

Review Article

Decompressive Craniectomy in Malignant Middle Cerebral Artery Infarction: Functional Outcomes at One Year

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Abstract

Background: Malignant middle cerebral artery infarction causes life-threatening cerebral edema; untreated mortality approaches 80%. Decompressive craniectomy reduces death, but survival often comes with substantial residual disability.

Objective: To synthesise trial and cohort evidence on one-year functional outcome after decompressive craniectomy for malignant middle cerebral artery infarction.

Methods: Narrative review of pivotal trials (DECIMAL, DESTINY, HAMLET, DESTINY II, HeADDFIRST), their pooled and individual-patient-data meta-analyses, and quality-of-life and patient-perspective studies.

Findings: In patients under 60, surgery within 48 hours roughly halves mortality and increases the proportion achieving modified Rankin Scale 4 or better, without increasing severely disabled survivors. In patients over 60, DESTINY II confirmed a large survival benefit but little gain in independence; most survivors remained moderately to severely disabled. Quality-of-life and retrospective-consent studies show many survivors and caregivers nonetheless endorse the decision to operate.

Conclusions: Decompressive craniectomy shifts, rather than eliminates, disability; counselling before surgery should reflect reported patient experience alongside clinician judgement.

Keywords: Decompressive craniectomy; Malignant middle cerebral artery infarction; Modified Rankin Scale; Functional outcome; Hemicraniectomy

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Introduction

Malignant infarction of the middle cerebral artery (MCA) territory affects roughly 1-10% of patients with ischemic stroke and follows a recognisable, often devastating course. Infarction of most or all of the MCA territory produces progressive cytotoxic and vasogenic edema over the first two to five days, raising intracranial pressure, causing midline shift, and ultimately transtentorial herniation. Without surgical intervention, mortality from

malignant MCA infarction has historically been reported at 70-80%, largely from herniation rather than the primary ischemic insult itself [1]. Decompressive craniectomy — removal of a large bone flap with duraplasty to allow the swollen hemisphere to expand outward rather than inward — was proposed as a mechanical solution to this otherwise fatal mass effect, and case-series evidence accumulating through the 1990s and early 2000s suggested it could substantially reduce mortality [1].

That early evidence, however, was confounded by selection and could not resolve the central clinical question: does converting death into survival mean converting death into meaningful recovery, or merely into survival with severe disability? This distinction matters acutely for a lesion that, unlike many neurosurgical emergencies, typically strikes cognitively intact patients who face an immediate, largely irreversible decision about an intervention whose principal effect on outcome is measured not in months but in functional independence at one year, most commonly quantified using the modified Rankin Scale (mRS), a seven-point ordinal measure of global disability ranging from no symptoms (0) through death (6), with mRS 4-5 generally regarded as severe dependency. This review synthesises the randomised trial evidence, its pooled and individual-patient-data reanalyses, systematic reviews and guidelines, and the quality-of-life and patient-perspective literature that together define what a "good" one-year outcome after decompressive craniectomy actually looks like, and for whom that tradeoff is most favourable.

The Pivotal Randomised Trials

Three European trials, largely contemporaneous, established the modern evidence base. DECIMAL, a French sequential-design trial, randomised patients aged 18-55 to early craniectomy (within 30 hours of a clinical/radiological definition of malignant infarction) or

best medical care, and was stopped early for a marked mortality difference despite the primary functional endpoint not reaching significance in the interim analysis [2]. DESTINY, a German trial with similar inclusion criteria (18-60 years), was also stopped early after an independent analysis suggested a mortality benefit sufficiently large that continued randomisation was considered unethical [3]. HAMLET, a Dutch trial designed with a wider therapeutic window of up to 96 hours [4], found no significant reduction in poor outcome (modified Rankin Scale [mRS] >3) when all randomised patients were analysed together, but a substantial benefit confined to patients operated on within 48 hours — a timing effect the investigators highlighted in a subsequent reassessment as the trial's most clinically important finding [5,6]. A fourth, smaller US pilot trial, HeADDFIRST, used intracranial-pressure-based rather than purely clinical entry criteria and closed early because of slow enrollment, but its data were later incorporated into pooled analyses [7].

Table 1: Pivotal randomised controlled trials of decompressive craniectomy for malignant middle cerebral artery infarction [2,3,5,13,7].				
Trial (country)	Age range	Time window	Primary outcome at 1 year	Key result
DECIMAL (France)	18-55 y	Within 30 h	mRS ≤3	Stopped early; large mortality reduction
DESTINY (Germany)	18-60 y	Within 36 h	mRS ≤3 (dichotomised ≤4)	Stopped early; large mortality reduction
HAMLET (Netherlands)	18-60 y	Within 96 h	mRS >3	No overall benefit; benefit if operated ≤48 h
DESTINY II (Germany)	≥61 y	Within 48 h	mRS ≤4	Survival benefit; little gain in independence
HeADDFIRST (USA)	18-75 y	Within 96 h (ICP-based)	mRS ≤4	Closed early, slow enrollment; pooled post hoc

Pooled and Individual-Patient-Data Analyses

Because each trial alone was underpowered for functional outcome, DECIMAL, DESTINY and HAMLET investigators combined patient-level data from 93 patients under 60 randomised within 48 hours. Surgery reduced case fatality from 71% to 22% (an absolute risk reduction of about 50 percentage points) and increased the proportion surviving with mRS ≤4 from 24% to 75% (number needed to treat of 2) and with mRS ≤3 from 21% to 43% (number needed to treat of 4), critically without increasing the absolute number of survivors left with the most severe disability, mRS 5 [8]. This pooled analysis remains the central evidence justifying early surgery in younger patients and underpins current guideline recommendations [9].

A later individual-patient-data meta-analysis extended pooling to DESTINY II and HeADDFIRST, confirming the mortality and shift-in-disability findings across a wider age range and reinforcing that the principal effect of surgery is to convert death into survival across the full spectrum of the mRS, including in patients who remain dependent [10]. Contemporary systematic reviews and meta-analyses of cohort and trial data, some using outcomes assessed at 3, 6 and 12 months, corroborate a consistent pooled effect favouring craniectomy on unfavourable-outcome measures, with a suggestion that the magnitude of benefit is somewhat attenuated in older patients [11]. A 2022 Cochrane review reached the same overall conclusion using the accumulated randomised evidence: surgical decompression reduces death and death-or-severe-disability, at the cost of more survivors with moderate-to-severe residual impairment [12].

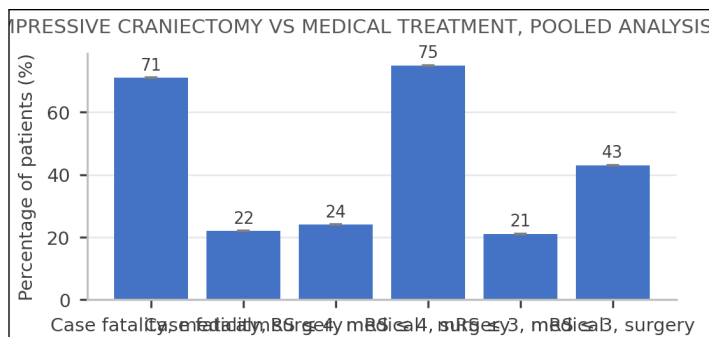


Figure 1: One-year outcomes in patients under 60 randomised within 48 hours, pooled analysis of DECIMAL, DESTINY and HAMLET: case fatality fell from 71% to 22%, mRS ≤4 rose from 24% to 75%, and mRS ≤3 rose from 21% to 43% with surgery versus medical treatment [8].

Older Patients: The DESTINY II Trial

The original trials excluded patients over 60, whose baseline prognosis and capacity for functional recovery differ substantially from younger patients. DESTINY II specifically randomised patients aged 61 and older with malignant MCA infarction to early craniectomy or medical management. At 12 months, survival was markedly higher with surgery (mortality 33% versus 70%), replicating the mortality effect seen in younger cohorts. However, the trial did not show a significant increase in survival without severe disability: very few patients in either group achieved mRS ≤3, and most surgical survivors remained at mRS 4 (dependent, requiring assistance with bodily needs) [13]. This result reframed the clinical question for older patients specifically as a tradeoff between survival and an outcome many would classify as severe disability, rather than a straightforward benefit as in younger patients, and it substantially shaped subsequent counselling and guideline language for this age group [14].

Timing of Surgery

Across the trial evidence, earlier intervention is consistently associated with better outcomes. HAMLET's stratified analysis showing benefit largely confined to surgery within 48 hours, versus no demonstrable benefit and a signal toward harm beyond that window, is the most

direct trial-level evidence for this effect [5,6]. The pooled and individual-patient-data analyses restricted their primary comparisons to patients randomised within 48 hours specifically because later intervention appeared to lose efficacy as irreversible herniation-related injury accumulates [8,10]. Commentary on this body of evidence has emphasised that decompressive craniectomy is fundamentally a race against a predictable secondary injury cascade, such that delay for observation of clinical deterioration — rather than early intervention on clinical and radiological criteria predicting malignant course — measurably erodes the achievable benefit [15].

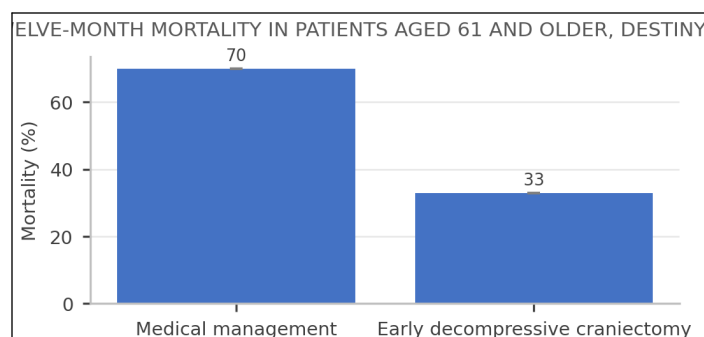


Figure 2: Twelve-month mortality in patients aged 61 and older randomised to early decompressive craniectomy versus medical management in the DESTINY II trial [13].

Dominant-Hemisphere Infarction and Language Outcome

Infarction of the speech-dominant (usually left) hemisphere was historically viewed with particular caution, given concern that aphasia would compound physical disability. Case-based evidence and literature review, however, indicate that meaningful recovery of language function is possible after dominant-hemisphere decompressive surgery, and that hemisphere laterality alone should not exclude patients from consideration for surgery when the other selection criteria are met [16]. Predictors of outcome identified in early cohort studies — age and pre-operative clinical status rather than infarct laterality or size alone — further support individualising

the decision rather than applying blanket exclusions [17].

Quality of Life and the Patient/Caregiver Perspective

A recurring finding across quality-of-life studies is that objective disability measured by the mRS or Barthel Index correlates only loosely with survivors' and caregivers' subjective assessment of quality of life: many patients with substantial physical disability nonetheless report their quality of life as acceptable [18,19]. Longer-term follow-up confirms that health status and life satisfaction, while reduced compared with the general population, are often rated more favourably by survivors than clinicians might predict from functional scores alone [20], though persistent neurobehavioural and neuropsychological deficits remain common and are less well captured by the mRS [21].

Table 2: Selected quality-of-life and patient/caregiver perspective studies in survivors of decompressive craniectomy for malignant middle cerebral artery infarction [18,22,23,25,27].			
Study	Population	Focus	Key finding
Foerch 2004	Survivors, single centre	Self-rated quality of life vs mRS/Barthel	Weak correlation; many disabled survivors rate QoL acceptable
Rahme 2012	Long-term survivors and caregivers	Retrospective consent	Most would consent to surgery again
Ragoschke-Schumm 2015	Elderly (>60y) vs younger survivors	Retrospective consent by age	Elderly families as or more likely to endorse surgery
Klein 2012	General population survey	Hypothetical preference	Only 2% would choose surgery if severe impairment expected
Honeybul 2016 (ORACLE)	Patients, families, clinicians	Definition of "acceptable" outcome	Wide, only partly reconcilable variation between groups

Two directly relevant retrospective-consent studies reinforce this pattern. Long-term survivors and caregivers surveyed by Rahme and colleagues largely indicated they would consent to the same surgery again, despite significant residual disability [22]. A separate cohort found that elderly survivors (over 60) and their families were, if anything, more likely than younger patients' families to retrospectively endorse the decision to operate, even though older survivors had worse functional outcomes on average [23]. The original Swedish prospective cohort combining hemicraniectomy with standardised neurointensive care similarly reported favourable long-term functional and satisfaction outcomes relative to what pre-operative disability scores alone would predict [24]. These findings sit in tension with prospective, hypothetical-scenario surveys: a German population-based survey found that only 2% of respondents who understood a scenario of anticipated severe impairment would choose surgery for themselves, though this rose sharply when only slight impairment was anticipated [25], and both patients with lived experience of stroke and their relatives tend to rate a broader range of disability states as acceptable than healthy control respondents predict they would [26]. Structured attempts to define what functional outcome patients, families and clinicians consider "acceptable" after surgery have likewise found wide and only partly reconcilable variation between these groups [27].

Guideline Recommendations and Clinical Practice

Current American Heart Association/American Stroke Association guidelines give a Class I recommendation for decompressive craniectomy in patients 60 years or younger with deteriorating malignant MCA infarction who can be treated within a defined time window, reflecting the strength and consistency of the pooled trial evidence in this group [9]. Recommendations for older patients are more qualified, given the DESTINY II tradeoff between

survival and independence, and guidelines and reviews alike emphasise that the decision in this age group should be shared with patients (via advance directives where available) and families rather than driven by age cutoffs alone [13,14]. Despite this guideline endorsement, uptake in routine practice remains inconsistent, with surveys of neurosurgeons and stroke physicians describing continued variation in perceived eligibility, timing thresholds and willingness to offer surgery outside the narrow age and time windows studied in the pivotal trials, underscoring a persistent gap between trial evidence and everyday decision-making at the bedside.

Conclusion

The randomised trial evidence, now more than a decade old but repeatedly reaffirmed by pooled, individual-patient-data and cohort analyses, establishes decompressive craniectomy as a highly effective means of preventing death from malignant MCA infarction, with the strongest and most favourable functional tradeoff in patients 60 years and younger operated on within 48 hours of stroke onset. In older patients, the same procedure confers a comparable survival benefit but a much smaller gain in independence, converting many deaths into survival with moderate-to-severe disability rather than into functional recovery. Dominant-hemisphere involvement need not itself be a contraindication. Critically, the quality-of-life and retrospective-consent literature consistently shows that survivors and caregivers judge their outcomes more favourably than functional scales, or hypothetical public preference surveys, would predict — a gap that should inform, rather than be overridden by, clinician judgement at the bedside. Individualised, values-based counselling that presents the realistic one-year distribution of outcomes, alongside what survivors themselves report about living with them, remains the most defensible basis for this time-critical decision.

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