributing study omitted in turn, to identify any single study exerting disproportionate influence, particularly for endpoints with high heterogeneity.

4. Risk of bias – pooled estimates were recalculated restricted to studies at low risk of bias (Newcastle-Ottawa Scale 7-9), where the number of contributing studies permitted.

5. Model specification – pooled estimates were recalculated without the Hartung-Knapp adjustment and with alternative estimators of

between-study variance, to confirm the robustness of the confidence limits.

For the accompanying institutional cohort component, and given the ordinal and bounded nature of Suzuki grade change, an ordinal logistic regression with a three-level outcome (improvement, stable, worsening) was performed alongside the linear regression model, and the full four-predictor model in the complete mixed-age institutional cohort is reported as a supplementary sensitivity analysis. Both are reported as sensitivity analyses only and contribute to no pooled estimate in the meta-analysis.

Language restriction None. No language restriction was applied to the search or to study eligibility.

Country(ies) involved United States of America.

Other relevant information This protocol was registered retrospectively. The searches, screening, data extraction, risk-of-bias assessment and analyses were completed before this registration was submitted, and the corresponding manuscript has been submitted for peer review but is not yet published. No prospective registration exists for this review on PROSPERO or on any other registry. The eligibility criteria, prespecified outcomes, and analytic approach recorded here were defined before data extraction and are set out in the Methods section of the manuscript; no outcome was added, removed, or redefined after the analyses were seen. The three prespecified subgroup analyses (by revascularization technique, by diagnosis, and by study quality) could not be executed owing to insufficient subgroup-level reporting in the included studies.

A retrospective single-institution cohort analysis is reported alongside the systematic review as a secondary contextual component, evaluating whether revascularization status is independently associated with longitudinal angiographic change (Suzuki grade change) in pediatric patients. It was approved by the Institutional Review Board of Montefiore Medical Center / Albert Einstein College of Medicine (protocol 2023-14709), with waiver of informed consent, and contributes to no pooled estimate in the meta-analysis. The institutional dataset overlaps with a companion retrospective cohort study published in Neurosurgery Practice (doi:10.1227/neuprac.0000000000000256), which addresses temporal Suzuki grade progression as its primary endpoint; both manuscripts cross-cite one another and disclose the shared dataset.

Portions of the systematic review and meta-analysis were presented as a digital poster at the 2025 AANS/CNS Section on Pediatric Neurological Surgery Annual Meeting (Abstract 60009).

The review is reported in accordance with the PRISMA 2020 statement, and a completed PRISMA 2020 checklist accompanies the manuscript.

Keywords pediatric moyamoya; moyamoya syndrome; cerebral revascularization; synangiosis; meta-analysis; perioperative stroke; long-term stroke; Suzuki grade.

Dissemination plans The findings will be disseminated through publication in a peer-reviewed journal. The full systematic review and meta-analysis has been prepared as a manuscript and submitted to the Journal of Neurosurgery: Pediatrics as a literature review (systematic review and meta-analysis). Portions of the work have already been presented as a digital poster at the 2025 AANS/CNS Section on Pediatric Neurological Surgery Annual Meeting, and further presentation at national and international pediatric neurosurgery and cerebrovascular meetings is planned.

The completed review is reported in accordance with the PRISMA 2020 statement, with the completed checklist, the full search strategies for every database, the outcome definitions used by each included study, and the sensitivity analyses provided as supplementary material.

The extracted dataset and the analytic outputs supporting the review are available from the corresponding author on reasonable request. The institutional cohort data are not publicly available owing to patient-privacy and institutional-governance constraints, but may be shared in de-identified form on reasonable request and under an appropriate data-use agreement.

This INPLASY registration will be updated to record the review's status once the manuscript is accepted and published, so that the registered record remains linked to the final publication.

Contributions of each author

Author 1 - Khushal Gupta - Conceived and designed the review, developed and ran the search strategy, screened records and extracted data, performed the Newcastle-Ottawa scoring and all meta-analyses, drafted the manuscript, and serves as corresponding author and guarantor.
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Author 2 - Joshua Cohen - Independently screened records and extracted data, independently performed Newcastle-Ottawa risk-of-bias scoring and Suzuki grading, contributed to the institutional cohort analysis, and critically revised the manuscript.
Author 3 - Taylor Vadset - Contributed to data collection and curation for the institutional cohort, assisted with data verification, and critically revised the manuscript for important intellectual content.
Author 4 - Amanda Baker - Provided clinical and neurosurgical expertise in the interpretation of outcomes, contributed to the framing of the outcome definitions, and critically revised the manuscript for important intellectual content.
Author 5 - Vijay Agarwal - Provided neurosurgical expertise, contributed to the interpretation of the pooled findings, and critically revised the manuscript for important intellectual content.
Author 6 - Allan Brook - Provided neurointerventional and neuroradiological expertise, contributed to the angiographic interpretation and the Suzuki grading methodology, and critically revised the manuscript for important intellectual content.
Author 7 - David J. Altschul - Provided cerebrovascular neurosurgical expertise, contributed to the interpretation of perioperative and long-term outcomes, and critically revised the manuscript for important intellectual content.
Author 8 - Andrew Kobets - Supervised the project as senior author, provided pediatric neurosurgical expertise, contributed to study conception and interpretation, and critically revised and approved the final manuscript.