

Functional Outcomes After Decompressive Craniectomy



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KEYWORDS

- Decompressive craniectomy • Brain injury rehabilitation • Functional outcomes
- Traumatic brain injury • Stroke

KEY POINTS

- Mortality rates, timing of surgery, postoperative complications, and expected functional outcomes are important considerations when counseling patients and families.
- There are a multitude of scales available for rating functional outcomes following decompressive craniectomy (DC).
- Disability following DC is a difficult concept to measure and compare, as scales often categorize patients into broad, indistinct categories of functional level.
- There is more work to be done in defining the prevalence, types, and severity of functional and cognitive impairments for patients who have undergone DC.

INTRODUCTION

Decompressive craniectomy (DC) is often required in the treatment of intracranial hypertension when nonoperative techniques fail and have been shown to minimize morbidity and mortality after closed brain injury. DC is a surgical procedure wherein a portion of the skull is removed, and the dura is opened to allow space for the brain to swell,¹ allowing for reduced intracranial pressure and lowering the rate of complications such as brain herniation and decreased cerebral perfusion pressures with resultant ischemia.² DC can be performed either as a primary procedure, where there is evacuation of an intracranial lesion in addition to DC,³ or as a secondary procedure for severe intracranial hypertension that is resistant to medical management.⁴ DC carries risks inherent to the initial procedure, such as infection, seizures,

hemorrhage, cerebral herniation, and cerebrospinal fluid leak, along with delayed risks that can develop weeks to months after the initial procedure, such as subdural hygroma, hydrocephalus, and syndrome of the trephined.⁵ Additionally, all patients subsequently undergo cranioplasty to replace the removed portion of the skull or to place an alternative such as titanium or custom-made implant. Despite the risks associated with these surgical procedures, DC and subsequent cranioplasty may improve survival in patients with stroke and brain injury. It should be noted, however, that there is a higher incidence of disability in survivors with DC.⁶

How is “disability” measured? The bulk of the relevant literature regarding outcomes following DC investigates the rates of mortality and “functional outcomes” with varying clinical measurement scales after DC. The most commonly

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Abbreviations

CRS-R	Coma Recovery Scale—Revised
DC	decompressive craniectomy
DOC	disorder of consciousness
FIM	functional independent measure
GOS	Glasgow Outcomes Scale
GOS-E	Glasgow Outcomes Scale—Extended
IPR	inpatient rehabilitation
MCS	minimally conscious state
mRS	Modified Rankin Scale
PSH	paroxysmal sympathetic hyperactivity
PTS	posttraumatic seizure
SoT	Syndrome of the Trepined
TBI	traumatic brain injury
UWS	unresponsive wakefulness syndrome

referenced outcome measures in the literature are the Functional Independent Measure (FIM), the Glasgow Outcomes Scale (GOS) or the updated Glasgow Outcomes Scale—Extended (GOS-E), the Modified Rankin Scale (mRS), and then less commonly, the Coma Recovery Scale—Revised (CRS-R) and the Disability Rating Scale.

The aims of this review are to summarize the current literature on functional outcomes after DC, describe the most commonly used outcome measures, and discuss the limitations of these outcomes. Additionally, the paper will discuss other considerations for reducing complications from a rehabilitation perspective.

FUNCTIONAL OUTCOME MEASURES IN NEUROREHABILITATION

Brain injury is a leading cause of disability due to a variety of cognitive, physical, and emotional sequelae. The use of functional outcome measures to objectively track a patient's cognitive, physical, and behavioral function over time allows health care professionals to track the efficacy of treatment, predict future care needs,⁷ and provide prognosis for long-term outcomes.⁸

Many scales exist to assess functional outcomes after brain injury, with the focus of the assessment primarily geared toward cognitive and physical measures. While an initial functional assessment may be done by a medical provider, the majority of functional outcomes assessments and tracking are done by therapy or nursing staff.

Scores are assessed at the time of initial evaluation and tracked throughout the hospital stay. The scores are documented for justification for ongoing medical and therapy needs, readiness for discharge to postacute care, and for outpatient and home care services.

The FIM (Tables 1 and 2) has historically been the most widely used and accepted functional

assessment in rehabilitation settings. It has been validated for a variety of rehabilitation diagnoses, including traumatic brain injury (TBI) and stroke. The assessment previously was performed on admission to and discharge from inpatient rehabilitation (IPR) facilities^{9,10} as an objective measure of progress. This scale consists of 18 measured items, including 13 motor tasks and 5 cognitive tasks. Each task is rated on a 7 point ordinal scale with total assessment scores ranging from 18 to 126 with higher scores consistent with more desirable, higher-functioning outcomes.¹¹ The scores indicate the level of external assistance a patient may need. Scores of 6 or higher in each subsection indicate no external help required for the task. Despite its widespread use, it has only 5 domains that directly address cognitive, behavioral, and communication issues, which limit its usefulness for TBI outcomes research.¹² Additionally, FIM scores may vary markedly between each subsection tested, so gathering an accurate assessment of the patient's overall clinical status based on one score is challenging. Currently, FIM scores are being phased out of TBI-related research and are no longer commonly reported. In 2019, Medicare transitioned from the FIM scores to quality metrics outlined in Section GG of the Continuity Assessment Record and Evaluation (CARE) Item Set, but due to the recent change, FIM scores are still a prevalent rehabilitation outcome measure in the literature. Future literature will need to be updated to reflect outcomes scoring according to Section GG's quality indicators.^{13,14}

The transition to Section GG was initiated to avoid discrepancies with how functional status, care, and services are evaluated and reimbursed across postacute care settings. While there are 7 self-care and 17 mobility items, there is only one item that directly relates to functional cognition which may potentially limit its usefulness for brain injury outcomes. While there is variation in scoring between the 2 scales, it should be noted that one is not more valid or accurate, but they were developed for different purposes—FIM scores for acute IPR and Section GG for the full postacute care continuum hospitals, acute IPR, skilled nursing, long-term care, and home health care. Further research is needed as to the full impact of Section GG on the evaluation and treatment of functional disabilities.

The most widely utilized and accepted primary outcome measurement after brain injury by the US Food and Drug Administration (FDA), Traumatic Brain Injury Clinic Trials Network, and interagency Traumatic Brain Injury Outcomes Workgroup is the GOS-E.^{7,15} The GOS was initially created in 1975 by Jennett and Bond¹⁶ and utilized

Table 1
Functional independence measures¹¹

Task	Level of Independence
Eating	1. Total dependence
Grooming	• Patient performs <25% of task
Bathing	2. Maximal assistance
Upper body dressing	• Patient performs <50% of the task
Lower body dressing	3. Moderate assistance
Toileting	• Patient performs 50% to 74% of the task
Bladder management	4. Minimal assistance/Contact Guard
Bowel management	• Patient performs 75% or more of the task
Bed to chair transfer	5. Supervision/setup
Toilet transfer	• Patient requires only standby assistance, cueing, or set up assistance
Shower transfer	6. Modified independence
Locomotion (ambulatory or wheelchair)	• Performs the activity safely and independently with an assistive device or with more than a reasonable amount of time
Stairs	7. Complete independence
Cognitive comprehension	• Performs the activity with no assistance, no assistive devices, and within a reasonable amount of time.
Expression	
Social interaction	
Problem solving	
Memory	

predominantly as an assessment of global outcomes as opposed to a scored system, which made standardization among clinicians a challenge. The GOS—extended (Table 3) expanded

upon the GOS to include Upper and Lower sub-sections, which more accurately stratify expected outcomes.¹⁷ This is an 8-point ordinal scale including death (1), vegetative state (2), lower severe disability (3), upper severe disability (4), lower moderate disability (5), upper moderate disability (6), lower good recovery (7), and upper good recovery (8) employing discrete categories to differentiate hierarchy of recovery.^{18,19} Although its generalizability makes it useful for research, consistent application has been difficult among different centers,¹⁹ and each GOS-E level captures a broad range of functional outcomes and may miss specific or meaningful clinical differences among individual patients.²⁰

Similar limitations exist for the mRS (Table 4), another commonly used outcome measure. The Rankin scale was initially developed in 1957²¹ and updated to the mRS in 1991.²² While it can be used for assessment after brain injury, the mRS is most used for evaluation of stroke severity and functional disability outcomes after stroke, a population for which the scale is extensively validated and highly reliable.^{23,24} The scale is intended to measure the degree of dependence or disability in performing activities of daily living by patients who have suffered a stroke or other causes of neurologic disability. It is a 7-point ordinal scale with zero being no disability and 6 indicating death. It is a clinician-reported scale and may be impacted by patient comorbidities and socioeconomic status. It is heavily weighted toward motor or physical disability and the need for assistance. The broad categories of mRS assess instrumental activities of daily living

Table 2
Functional independent measure items by category¹¹

Motor Items	Cognition Items
Self-care	Communication
• Eating	• Comprehension
• Grooming	• Expression
• Bathing	• Reading
• Dressing Upper/ Lower Body	• Writing
• Toileting	• Speech
• Swallowing	Intelligibility
Sphincter control	Psychosocial
• Bladder management	Adjustment
• Bowel management	• Social interaction
	• Emotional status
	• Adjustment to limitations
	• Employability
Mobility	Cognitive Function
• Bed/chair/wheelchair transfers	• Problem-solving
• Toilet transfer	• Memory
• Tub/shower transfer	• Orientation
• Car transfer	• Attention
• Walking/wheelchair locomotion	• Safety Judgment
• Stairs	
• Community access	

Table 3
Glasgow outcomes scale—extended^{17,19}

Score	Level of Disability	Criteria
1	Death	Death
2	Vegetative state	Prolonged unconsciousness with no verbalization, periods of spontaneous eye opening
3	Low severe disability	Dependent on daily support. Patient cannot be left alone >8 h per day
4	Upper severe disability	Dependent for daily support. Patient can be left alone >8 h per day but unable to shop or travel
5	Lower moderate disability	Independent in home setting, dependent in community setting. They are unable to return to work, unable to participate in social or leisure activities, or present with constant family and friendship problems
6	Upper moderate disability	Independent in home setting, dependent in community setting. They are able to return to work with a reduced capacity, limited social participation, or present with frequent family and friendship problems
7	Low good recovery	Resumption of normal life. Mild deficits in social participation, occasional family and friendship problems, or some mild symptoms affecting daily life
8	Upper good recovery	Resumption of normal life. No persistent symptoms

(eg, meal preparation, money management, shopping) and basic activities of daily living (eg, dressing, grooming, ambulation). The global nature of this scale allows the clinician to consider the impact of cognition, language, social functioning, and mood on perceived disability.²⁵ Similar to the GOS-E, the broad outcomes that could comprise each designation can miss clinically relevant differences.²⁶

Table 4
Modified Rankin scale^{21,22}

Score	Description
0	No symptoms
1	No significant disability despite symptoms; able to carry out all usual duties and activities
2	Slight disability: unable to carry out all previous activities but able to look after own affairs without assistance
3	Moderate disability: requiring some help but able to walk without assistance
4	Moderately severe disability: unable to walk without assistance, and unable to attend to own bodily needs without assistance
5	Severe disability: bedridden, incontinent, and requiring constant nursing care and attention

For patients with a disorder of consciousness (DOC) such as coma, unresponsive wakefulness syndrome (UWS, previously referred to as a vegetative state), or minimally conscious state (MCS), the most appropriate measure is the Coma Recovery Scale-Revised (**Table 5**). This scale consists of 6 subscales that assess auditory function, receptive and expressive language, visual perception, communication ability, motor function, and arousal level with scores ranging from 0 to 23.²⁷ Generally, higher scores are consistent with better outcomes, and a score of 10 or higher indicates consciousness. Consciousness in this context refers to achieving at least a MCS defined as “a condition of severely altered consciousness in which minimal, but definite, behavioral evidence of self or environmental awareness is demonstrated.”²⁸ While no definitive score has been outlined as a “good” outcome and scores are more trended over time to show improvements in this specific patient population, it is the only standardized assessment that incorporates criteria for coma, UWS, MCS, and emergence of consciousness. For this reason, it is strongly recommended for all studies involving patients with DOC.²⁹ The measure was revised in 2020 due to analyses demonstrating concerns for the psychometric characteristics and due to changes in diagnostic parameters pertinent to patients with disorders of consciousness, specifically clarification of features within the MCS.³⁰ The CRS-R, by design,

Table 5 Coma recovery scale—revised^{27,30}							
Subsection	0	1	2	3	4	5	6
Auditory Function Scale	None	Auditory startle	Localization to sound	Reproducible movement to command	Consistent movement to command	N/A	N/A
Visual Function Scale	None	Visual startle	Fixation	Visual pursuit	Object localization, reaching	Object recognition	N/A
Motor Function Scale	None	Abnormal posturing	Flexion withdrawal	Localization to noxious stimulation	Object manipulation	Automatic motor response	Functional object use
Oro-motor/Verbal Functional Scale	None	Oral reflexive movement	Vocalization/oral movement	Intelligible verbalization	N/A	N/A	N/A
Communication Scale	None	Nonfunctional/intentional	Functional- Accurate	Oriented	N/A	N/A	N/A
Arousal Scale	None	Eye opening with stimulation	Eye opening without stimulation	Attention	N/A	N/A	N/A

does not have the same challenges with interrater reliability as the initial GOS.^{27,31,32}

FUNCTIONAL OUTCOME AFTER DECOMPRESSIVE CRANIECTOMY

There are a wide variety of studies that have looked at outcomes after DC. This broad category includes everything from acute complications after surgery such as mortality, occurrence of late seizure, hemorrhage, hydrocephalus, infection etc. along with subacute “functional outcomes” that vary in length of follow-up time, assessment used, and score cutoffs to define “good” versus “poor” outcomes. This section of the paper will delve into functional outcomes after DC.

The literature on functional outcomes after DC includes the TBI population and the stroke population which, for the purposes of this paper, will include malignant ischemic stroke, intracerebral hemorrhage, spontaneous subarachnoid hemorrhage, and venous sinus thrombosis.

The effect of DC on mortality has mixed results in the literature. It has been shown in some studies to reduce mortality in patients suffering from elevated intracranial pressure refractory to maximal medical management,^{33–43} but others showed no difference in mortality when compared to more conservative management.^{44–50}

Functional outcomes also vary widely and range from full independence and return to preinjury function to dependency for all basic needs.⁴⁸ Many studies show improved functional outcomes, whether those results are statistically significant or not,^{3,4,33,35–38,40,43,44,51–55} but many of the results are not correlated with the DC itself, but other factors such as age, initial Glasgow Coma Scale (GCS), lesion size, etc., further discussed later. Most of the consistently “good” outcome studies are also found in the stroke population, with the TBI population showing mostly worse or equivalent functional outcomes as controls.^{47–49,56–60} Several studies were not controlled, but showed only 16% to 30% of patients post-DC with “good” outcomes.^{61–63}

Three major studies looked at mortality and functional outcomes after DC in stroke patients. DESTINY, DECIMAL, and HAMLET showed better mortality rates among DC patients and better, but not statistically significant, functional outcomes in this cohort as well.^{36,38,40}

Many of the studies did not find that the DC itself was predictive of mortality or “good” versus “poor” functional outcomes but did note other predictive factors such as age, timing of DC, size of DC, GCS etc.

Age appears to be predictive of outcomes with multiple studies noting patients above the age of

60 having worse mortality and functional outcomes after DC.^{3,35,43,50–53,57,58,61,63–68} Although, the DESTINY II trial by Jüttler and colleagues showed improved mortality and reduction in severe disability, as defined by an mRS ≤ 4 in patients greater than 61 year old with DC after malignant MCA stroke,³⁷ and Shen and colleagues showed no difference in mortality or functional outcome based on age.⁶⁴

Current literature also describes specific surgical factors associated with good or poor functional outcomes such as timing of DC after stroke, with “early” DC favored in most papers. In the case of DC after malignant ischemic stroke, DC within 24 to 48 hours of injury produced better outcomes in studies by Schwab and Vibbert and colleagues^{69,70} However, Schwab and colleagues used the Barthel Index and did not define their cutoff for a “good outcome” and Vibbert and colleagues utilized the mRS and considered scores ≤ 4 as a “good outcome” despite many other studies considering 4 or “moderately severe disability” a “poor outcome.” Additional studies were mixed in whether early DC improved mortality or functional outcomes, and although all studies utilized the mRS as their outcome measure, they varied in whether their cutoff for a “good” outcome was ≤ 3 or ≤ 4 .^{40,44,46,51,53,64,71}

The optimal timing of DC after TBI was assessed in the DECRA and RESCUE-icp trials, looking at DC for patients with “early refractory ICP elevation”⁴⁸ and patients with “late refractory ICP elevation.”⁵⁴ Based on the findings of DECRA, which showed no difference in mortality and worse functional outcomes at 6 months, DC for early refractory ICP is not recommended in the updated 2020 guidelines regarding DC after TBI.⁷² However, in the follow-up assessment of DECRA 2.0 in 2020, which extended follow-up to 12 months, there was still a higher portion of DC patients with “poor” functional outcomes, but the difference was no longer statistically significant. This led the authors to postulate that the benefits of DC or healing from complications after DC may require longer follow-up to see the benefits. RESCUE-icp showed a reduction in mortality at both the 6 month and 12 month timelines and favorable functional outcomes at 12month, although their definition of a “good” outcome on the GOS-E was 4 to 8, which includes “upper severe disability,” not usually considered a “good” outcome in the TBI literature.

The size of the surgical site has also been investigated with improved mortality and functional outcomes on the GOS at 6 and 12 months in patients with large frontoparietal DCs rather than “limited smaller temporoparietal craniectomy.”^{73,74} As a

result of these studies, the 2020 guidelines recommend a large frontoparietal DC of 15 cm in diameter.^{48,72} Interestingly, however, the RESCUE-ASDH trial did not find a difference in mortality or functional outcome when investigating decompressive craniectomy versus craniotomy with subdural hemorrhage evacuation alone.⁴⁹ Further studies are needed to see if craniotomies with subdural hemorrhage evacuation are acceptable alternatives to DCs.⁷⁵

Finally, a host of other factors have been investigated as they pertain to functional outcomes after DC as “poor” outcomes are seen with increased systolic blood pressure variability in the malignant stroke population⁷⁶; lower initial GCS score^{3,35,43,45,50,58,61,63,64,67,68}; larger midline shift, hematoma, or size of infarct^{4,45,64,66,71} and presence of intraventricular hemorrhage⁴⁵; or dominant hemisphere infarct.⁷¹

Very few studies mentioned patient outcomes after IPR. Hakiki and colleagues noted that DC patients had similar functional outcomes on the GOS-E and CRS-R by discharge from IPR, but it took twice as long to reach these outcomes as patients without DC.⁵⁹ Pingue and colleagues found in one study that DC was not a predictor of mortality or “poor” functional outcome after IPR when compared to control TBI patients without DC, but their other study looked at DC versus craniotomy and found worse functional outcomes after IPR correlated with DC. Pingue and colleagues, however, utilized the GCS and the FIM as the outcome measures and did not define the FIM value indicative of a “good” outcome.^{50,60} No other studies reviewed mentioned the use of IPR.

The GOS, GOS-E, and mRS were the most frequently used functional outcome measures found in this review. Nearly all stroke literature utilized the mRS, although they varied on what was considered a “good” outcome. Most reported ≤ 3 or “moderate disability” or better as a “good” outcome; however, some studies considered ≤ 4 or “moderately severe disability” or better as a “good” outcome.^{4,33,37,76} Almost all of the TBI literature utilized the GOS or the GOS-E and were fairly consistent with what was considered a “good” outcome (5–8) with only a few outliers. Goncalves and colleagues was stricter, using only GOS-E of 7 to 8 as a “good” outcome,⁵⁷ and Hutchinson and colleagues were more lenient with a GOS-E score of 4 to 8 considered a “good” outcome.⁵⁴ Predictably, Goncalves and colleagues showed worse outcomes after DC, whereas Hutchinson and colleagues showed improved outcomes.

The timing of assessing outcomes also differed considerably between the studies. It is generally accepted that the most rapid period of recovery

following TBI occurs in the first 3 to 6 months following the injury, however continued improvements in outcomes and the percentage of patients who achieve “good outcomes” (being defined as a GOS-E of 0–3 which translated to the ability to be independent in the home) can be seen up to 5 years postinjury.⁷⁷ Most DC studies reviewed followed up at 6 months or less, but some studies had follow-up extending to 1 year and beyond.^{33,36,40,44,47,49,52,54,56,57,65,71,78} Longer-term follow-up (greater than 12 months) was much less common^{34,43,55,61,79} despite brain injury literature noting improvements after 1 year.⁷⁷

REDUCING COMPLICATIONS—A REHABILITATION PERSPECTIVE

Once medically stable after an acute brain injury, the reduction of complications is key to improving future functional outcomes. Common complications following brain injury include pressure injuries, aspiration, venous thromboembolism, paroxysmal sympathetic hyperactivity (PSH), agitation or motor restlessness, seizures, and spasticity/joint contractures.

Prevention of secondary complications begins in the intensive care unit. For patients with a DOC or those with reduced volitional movements, interventions can be directed at complications that come from lack of movement or response to the patient’s environment. Rehabilitation measures are usually focused on reducing pressure injuries, spasticity and joint contractures, aspirations, and blood clots. Additional consideration should be given to ocular care in patients with reflexive eye opening or incomplete eye closure, putting them at risk for corneal injury. Risk reduction strategies include frequent repositioning, regular passive or active range of motion, oral antispasmodics (eg, baclofen, tizanidine, or dantrolene) or chemodenervation in the event of spasticity development, eye lubrication and assisted closure with tape or gauze, adequate oral hygiene, swallow assessments and modified diets, and prophylaxis (chemical or mechanical) against deep venous thrombosis.

Other complications after brain injury that can affect DC patients include PSH, agitation, and seizures.

PSH, also commonly referred to as “storming,” is a condition that can occur within the first few weeks after brain injury and is characterized by hyperthermia, tachycardia, hypertension, diaphoresis, posturing, and agitation. Its pathophysiology is not fully understood but is assumed to be related to loss of sympathetic inhibition and lack of parasympathetic antagonism.^{80–82} PSH is a

diagnosis of exclusion, as it can mimic many other conditions, such as infection, sedation withdrawal, pain, and neuroleptic malignant syndrome, to name a few. Early identification and treatment of PSH, when present, is paramount as it is associated with prolonged hospital stays and poorer neurologic outcomes.⁸³

Agitation can occur in over half of patients with brain injury and occurs in patients with posttraumatic amnesia.⁸⁴ It is characterized by “restlessness, perseveration, impulsivity, emotional lability and aggression,” causes a safety risk for patients and staff, and is associated with longer rehabilitation stays and decreased engagement in rehabilitation.^{85,86} In post-DC patients, agitation can pose a greater risk as impulsivity, motor restlessness, and aggression can put patients at risk for hitting their surgical site and damaging their exposed brain tissue. Management of agitation requires a combination of environmental modification and pharmacologic treatment, but just as important is educating staff on how to de-escalate agitated patients. This patient population is treated differently than delirious or psychotic patients, although their presentations may seem similar.^{84,85,87}

Posttraumatic seizures (PTS) have been widely studied due to an incidence of up to 17% following severe TBI (defined as GCS of 8 or less).⁸⁸ Seizures are subdivided into 3 categories based on timing: immediate (within initial 24 hours of injury), early (24 hours to 7 days after injury), and late (any seizures >7 days after injury). Current clinical guidelines support antiseizure prophylaxis following severe TBI due to effectiveness in preventing early PTS.^{89,90} The exact optimal timing of prophylaxis remains unclear, but no clinical benefit has been demonstrated for its use longer than 1-week postinjury. Avoiding iatrogenic factors that would increase seizure risk such as medications that lower seizure threshold like amantadine and tramadol, metabolic abnormalities (eg, hyponatremia), and sleep deprivation among others are considerations clinicians must consider as well.

Risks specific to DC patients include injury to the craniectomy site and Syndrome of the Trepined or “Sinking Skin Flap Syndrome/Sunken Flap Syndrome.” These are often encountered during the rehabilitation phase, and physicians should be aware of ways to mitigate these risks.

Regarding direct injury to the craniectomy site, all patients should have a helmet and instructions from the surgical team about when to wear the helmet, for example, at all times, when out of bed etc. If patients are impulsive, motor restless, and/or not oriented and at risk of getting up

without supervision or when the helmet is doffed, use of bed alarms, chair alarms, virtual monitoring, physical 1:1 supervision, or enclosure beds should be employed to maximize safety. As discussed above, medications to address agitation/motor restlessness may also be helpful in these cases.

Syndrome of the Trepined (SoT) is another complication that can occur after DC. It is characterized by functional or cognitive worsening after craniectomy and can be associated with a “sinking skin morphology, a radiologic, and clinical sign” with temporary improvement in symptoms in the supine position.⁹¹ Symptoms that have been associated with SoT include “headache, dizziness, pain/discomfort at the craniectomy site, apprehension, and/or mental depression” although in the systematic review by Ashayeri and colleagues, motor weakness was the most commonly reported symptom, present in 57% of patients and cognitive decline the second most in 47%. Headache was only noted in 19%.⁹² Unfortunately, there are no well-defined diagnostic criteria that can consistently identify SoT as difficult. In the study by Sveikata and colleagues, 65% of patients were found to suffer from SoT⁹¹ and in a systematic review by Ashayeri and colleagues, the average time between craniectomy and onset of symptoms was around 5 months with a wide range of onset (3 days to 7 years).⁹² In addition, Sveikata and colleagues found 2 cohorts of SoT patients; those who developed new neurologic symptoms or deteriorated clinically before their cranioplasty and then showed improvement within 4 days after cranioplasty, and those who did not develop new neurologic symptoms but failed to progress in rehabilitation and who improved within 4 days after cranioplasty. It is important for physicians to be aware of the latter group as it is a more subtle presentation of SoT that may be missed, and increasing delay to cranioplasty has been found to be “independently associated with less neurologic improvement.”⁹¹

FUTURE CONSIDERATIONS

After reviewing the literature on functional outcomes following DC, the need for more research is clear. Much of the work that has been done to date is limited in its scope regarding delineation of long-term functional outcomes (greater than 6–12 months), assessing outcomes after utilization of aggressive rehabilitation, and establishing consistent standards by which we assess functional outcomes and quality of life with particular attention to investigating patient-reported outcome measures in addition to physician assessments. Many of the available studies evaluating functional

outcomes following DC are performed using assessments that place patients into broad function-based categories, often at the expense of nuance and individualization of functional assessment. It is common practice for outcomes to be designated loosely as “good” or “acceptable” as opposed to “poor” or “unacceptable” to simplify statistical analysis and interpretation. However, there is no universally accepted definition of a “good” outcome for this patient population. While the GOS-E has an established cutoff for a good outcome (>5), other commonly used measures (eg, CRS-R, FIM) lack well-described numerical cutoffs that help to define those distinctions between “good” and “poor” functional outcomes. This lack of standardization has resulted in multiple trials using the same functional scales but differing on the numerical cutoffs defining their outcomes.⁹³

There currently exists no all-encompassing assessment for patients who have undergone DC that encapsulates the level of consciousness, rate of neurologic recovery, objective changes in rehabilitation measures of function, long-term functional outcomes, and quality of life. As a result, surgical specialists, researchers, and rehabilitation clinicians are often left to sift through incongruent and, at times, disjointed data sets to guide comprehensive management and counseling for these patients and their families.²⁰ Although clinical decision-making regarding the need for DC is often based on measures of intracranial pressure and imaging findings, there may also be added utility in shaping those decisions around the expected quality of life, mortality estimates, and risk of postoperative complications.

SUMMARY

Much of the literature shows equivocal or improved mortality and functional outcomes after DC in both stroke and TBI patients. While the majority of studies utilize consistent outcome measures and cutoffs for what is considered a “good” outcome, there is still variation in many studies, along with limitations in the follow-up timeline and adequacy of the outcome measures to fully address the functional status, not to mention quality of life, of the patients. Further studies are needed to assess the appropriateness of the existing outcome measures to address the functional status of patients based on their function and their quality of life.

CLINICS CARE POINTS

- Mortality rates, timing of surgical intervention, risk of post-operative complications,

and expected functional outcomes are important considerations when counseling patients and their families before deciding to pursue decompressive craniectomy.

- There are a multitude of scales available for rating functional outcomes following decompressive craniectomy, none of which are all-encompassing.
- Disability following decompressive craniectomy is a difficult concept to measure as scales often group patients into broad, indistinct categories of functional level.
- More work is needed to define prevalence, types, and severity of cognitive impairments for patients who have undergone a decompressive craniectomy procedure.

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