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Decompressive craniectomy for traumatic brain injury: a review of recent landmark trials

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SUMMARY

Traumatic brain injury (TBI) is a leading cause of trauma-related morbidity and mortality worldwide, with decompressive craniectomy (DC) serving as a critical surgical intervention. This article reviews the recent studies evaluating the role of DC in the management of elevated intracranial pressures (ICPs) associated with TBI and its impact on functional outcomes. Decompressive Craniectomy in Diffuse Traumatic Brain Injury (DECRA), Randomized Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of intracranial pressure (RESCUEicp), and Randomized Evaluation of Surgery with Craniectomy for patients Undergoing Evacuation of Acute Subdural Hematoma (RESCUE-ASDH) are three landmark trials that used varying thresholds for surgical intervention after TBI and examined how functional outcomes improved with time. The DECRA trial evaluated early DC in patients with moderate ICP elevations, demonstrating reduced intensive care unit and hospital stays but poorer functional outcomes at 6 months. Conversely, the RESCUEicp trial emphasized the benefits of delayed DC as a rescue strategy for refractory ICP, showing reduced mortality and improved Glasgow Outcome Scale-Extended scores at 24 months. The RESCUE-ASDH trial compared DC and craniotomy for acute subdural hematoma, finding no significant differences in functional outcomes but distinct profiles of surgical complications. Key recommendations emphasize individualized decision-making based on patient-specific factors, including preinjury functional status and family involvement. This comprehensive review underscores the importance of tailoring DC timing and techniques to optimize functional recovery and align with patient-centered goals, advancing the multidisciplinary management of severe TBI.

INTRODUCTION

Traumatic brain injury (TBI) is one of the most common indications for brain surgery. Decompressive craniectomy (DC), where a portion of the skull is removed, and craniotomy, where an opening in the skull is created for the evacuation of blood and the skull flap is replaced in the same surgery, are the two most frequently completed procedures in brain-injured patients.[1] Although surgical intervention remains a large part of the management of severe TBI, indications and the optimal technical approach remain unclear. Several randomized controlled trials have recently been completed to see what therapies result in the best functional outcomes and better guide the surgical management of these patients. Functional outcomes are commonly scored by the Glasgow Outcome Scale (GOS) and the extended Glasgow Outcome Scale (GOSE).[2] GOS divides functional status into five categories, whereas GOSE further describes these using numeric values ranging from one representing death to eight demonstrating upper good recovery (table 1). GOSE can be measured at predetermined time intervals to assess functional progression after brain injury and is often used in TBI research.

DECOMPRESSIVE CRANIECTOMY

DC is a surgical procedure employed to alleviate elevated intracranial pressure (ICP) in patients with severe traumatic brain injury (TBI). Primary DC can be completed as an initial therapeutic option, and a secondary DC is completed as a rescue for elevated ICP refractory to tiered medical therapies. Primary DC is usually completed early for space-occupying lesions requiring evacuation due to significant mass effects and brain swelling. When performing a DC, technique and size matter. A large bone flap measuring at minimum 12–15 cm should be created.[3 4] An additional option may be a 'hinge' craniectomy, where the bone flap is elevated but remains secured in one area.[5] This still provides the advantages of DC with a reduction of ICP but eliminates the need for cranioplasty in the future which may be challenging in resource-limited areas.

LANDMARK TRIALS ON DC IN PATIENTS WITH TBI

DECRA TRIAL

This trial evaluated the role of early bifrontotemporoparietal DC versus medical therapy on functional outcomes in patients with severe non-penetrating TBI and elevated ICP after first-line therapy.[3] Patients were provided sedation, hyperosmolar therapies, carbon dioxide (CO_2) optimization, paralytics, and extraventricular drainage for sustained elevations of ICP. Refractory ICP elevations were defined as ICP >20 for more than 15 min in an hour. Randomization occurred within 72 hours of admission. Most underwent DC within 40 hours of injury.

The main finding was that patients undergoing a DC had less time with elevated ICP, required less treatment for elevated ICP, had less vent days (11 vs 15), less days in the ICU (13 vs 18), and less overall hospital length of stay (28 vs 37). Despite these positive markers, the DC group had significantly worse GOSE scores at 6 months with more unfavorable outcomes. Mortality remained similar at 6 months between groups. Overall, although ICP was

Table 1 GOS and GOSE scores and functional status interpretation

GOS score	GOSE score		Functional implications
Dead	1	Dead	
Vegetative state	2	Vegetative state	No consciousness; unaware of surroundings
Severe disability—full dependence for ADLs	3	Lower severe disability	Limited capacity to care for themselves to <8 hour; restricted to home
	4	Upper severe disability	Limited capacity to care for themselves all day; minimal function outside home
Moderate disability—some independence but requires assistance	5	Lower moderate disability	Unable to work OR participate in social events. Constant interpersonal issues
	6	Upper moderate disability	Limited work abilities OR reduced social participation. Frequent interpersonal issues
Good recovery—return to preinjury state	7	Lower good recovery	Mildly reduced work abilities OR minimal assistance with ADLs. Occasional interpersonal issues
	8	Upper good recovery	No limitations

ADL, activities of daily living; GOS, Glasgow Outcome Scale; GOSE, extended Galsgow Outcome Scale.

reduced in the DC group, GOSE scores at 6 months was worse, questioning the utility of early DC.

RESCUEicp Trial

This trial evaluated the role of DC versus medical therapy in refractory ICP, using DC as a rescue method once medical therapies had been maximized.[4] The goal was to maintain an ICP of 25 mm Hg or less. All patients in both groups were treated with tier 1 and 2 therapies. These included positional changes, optimizing CO_2, maximizing sedation and pain medications, and optional paralytic use. Second-tier therapies included osmotic agents and vasopressors to increase mean arterial pressure to enhance cerebral perfusion pressure, extraventricular drainage, and moderate hypothermia. If ICP remained >25 for 1–12 hours despite these interventions, patients were randomized into the DC or medical therapy groups. Medical treatments included continued management with tier 1 and 2 therapies with the addition of barbiturate infusion, which occurred in 88% of patients. Surgical options included large unilateral frontotemporoparietal craniectomy for those patients with hemispheric injury versus bifrontal craniectomy used in those with diffuse injury. Most DC occurred within 3 hours of randomization.

The DC group had a significant decrease in ICP and much lower time spent with elevated ICP >25 after the surgery compared with maximal medical therapy. The most important findings of RESCUEicp were that the DC group had significantly lower mortality rates at 6 months, 26.9% vs 48.9% in the medical therapy group. The survivors in the DC group also had higher GOSE scores at 6 months compared with the medical therapy group; however, a majority of surgical survivors remained in a vegetative state or had severe disability. This improvement in mortality and GOSE scores continued for 24 months after the initial injury.[6] In that time frame, a net improvement of GOSE ≥1 grade was noted in 30.4% of the surgical group versus 14.5% of the medical therapy group, demonstrating increased recovery potential in the DC group (table 2). One significant limitation was that over a third of medically managed patients underwent a DC as a life-saving procedure, which may have impacted the observed treatment effect.

RESCUE-ASDH Trial

Many think that removal of the bone with a DC after an ASDH will result in less postoperative intracranial hypertension and allow for brain swelling without tissue injury resulting in improved functional outcomes.[7] This trial assessed patient outcomes after a large DC measuring a minimum of 11cm versus a craniotomy in those requiring evacuation after an ASDH. Randomization occurred at the time of the operation. Patients with excessive brain swelling where replacing the bone was determined to be detrimental were excluded from randomization. In the craniotomy group, the bone flap was replaced and fixed to the surrounding skull at the time of the initial operation, when the DC group had their bone flap removed.

Overall, this study demonstrates that mortality is unchanged by replacing the bone flap at the initial operation. There were also no functional differences with GOSE scores at 12 months seen between groups. Wound-related complications, including surgical site infection, were more frequent in the DC group versus the craniotomy group (17 vs 4). Repeat surgical intervention within 2 weeks was required more often in the craniotomy versus DC group (28 vs 13) with 64% requiring DCs. Overall, this study demonstrates that it is okay to replace the bone flap at the time of initial surgery if it can be completed without compressing the brain tissue. This should only be done where close postoperative monitoring for elevated ICP can be completed, as approximately 10% of patients may require a return to the operating room for subsequent decompression via craniectomy.

The major points from these three trials are summarized in table 3.

Table 2 Randomized Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of intracranial pressure GOSE scores for 24 months

GOSE scores	1	2	3	4	5	6	7	8
Med TX 6 months	48.9%	2.1%	14.4%	8%	10.1%	9.6%	3.2%	3.7%
s/p DC 6 months	26.9%	8.5%	21.9%	15.4%	10%	13.4%	2.5%	1.5%
Med TX 24 months	54%	2.3%	12.6%	2.3%	5.7%	12.1%	5.2%	5.7%
s/p DC 24 months	33.5%	6.6%	14.8%	8.8%	10.4%	14.8%	7.7%	3.3%

GOSE, extended Glasgow Outcome Scale; Med TX, medical treatment; s/p DC, after decompressive craniectomy.

Table 3 Summary of randomized control trials

	DECRA[3]	RESCUEicp[4]	RESCUE-ASDH[7]
# Patients	DC=73; Med TX=82	DC=202; Med TX=196	DC=222; Craniotomy=228
Inclusion age	15–59	10–65	> 16
Mean age	24	33	48
Inclusion TBI	Severe TBI	TBI+↑ICP>25	ASDH+surgery
Randomization	After tier 1 TX	After tier 1+2 TX	ASDH evacuation
Treatment	DC versus MedTx	DC versus MedTx	DC versus craniotomy
Outcomes	DC: LESS time ↑ICP, ↓ ICU days GOSE scores at 6 months: DC worse, **↑unfavorable outcomes** GOSE scores at 12 months: no difference **No mortality difference**	DC at 6 months: **↓ mortality,** ↑ GOSE scores at 6 and 24 months	**No mortality difference** GOSE scores at 12 months: slight ↑ favorable for craniotomy group
Takeaway	**Early DC did NOT improve functional outcomes or decrease mortality**	**Rescue/ delayed DC DOES IMPROVE functional outcomes**	**Craniotomy is a good option versus DC for ASDH in patients without brain swelling**

ASDH, acute subdural hematoma; DC, decompressive craniectomy; GOSE, extended Glasgow Outcome Scale; ICP, intracranial pressure; MedTx, medical treatment; TBI, traumatic brain injury; TX, treatment.

BRAIN TRAUMA FOUNDATION: 2020 UPDATE TO DC RECOMMENDATIONS

The Brain Trauma Foundation has put forth three new Level IIA recommendations and has maintained the previously published Level IIA recommendation.[8]

1. Secondary DC in the setting of late, refractory ICP elevations is recommended to improve mortality and favorable outcomes (based on results of RESCUEicp).
2. Secondary DC for early refractory ICP elevation is NOT recommended to improve mortality and favorable outcomes (based on results of DECRA).
3. Large frontotemporoparietal DC (12–15 cm in diameter) is recommended for decreased mortality and improved neurological outcomes in patients with severe TBI (maintained from previous recommendations).
4. Secondary DC, either early or late, likely reduces ICP and length of ICU stay; however, the impact of this on functional outcomes is unclear.

DC is most beneficial in patients with 'good' brain function who have a clinical decompensation and decline in neurological examination that can be directly attributed to an elevated ICP event.

ADDITIONAL CONSIDERATIONS

Caring for severely brain-injured patients requires a multidisciplinary approach with shared decision-making with the family. Although DC for management of refractory intracranial hypertension does lead to increased survival, many of these patients still face significant limitations, with most requiring assistance or full-time care for activities of daily living.[9] Prior to moving forward with DC, the patient's family or surrogate decision-maker should be informed of the likely outcome and the low chance of the patient returning to their previous function. What may be an acceptable outcome for one patient may be unacceptable for another. Although it is challenging for a physician and surgeon to withhold a potentially lifesaving intervention, this must be balanced against the low odds of functional recovery. The decision to offer surgical decompression should be individualized with patient-specific factors taken into consideration.

TAKE HOME POINTS

- The DECRA trial aimed to assess the effectiveness of EARLY craniectomy in patients with TBI with moderate intracranial hypertension, (ICP >20 mm Hg for 15 min within 1 hour). DC reduced ICP, number of treatments, vent days, and ICU and hospital days, but was associated with worse functional outcomes.
- RESCUEicp demonstrated improved functional outcomes in the DC group when completed for sustained refractory ICP elevations >25 mm Hg after maximizing tier 1 and 2 medical therapies in the first 10 days after injury. Subjects undergoing DC had better GOSE scores at 6 months which continued to improve at 24 months.
- RESCUE-ASDH showed minimal differences in functional outcomes or mortality between DC versus craniotomy for ASDH. Notable was an increase in surgical site infections and wound complications in the DC group and more need for additional surgery in the craniotomy group.
- Key updates in the brain trauma foundation guidelines: recommend delayed secondary DC for late refractory ICP elevation.
- When performing a DC, ensure a large bone flap measuring ≥12 cm.
- Decisions regarding pursuing DC must be individualized and include the patient's surrogate decision-maker, be in the context of the patient's previous functional status and expressed advanced directives and provide informed projections on future functional outcomes.

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