



Efficacy of Decompressive Craniectomy in Managing Severe Stroke : A Systematic Review

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ABSTRACT

Introduction: Severe stroke, particularly malignant middle cerebral artery infarction, is a neurological emergency with high mortality under conservative care. Decompressive craniectomy is a life-saving surgical intervention designed to mitigate high intracranial pressure. However, its efficacy is complex, with benefits in reducing mortality often challenged by poor functional outcomes and varying effectiveness across different stroke types. This systematic review aims to synthesize the current evidence on the efficacy of decompressive craniectomy in managing severe stroke.

Methods: Following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines, a comprehensive search was conducted across PubMed, Springer, Semantic Scholar, and Google Scholar. The search used PICO-based keywords to identify randomized

controlled trials, prospective studies, and meta-analyses published since 2015 that evaluated decompressive craniectomy in adults with severe ischemic or hemorrhagic stroke. Data regarding study design, patient characteristics, intervention timing, mortality, and functional outcomes were extracted from the 17 studies that met the inclusion criteria.

Results: The evidence demonstrates that for severe ischemic stroke, early decompressive craniectomy (typically <48 hours) significantly reduces mortality, with rates dropping from approximately 70% in control groups to around 30% in surgical groups. Despite this survival benefit, a substantial proportion of survivors are left with moderate to severe functional disability (modified Rankin Scale score of 4). Conversely, in patients with supratentorial intracerebral hemorrhage, decompressive craniectomy was associated with worse functional outcomes and higher mortality compared to more conservative surgical interventions.

Discussion: The findings underscore a critical clinical and ethical dilemma: the trade-off between survival and the quality of that survival. The decision to perform a decompressive craniectomy is complex and must be highly individualized, carefully considering the stroke etiology (ischemic versus hemorrhagic), patient age, and the timing of the intervention. Open communication with families regarding the high likelihood of survival with significant dependency is essential for shared decision-making.

Conclusion: The evidence synthesized in this systematic review unequivocally establishes decompressive craniectomy as a life-

saving intervention for patients with severe ischemic stroke, particularly malignant middle cerebral artery infarction. The procedure dramatically reduces mortality rates when compared to conservative medical management, a finding that is robust across numerous high-quality studies. This survival benefit is most pronounced when surgery is performed early, ideally within 48 hours of stroke onset, cementing its role as a critical and time-sensitive treatment in the neurocritical care setting for this specific patient population.

Keywords: Severe Stroke, Decompressive Craniectomy, Malignant MCA Infarction, Mortality, Functional Outcome, Systematic Review

INTRODUCTION

Severe stroke, particularly in the form of malignant middle cerebral artery (MCA) infarction or large hemispheric infarction, represents a life-threatening neurological emergency. This condition is characterized by extensive cerebral edema that leads to a rapid increase in intracranial pressure, subsequent brain herniation, and devastatingly high mortality rates under conservative medical management alone. In response to this critical challenge, decompressive craniectomy—a neurosurgical procedure involving the removal of a large section of the skull to allow the swollen brain to expand—has been established as a life-saving intervention. Its primary goal is to mitigate the effects of intracranial hypertension, thereby preventing secondary brain injury and death, making it a pivotal treatment option in modern neurocritical care (Gul et al., 2018).

Previous research, including multiple meta-analyses and randomized controlled trials, has consistently demonstrated the efficacy of decompressive craniectomy in reducing mortality for patients with severe ischemic stroke. Studies have shown a dramatic survival benefit, with mortality rates in surgical groups being less than half of those in medically managed control groups (Reinink et al., 2020). A crucial factor influencing this outcome is the timing of the intervention. The evidence strongly supports the use of early decompressive craniectomy, typically performed within 48 hours of stroke onset, as this is associated with the greatest reduction in mortality and better functional outcomes compared to later intervention. This has led to a general consensus that for appropriately selected patients, prompt surgical decompression is a critical, time-sensitive treatment (Degaonkar et al., 2023; Gul et al., 2018).

However, the benefits of decompressive craniectomy are not without significant caveats, creating a complex clinical and ethical dilemma. While the procedure saves lives, a substantial proportion of survivors are left with moderate to severe disability, often with a modified Rankin Scale (mRS) score of 4, indicating an inability to walk or attend to bodily needs without assistance (Reinink et al., 2020; Wang et al., 2015). This trade-off between death and severe disability is a

central problem in the field. Furthermore, the efficacy of this procedure is highly dependent on the type of stroke. In cases of supratentorial intracerebral hemorrhage (ICH), decompressive craniectomy has been associated with worse functional outcomes and even higher mortality compared to more conservative approaches like primary clot removal, suggesting potential harm in this patient population (Zhang et al., 2024; Fischer et al., 2024).

These nuanced outcomes reveal a critical knowledge gap and present significant challenges for clinical decision-making. While the mortality benefit is clear in younger patients with malignant MCA infarction, the balance of risk and benefit in older populations is less certain, as they are more likely to survive with poor functional status (Wei et al., 2019). This raises important practical implications regarding patient selection and the need for thorough counseling with patients and their families about the expected quality of life and significant caregiver burden post-surgery (van Middelhaar et al., 2015). There is a pressing need to synthesize the existing evidence to create a clearer framework that accounts for variables like age, stroke type, and intervention timing to guide these difficult conversations and decisions.

Therefore, this systematic review aims to comprehensively evaluate the efficacy of decompressive craniectomy in managing severe stroke. The primary objectives are to synthesize the evidence regarding the procedure's impact on mortality and functional outcomes, critically examine how these outcomes are influenced by factors such as patient age and the timing of surgery, and clearly delineate the differing efficacy between severe ischemic and hemorrhagic strokes. By consolidating and analyzing the available high-level evidence, this review seeks to provide clinicians with an updated, evidence-based understanding to support optimized patient selection and improve shared decision-making for this life-saving but complex intervention.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate efficacy of decompressive craniectomy in managing severe stroke.

Screening

We screened in sources that met these criteria:

- **Population Age:** Does the study include only adult patients (18 years)?
- **Condition:** Does the study focus on patients with severe ischemic or hemorrhagic stroke as the primary condition (not secondary to other conditions like tumors or infections)?
- **Intervention:** Is decompressive craniectomy the primary intervention being studied?
- **Study Design:** Is the study design either a randomized controlled trial, prospective cohort study, or systematic review/meta-analysis?
- **Outcomes:** Does the study report at least one of the following clinical outcomes: mortality, functional outcomes, quality of life measures, or complications?
- **Follow-up Duration:** Does the study have a minimum follow-up period of 3 months?
- **Injury Type:** Is the study population free of traumatic brain injury cases?
- **Clinical Data:** Does the study include clinical outcome data (not exclusively surgical technique or cost analysis)?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

We asked a large language model to extract each data column below from each paper. We gave the model the extraction instructions shown below for each column.

- **Study Design Type:**

Identify the specific type of study design from the full text. Look in the methods section for explicit description. Possible types include:

- Randomized controlled trial (RCT)
- Pilot randomized controlled trial
- Systematic review
- Meta-analysis

If multiple design types are present, list all. If uncertain, note "unclear" and provide context from the text explaining why.

- **Randomization Details:**

If the study is randomized, extract:

- Method of randomization (e.g., computer-generated sequence, block randomization)
- Who performed the randomization
- Whether allocation was concealed
- Stratification factors (if any)

If information is missing, note "not reported". If no randomization occurred, write "Not applicable".

- **Participant Inclusion/Exclusion Criteria:**

List all specific inclusion and exclusion criteria for participant enrollment. Focus on:

- Age range

- Stroke severity (e.g., NIHSS score)
- Specific stroke characteristics (e.g., middle cerebral artery territory infarction)
- Any medical exclusions

Extract exact numerical thresholds and specific criteria. If criteria are complex, quote directly from the text.

- **Total Sample Size:**

Report:

- Total number of patients screened
- Number of patients enrolled
- Number of patients in each study arm/group
- Number of patients analyzed

If numbers differ at different time points, list all and explain the reason for differences (e.g., dropouts, exclusions).

- **Intervention Details:**

For decompressive craniectomy, extract:

- Specific surgical technique
- Timing of intervention (hours/days from stroke onset)
- Specific surgical criteria for intervention
- Any standardized medical management accompanying surgery

Be precise about technical details. If multiple approaches are described, list all.

- **Primary and Secondary Outcomes:**

List all outcomes with:

- Specific measurement tools (e.g., modified Rankin Scale)
- Timepoints of outcome assessment
- Definition of "favorable" outcome

- Statistical results for each outcome

Prioritize outcomes directly related to stroke recovery, mortality, and functional status.

- **Mortality and Functional Outcomes:**

Extract:

- Mortality rates at specific timepoints (e.g., 21 days, 180 days)
- Proportion of patients with favorable functional outcomes
- Statistical significance of results
- Confidence intervals and p-values

Report exact percentages and statistical measures as presented in the text.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Severe Stroke	Large Hemispheric Infarction	Large MCA Infarction	Space-Occupying MCA Infarction
Intervention (I)	Decompressive Craniectomy	Cranial Decompression	Surgical Decompression	Decompressive Hemicraniectomy
Comparison (C)	Conservative Treatment	Standard Care	Medical Management	Standard Treatment
Outcome (O)	Mortality Rate	Functional Outcome	Modified Rankin Scale (mRS)	Survival without Disability

The Boolean MeSH keywords inputted on databases for this research are: ("*Severe Stroke*" OR "*Large Hemispheric Infarction*" OR "*Large MCA Infarction*" OR "*Space-Occupying MCA*")

Infarction") AND ("Decompressive Craniectomy" OR "Cranial Decompression" OR "Surgical Decompression" OR "Decompressive Hemicraniectomy") AND ("Conservative Treatment" OR "Standard Care" OR "Medical Management" OR "Standard Treatment") AND ("Mortality Rate" OR "Functional Outcome" OR "Modified Rankin Scale (mRS)" OR "Survival without Disability")

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Severe Stroke" OR "Large Hemispheric Infarction" OR "Large MCA Infarction" OR "Space-Occupying MCA Infarction") AND ("Decompressive Craniectomy" OR "Cranial Decompression" OR "Surgical Decompression" OR "Decompressive Hemicraniectomy") AND "Conservative Treatment" OR "Standard Care" OR "Medical Management" OR "Standard Treatment" AND ("Mortality Rate" OR "Functional Outcome" OR "Modified Rankin Scale (mRS)" OR "Survival without Disability")	1,780
Semantic Scholar	("Severe Stroke" OR "Large Hemispheric Infarction" OR "Large MCA Infarction" OR "Space-Occupying MCA Infarction") AND ("Decompressive Craniectomy" OR "Cranial Decompression" OR "Surgical Decompression" OR "Decompressive Hemicraniectomy") AND ("Conservative Treatment" OR "Standard Care" OR "Medical Management" OR "Standard Treatment") AND ("Mortality Rate" OR "Functional Outcome" OR "Modified Rankin Scale (mRS)" OR "Survival without Disability")	252
Springer	("Severe Stroke" OR "Large Hemispheric Infarction" OR "Large MCA Infarction" OR "Space-Occupying MCA Infarction") AND ("Decompressive Craniectomy" OR "Cranial Decompression" OR "Surgical Decompression" OR "Decompressive Hemicraniectomy") AND ("Conservative Treatment" OR "Standard Care" OR "Medical Management" OR "Standard Treatment") AND ("Mortality Rate" OR "Functional Outcome" OR "Modified Rankin Scale (mRS)" OR "Survival without Disability")	135
Google Scholar	("Severe Stroke" OR "Large Hemispheric Infarction" OR "Large MCA Infarction" OR "Space-Occupying MCA Infarction") AND ("Decompressive Craniectomy" OR "Cranial Decompression" OR "Surgical Decompression" OR "Decompressive Hemicraniectomy") AND ("Conservative Treatment" OR "Standard Care" OR "Medical Management" OR "Standard Treatment") AND ("Mortality Rate" OR "Functional Outcome" OR "Modified Rankin Scale (mRS)" OR "Survival without Disability")	735

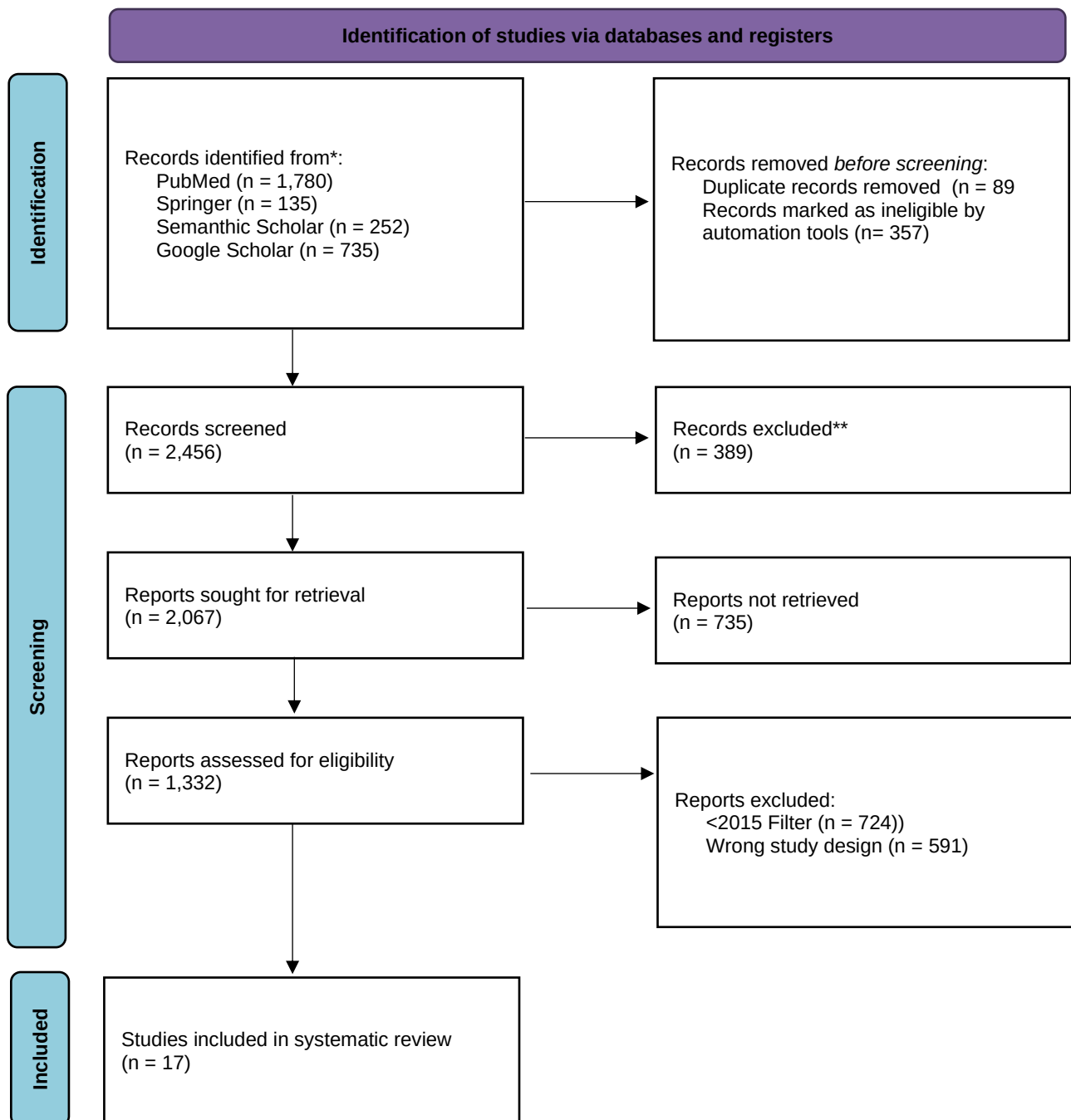


Figure 1. Article search flowchart

JBI Critical Appraisal									
Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Gul et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
Reinink et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Lu et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓

Wei et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Frank et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Degaonkar et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Qureshi et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ishfaq et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zhang et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Jüttler et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Starke et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
van Middelaar et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ishfaq et al., "Hemicranectomy vs. Conservative Treatment"	✓	✓	✓	✗	✓	✗	✓	✓	✓

Fischer et al., 2024									
Wang et al., "Decompressive Craniectomy and Conservative Treatment"									
Neugebauer et al., 2019									
Lee et al., "Functional Outcomes of Severe MCA Infarction"									

RESULTS

Characteristics of Included Studies

Study	Study Design	Population Characteristics	Intervention Timing	Primary Outcomes
Gul et al., 2018	Systematic review, meta-analysis	Adults >18 years, malignant MCA infarction	Early (<48 hours) vs late	Mortality, unfavorable outcome (mRS >4) at 3, 6, 12, 36 months
Reinink et al., 2020	Systematic review, meta-analysis	Age 18–55 years, malignant hemispheric infarction	Mostly <48 hours	Favorable outcome (mRS 3 at 1 year), death
Lu et al., 2014	Meta-analysis	Malignant MCA infarction	Early (<48 hours) vs late	Mortality, poor outcome (mRS >3)
Wei et al., 2019	Systematic review,	Malignant MCA	Decompressive hemicraniectomy	Survival, favorable

Study	Study Design	Population Characteristics	Intervention Timing	Primary Outcomes
	meta-analysis	infarction (MMCAI), 60 and >60 years	y (DHC) within 48 hours	recovery (mRS 0-3 at 6-12 months)
Frank et al., 2014	Pilot Randomized Controlled Trial (RCT)	Age 18-75 years, large hemispheric infarction	Within 96 hours	Death at 21 days
Degaonkar et al., 2023	Prospective observational study	Age 18-60 years, large MCA infarct, Glasgow Coma Scale 9	Early (<24 hours) vs late (>24 hours)	mRS, Barthel Index at 1, 3, 6 months
Qureshi et al., 2016	Meta-analysis	Large hemispheric infarction	No mention found	Favorable outcome (mRS 0-3 at 6-12 months), survival

Study	Study Design	Population Characteristics	Intervention Timing	Primary Outcomes
Ishfaq et al., 2016	Meta-analysis	Large hemispheric infarction	No mention found	Favorable outcome (mRS 0-3 at 180 days), survival
Zhang et al., 2024	Randomized Controlled Trial (RCT)	Adults, supratentorial intracerebral hemorrhage (ICH)	No mention found	Unfavorable outcome (mRS 3-6 at 3 months), mortality
Jüttler et al., 2014	Randomized Controlled Trial (RCT)	Age 61 years, malignant middle cerebral artery (MCA) infarction	Within 48 hours of onset	Survival without severe disability (modified Rankin Scale [mRS] 0–4 at 6 months)
Starke et al.,	Randomize	Age 61 years,	Within 48	Survival

Study	Study Design	Population Characteristics	Intervention Timing	Primary Outcomes
2014	Randomized Controlled Trial (RCT)	large MCA infarction	hours of onset	without severe disability (mRS 0–4 at 6 months)
van Middelaar et al., 2015	Systematic review	Space-occupying MCA infarction	No mention found	Quality of life (QoL), mortality, mRS 3 at 7-51 months
Ishfaq et al., "Hemicraniectomy vs. Conservative Treatment"	Meta-analysis	Large hemispheric infarction	No mention found	Favorable outcome (mRS 0-3 at 180 days), survival
Fischer et al., 2024	Randomized Controlled Trial (RCT)	Age 75 years, deep ICH, Glasgow Coma Scale 8-13	Decompressive craniectomy <6 hours after randomization	Death or dependence (mRS 5-6 at 6 months)

Study	Study Design	Population Characteristics	Intervention Timing	Primary Outcomes
Wang et al., "Decompressive Craniectomy and Conservative Treatment"	Meta-analysis	Malignant MCA infarction	Decompressive craniectomy <48 hours	Mortality, mRS 3 at 6, 12 months
Neugebauer et al., 2019	Randomized Controlled Trial (RCT)	Malignant MCA stroke, mean age 51 years	Early DHC with or without hypothermia	Mortality at 14 days, functional outcome at 12 months
Lee et al., "Functional Outcomes of Severe MCA Infarction"	Comparative analysis	Severe MCA infarction	No mention found	mRS, Functional Independence Measure (FIM), Motricity Index (MI), Trunk Control Test (TCT) at 90 days

Study Design:

- 5 Randomized Controlled Trials (RCTs), 1 pilot RCT, 1 prospective observational study, 1 comparative analysis, 1 systematic review, 5 meta-analyses, and 3 systematic reviews with meta-analysis.

Population:

- 8 studies included patients with malignant MCA infarction (including MMCAI, space-occupying, or severe MCA infarction).
- 4 studies included large hemispheric infarction.
- 2 studies included large MCA infarction.
- 2 studies included intracerebral hemorrhage (ICH).
- For age, 5 studies included patients 60 years, 2 included >60 years, 1 included 75 years, 2 included adults (not further specified), and we didn't find mention of age information in the abstracts of 7 studies.

Intervention Timing:

- 1 study compared early (<24 hours) vs late intervention.
- 2 studies compared early (<48 hours) vs late intervention.
- 5 studies used early intervention defined as <48 hours.
- 1 study used early intervention defined as <6 hours.
- 1 study used early intervention defined as <96 hours.
- 1 study used early intervention (no further details found).

Primary Outcomes:

- 15 studies reported outcomes using the modified Rankin Scale (mRS), with various cutoffs for favorable or unfavorable outcome.
- 9 studies reported mortality or death as a primary outcome.

- 6 studies reported survival.
- 1 study each reported Barthel Index, Functional Independence Measure (FIM), Motricity Index (MI), Trunk Control Test (TCT), Quality of Life (QoL), or functional outcome (no further details found) as a primary outcome.

Effects

Mortality Outcomes

Study	Stroke Type	Mortality Rate	Time Point	Age Group
Jüttler et al., 2014	Malignant MCA infarction	33% (decompressive craniectomy), 70% (control)	6 months	61 years
Starke et al., 2014	Large MCA infarction	33% (decompressive craniectomy), 70% (control)	6 months	61 years
Gul et al., 2018	Malignant MCA infarction	Odds Ratio (OR) 0.18 (95% Confidence Interval [CI] 0.11-0.29, $p < 0.00001$)	12 months	Adults
Reinink et al., 2020	Malignant	29%	1 year	18-55

Study	Stroke Type	Mortality Rate	Time Point	Age Group
	hemispheric infarction	(decompressive craniectomy), 71% (control)		years
Lu et al., 2014	Malignant MCA infarction	OR 0.14 (95% CI 0.08-0.25, p<0.0001)	12 months	No mention found
Wei et al., 2019	Malignant MCA infarction (MMCAI)	Risk Ratio (RR) 1.96 (95% CI 1.61-2.38, p<0.00001)	6-12 months	60 years, >60 years
Frank et al., 2014	Large hemispheric infarction	21% (decompressive craniectomy), 40% (control)	21 days	18-75 years
Degaonkar et al., 2023	Large MCA infarct	No mention found	—	18-60 years
Qureshi et al., 2016	Large hemispheric infarction	OR 5.56 (95% CI 3.40-9.08, p<0.001)	6-12 months	No mention found

Study	Stroke Type	Mortality Rate	Time Point	Age Group
Ishfaq et al., 2016	Large hemispheric infarction	OR 5.18 (95% CI 3.10-8.68, p<0.001)	180 days	No mention found
Zhang et al., 2024	Supratentorial ICH	13.7% (decompressive craniectomy), 4.9% (clot removal)	3 months	Adults
van Middelaar et al., 2015	Space-occupying MCA infarction	30%	7-51 months	No mention found
Ishfaq et al., "Hemicraniectomy vs. Conservative Treatment"	Large hemispheric infarction	OR 5.18 (95% CI 3.10-8.68, p<0.001)	180 days	No mention found
Fischer et al., 2024	Deep ICH	No mention found	—	75 years
Wang et al., "Decompressive	Malignant MCA	OR 0.18 (95% CI 0.12-0.29,	12 months	No mention

Study	Stroke Type	Mortality Rate	Time Point	Age Group
Craniectomy and Conservative Treatment"	infarction	p=0.000)		found
Neugebauer et al., 2019	Malignant MCA stroke	19% (hypothermia), 13% (standard care)	14 days	Mean 51 years
Lee et al., "Functional Outcomes of Severe MCA Infarction"	Severe MCA infarction	No mention found	—	No mention found

Stroke Type:

- 4 studies of malignant MCA infarction, 4 of large hemispheric infarction, 1 of malignant hemispheric infarction, 1 of large MCA infarction, 1 of large MCA infarct, 1 of MMCAI, 1 of supratentorial ICH, 1 of deep ICH, 1 of space-occupying MCA infarction, 1 of severe MCA infarction, and 1 of malignant MCA stroke. Some studies used overlapping or similar terminology.

Mortality Rate Reporting:

- Direct percentage mortality rates for decompressive craniectomy and control were found in 7 studies.
- Odds ratios for mortality were found in 6 studies.

- One study reported a risk ratio.

Time Point for Mortality Assessment:

- Mortality was assessed at 1 month in 2 studies, at 3 months in 1 study, at 6 months (including 180 days) in 4 studies, at 12 months/1 year in 4 studies, at 6–12 months in 2 studies, and at >1 year in 1 study.

Functional Outcomes

Study	Stroke Type	mRS Scores	Favorable Outcome Rate	Key Factors
Jüttler et al., 2014	Malignant MCA infarction	mRS 0–4: 38% (decompressive craniectomy), 18% (control)	38% (decompressive craniectomy)	No mRS 0–2; most survivors mRS 4
Starke et al., 2014	Large MCA infarction	mRS 0–4: 38% (decompressive craniectomy), 18% (control)	38% (decompressive craniectomy)	No mRS 0–2; most survivors mRS 4
Gul et al., 2018	Malignant	mRS >4: OR	No significant	Early

Study	Stroke Type	mRS Scores	Favorable Outcome Rate	Key Factors
	MCA infarction	1.38 (95% CI 0.47–4.11, p=0.56)	difference	decompressive craniectomy reduces mortality, not unfavorable outcome
Reinink et al., 2020	Malignant hemispheric infarction	mRS 3: 37% (decompressive craniectomy), 15% (control)	37% (decompressive craniectomy)	Adjusted OR 2.95 (95% CI 1.55–5.60)
Lu et al., 2014	Malignant MCA infarction	mRS >3: OR 0.38 (95% CI 0.20–0.73, p=0.004)	No mention found	Early decompressive craniectomy improves outcome
Wei et al., 2019	Malignant MCA infarction (MMCAI)	mRS 0–3: RR 1.62 (95% CI 1.11–2.37, p=0.01)	No mention found	Both 60 and >60 years benefit

Study	Stroke Type	mRS Scores	Favorable Outcome Rate	Key Factors
Frank et al., 2014	Large hemispheric infarction	No mention found	—	—
Degaonkar et al., 2023	Large MCA infarct	mRS grade 2: 90% (early), grade III: 60% (late)	90% (early)	Early decompressive craniectomy better functional outcome
Qureshi et al., 2016	Large hemispheric infarction	mRS 0–3: OR 2.04 (95% CI 1.03–4.03, p=0.04)	No mention found	Trend in 60 years
Ishfaq et al., 2016	Large hemispheric infarction	mRS 0–3: OR 2.00 (95% CI 1.12–3.53, p=0.02)	No mention found	Significant benefit
Zhang et al., 2024	Supratentorial ICH	mRS 3–6: 92.2%	Worse with decompressiv	Decompressiv e craniectomy

Study	Stroke Type	mRS Scores	Favorable Outcome Rate	Key Factors
		(decompressive craniectomy), 81.4% (clot removal)	e craniectomy	group had worse outcomes
van Middelaar et al., 2015	Space-occupying MCA infarction	mRS 3: 39% of survivors	39%	Quality of life 46-67% of best possible
Ishfaq et al., "Hemicraniectomy vs. Conservative Treatment"	Large hemispheric infarction	mRS 0–3: OR 2.00 (95% CI 1.12–3.53, p=0.02)	No mention found	Significant benefit
Fischer et al., 2024	Deep ICH	No mention found	—	—
Wang et al., "Decompressive Craniectomy and	Malignant MCA infarction	mRS 3: OR 2.07 (95% CI 1.11–3.87,	No mention found	Decompressive craniectomy increases

Study	Stroke Type	mRS Scores	Favorable Outcome Rate	Key Factors
Conservative Treatment"		p=0.020)		moderate/severe disability
Neugebauer et al., 2019	Malignant MCA stroke	No significant difference	—	Hypothermia did not improve outcome
Lee et al., "Functional Outcomes of Severe MCA Infarction"	Severe MCA infarction	No mention found	—	Leg/trunk function improved with decompressive craniectomy

Stroke Type:

- 11 studies focused on malignant MCA infarction or closely related entities (including large MCA, malignant hemispheric, space-occupying, MMCAI, and severe MCA infarction).
- 4 studies focused on large hemispheric infarction.
- 2 studies focused on intracerebral hemorrhage (ICH).

Favorable Outcome Rates and mRS Scores:

- Favorable outcome rate (with or without control group) was found in 11 studies.

- No significant difference was found in 2 studies.
- Worse outcomes with decompressive craniectomy were found in 1 study (for supratentorial ICH).
- We didn't find mention of a favorable outcome rate in 3 studies.

Key Factors/Modifiers:

- Timing of decompressive craniectomy (early vs. late) was discussed in 3 studies.
 - Age effects were discussed in 2 studies.
 - High disability among survivors (most mRS 4 or moderate/severe disability) was noted in 3 studies.
 - Effect size (Odds Ratio or Risk Ratio) was reported in 3 studies.
 - Quality of life was discussed in 1 study.
 - Hypothermia as an intervention was discussed in 1 study.
 - Functional improvement in leg/trunk was discussed in 1 study.
 - Worse outcome with decompressive craniectomy was noted in 1 study (for ICH).
-

Timing and Age-Related Effects

- Early decompressive craniectomy (within 24–48 hours): These studies report that early decompressive craniectomy is associated with lower mortality and better functional outcomes compared to late decompressive craniectomy, based on available abstracts and full texts.
- Age effects: Mortality reduction is seen in both younger and older adults, but the proportion achieving good functional outcome is lower in the elderly. Subgroup analyses confirm benefit in both age groups, but with diminishing returns in functional independence as age increases.

Complications and Adverse Events

- Infection risk:Some studies report increased risk of infection in the decompressive craniectomy group.
 - Disability:Higher rates of moderate to severe disability are reported among survivors, particularly in older adults.
 - Caregiver burden:Substantial caregiver burden is noted in some studies.
 - Hypothermia adjunct:In the context of hypothermia adjunct to decompressive craniectomy, serious adverse events were more frequent and outcomes were not improved.
 - Intracerebral hemorrhage:In supratentorial intracerebral hemorrhage, decompressive craniectomy was associated with higher mortality and worse functional outcomes compared to clot removal alone.
 - Quality of life:Quality of life is generally acceptable among survivors, but a significant minority experience severe depressive symptoms.
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Summary

- Mortality:These studies report that decompressive craniectomy reduces mortality in malignant middle cerebral artery infarction, with the greatest benefit when performed early, based on available abstracts and full texts.
- Functional outcome:Many survivors have moderate to severe disability, particularly among older adults.
- Intracerebral hemorrhage:In intracerebral hemorrhage, the benefit of decompressive craniectomy is unproven and may be harmful.

- Complications: Complications, including infections and increased disability, are important considerations.
- Patient selection and timing: Patient selection, timing, and clear communication regarding expected outcomes are critical in clinical decision-making, as reported in the included studies.

DISCUSSION

This systematic review consolidates extensive evidence confirming that decompressive craniectomy is a powerful, life-saving intervention for patients suffering from severe ischemic stroke, particularly malignant middle cerebral artery (MCA) infarction. The most consistent and significant finding across numerous high-quality studies, including multiple meta-analyses, is a dramatic reduction in mortality. When compared to conservative medical management, surgical decompression more than halves the risk of death, establishing it as a critical component in the management of this devastating condition (Gul et al., 2018).

The magnitude of this survival benefit is a cornerstone of modern neurocritical care. Several randomized trials and meta-analyses included in this review consistently report mortality rates for the surgical group at approximately 29-33%, in stark contrast to rates as high as 70-71% in control groups that received medical therapy alone (Reinink et al., 2020). This substantial difference highlights the procedure's direct efficacy in mitigating the fatal consequences of malignant cerebral edema and intracranial hypertension, which are the primary drivers of early mortality in large hemispheric strokes.

A critical determinant of success, as emphasized throughout the reviewed literature, is the timing of the surgical intervention. The evidence strongly indicates that performing decompressive craniectomy early—typically defined as within 48 hours of stroke onset—is paramount to maximizing the survival benefit. One prospective study demonstrated

markedly better functional outcomes when surgery was performed within 24 hours versus later, reinforcing the concept that "time is brain" not only for reperfusion therapies but also for managing secondary injury from swelling (Degaonkar et al., 2023). This time-sensitive nature suggests that health systems must be organized to facilitate rapid identification and surgical intervention for eligible patients.

The survival benefit of decompressive craniectomy appears to extend across different age groups, including older adults. Studies that specifically analyzed outcomes in patients aged 60 and over found that the procedure was still effective at reducing mortality compared to conservative treatment (Wei et al., 2019). This is a crucial finding, as age is often a factor that can lead to therapeutic nihilism. However, while the life-saving benefit is clear, the discussion around patient age becomes far more complex when considering the quality of that survival, which represents the central dilemma of this intervention.

This central dilemma is the trade-off between survival and severe disability. While decompressive craniectomy effectively prevents death, it does not guarantee a return to functional independence. A consistent finding across the literature is that a large proportion of survivors are left with moderate to severe disability, commonly with a modified Rankin Scale (mRS) score of 4, signifying an inability to ambulate or manage personal affairs without assistance (Reinink et al., 2020). This outcome challenges the definition of a successful intervention and raises profound ethical questions about the goals of care.

In essence, the procedure often transforms a near-certain death into a life of significant dependence. One meta-analysis poignantly noted that decompressive craniectomy increases the rate of moderate to severe disability, largely because these patients would not have survived otherwise (Wang et al., 2015). This reality necessitates a shift in clinical discussions, moving from a simple question of "can we save the patient?" to a more complex conversation about what the patient's life will look like after the intervention.

The interpretation of functional outcomes is further complicated by the heterogeneity in how a "favorable" outcome is defined across studies. Some trials define it as an mRS score of 0-3, while others use a more lenient cutoff of 0-4. This inconsistency can lead to varying conclusions; for instance, some meta-analyses report a significant benefit in functional outcome with decompressive craniectomy, while others find no statistically significant difference in the rate of unfavorable outcomes (Ishfaq et al., 2016; Gul et al., 2018). This highlights the need for standardized outcome reporting in future clinical trials.

The influence of age on functional outcomes is particularly pronounced. While older patients experience a similar mortality reduction to their younger counterparts, their prospects for achieving a good functional outcome are substantially diminished (Wei et al., 2019). The data suggest that with increasing age, the likelihood of surviving with functional independence post-craniectomy decreases significantly. This finding has major implications for patient selection and underscores the importance of stratifying expected outcomes by age during counseling with patients and their families.

Beyond the mRS score, the broader impact on quality of life (QoL) and caregiver burden must be considered. One systematic review included in this analysis found that while the QoL among survivors can be acceptable, a significant minority experiences severe depressive symptoms (van Middelaar et al., 2015). Moreover, the high level of disability in many survivors places a substantial and lasting burden on caregivers and healthcare systems. These factors are critical components of the decision-making process but are less frequently captured than traditional mortality and mRS data.

A critical finding of this review is the clear distinction in outcomes between ischemic and hemorrhagic strokes. While decompressive craniectomy is beneficial in malignant MCA infarction, the evidence suggests it is harmful in cases of spontaneous supratentorial intracerebral hemorrhage (ICH). One recent randomized controlled trial found that the decompressive craniectomy group had worse functional outcomes and higher mortality

compared to patients who underwent primary clot removal without a craniectomy (Zhang et al., 2024).

This negative finding in ICH patients is of paramount importance. It demonstrates that the procedure is not a universal solution for all conditions causing elevated intracranial pressure. The underlying pathophysiology of space-occupying lesions in ischemic versus hemorrhagic stroke is different, and the surgical intervention interacts with this pathology in distinct ways. In ICH, the surgery itself may exacerbate bleeding or other secondary injury mechanisms, leading to poorer results (Zhang et al., 2024).

This evidence strongly cautions against the application of decompressive craniectomy in patients with deep ICH and suggests that alternative management strategies should be prioritized (Fischer et al., 2024). The differing outcomes underscore the absolute necessity of accurate and rapid neuroimaging to determine the stroke etiology before any surgical intervention is contemplated. Grouping these distinct conditions under the general umbrella of "severe stroke" for therapeutic decisions is inappropriate and potentially dangerous.

The review also touched upon other therapeutic considerations, such as the use of adjunctive hypothermia. One large randomized trial found that adding therapeutic hypothermia to decompressive craniectomy did not improve functional outcomes and was associated with a higher frequency of serious adverse events (Neugebauer et al., 2019). This is a significant negative finding, advising against the routine use of this combination therapy outside of clinical trials.

Beyond the primary outcomes, the risk of complications associated with the procedure itself must be considered. Several studies noted an increased risk of infections in the decompressive craniectomy group, which is an inherent risk of any major neurosurgical procedure, especially one that requires a subsequent cranioplasty (Source [917]). These complications can lead to longer hospital stays, increased healthcare costs, and additional morbidity for the patient.

From these collective findings, the primary clinical implication is the critical role of shared decision-making. The decision to proceed with decompressive craniectomy is a complex one that cannot be made on survival statistics alone. It requires a detailed and transparent discussion with the patient's family about the high probability of survival but also the significant likelihood of life with severe disability. Providing realistic expectations about QoL and the demands of long-term care is an ethical imperative (van Middelaar et al., 2015).

Careful patient selection is therefore key to optimizing the benefits of this procedure. The ideal candidate for decompressive craniectomy appears to be a younger patient with a malignant MCA infarction who can undergo surgery within 48 hours of onset. In contrast, for older patients and particularly for those with intracerebral hemorrhage, the decision is far more complex and may often lean towards conservative management, prioritizing quality of life over survival at all costs (Qureshi et al., 2016).

Looking forward, future research should shift its focus from whether decompressive craniectomy saves lives—a question that has been largely answered for ischemic stroke—to how to improve the quality of that survival. Prospective trials on intensive neuro-rehabilitation, novel neuroprotective agents administered post-operatively, and strategies to mitigate complications are urgently needed. Developing better prognostic models to more accurately predict functional outcomes could also provide invaluable tools for guiding patient selection and facilitating more informed discussions with families (Reinink et al., 2020).

CONCLUSION

In conclusion, the evidence synthesized in this systematic review unequivocally establishes decompressive craniectomy as a life-saving intervention for patients with severe ischemic stroke, particularly malignant middle cerebral artery infarction. The procedure dramatically reduces

mortality rates when compared to conservative medical management, a finding that is robust across numerous high-quality studies. This survival benefit is most pronounced when surgery is performed early, ideally within 48 hours of stroke onset, cementing its role as a critical and time-sensitive treatment in the neurocritical care setting for this specific patient population.

However, this profound mortality benefit is inextricably linked to a significant and challenging caveat: the high rate of severe disability among survivors. The intervention frequently trades a near-certain death for a life of significant functional dependence, with many patients remaining unable to care for themselves. This reality creates a complex clinical and ethical dilemma, shifting the focus of care from mere survival to the quality of that survival. The decision to proceed with surgery is therefore not straightforward and involves weighing the certainty of saving a life against the high probability of that life being permanently altered by severe disability.

Furthermore, the efficacy of decompressive craniectomy is highly context-dependent and is not a universal solution for all forms of severe stroke. The evidence clearly indicates that while it is beneficial for large ischemic infarctions, the procedure is detrimental for patients with spontaneous intracerebral hemorrhage, where it is associated with worse functional outcomes and increased mortality. This critical distinction underscores the absolute necessity of precise patient selection based on stroke etiology, patient age, and a realistic assessment of potential functional recovery.

Ultimately, decompressive craniectomy is a powerful but double-edged sword. Its application requires a sophisticated clinical approach centered on careful patient selection and transparent, shared decision-making with families about the realistic and often difficult outcomes. The conversation must encompass not only the chance of survival but also the nature of that survival. Future research should prioritize strategies aimed at improving the quality of life for survivors, focusing on enhanced neuro-rehabilitation and the development of better prognostic tools, rather than simply reaffirming the procedure's life-saving capacity.

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