SURGICAL MANAGEMENT OF TRAUMATIC PARENCHYMAL LESIONS

M. Ross Bullock, M.D., Ph.D.
Department of Neurological Surgery,
Virginia Commonwealth University
Medical Center,
Richmond, Virginia

Randall Chesnut, M.D.
Department of Neurological Surgery,
University of Washington
School of Medicine,
Harborview Medical Center,
Seattle, Washington

Jamshid Ghajar, M.D., Ph.D.
Department of Neurological Surgery,
Weil Cornell Medical College of
Cornell University,
New York, New York

David Gordon, M.D.
Department of Neurological Surgery,
Montefiore Medical Center,
Bronx, New York

Roger Hartl, M.D.
Department of Neurological Surgery,
Weil Cornell Medical College of
Cornell University,
New York, New York

David W. Newell, M.D.
Department of Neurological Surgery,
Swedish Medical Center,
Seattle, Washington

Franco Servadei, M.D.
Department of Neurological Surgery,
M. Bufalini Hospital,
Cesena, Italy

Beverly C. Walters, M.D., M.Sc.
Department of Neurological Surgery,
New York University
School of Medicine,
New York, New York

Jack Wilberger, M.D.
Department of Neurological Surgery,
Allegheny General Hospital,
Pittsburgh, Pennsylvania

Reprints requests:
Jamshid Ghajar, M.D., Ph.D.,
Brain Trauma Foundation,
523 East 72nd Street,
New York, NY 10021.
Email: ghajar@braintrauma.org

RECOMMENDATIONS

(see *Methodology*)

Indications

- Patients with parenchymal mass lesions and signs of progressive neurological deterioration referable to the lesion, medically refractory intracranial hypertension, or signs of mass effect on computed tomographic (CT) scan should be treated operatively.
- Patients with Glasgow Coma Scale (GCS) scores of 6 to 8 with frontal or temporal contusions greater than 20 cm^3 in volume with midline shift of at least 5 mm and/or cisternal compression on CT scan, and patients with any lesion greater than 50 cm^3 in volume should be treated operatively.
- Patients with parenchymal mass lesions who do not show evidence for neurological compromise, have controlled intracranial pressure (ICP), and no significant signs of mass effect on CT scan may be managed nonoperatively with intensive monitoring and serial imaging.

Timing and Methods

- Craniotomy with evacuation of mass lesion is recommended for those patients with focal lesions and the surgical indications listed above, under Indications.
- Bifrontal decompressive craniectomy within 48 hours of injury is a treatment option for patients with diffuse, medically refractory posttraumatic cerebral edema and resultant intracranial hypertension.
- Decompressive procedures, including subtemporal decompression, temporal lobectomy, and hemispheric decompressive craniectomy, are treatment options for patients with refractory intracranial hypertension and diffuse parenchymal injury with clinical and radiographic evidence for impending transtentorial herniation.

KEY WORDS: Coma, Computed tomographic parameters, Craniotomy, Decompressive craniectomy, Head injury, Herniation, Intracranial pressure monitoring, Parenchymal mass lesion, Surgical technique, Timing of surgery, Traumatic brain injury

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OVERVIEW

Traumatic parenchymal mass lesions are common sequelae of traumatic brain injury (TBI), occurring in up to 8.2% of all TBI (37) and 13 to 35% of severe TBI, (6, 35, 44, 47, 57, 58) and comprising as much as 20% of operative intracranial lesions in representative series (44, 68). Most small parenchymal lesions do not require surgical evacuation (18, 19, 57). However, the development of mass effect from larger lesions may result in secondary brain injury, placing the patient at risk of further neurological deterioration, herniation, and death (6). Because parenchymal lesions tend to evolve, (36, 54, 55, 58) and because timing of surgery with respect to the occurrence of neurological deterioration clearly affects outcome (41), much effort has been directed at defining patients at risk of progressive neurological compromise as a result of their traumatic injuries (6, 50). Becker et al. (3) advocated early evacuation of traumatic intracranial hematomas and contusions for the purpose of avoiding secondary complications. A selective approach was envisioned by Gallbraith and Teasdale (18), who stated, "if those who are going to deteriorate could be identified soon after the hematoma has been detected they could be operated on immediately without incurring the risks of delay, and the remainder would be spared unnecessary operation." The literature addressing these issues in the CT era is reviewed here in an attempt to define appropriate surgical indications, methods, and timing for the patient with traumatic parenchymal injuries.

Although the majority of relevant data retrospectively addresses prognostic variables, differential classification, and clinical course of parenchymal lesions, several studies attempt to assess the efficacy of surgical intervention in a retrospective, historically controlled fashion. Only one randomized, controlled trial has been published (61). In addition, the topics of delayed traumatic intracerebral hematoma (DTICH) and decompressive operations for diffuse parenchymal injury and persistent intracranial hypertension deserve specific consideration, and are also addressed here.

PROCESS

A MEDLINE computer search using the following key words: "intracerebral" or "intraparenchymal" or "ICH" or "IPH and "hematoma" or "hematoma" or "hemorrhage" and "surgery" or "craniotomy" or "craniectomy" or "burr hole" or "craniostomy" and "trauma" or "traumatic" or "TBI" or "CHI" between 1975 and 2001 and limited to humans was performed. A total of 330 documents were found. An additional search using the following key words: "brain" or "cortex" and "laceration" between 1975 and 2001 was performed, yielding 101 additional articles. This search was narrowed to include the following key words: "surgery" or "operative" or "craniotomy" or "craniectomy" or "decompressive craniectomy" or "repair" and "outcome," yielding 49 articles. A third search using the following key words: "contusion" or "hemorrhagic contusion" and "brain" and "surgery" or "craniotomy" or "craniectomy" or "burr hole" or "craniostomy" was performed, yielding 174 articles. A fourth search, using the key words "DTICH" or "DTIPH," yielded 11 articles. A fifth search, using the key word "TICH," yielded eight articles. All five searches were combined. Duplicates between searches were discarded. A total of 495 references resulted. In addition, the reference lists of selected articles were reviewed, and a total of 51 articles were selected for critical analysis. The results of this analysis were incorporated into the review presented here. Papers primarily addressing the following topics were not included: nontraumatic lesions (e.g., spontaneous intraparenchymal hemorrhage or infarction), patients with other associated nontraumatic lesions (e.g., tumors or arteriovenous malformations), posttraumatic aneurysms, chronic lesions, penetrating trauma, carotid-cavernous fistulae, patients undergoing anticoagulation therapy, patients with associated illnesses (e.g., acquired immunodeficiency syndrome; concomitant infection; hemophilia; thrombotic thrombocytopenic purpura; or hemolysis, elevated liver enzymes, and low platelet count), pregnant patients, birth trauma, traumatic intraventricular hemorrhage, traumatic hydrocephalus, external ventricular drainage, sagittal sinus injury, pre-CT era reports, and book chapters. Papers with the following characteristics were also excluded: case series with fewer than 10 patients evaluated by CT scan and with incomplete outcome data (mortality or Glasgow outcome score [GOS]), case reports, operative series with operations occurring greater than 14 days from injury. Posterior fossa parenchymal injuries are addressed in *Surgical Management of Posterior Fossa Mass Lesions*. Selected articles were evaluated for design, prognostic significance, therapeutic efficacy, and overall outcome. In addition, several articles were reviewed for the purposes of historical perspective.

SCIENTIFIC FOUNDATION

Traumatic Parenchymal Lesions

Traumatic parenchymal lesions are a heterogeneous group, and are traditionally divided into focal and nonfocal lesions. Focal lesions include intracerebral hematomas (ICH), DTICH, contusions, and infarctions. Nonfocal lesions include cerebral edema, hemispheric swelling, and diffuse injury. Although these lesions often do not occur in isolation, their presence has been shown to adversely affect prognosis (16, 44). Indeed, Fearnside et al. (16) prospectively collected data on 315 severely head-injured patients and found that "the model which provided the most accurate prediction of poor outcome included age, hypotension and three different CT characteristics: subarachnoid blood, ICH or intracerebral contusion (accuracy 72.5%)." Parenchymal lesions have been further subclassified by multiple authors, and outcome has clearly been shown to differ among lesion types (19, 35, 39–41, 44, 65). Marshall (39) demonstrated that CT-defined injury type was a highly significant independent predictor of mortality, even when age and GCS motor score were included in the predictive model. Given the heterogeneity of the pathophysiology and prognostic significance of "parenchymal" lesions, the task of defining clear surgical indications and methods becomes difficult.

Prognostic Factors

Despite proven differences among lesion types, outcome within the broad category of "parenchymal" lesions correlates with known prognostic variables of TBI in general (5). These include age (26, 44, 45, 56, 58, 66, 70), admission or postresuscitation GCS (6, 19, 23, 40, 44, 45, 49, 51, 58), presence of cranial fracture (56), presence of pupillary response/brainstem reflexes (7, 44), respiratory insufficiency (8), ICP (6, 7, 23, 39, 44, 50, 51), and the status of the basal cisterns (6, 41, 62) or third ventricle (6, 41, 62) on CT scan. Moreover, other variables significantly correlate with outcome. These include location of the lesion (2, 32, 50, 58), ICH volume (8, 63), GCS at time of follow-up CT (63), lowest recorded GCS (7), severity of surrounding edema (6), timing of surgery (41, 51, 53), occurrence of preoperative neurological deterioration (41), and presence of acute hemispheric swelling or concomitant subdural hematoma (7, 35). Although their study included nontraumatic lesions, Andrews et al.

(2) showed that patients with a temporal or temporoparietal ICH of 30 cm^3 or greater, as defined by product of anteroposterior, mediolateral, and superoinferior diameters on CT scan, were significantly more likely to develop signs of brainstem compression or tentorial herniation, implying that these patients should undergo early evacuation of the offending mass lesion. However, these prognostic variables alone do not define the patient who should undergo operative intervention.

Operative Indications

As stated above, in Overview, several studies have focused on defining the patient at risk for subsequent neurological deterioration, making the assumption that operative intervention for this patient will improve the likelihood of a more favorable outcome. Predictors of failure of nonoperative management (defined by subsequent neurological deterioration and need for craniotomy) include lesion location (50), intracranial hypertension (6, 18, 50), presence of subarachnoid hemorrhage (41), cisternal effacement (41), lesion volume (41), and hypoxic events (41).

Bullock et al. (6) prospectively studied 85 patients with ICH whose initial need for craniotomy was uncertain. These patients underwent ICP monitoring in an attempt to better define the need for surgical intervention. The authors then retrospectively reviewed the CT scans of those patients for whom ICP monitoring failed to predict late deterioration and, thus, the need for ICH evacuation. With multiple linear regression analysis, they found the peak ICP to be the strongest predictor of outcome. However, ICP monitoring failed to predict late deterioration or death secondary to high ICP in 5 of 30 patients who did not undergo initial surgery. After critical analysis of CT factors, they concluded that the decision to operate "should be based on a spectrum of clinical, CT scanning and ICP findings". CT and clinical predictors included cisternal status, edema severity, and admission GCS. Interestingly, the authors found that the weight of each predictor depended on the location of the ICH. For temporoparietal lesions, hematoma size, degree of edema, GCS, basal cistern status, and ICP data correlated with outcome. However, for frontal lesions, peak ICP alone was predictive of outcome. These findings expand on those reported by Gallbraith and Teasdale (18), who found that all patients with "intradural" lesions (including subdural hematoma, ICH, and "burst lobes") and sustained ICP greater than 30 mm Hg, versus only one patient with an ICP less than 20 mm Hg, required operative intervention, as defined by clinical deterioration or failure to improve in the setting of increased ICP.

Mathiesen et al. (41) reviewed data collected prospectively for the Head Injury Trial-2 nimodipine trial on 218 TBI patients not obeying commands within 24 hours of injury. These authors found that the initial CT characteristics of presence of subarachnoid hemorrhage, presence of focal lesion with volume greater than 40 cm^3, and compressed or absent cisterns were associated with neurological deterioration, defined as a fall in GCS by 2 points or from 4 to 3, or as the development of pupillary dilation. They also found that the incidence of secondary (greater than 5 d after injury) deterioration was associated with the occurrence of hypoxic events. The occurrence of neurological deterioration, in turn, was found to adversely affect outcome from craniotomy, suggesting that patients with factors strongly associated with neurological deterioration should be considered for early surgery (i.e., before the onset of neurological deterioration). The authors directly demonstrated that a subgroup of patients with admission GCS of at least 6 and focal lesion volume of at least 20 cm^3 who underwent surgery without previous neurological deterioration had significantly better outcomes compared with those who either did not undergo surgery or who underwent surgery after deterioration. Furthermore, if a radiological sign of mass effect (i.e., compression or obliteration of the cisterns and/or a midline shift $\geq$ 5 mm) was present, craniotomy significantly improved the outcome in this group. Craniotomy was also directly shown to improve outcome in a small subgroup of patients with admission GCS of at least 10, temporal contusions, and a radiological sign of mass effect (i.e., a midline shift and/or compression or obliteration of the basal cisterns. Additionally, patients admitted with a GCS of at least 6 and a lesion volume of at least 50 cm^3 had better outcome with surgery before or immediately after deterioration than without surgery or with delayed operation.

Although the goal of identifying those patients who are likely to deteriorate neurologically is paramount, the question of whether surgery itself is beneficial remains unanswered. Few studies compare surgical outcome with matched, nonsurgically managed controls. In a retrospective study of 21 patients with frontal lobe contusions and medically intractable intracranial hypertension (>40 mm Hg), mortality was significantly decreased in the surgical group compared with a nonsurgical historical group (22% versus 88%, respectively) (28). These patients were matched for age, sex, GCS, and ICP levels, although statistics for these variables are not provided by the authors. Choksey et al. (8) retrospectively reviewed 202 patients with traumatic ICH and showed, with logistic regression analysis, that craniotomy significantly improved the probability of good outcome. Factors taken into consideration for this analysis included low GCS and hematoma volume greater than 16 cm^3, each of which independently predicted poor outcome in these patients. Several other studies examine outcome relative to specific decompressive procedures, and are discussed in the surgical treatment section.

For the purposes of CT classification, Marshall (39) defined a "mass lesion" as a lesion of volume greater than 25 cm^3. They showed differential outcome between patients with evacuated and nonevacuated mass lesions (23% versus 11% favorable outcome, respectively) in a series of 746 severe TBI patients (i.e., after resuscitation, GCS $\leq$ 8). In contrast, a recent paper from the European Brain Injury Consortium (54) evaluating a series of 724 TBI patients with a GCS of 3 to 12 showed a 45% rate of favorable results in evacuated mass lesions versus 42% in nonevacuated mass lesions using the same classification system. Sample size between these two studies was noticeably different: the former series included 276 patients with evacuated mass lesions and 36 with nonevacuated mass lesions, whereas the latter included 195 and 148 patients, respectively. These studies reviewed illustrate that a classification system based solely on lesion volume is unable to consistently show the relationship between surgery and outcome. Surgical indications are, in fact, related to many factors, including CT parameters (i.e., volume, midline shift, and basal cistern compression), clinical status, and the occurrence of clinical deterioration, among others.

One fundamental problem in using initial CT parameters as independent indications for surgery is that CT pathology has clearly been shown to be a dynamic process. Using the Traumatic Coma Data Bank classification system (39), Lobato et al. (36) showed that 51.2% of 587 severely injured patients (GCS $\leq$ 8) developed significant changes between initial and "control" CT scans, the latter of which more accurately predicted outcome. Similarly, Servadei et al. (54) showed that 16% of moderately-to-severely injured patients (GCS of 3–12) with diffuse injury showed radiological progression across Traumatic Coma Data Bank classes. Yamaki et al. (69) showed that only 56% of ICH greater than 3 cm in diameter developed within 6 hours of injury, and that only 84% of ICH reached maximal size within 12 hours. These studies highlight the dynamic nature of parenchymal injuries and the dangers inherent in placing too much emphasis on a single, static CT scan for management decisions.

The data reviewed shows that there are subpopulations of patients with traumatic intraparenchymal lesions that will benefit from surgical intervention. However, the precise characteristics of these subpopulations are not, as yet, clearly defined. The literature supports taking into account an amalgam of clinical and radiographic criteria, including GCS, location, volume, CT appearance, ICP, and the presence of neurological deterioration, to make an informed decision to subject a patient with a parenchymal lesion to a craniotomy. It seems that all factors must be taken into consideration to best define the patient population that will benefit from surgery.

DTICH

ICH have been shown to evolve over time (55, 58, 69). The entity of DTICH was initially described by Bollinger in 1891 (4), and is now defined by most authors as occurring in areas of radiographically normal brain in patients with otherwise abnormal initial CT scans (20, 22, 59, 63). It is defined by Gentleman et al. (20) as a ″lesion of increased attenuation developing after admission to hospital, in a part of the brain which the admission CT scan had suggested was normal″. Other authors, however, have noted DTICH to occur in areas of contusion on initial, high-resolution CT scan (72). The incidence of DTICH ranges from 3.3 to 7.4% in patients with moderate-to-severe TBI (15, 20, 22, 29, 59, 63). Evacuated DTICH represent approximately 1.6% of all evacuated traumatic ICH (20), and mortality ranges from 16 to 72% (15, 20, 22, 59, 63) Therefore, the importance of careful monitoring and of serial CT scanning cannot be overemphasized (55, 63, 72).

In a retrospective review of 32 patients with DTICH, Tseng (63) found that greater lesion volume, cisternal compression, earlier timing of appearance, occurrence of clinical deterioration, and lower GCS at time of a second, follow-up CT adversely affected outcome. Mortality occurred only with clinical presentation of DTICH within 48 hours of injury. In this small series, no patient with DTICH requiring craniotomy presented after 72 hours of injury. Sprick et al. (59) similarly found that approximately 70% of clinically significant DTICH presented within 48 hours of injury. Additionally, DTICH has been shown to be significantly associated with an increased incidence of secondary, systemic insults (22), an increased incidence after decompressive surgery for other mass lesions (22), and an increased incidence of abnormal clotting parameters (29), suggesting a complex etiology for this lesion beyond the mechanical disruption of the parenchyma (22, 27).

Although DTICH is most likely a distinct pathophysiological entity, it is still a parenchymal lesion from which many patients either fail to recover or clinically deteriorate. The findings of Mathiesen et al. (41) indicate that patients with intracerebral lesions undergoing surgery before neurological deterioration have improved outcomes. It follows logically that a subset of DTICH patients would benefit from rapid surgical intervention after discovery of the lesion. However no CT-era studies have critically examined surgical outcome. Because the majority of studies show that all patients who develop clinically relevant DTICH have abnormal initial CT scans (20, 63, 72), it is essential that patients with initially abnormal scans undergo intensive monitoring and serial imaging to ensure rapid intervention, if necessary.

Surgical Methods

The standard surgical treatment of focal lesions, such as intracerebral hemorrhages or contusions, is craniotomy with evacuation of the lesion. Location of the lesion and proximity to critical structures are considerations when contemplating the choice of surgical options. Evacuation of traumatic mass lesions is often effective in amelioration of brain shift and reduction of ICP, and can decrease the requirement for intensive medical treatment. Other methods, such as stereotactic evacuation of focal mass lesions, have also been used, although much less commonly (12). These procedures, however, become less effective when the patient's intracranial pathology is diffuse and involves intracranial hypertension as a result of posttraumatic edema or hemispheric swelling—factors known to be associated with poor outcome (6, 19, 35, 38, 44, 51). Even with focal ICH, a significant proportion of patients have medically intractable intracranial hypertension after standard craniotomy, and these patients fare the worst (44).

Surgical Treatment of Intracranial Hypertension

Rationale

A variety of operations have been developed for, or applied to, decompression of the brain at risk for the sequelae of traumatically elevated ICP. These include Cushing's subtemporal decompression (13), temporal lobectomy (34, 48), manual reduction of the temporal lobe (64), circumferential craniotomy (9), and the more widely used hemispheric decompressive craniectomy (52) and bifrontal decompressive craniectomy (30). The rationale for such an approach is supported from a physiological perspective by both human and animal studies. Particular attention has been directed at the study of changes in ICP and CT scan features, such as cisternal effacement and midline shift, after decompression, with the goal of correlating significant postoperative reduction of these parameters with improved outcome.

Hatashita and Hoff (25) showed that decompressive frontoparietal craniectomy in cats led to significant reduction in ICP, reduction in cortical gray and white matter tissue pressure, increased pressure-volume index, and increased tissue compliance. The authors found that craniectomy significantly increased the volumetric compensatory capacity of the intracranial cavity, a finding consistent with those of Hase et al. (24), in which ventricular catheter ICP measurements in 47 severe TBI patients, 33 of whom underwent external decompression, documented a dramatic increase in intracranial compliance after decompression. Yoo et al. (71) studied intraoperative ventricular pressures in a cohort of 20 patients with refractory intracranial hypertension after both traumatic and nontraumatic insults who underwent bilateral frontotemporoparietal decompressive craniectomy with dural expansion and grafting. These authors found a 50.2 ± 16.6% reduction of initial ICP after craniectomy, and a further reduction to 15.7 ± 10.7% of initial ICP after dural opening.

Polin et al. (51) showed a significant decrease in ICP after bifrontal decompressive craniectomy, as well as a significant difference in postoperative ICP when compared with ICP measured 48 to 72 hours after injury in a cohort of historically matched controls. Gower et al. (21) found that 7 of 10 patients who underwent subtemporal decompression for medically refractory intracranial hypertension had an average decrease in ICP of 34%. Kunze et al. (33) found a reduction in mean ICP from 41.7 to 20.6 mm Hg in 28 patients after unilateral or bilateral decompressive craniectomy for posttraumatic edema refractory to maximal medical therapy. And Whitfield et al. (67) demonstrated a significant reduction of ICP from 37.5 to 18.1 mm Hg ($P = 0.003$) in 26 patients who underwent bifrontal decompressive craniectomy for refractory intracranial hypertension managed using a standardized ICP/cerebral perfusion pressure (CPP) treatment algorithm. The amplitude of the ICP waveform and of slow waves were significantly reduced, and compensatory reserve was significantly increased postoperatively in a subgroup of eight patients in this study. Munch et al. (45), however, failed to show a significant postoperative reduction in ICP or increase in CPP after unilateral hemispheric decompression. From a radiological perspective, however, this group found a significant improvement in the visibility of mesencephalic cisterns and a significant decrease in midline shift after decompressive craniectomy—both known to correlate with improved outcome. Furthermore, the change in cistern visibility correlated with the distance between the lower craniectomy border and cranial base. Additionally, Alexander et al. (1) found an average increase in intracranial volume of 26 cm^3 in an analysis of CT scans in patients with traumatic and nontraumatic lesions undergoing subtemporal decompression. In contrast, experimental evidence from Cooper et al. (10) supports the notion that decompressive procedures may aggravate cerebral edema formation, thus, resulting in increased secondary injury. Such studies may help explain why, despite laboratory success, actual improvement in patient outcome has not been consistently demonstrated.

Procedures and Outcome

There are several studies that suggest an important role for decompressive procedures in the management of parenchymal injury. In a retrospective review of 28 patients undergoing unilateral or bilateral decompressive craniectomy for posttraumatic edema and intracranial hypertension refractory to head elevation, moderate hyperventilation, osmodiuretics, barbiturates, tromethamine, and cerebrospinal fluid drainage, 57% of patients had good outcome or moderate disability at 1 year. However, the authors excluded patients with "vast" primary lesions, hypoxia, ischemic infarction, brainstem injury, "central" herniation, and primary anisocoria, thus, biasing results toward favorable recovery (33). Nussbaum et al. (48) showed that complete temporal lobectomy performed within 2 hours of the development of clinical signs of transtentorial herniation in 10 patients with unilateral hemispheric swelling and a GCS of less than 7 resulted in 40% functional independence. All patients demonstrated displacement of the brainstem, compression of the contralateral peduncle, and progressive obliteration of the parasellar and interpeduncular cisterns on CT scan, along with fixed pupillary dilation, and therefore, represent a particularly compromised patient population.

Guerra et al. (23) prospectively performed decompressive craniectomy following a standardized treatment protocol with standardized surgical technique for posttraumatic diffuse brain swelling in 57 severe TBI patients (GCS, 4–6). Thirty-nine of these patients underwent primary decompression, and 18 others underwent secondary decompression because of persistent intracranial hypertension after evacuation of a surgical mass lesion. Intracranial hypertension in these patients was refractory to a standardized medical protocol that included hemodynamic stabilization, head elevation, sedation with or without muscle relaxation, controlled hyperventilation to an arterial carbon dioxide pressure of 28 to 32 mm Hg, mannitol, tromethamine for acute rises in ICP, and electroencephalogram burst suppression with barbiturates. Fifty-eight percent of the first group and 65% of the second group experienced good outcome or moderate disability at 1 year. These results compare favorably with published outcomes of alternative second-tier therapy. However, a direct comparison with matched nonsurgical controls was not performed. Whitfield et al. (67) demonstrated a favorable outcome (GOS, 4–5) in 61% of a severe TBI population that underwent bifrontal decompressive craniectomy for ICP greater than 30 mm Hg with CPP less than 70 mm Hg, or for ICP greater than 35 mm Hg, irrespective of CPP, despite a medical management protocol that involved head elevation, propofol sedation, mannitol and/or hypertonic saline, normocarbia, mild hypothermia to 33°C to 35°C, and electroencephalogram burst suppression. Only 55% of eligible patients, however, underwent craniectomy, and the reasons for nonsurgical management despite eligibility were not documented or discussed.

Munch et al. (45) were able to show a significant difference in outcome between patients undergoing rapid decompressive craniectomy and those undergoing delayed decompressive craniectomy. However, the nature of the lesions differed between the two groups, and, thus, the outcomes cannot be meaningfully compared. Tseng (64) noted that the addition of gentle elevation of the temporal lobe until the tentorium was visualized and CSF egress was noted decreased mortality and improved the incidence of good outcome when compared with a standard craniotomy with hematoma evacuation and contusion resection in a series of 32 severe TBI patients with anisocoria, hemiparesis, and CT evidence for uncal herniation. However, no statistical analysis was performed, and the author notes that preoperative selection was biased and that operative timing and intraoperative judgements may have influenced the choice of surgical procedure. Gower et al. (21) retrospectively studied 115 patients with admission GCS of 8 or less who had adequate ICP monitoring data and no operative mass lesion on admission. These patients were managed under a standard treatment protocol. Outcome was compared between 10 patients who underwent subtemporal decompression and 17 patients managed by induction of pentobarbital coma. They found that subtemporal decompression afforded significantly lower mortality than pentobarbital coma, despite the fact that the surgical group had a lower (but not statistically significant) average admission GCS. However, 10 of the patients treated medically had been determined not to be operative candidates and subsequently died, greatly biasing results in favor of the operative group. In a retrospective review of 29 patients undergoing operation for a combination of acute subdural hematoma and severe contusion and swelling of the temporal lobe with uncal herniation, Lee et al. (34) documented a significant improvement in outcome with the addition of temporal lobectomy to subtemporal decompression and debridement of contused brain. Mortality decreased from 56% to 8%, with a concomitant increase in average GOS from 2.2. to 4.0. These two surgical groups did not differ with respect to preoperative GCS, age, or sex. However, patients with intraoperative "overswelling," defined as herniation of brain more than 2 cm above the craniectomy window, were excluded and underwent decompressive craniectomy with dural expansion, thus, potentially biasing these results.

Coplin et al. (11) retrospectively reviewed 29 consecutive patients with GCS of at most 9 and CT scans with a midline shift greater than the volume of a surgically amenable lesion to evaluate the safety and feasibility of decompressive craniectomy with duraplasty versus traditional craniotomy as the initial surgical procedure. No significant differences in age, gender, admission GCS, time to surgery, or serum ethanol concentration existed between the two groups. Despite a significantly lower GCS at time of surgery and significantly greater percentage of Diffuse Injury III and IV injuries (39), there was no significant difference in mortality, GOS, acute hospital length of stay, functional independence measure score on admission to a rehabilitation unit, change in functional independence measure score, or length of rehabilitation stay between craniectomy and craniotomy groups. Although this study is subject to the biases inherent in a retrospective, uncontrolled design, it strongly supports the safety of decompressive craniectomy as a first-line surgical intervention as opposed to its traditional role as a salvage procedure.

The studies briefly outlined here support the potential usefulness of decompressive procedures, but are clearly hampered by inherent biases.

The study by Polin et al. (51) deserves particular mention, because it offers more concrete evidence that a decompressive procedure may result in improved patient outcome. These authors report a retrospective evaluation of outcome in 35 patients undergoing bifrontal decompressive craniectomy for refractory posttraumatic cerebral edema matched for age, admission GCS, sex, and maximal ICP with historical controls selected from the Traumatic Coma Data Bank. Only patients with Diffuse Injury III (39) were eligible as controls. Highest postoperative ICP less than 24 hours after surgery in cases was matched with highest ICP 48 to 72 hours after injury in controls. Preoperative ICP in cases was matched with highest ICP less than 48 hours after injury in controls. Several findings are particularly relevant. In the operative group, surgery performed less than 48 hours after injury was significantly associated with favorable outcome when compared with surgery performed longer than 48 hours after injury (46% versus 0%, respectively). Medical management alone carried a 3.8 times relative risk of unfavorable outcome compared with decompressive craniectomy. Maximum benefit was achieved in patients undergoing decompression within 48 hours of injury and whose ICP elevations had not yet been sustained above 40 mm Hg (60% favorable outcome versus 18% in matched controls). This study argues strongly in favor of bifrontal decompressive craniectomy for patients with medically refractory posttraumatic cerebral edema and resultant intracranial hypertension not yet sustained above 40 mm Hg within 48 hours of injury, but does not have contemporaneous controls (51).

Overall, the literature suggests, but does not prove, that decompressive procedures may be the intervention of choice given the appropriate clinical context. A recent study by Taylor et al. (61) examined the use of early (median 19.2 h after injury) bitemporal craniectomy in addition to intensive medical management versus intensive medical management alone in 27 children with sustained intracranial hypertension in a prospective, randomized, controlled fashion. Their results showed a trend towards greater improvement in ICP, less time required in the intensive care unit, and improved outcome with surgical decompression. These trends, although promising, did not reach statistical significance. Additional prospective, controlled studies are, thus, needed to strengthen the argument for the use of surgical decompression in the management of intracranial hypertension and refractory cerebral edema.

SUMMARY

The majority of studies regarding surgical treatment of parenchymal lesions are case series. Only one prospective clinical trial of treatment using surgical versus nonsurgical management has been published (61). The majority of evidence indicates that the development of parenchymal mass lesions, which are associated with progressive neurological dysfunction, medically refractory intracranial hypertension, or radiological signs of mass effect, are associated with a poor outcome if treated nonsurgically. Specific surgical criteria, however, have not been firmly established.

Evidence also suggests that decompressive craniectomy may be the procedure of choice in patients with posttraumatic edema, hemispheric swelling, or diffuse injury, given the appropriate clinical context. This context has yet to be defined.

KEY ISSUES FOR FUTURE INVESTIGATION

The majority of studies on traumatic parenchymal lesions is observational, and the studies offer no means to meaningfully compare outcome between surgical and nonsurgical groups. Those studies that attempt this comparison fail to adequately control for known prognostic variables between surgically and nonsurgically managed groups in a prospective fashion. Prospective, controlled trials, such as that of Taylor et al. (61) need to be pursued and supported to define appropriate clinical criteria and surgical methods.

Additionally, the data of Coplin et al. (11) and Taylor et al. (61) strongly support the feasibility of performing trials of decompressive operations in the first instance, as opposed to a second- or third-tier therapy for posttraumatic intracranial hypertension.

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TABLE 1. Surgical Management of Traumatic Parenchymal Lesions[a]

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Bullock et al. (6)</td><td>85</td><td>III</td><td>Mean GCS 9</td><td>Nonsurgical</td><td>GOS 3 mo</td><td>Prospective study of 85 patients with ICH with uncertainty regarding need for immediate craniotomy. These patients were selected for ICP monitoring in an attempt to better define need for craniotomy. A retrospective analysis of CT scan characteristics was then performed for those patients for whom ICP monitoring did not predict late deterioration to create a better predictive model of those in need of ICH evacuation.</td><td>● Management "should be based on a spectrum of clinical, CT scanning, and ICP findings."
● Peak ICP was the strongest predictor of outcome, but failed to predict late deterioration or death in 16.7%.
● For temporal/parietal lesions, hematoma size, degree of edema, GCS, basal cistern status, and peak ICP correlated with outcome; for frontal lesions, peak ICP alone predicted outcome.
● Premesencephalic cistern status falsely predicted low ICP in only 2.3% of patients with elevated ICP (false negative).
● Authors conclude:
1)Basal cistern effacement on initial CT scan is indication for surgery, regardless of GCS.
2)Extensive surrounding edema should prompt ICP monitoring or serial CT scanning. If cisterns are effaced, evacuation should be considered.
3)ICP monitoring should be carried out in patients in coma.
<table>
<tr><th></th><th>No. of patients</th><th>GR/minimal disability (%)</th><th>MD (%)</th><th>VS/D (%)</th></tr>
<tr><td>Surgery</td><td>55</td><td>47</td><td>20</td><td>33</td></tr>
<tr><td>No initial surgery</td><td>30</td><td>47</td><td>23</td><td>30</td></tr>
</table></td></tr>
<tr><td>Caroli et al. (7)</td><td>36</td><td>III</td><td>Average GCS 9.3</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Retrospective review of 95 patients with multiple traumatic intracranial lesions to identify clinical factors and radiologic predictors of prognosis to establish management criteria. Patients were divided into 3 groups based on predominant lesion type; 36 patients with pure ICH as the predominant lesion were included in this analysis. Patients with parenchymal lesions <2 cm were excluded by the authors.</td><td>● Cisterns ($P < 0.01$), shift ($P < 0.05$), prolonged increased ICP ($P < 0.0001$) differed significantly between surgical and nonsurgical groups.
● 80.6% neurologically worsened within 12–24 h of initial assessment.
● 44.4% incidence of DTICH.
●Type of lesion (SDH + ICH), lowest recorded GCS, presence of prolonged increased ICP, absence of pupillary reflexes were significant predictors of bad outcome (VS/D) based on multiple regression analysis.
● Decompressive craniectomy was a "useful means of controlling intracranial pressure in 19/22 patients undergoing procedure."
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>ICH</td><td>36</td><td>33.3</td><td>38.9</td><td>16.7</td><td>0</td><td>11.1</td></tr>
<tr><td>Operated</td><td></td><td></td><td></td><td></td><td>13.3</td><td></td></tr>
<tr><td>Nonoperated</td><td>21</td><td></td><td></td><td></td><td></td><td>9.5</td></tr>
</table></td></tr>
<tr><td>Choksey et al. (8)</td><td>202</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Retrospective study of 202 patients with traumatic ICH to ascertain factors influencing outcome.</td><td>● Hematoma volume >16 cm3 increased probability of clinical deterioration.
● Respiratory insufficiency, low GCS and hematoma volume >16 cm3 were significantly associated with a poor outcome.
● With these factors taken into consideration, craniotomy significantly improved probability of good outcome.
● Location of peripheral hematomas did not predict outcome.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th></tr>
<tr><td>1 Hematoma</td><td>169</td><td>58</td><td>42</td></tr>
<tr><td>2 Hematomas</td><td>19</td><td>21</td><td>79</td></tr>
<tr><td>≥ 3 Hematomas</td><td>14</td><td>0</td><td>100</td></tr>
<tr><td>Hypoxia, respiratory insufficiency</td><td>35</td><td>20</td><td>80</td></tr>
<tr><td>No respiratory insufficiency</td><td>167</td><td>57</td><td>43</td></tr>
<tr><td>Evacuation</td><td>84</td><td>62</td><td>38</td></tr>
<tr><td>Nonevacuation</td><td>118</td><td>42</td><td>58</td></tr>
<tr><td>Age 0–20 yr</td><td>56</td><td>29</td><td>71</td></tr>
<tr><td>Age 21–40 yr</td><td>54</td><td>67</td><td>33</td></tr>
<tr><td>Age 41–64 yr</td><td>44</td><td>68</td><td>32</td></tr>
<tr><td>Age ≥65 yr</td><td>48</td><td>42</td><td>58</td></tr>
<tr><td>GCS 3–7</td><td>112</td><td>31</td><td>69</td></tr>
<tr><td>GCS 8–11</td><td>45</td><td>62</td><td>38</td></tr>
</table></td></tr>
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TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td><table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th></tr>
<tr><td>GCS 12–15</td><td>45</td><td>87</td><td>13</td></tr>
<tr><td>Volume 1–5 cm^3</td><td>26</td><td>81</td><td>19</td></tr>
<tr><td>Volume 6–15 cm^3</td><td>58</td><td>57</td><td>43</td></tr>
<tr><td>Volume 16–35 cm^3</td><td>67</td><td>46</td><td>54</td></tr>
<tr><td>Volume >36 cm^3</td><td>51</td><td>33</td><td>67</td></tr>
<tr><td>Neurological deterioration</td><td>135</td><td>47</td><td>53</td></tr>
<tr><td>No neurological deterioration</td><td>49</td><td>80</td><td>20</td></tr>
<tr><td>Initial GCS < 4</td><td>20</td><td>0</td><td>100</td></tr>
<tr><td>Frontal</td><td>93</td><td>48</td><td>52</td></tr>
<tr><td>Parietal</td><td>12</td><td>50</td><td>50</td></tr>
<tr><td>Temporal</td><td>63</td><td>63</td><td>37</td></tr>
<tr><td>Occipital</td><td>9</td><td>67</td><td>33</td></tr>
<tr><td>Central</td><td>25</td><td>20</td><td>80</td></tr>
</table></td></tr>
<tr><td>Coplin et al. (11)</td><td>29</td><td>III</td><td>GCS 3–9</td><td>Decompressive craniectomy</td><td>GOS at discharge; FIM at admission and discharge from rehabiliation</td><td>Retrospective review of 29 consecutive patients with GCS ≤ 9 and CT scans with midline shift greater than the volume of a surgically amenable lesion to evaluate the safety and feasibility of decompressive craniectomy with duraplasty versus traditional craniotomy as the initial surgical procedure. Exclusion criteria included age <16 yr, injury >24 h before admission, Diffuse Injury II (TCDB classification), isolated EDH, preexisting illness limiting life expectancy to <1 yr from ictus, age >40 yr with extensor posturing, and bilateral unreactive pupils ≥ 4 mm in diameter.</td><td>● Nonsignificant difference between craniotomy and craniectomy groups with regards to age ($P = 0.8$), gender ($P = 1.0$), admission GCS score ($P = 0.07$), time to surgery ($P = 1.0$), serum ethanol concentration ($P = 0.6$).
● Craniectomy group had significantly lower GCS score at surgery ($P = 0.04$).
● Craniectomy group had significantly more patients with Diffuse Injury III and IV (56% versus 9%).
● No significant difference between groups with respect to mortality, GOS, acute hospital length of stay, initial FIM score, change in FIM score, or length of rehabilitation stay.
● Despite significantly lower GCS at time of surgery and worse injury classification by CT scan, decompressive craniectomy with duraplasty afforded equivalent outcome to traditional craniotomy, establishing its safety and feasibility as a first-line surgical intervention as opposed to its traditional role as a "salvage" procedure.
● Authors emphasize importance of craniectomy extending down to the floor of the middle cranial fossa at the root of the zygoma.<table>
<tr><th></th><th>All</th><th>Craniotomy</th><th>Craniectomy</th><th>P value</th></tr>
<tr><td>No. of patients</td><td>29</td><td>17</td><td>12</td><td></td></tr>
<tr><td>Discharge GOS</td><td>4</td><td>4</td><td>4</td><td>0.8</td></tr>
<tr><td>Mortality (%)</td><td>34.5</td><td>41.2</td><td>25</td><td>0.4</td></tr>
<tr><td>Hospital length of stay (d)</td><td>17</td><td>18</td><td>18</td><td>0.4</td></tr>
<tr><td>Admission FIM</td><td>63</td><td>64</td><td>38</td><td>0.7</td></tr>
<tr><td>Discharge FIM</td><td>90</td><td>92</td><td>71</td><td>0.6</td></tr>
<tr><td>Change in FIM</td><td>27</td><td>27</td><td>23</td><td>1.0</td></tr>
</table></td></tr>
<tr><td>Coraddu et al. (12)</td><td>37</td><td>III</td><td>GCS 3–5 to >7</td><td>Stereotactic evacuation</td><td>Mortality at discharge</td><td>Retrospective series of 37 patients with traumatic ICH treated by stereotactic evacuation through an enlarged burr hole to evaluate outcome using this technique. Surgical indications included coma, deteriorating consciousness, or focal neurological deficit.</td><td>● No mortality with admission GCS > 7.
● Admission GCS related inversely to mortality (no statistics).
● Temporal location had higher mortality (no statistics).<table>
<tr><th></th><th>No. of patients</th><th>D (%)</th></tr>
<tr><td>ICH, total</td><td>37</td><td>30</td></tr>
<tr><td>GCS 3–5</td><td>10</td><td>80</td></tr>
<tr><td>GCS 6–7</td><td>12</td><td>25</td></tr>
<tr><td>GCS > 7</td><td>15</td><td>0</td></tr>
<tr><td>Frontal</td><td>18</td><td>5.5</td></tr>
<tr><td>Temporal</td><td>18</td><td>55</td></tr>
</table></td></tr>
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TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>De Luca et al. (14)</td><td>22</td><td>III</td><td>GCS 3–12</td><td>Decompressive craniectomy</td><td>GOS at discharge</td><td>Retrospective review of 22 patients who underwent decompressive craniectomy for cerebral edema with refractory intracranial hypertension or for "imminent herniation" during the evacuation of a space-occupying traumatic lesion. Surgical methods are described.</td><td><table>
<tr><th></th><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Decompressive craniectomy</td><td>22</td><td>41</td><td>18</td><td>23</td><td>18</td><td></td></tr>
</table></td></tr>
<tr><td>Diaz et al. (15)</td><td>9</td><td>III</td><td>Unknown</td><td>Surgery</td><td>Mortality at discharge</td><td>Retrospective series of 9 patients with DTICH to evaluate clinical characteristics and outcome.</td><td>● 55.6% mortality.
● Included with n = 9 for well-presented data on DTICH.
● Definition of DTICH: 1) history of head injury with head in motion producing transient or permanent LOC, focal neurological findings, or cranial fracture; 2) interval between injury and development of DTICH of <2 wk.<table>
<tr><th></th><th>No. of patients</th><th>D (%)</th></tr>
<tr><td>DTICH</td><td>9</td><td>55.6</td></tr>
</table></td></tr>
<tr><td>Gaab et al. (17)</td><td>37</td><td>III</td><td>Unknown</td><td>Decompressive craniectomy</td><td>GOS 1 yr</td><td>Prospective series of 37 patients who underwent decompressive craniectomy because of traumatic brain swelling to assess efficacy of treatment protocol at 1 yr after trauma. Surgical indications and exclusion criteria detailed.</td><td>●14.7% mortality using standardized protocol.
● Initial GCS ≥ 6, day 1 GCS ≥ 8 associated with better outcome (no statistics).
● All patients with GOS 1–2 had GCS 3 with pupillary abnormality.
● Represents early report of Guerra et al. study.<table>
<tr><th></th><th>No. of patients</th><th>Full (%)</th><th>Disabled (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Decompressive craniectomy</td><td>34</td><td>41.2</td><td>35.3</td><td>8.8</td><td>14.7</td></tr>
</table></td></tr>
<tr><td>Gennarelli et al. (19)</td><td>1107</td><td>III</td><td>GCS 3–8</td><td>Surgery and nonsurgical</td><td>GOS 3 mo</td><td>Multicenter prospective series of 1107 patients with severe blunt traumatic brain injury (GCS ≤ 8) to examine differences in type of injury, severity of injury, and GOS at 3 mo. Subgroups of patients with "other focal injury" (n = 205) and "diffuse injury" (n = 487) were examined for this chapter. Of note, "other focal injury" included ICH, contusions, but also depressed cranial fracture, SDH, and EDH that were not the primary lesions, and combined EDH/SDH in which the most important lesion was unknown.</td><td>● Lower GCS was strongly correlated with worse outcome for each lesion type.
● Given the same presenting GCS, lesion types differed markedly with respect to outcome.
● Authors main point is that outcome differs markedly among lesion types within the realm of severe head injury, and that outcome depends in part on type of lesion as well as on injury severity as measured by GCS.<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Other focal lesion, total</td><td>205</td><td>21</td><td>18</td><td>19</td><td>3</td><td>39</td></tr>
<tr><td>GCS 3–5</td><td>112</td><td>7</td><td>14</td><td>18</td><td>4</td><td>56</td></tr>
<tr><td>GCS 6–8</td><td>93</td><td>38</td><td>23</td><td>19</td><td>2</td><td>18</td></tr>
<tr><td>Operated</td><td>71</td><td>21</td><td>15</td><td>20</td><td>4</td><td>39</td></tr>
<tr><td>Operated, GCS 3–5</td><td>35</td><td>9</td><td>9</td><td>20</td><td>6</td><td>57</td></tr>
<tr><td>Operated, GCS 6–8</td><td>36</td><td>33</td><td>22</td><td>19</td><td>3</td><td>22</td></tr>
<tr><td>Nonoperated</td><td>134</td><td>21</td><td>19</td><td>18</td><td>3</td><td>39</td></tr>
<tr><td>Nonoperated, GCS 3–5</td><td>77</td><td>6</td><td>17</td><td>17</td><td>4</td><td>56</td></tr>
<tr><td>Diffuse injury, total</td><td>487</td><td>34</td><td>17</td><td>11</td><td>5</td><td>32</td></tr>
<tr><td>GCS 3–5</td><td>237</td><td>16</td><td>10</td><td>14</td><td>8</td><td>51</td></tr>
<tr><td>GCS 6–8</td><td>250</td><td>52</td><td>24</td><td>9</td><td>2</td><td>13</td></tr>
<tr><td>Coma 6–24 h</td><td>92</td><td>63</td><td>15</td><td>2</td><td>1</td><td>15</td></tr>
<tr><td>Coma 6–24 h, GCS 3–5</td><td>27</td><td>52</td><td>7</td><td>7</td><td>4</td><td>30</td></tr>
<tr><td>Coma 6–24 h, GCS 6–8</td><td>65</td><td>68</td><td>18</td><td>5</td><td>0</td><td>9</td></tr>
<tr><td>Coma >24h</td><td>395</td><td>28</td><td>17</td><td>13</td><td>6</td><td>36</td></tr>
</table></td></tr>
</table>

TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Coma >24 h, GCS 3–5</td><td>210</td><td>11</td><td>10</td><td>15</td><td>9</td><td>54</td></tr>
<tr><td>Coma >24 h, GCS 6–8</td><td>185</td><td>46</td><td>25</td><td>10</td><td>3</td><td>15</td></tr>
<tr><td>Coma >24 h, not decerebrate</td><td>219</td><td>38</td><td>21</td><td>12</td><td>5</td><td>24</td></tr>
<tr><td>Coma >24 h, not decerebrate, GCS 3–5</td><td>77</td><td>21</td><td>8</td><td>13</td><td>12</td><td>47</td></tr>
<tr><td>Coma >24 h, not decerebrate, GCS 6–8</td><td>142</td><td>47</td><td>29</td><td>11</td><td>1</td><td>11</td></tr>
<tr><td>Coma >24 h, decerebrate</td><td>176</td><td>15</td><td>13</td><td>14</td><td>7</td><td>51</td></tr>
<tr><td>Coma >24 h, decerebrate, GCS 3–5</td><td>136</td><td>6</td><td>12</td><td>16</td><td>9</td><td>57</td></tr>
<tr><td>Coma >24 h, decerebrate, GCS 6–8</td><td>40</td><td>48</td><td>15</td><td>8</td><td>3</td><td>28</td></tr>
</table>
</td></tr>
<tr><td>Gentleman et al. (20)</td><td>23</td><td>III</td><td>Coma versus not coma</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Retrospective review of 2701 head-injured patients distilled to a cohort of 23 patients with DTICH. Volume of hematoma and timing of repeat CT scan are related to management. Operative versus nonoperative management is related to GOS at 6 mo.</td><td>● Operative versus nonoperative lesions differed in average volume (24 versus 7 cm^3) and time to repeat CT based on clinical criteria (41 versus 99 h). Outcome between groups was not statistically significant.
● 39% of DTICH requied evacuation; criteria not described.
● All patients with DTICH had abnormal CT on admission.
● Definition of DTICH: "lesion of increased attenuation developing after admission to hospital, in a part of the brain which the admission CT scan had suggested was normal."
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th></tr>
<tr><td>Operated DTICH</td><td>9</td><td>56</td><td>44[b]</td></tr>
<tr><td>Nonoperated DTICH</td><td>14</td><td>57</td><td>43</td></tr>
<tr><td>DTICH, total</td><td>23</td><td>57</td><td>43</td></tr>
</table>
[b] P = n.s.</td></tr>
<tr><td>Gower et al. (21)</td><td>10</td><td>III</td><td>GCS <8</td><td>Subtemporal decompression versus pentobarbital coma</td><td>Mortality 1 yr</td><td>Retrospective series of 115 patients with GCS < 8 with no operative mass lesion at time of admission managed on a standard treatment protocol. 10 patients underwent subtemporal decompression because of medically refractory intracranial hypertension, and outcome was compared with those patients managed by pentobarbital coma without surgery. Technique described.</td><td>● Patients undergoing subtemporal decompression had significantly lower mortality than those treated with pentobarbital coma despite having lower (but not statistically significant) average admission GCS (4.9 versus 6.1). However, 10 patients undergoing pentobarbital coma were determined not to be operative candidates and subsequently died; biases results in favor of operated group.
● 70% of operated patients had average decrease in ICP of 34%.
<table>
<tr><th></th><th>No. of patients</th><th>D (%)</th></tr>
<tr><td>Pentobarbital coma</td><td>17</td><td>82.4</td></tr>
<tr><td>Subtemporal decompression</td><td>10</td><td>40[c]</td></tr>
</table>
[c] $P = 0.039$.</td></tr>
<tr><td>Gudeman et al. (22)</td><td>III</td><td>12</td><td>GCS 4–10</td><td>Surgery and nonsurgical</td><td>GOS 3 mo, 1 yr</td><td>Prospective study of 162 patients with severe head injury, 12 of whom developed DTICH by CT scan. These patients were analyzed for clinical associations and outcomes to better understand this lesion.</td><td>● 92% DTICH detected <48 h from injury.
● 50% developed after decompressive surgery.
● DTICH had 50% mortality; higher but not statistically significant compared with all severe head injuries during the same period.
● Significantly higher incidence of secondary systemic insults at time of admission in DTICH patients versus all severe CHI patients (92% versus 44%).
● No significant temporal relationship between development of DTICH, ICP levels, neurological change.
● Authors believe that development of DTICH is an epiphenomenon of secondary insult to a damaged brain as opposed to a causative factor for neurological deterioration—thus, treatment should be aimed at prevention of secondary hypoxic insults.
● Definition of DTICH: new parenchymal high density lesion when no lesion or a negligible abnormality was present on initial CT.
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>DTICH</td><td>12</td><td>25</td><td>25</td><td>0</td><td>0</td><td>50</td></tr>
</table>
</td></tr>
</table>

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Guerra et al. (23)	57	III	GCS4–6	Decompressive craniectomy	GOS 1 yr	Prospective series of 57 patients who underwent decompressive craniectomy under a standardized treatment protocol and standardized surgical technique for posttraumatic diffuse brain swelling. The patients were divided into a group undergoing primary decompression (n = 39) and a group undergoing secondary decompression because of therapy-resistant intracranial hypertension after evacuation of a surgical mass lesion (n = 18). Surgical indications and methods are detailed. Patients with GCS 3 and/or bilateral fixed/dilated pupils were excluded. Age >30 yr, >40 yr, and >50 yr variably used as exclusion criteria throughout study.	● 37% GOS 5, 19% mortality overall. ● GCS on posttrauma day 1 predictive of outcome. ● Significantly better outcome with no loss of B waves and presence of plateau waves on ICP monitoring. ● Inclusion of SEP, ICP/CPP, and AEP monitoring techniques helped to define indications for the authors. ● Authors conclude that decompressive craniectomy should be 1st among second-tier therapies for resistant intracranial hypertension. **No. of patients** **GR/MD (%)** **SD/VS/D (%)** Primary decompression 38 58 42 Secondary decompression 17 65 35 P = n.s. **No. of patients** **GR (%)** **MD (%)** **SD (%)** **VS (%)** **D (%)** All patients 55 37 21 11 9 19
Katayama et al. (28)	21	III	Unknown	Surgery and nonsurgical	Mortality	Retrospective case control study of 21 patients with frontal lobe contusions and medically intractable intracranial hypertension >40 mm Hg, comparing mortality between the group treated medically (n = 8) and the group treated with surgical evacuation of contused brain (n = 13). Authors state that age, sex, GCS, and ICP levels were comparable between groups, but do not provide statistics.	● Mortality was significantly decreased in the surgical group (22% versus 88%). ● Authors note that progressive ICP increase and neurological deterioration often continued past the timing of maximal enlargement of intracerebral lesions on CT. ● Authors advocate surgical excision of contused brain in the setting of medically uncontrollable ICP elevation. **No. of patients** **D (%)** Nonoperative 8 88 Surgery 13 22^d ^{d} $P < 0.01$
Kaufman et al. (29)	8	III	AllGCS	Surgery and nonsurgical	Mortality at discharge	Retrospective series of 12 patients with DTICH or recurrent hematoma after head injury to examine the association of disseminated intravascular clotting and fibrinolysis with occurrence of these lesions. A subset of 8 patients with DTICH was evaluated for this chapter.	● 7 of 8 DTICH patients had abnormal clotting parameters. ● Included with n = 8 because of presentation of data and evaluation of clotting parameters. **No. of patients** **D (%)** **Clotting abnormalities (%)** DTICH, total 8 37.5 87.5
Kotwica and Jakubowski (31)	48	III	AllGCS	Surgery and nonsurgical	GOS, not specified	Retrospective series of 136 patients aged 70–91 yr with TBI to evaluate outcome from TBI in an aged population. 48 patients with ICH/contusion reviewed.	● Overall mortality from ICH/contusions was 50%; 8 of 13 in operated cases, and 16 of 35 in nonoperated cases. ● Mortality correlated with admission GCS (no statistics). ● Authors feel that because the mortality rate for patients >70 yr with GCS < 9 is so high (>80%), limited attempts should be made at resuscitation, intensive care, and surgery. **No. of patients** **GR (%)** **MD (%)** **SD (%)** **VS (%)** **D (%)** ICH + contusion, surgery 13 7.7 7.7 15.4 7.7 61.5 ICH + contusion, no surgery 35 11.4 11.4 22.9 8.6 45.7

TABLE 1. Continued

<table>
<thead>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
</thead>
<tbody>
<tr><td>Kumchev et al. (32)</td><td>79</td><td>III</td><td>GCS 3–6 to 12–15</td><td>Surgery and nonsurgical</td><td>Mortality</td><td>Retrospective review of 79 patients with intracerebral hematomas, comparing location of hematoma with mortality, and outcome of surgery versus nonsurgical therapy. Treatment protocol was not standardized; surgical indications were not reported.</td><td>● Those patients with temporal ICH were more likely to die.
● Surgery did not alter mortality. Surgically managed patients were more likely to show clinical improvement.
<table>
<tr><th>Location</th><th>No. of patients</th><th>D (%)</th><th>P values</th></tr>
<tr><td>Frontal</td><td>16</td><td>6</td><td><0.001</td></tr>
<tr><td>Temporal</td><td>36</td><td>57.6</td><td><0.01</td></tr>
<tr><td>Parieto-occipital</td><td>14</td><td>18.2</td><td>>0.01</td></tr>
<tr><td>Multiple sites</td><td>13</td><td>18.2</td><td>>0.01</td></tr>
</table></td></tr>
<tr><td>Kunze et al. (33)</td><td>28</td><td>III</td><td>All GCS</td><td>Decompressive craniectomy</td><td>GOS 1 yr</td><td>Retrospective study of 28 patients undergoing uni/bilateral decompressive craniectomy for posttraumatic edema after ″maximal″ medical therapy.</td><td>● 57% overall favorable outcome (GOS 4–5) at 1 yr.
● Mean ICP decreased from 41.7 to 20.6 mm Hg after decompression.
● Patients with “vast” primary lesions, hypoxia, ischemic infarction, brainstem injury, “central” herniation, and primary anisocoria excluded.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Decompressive craniectomy</td><td>28</td><td>57</td><td>18</td><td>14</td><td>11</td></tr>
</table></td></tr>
<tr><td>Lee et al. (34)</td><td>29</td><td>III</td><td>GCS ≤8</td><td>Subtemporal decompression ± temporal lobectomy</td><td>GOS 1 yr</td><td>Retrospective series of 29 patients operated on for acute SDH and severe contusion/ swelling of temporal lobe with uncal herniation. 16 patients underwent subtemporal decompression and debridement of contused brain whereas 13 subsequent patients underwent temporal lobectomy in addition. These two groups were compared with respect to outcome at 1 yr or longer.</td><td>● Addition of temporal lobectomy to subtemporal decompression and debridement of contused brain significantly decreased mortality from 56% to 8% and significantly improved average GOS from 2.2 to 4.0. Preoperative GCS, age, and sex were not significantly different between groups.
● Incidence of motor recovery, cognitive deficits, and seizures were not significantly different between groups.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th><th>D (%)</th></tr>
<tr><td>STD, debridement</td><td>16</td><td>25</td><td>75</td><td>56</td></tr>
<tr><td>STD, debridement, TL</td><td>13</td><td>77</td><td>23</td><td>8^e</td></tr>
<tr><td>STD, debridement, complete TL</td><td>10</td><td>100</td><td>0</td><td>0</td></tr>
<tr><td>STD, debridement, anterior TL</td><td>3</td><td>0</td><td>100</td><td>33</td></tr>
</table>
[e] $P < 0.01$.</td></tr>
<tr><td>Lobato et al. (35)</td><td>277</td><td>III</td><td>GCS 3–7</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Prospective series of 277 severely head-injured patients classified by CT scan into 8 injury types to examine GOS at 6 mo related to lesion type. ICP was monitored in all patients. Patients brain dead on arrival were excluded. A standardized management protocol was used and is described. GCS, ICP, and interval to operation varied between CT groups.</td><td>● Patients with pure extracerebral hematoma, single brain contusion, general brain swelling, and normal CT scans had a significantly better outcome than patients with extracerebral hematoma and acute hemispheric swelling, multiple brain contusions, and patients with diffuse axonal injury.
● Acute hemispheric swelling significantly increased mortality.
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Single contusion (SC)</td><td>25</td><td>72</td><td>8</td><td>4</td><td>4</td><td>12</td></tr>
<tr><td>SC + EDH</td><td>7</td><td>14</td><td>86</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>SC + SDH</td><td>13</td><td>15</td><td>46</td><td>15</td><td>0</td><td>23</td></tr>
<tr><td>MUC</td><td>20</td><td>0</td><td>15</td><td>10</td><td>0</td><td>75</td></tr>
<tr><td>MUC + SDH</td><td>12</td><td>0</td><td>17</td><td>8</td><td>0</td><td>75</td></tr>
<tr><td>Multiple bilateral contusion</td><td>42</td><td>19</td><td>26</td><td>5</td><td>0</td><td>50</td></tr>
<tr><td>GBS</td><td>25</td><td>76</td><td>8</td><td>4</td><td>0</td><td>12</td></tr>
<tr><td>GBS + EDH</td><td>16</td><td>88</td><td>6</td><td>0</td><td>0</td><td>6</td></tr>
<tr><td>DAI</td><td>43</td><td>5</td><td>9</td><td>21</td><td>12</td><td>53</td></tr>
<tr><td>Normal CT</td><td>28</td><td>39</td><td>29</td><td>18</td><td>11</td><td>4</td></tr>
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TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Lobato et al. (36)</td><td>587</td><td>III</td><td>GCS 3–8</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Retrospective series of 587 patients with GC S≤ 8 and at least one control CT scan (average 36.7 h after initial CT) to evaluate incidence of changes in CT classification over time and to assess the relative prognostic significance of a second CT scan versus the first.</td><td>● 51.2% developed significant CT changes requiring change in diagnostic category.
● Final outcome was more accurately predicted by control CT diagnosis than by initial CT diagnosis.
● 19% of diffuse injuries evolved to mass lesions.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS (%)</th><th>D (%)</th></tr>
<tr><td>Diffuse injury I</td><td>24</td><td>75</td><td>8.3</td><td>16.6</td></tr>
<tr><td>Diffuse injury II</td><td>247</td><td>54.6</td><td>19.4</td><td>25.9</td></tr>
<tr><td>Diffuse injury III</td><td>123</td><td>20.3</td><td>10.5</td><td>69.1</td></tr>
<tr><td>Diffuse injury IV</td><td>25</td><td>16</td><td>4</td><td>80</td></tr>
</table></td></tr>
<tr><td>Mandera et al. (37)</td><td>31</td><td>III</td><td>GCS 3–8 to 13–15</td><td>Surgery and nonsurgical</td><td>GOS, not specified</td><td>Retrospective study of 31 children with traumatic ICH to examine factors related to surgical decision making and assess outcome.</td><td>● Outcome did not differ between surgical and conservative groups despite the fact that more patients with severe injury were treated surgically.
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Surgery</td><td>20</td><td>35</td><td>20</td><td>30</td><td>0</td><td>15</td></tr>
<tr><td>Nonsurgical</td><td>11</td><td>45</td><td>18</td><td>18</td><td>0</td><td>18</td></tr>
</table></td></tr>
<tr><td>Marshall (39)</td><td>414</td><td>III</td><td>GCS 3–8</td><td>Nonsurgical</td><td>GOS 11 d–2 yr</td><td>Prospective series of 746 patients from TCDB to identify patients at risk for developing intracranial hypertension in the absence of significant mass lesions on initial CT. The authors propose a new classification of head injury based on CT and relate the new classification categories to outcome. Nonsurgical diffuse injury categories are included.</td><td>● CT diagnosis was a highly significant independent predictor of mortality when age and motor score were included in the model.
● In Diffuse Injury III, highest ICP and postresuscitation pupillary reactivity were significant predictors of outcome.</td></tr>
<tr><td>Marshall et al. (40)</td><td>502</td><td>III</td><td>GCS 3–8</td><td>Surgery (ICH) and nonsurgical (Diffuse Injury I–IV)</td><td>GOS 11 d–2 yr</td><td>Prospective series of 746 patients selected from TCDB to assess importance of prognostic variables in determining outcome from severe head injury. Subgroups of nonoperated patients with Diffuse Injury patterns I–IV and patients with evacuated ICH are included.</td><td>● 90% of deaths occurred within 2 wk.
● Intracranial diagnosis strongly correlated with outcome; e.g., higher % of Diffuse Injury III/IV patients were vegetative.
● In Diffuse Injury II group, age >40 yr strongly correlated with poor outcome.
● GOS for evacuated ICH patients correlated negativelywith age >40 yr.
● For all patients, postresuscitation GCS, pupillary reactivity, and age correlated with outcome.
<table>
<tr><th>CT diagnosis [f]</th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Diffuse Injury I</td><td>52</td><td>27</td><td>34.6</td><td>19.2</td><td>9.6</td><td>9.6</td></tr>
<tr><td>Diffuse Injury II</td><td>177</td><td>8.5</td><td>26</td><td>40.7</td><td>11.3</td><td>13.5</td></tr>
<tr><td>Diffuse Injury III</td><td>153</td><td>3.3</td><td>13.1</td><td>26.8</td><td>22.9</td><td>34</td></tr>
<tr><td>Diffuse Injury IV</td><td>32</td><td>3.1</td><td>3.1</td><td>18.8</td><td>18.8</td><td>56.2</td></tr>
<tr><td>Diffuse Injury II, age ≤ 40 yr</td><td>153</td><td>10</td><td>28.7</td><td>41.1</td><td>11.1</td><td>9.1</td></tr>
<tr><td>Diffuse Injury II, age >40 yr</td><td>24</td><td>0</td><td>8.3</td><td>37.5</td><td>12.5</td><td>41.7</td></tr>
</table>
[f] $P < 0.001$</td></tr>
</table>

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Mathiesen et al. (41)	218	III	Mean GCS 6.9	Surgery and nonsurgical	GOS 6 mo	Retrospective review of data accumulated in prospective, randomized, double-blind HIT-2 study on nimodipine in head injury. 218 patients not following commands within 24 h of trauma with intracerebral lesions only on CT were chosen for analysis. Patients with extracerebral lesions, normal CT, gunshot wounds, pregnancy, bilaterally fixed/dilated pupils, GCS 3 for >2 h, and previous drug administration interfering with neurological assessment were excluded. Clinical management was not standardized. Patients were divided into 4 subgroups based on CT appearance within 24 h of trauma: 1) contusions; 2) fracture contusions (directly underlying depressed fx); 3) DAI; and 4) ICH (>10 cm^3), and analyzed with respect to GOS at 6 mo. A subgroup of patients with GCS ≥ 6 and lesion ≥ 20 cm^3 were analyzed for the effect of surgery and timing of surgery on outcome. A subgroup of patients who "talked and died" were analyzed to determine the value of early surgery.	● Initial CT characteristics associated with neurological deterioration, defined as fall in GCS by 2, GCS from 4 to 3, or pupillary dilatation, were SAH, focal lesion with volume >40 cm^3, and compressed/absent cisterns. ● Secondary (≥5 d) deterioration correlated with SAH on initial CT, hypoxic events. ● For the 4 groups: 1) Contusions: outcome adversely affected by presence of IVH. 2) Fracture/contusions: outcome significantly worse than other groups; outcome adversely affected by presence of SAH. 3) DAI: mean admission GCS significantly worse than other groups. No patients operated. 4) ICH: mean admission GCS significantly better than other groups; outcome adversely affected by presence of IVH. ● Patients with lesions ≥ 20 cm^3 and admission GCS ≥ 6: 1) Patients operated without previous deterioration (n = 9) had better outcome than those not operated on or operated on after deterioration (n = 66). 2) Patients with radiological signs of mass effect (compression/obliteration of cistern and/or midline shift ≥ 5 mm) had better outcome with surgery versus no surgery, and those operated before deterioration had better outcome than those operated after deterioration. 3) Surgery did not influence outcome in patients admitted with GCS ≤ 5. ●11 patients with temporal contusion, radiological signs of mass effect, admission GCS ≥ 10: outcome significantly better in those operated before or immediately after deterioration compared with delayed or no surgery. ●Authors points: 1) Patients with frontal or temporal contusions with midline shift or cisternal compression had statistically better outcome with surgery. 2) Surgical outcome was better the earlier it was performed related to deterioration. 3) Patients with temporal contusions and radiological signs of mass effect should be operated on before deterioration. 4) Authors offer indications for surgery: all patients with contusions > 20 cm^3 with radiological signs of mass effect or with any lesion > 50 cm^3.

	No. of patients	GR/MD (%)	D (%)	Mean GOS
All patients	218	56	27.5	3.2

Lesion type	No. of patients	GR (%)	MD (%)	SD (%)	VS (%)	D (%)
Contusions	122	24	30	11	5	30
Contusions/depressed cranial fracture ^{g}	24	12	17	25	4	42
DAI	39	23	25	30	5	17
ICH	32	31	28	16	3	22

	No. of patients	GR/MD/SD (%)	VS/D (%)
GCS ≥ 6, volume ≥ 20 cm^3			
No surgery	42	50	50
Surgery before deterioration^g	6	100	0
Surgery on day of deterioration	9	67	33
Surgery ≥ 1 d after deterioration	9	55	44
GCS ≥ 6, volume ≥ 20 cm^3, CT mass effect			
No surgery	19	26	74
Surgery before deterioration^g	6	100	0
Surgery on day of deterioration	8	62.5	37.5
Surgery ≥ 1 d after deterioration	1	0	100
GCS ≥ 6, volume ≥ 50 cm^3			
No surgery	14	36	64
Surgery before deterioration^g	3	100	0
Surgery on day of deterioration^g	10	70	30
Surgery ≥ 1 d after deterioration	1	0	100
GCS ≥ 10 cm^3, temporal contusion, CT mass effect			
Delayed or no surgery	8	0	100
Surgery before or at time of deterioration^g	3	100	0

^{g} $P < 0.05$.

TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Meier et al. (42)</td><td>38</td><td>III</td><td>All GCS</td><td>Surgery</td><td>GOS at discharge</td><td>Retrospective series of 936 patients who underwent surgery for TBI, 38 of whom were children with ICH/contusion as primary pathology. GOS is related to admission GCS.</td><td>• Children with admission GCS 6–8 had better overall outcome than adults with admission GCS 6–8.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS (%)</th><th>D (%)</th></tr>
<tr><td>Children with contusions</td><td>38</td><td>53</td><td>10</td><td>37</td></tr>
</table></td></tr>
<tr><td>Meier et al. (43)</td><td>19</td><td>III</td><td>GCS 3–12</td><td>Decompressive craniectomy</td><td>GOS at discharge</td><td>Retrospective series of 19 patients with intractable intracranial hypertension undergoing decompressive craniectomy to evaluate factors related to prognosis. Surgical indications included failure of conservative intervention for intracranial hypertension, age <50 yr without multiple trauma, age <30 yr in presence of major extracranial injuries, severe brain swelling on CT (or intraoperatively). 11 patients underwent decompressive craniectomy because generalized brain edema was evident during evacuation of a space-occupying lesion; 8 patients underwent decompressive craniectomy secondary to failure of conservative treatment.</td><td>• 2 patients >60 yr had GOS 2 (VS).
• Age and GCS related to GOS (no statistics).
•Mortality increased with the presence of extracranial injuries (no statistics).
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>All</td><td>19</td><td>26</td><td>5</td><td>26</td><td>43</td></tr>
<tr><td>Operated</td><td></td><td></td><td></td><td></td><td>63</td></tr>
<tr><td>Nonoperated</td><td></td><td></td><td></td><td></td><td>27</td></tr>
</table></td></tr>
<tr><td>Miller et al. (44)</td><td>20</td><td>III</td><td>GCS 3–8</td><td>Surgical and nonsurgical</td><td>GOS 3 mo</td><td>Prospective series of 225 patients with severe head injury managed by standardized protocol to identify prognostic variables and to validate results of a previous study. Subgroups with surgical and nonsurgical lesions are identified and outcome is specified for each lesion. The definition of ICH included >5 mm midline shift, and, thus, all were taken to surgery.</td><td>• Correlation between age, abnormal motor response, bilateral loss of light reflex, impaired/absent oculocephalic reflex, and outcome in nonoperatively managed patients.
• Parenchymal lesions of increased density on CT were associated with severe disability/vegetative state compared with other lesions.
• 31% incidence of uncontrollable postoperative elevated ICP in ICH patients. Surgical and nonsurgical groups were not comparable.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS (%)</th><th>D (%)</th></tr>
<tr><td>ICH</td><td>20</td><td>26</td><td>16</td><td>58</td></tr>
<tr><td>Contusion, no surgery</td><td>31</td><td>64</td><td>13</td><td>23</td></tr>
<tr><td>Diffuse, no surgery</td><td>101</td><td>73</td><td>10</td><td>17</td></tr>
</table></td></tr>
<tr><td>Munch et al. (45)</td><td>49</td><td>III</td><td>GCS < 8 to ≥ 8</td><td>Decompressive craniectomy</td><td>GOS 6 mo</td><td>Retrospective series of 49 patients undergoing unilateral decompressive craniectomy for TBI under standardized treatment protocol to evaluate preoperative and postoperative CT characteristics, ICP/CPP change, and to assess outcome. A subdivision into rapid and delayed groups was also analyzed according to outcome. Surgical indications detailed. Patients with bilateral intracranial lesions; bilaterally fixed and dilated pupils; and life-threatening concomitant medical disease were excluded. All patients undergoing rapid decompression had acute SDH. All patients undergoing delayed decompression had diffuse brain swelling.</td><td>• 41% good outcome at 6 mo.
• Visibility of mesencephalic cisterns and midline shift improved significantly after craniectomy; gyral pattern and visibility of ventricles did not.
• No change in mean therapeutic intensity level before versus after decompression.
• Age <50 yr, GCS ≥ 8 correlated significantly with better outcome.
• GOS at 6 mo significantly better in rapid versus delayed decompression groups, but GOS at discharge from ICU not significantly different.
• No significant difference between before and after decompression ICP and CPP.
• Change in mesencephalic cistern visibility correlated with distance between lower craniectomy border and cranial base (more than area of decompression).
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th></tr>
<tr><td>At discharge from ICU</td><td>49</td><td>28</td><td>72</td></tr>
<tr><td>At 6 mo</td><td>49</td><td>41</td><td>59</td></tr>
</table>
<table>
<tr><th></th><th>GCS 8</th><th>GCS < 8</th><th>Rapid</th><th>Delayed</th><th>Age <50 yr</th><th>Age 50 yr</th></tr>
<tr><td>Mean GOS</td><td>3.9</td><td>1.4^{h}</td><td>3.1</td><td>1.9^{i}</td><td>3.0</td><td>1.9^{i}</td></tr>
</table>
^{h} $P = 0.023$, ^{i} $P = 0.046$.</td></tr>
</table>

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Nagabhand and Sangcham (46)	10	III	Unknown	Surgery	Mortality	Retrospective review of 71 patients undergoing surgery for intracranial hematoma. Mortality compared between different intracranial lesions, and between groups treated before and after introduction of CT to the hospital. A subset of 10 patients with ICH receiving preoperative CT is included	No. of patients D (%) ICH/contusion 10 50
Nordstrom et al. (47)	587	III	GCS 3–8	Surgery and nonsurgical	GOS 6 mo	Retrospective series of 587 patients with severe TBI, primarily to analyze effect of institution of management protocol in a region in Sweden on outcome. Protocol instituted in 1983. For our purposes, epidemiology and outcome of ICH and severe TBI with no mass lesion are evaluated.	● Patients with ICH (including associated SDH/EDH) had 64% mortality and 15% good recovery at 6 mo. ● % of exploratory craniotomies and % mortality in local hospitals decreased following institution of management protocol. CT was not universally available at local hospitals. No. of patients GR (%) D (%) ICH 205 15 64 No mass lesion, exploratory craniotomy 30 73^j No mass lesion, no exploration 150 61 ^{j} P = n.s.
Nussbaum et al. (48)	10	III	GCS 3–6	Temporal lobectomy	Barthel index, minimum 8 mo	Retrospective series of 10 patients with GCS 3–6 and clinical signs of transtentorial herniation who underwent standardized temporal lobectomy for unilateral hemispheric swelling. All patients demonstrated fixed pupillary dilation; unilateral in 7, bilateral in 3. All failed medical therapy and underwent surgery within 2 h of signs of herniation.	● Overall 40% functionally independent survival with 30% mortality. No. of patients Functional independence (%) Minimal assistance (%) D (%) Total 10 40 30 30
Papo et al. (49)	29	III	GCS 4–5 to > 10	Surgery and nonsurgical	Mortality at discharge	Retrospective series of 29 patients with traumatic ICH/brain laceration to analyze the correlation between GCS, CT, and ICP data and outcome with or without operative treatment. ICP data recorded via intraventricular catheter.	●Patients with GCS 4–5 on admission treated by operation within 48 h of injury died (no statistics). No. of patients D (%) GCS 4–5 5 100 GCS 6–10 13 46.2 GCS > 10 11 0
Patel et al. (50)	38	III	GCS < 8 to >13	Nonsurgical	Mortality	Retrospective series of 57 patients initially managed nonoperatively who subsequently required craniotomy to attempt to identify factors that led to failure of nonoperative management. A subgroup of 38 patients with ICH reviewed.	● 54.5% of patients with ICP >20 mm Hg failed nonoperative management in <24 h. ● Frontal ICH were significantly more prone to early versus late failure. ● Mortality in failed ICH patients was 10.5%. No. of patients D (%) Failed ICH 38 10.5

TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Polin et al. (51)</td><td>35</td><td>III</td><td>Mean GCS 5.62</td><td>Bifrontal decompressive craniectomy</td><td>GOS at discharge</td><td>Retrospective case-control series of 35 patients undergoing bifrontal decompressive craniectomy for refractory posttraumatic cerebral edema comparing preoperative and postoperative ICP, age versus outcome, and comparing the group as a whole with the group from TCDB matched for age, admission GCS, sex, and maximal ICP in terms of outcome. Only TCDB patients with diffuse injury, no significant mass lesion, no midline shift (III) (Marshall et al. [39]) were eligible for consideration as controls.</td><td>● Admission GCS related to outcome.
● Operation <48 h associated with favorable outcome (46%) compared with >48 h (0%).
● Significant change in ICP before versus after decompression.
● Significant difference in postoperative ICP versus control ICP 48–72 h after injury.
● Coagulopathy did not affect outcome in surgical group.
● ICP > 40 mm Hg sustained and operation >48 h after injury had significantly less favorable outcomes.
● Age <18 yr had higher rate of favorable outcome in surgical group.
● Surgery age <18 yr had higher rate of favorable outcome than matched controls if operated <48 h and ICP < 40 mm Hg.
● Medical management alone carried 3.86 times relative risk of unfavorable outcome compared with decompressive craniectomy.
● Maximum benefit is achieved in patients operated on <48 h after injury and with ICP elevations sustained <40 mm Hg (60% favorable versus 18% in matched controls).
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Surgery ^{k}</td><td>35</td><td>11.4</td><td>25.7</td><td>31.4</td><td>8.6</td><td>22.9</td></tr>
<tr><td>Case control</td><td>92</td><td>7.6</td><td>8.8</td><td>35.2</td><td>18.7</td><td>30.8</td></tr>
</table>
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>D (%)</th></tr>
<tr><td>Coagulopathy</td><td>18</td><td>33^{l}</td><td>28</td></tr>
<tr><td>No coagulopathy</td><td>17</td><td>41</td><td>18</td></tr>
<tr><td>ICP > 40 mm Hg, OR >48 h</td><td>15</td><td>6.7^{m}</td><td></td></tr>
<tr><td>ICP < 40, OR <48 h</td><td>20</td><td>60</td><td></td></tr>
<tr><td>Age <18 yr</td><td>18</td><td>44</td><td></td></tr>
<tr><td>Age >18 yr</td><td>17</td><td>29</td><td></td></tr>
<tr><td>OR <48 h, ICP <40</td><td>20</td><td>60^{n}</td><td></td></tr>
<tr><td>ICP < 40, control</td><td>58</td><td>18</td><td></td></tr>
<tr><td>Age <18, ICP <40, OR <48 h</td><td>10</td><td>80^{o}</td><td></td></tr>
<tr><td>Age <18, ICP <40, control</td><td>25</td><td>24</td><td></td></tr>
</table>
^{k} favorable outcome, $P = 0.014$; ^{l} P = n.s., ^{m} $P = 0.0004$, ^{n} $P = 0.0001$, ^{o} $P = 0.02$.</td></tr>
<tr><td>Servadei et al. (54)</td><td>724</td><td>III</td><td>GCS 3–12</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Prospective study of 724 patients with moderate-to-severe TBI to determine the frequency of changes in CT findings and their prognostic implications.</td><td>● 16% of diffuse injuries on initial CT demonstrated deterioration on subsequent CT.
● 12% of diffuse injuries evolved to mass lesions.
● Evolution from diffuse injury without swelling or shift (Type II) to a mass lesion was associated with significant increase in risk of unfavorable outcome.
● Trend towards more favorable outcome in patients with nonevacuated versus evacuated mass lesions.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/ D (%)</th></tr>
<tr><td>Diffuse injury I, no change</td><td>75</td><td>87</td><td>13</td></tr>
<tr><td>Diffuse injury I, evolution</td><td>5</td><td>80</td><td>20</td></tr>
<tr><td>Diffuse Injury II, no change</td><td>185</td><td>62</td><td>38</td></tr>
<tr><td>Diffuse Injury II, evolution^{p}</td><td>34</td><td>38</td><td>62</td></tr>
<tr><td>Diffuse Injury III, no change</td><td>57</td><td>33</td><td>67</td></tr>
<tr><td>Diffuse Injury III, evolution</td><td>7</td><td>57</td><td>43</td></tr>
<tr><td>Diffuse Injury IV, no change</td><td>14</td><td>21</td><td>79</td></tr>
<tr><td>Diffuse Injury IV, evolution</td><td>4</td><td>75</td><td>25</td></tr>
<tr><td>Mass lesion</td><td>343</td><td>43</td><td>57</td></tr>
</table>
^{p} $P < 0.01$.
<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Diffuse injury I</td><td>80</td><td>74</td><td>12</td><td>9</td><td>0</td><td>5</td></tr>
<tr><td>Diffuse injury II</td><td>219</td><td>36</td><td>22</td><td>20</td><td>2</td><td>21</td></tr>
<tr><td>Diffuse injury III</td><td>64</td><td>20</td><td>16</td><td>9</td><td>2</td><td>53</td></tr>
<tr><td>Diffuse injury IV</td><td>18</td><td>11</td><td>22</td><td>11</td><td>0</td><td>56</td></tr>
</table></td></tr>
</table>

TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Singounas (57)</td><td>16</td><td>III</td><td>GCS 8–10</td><td>Unknown</td><td>Mortality</td><td>Retrospective review of 48 children $<$14 yr with severe head injury (extradural and subdural hematomas excluded) to comment on relatively good prognosis. Mortality for 16 patients with brain edema only was reported.</td><td><table>
<tr><th></th><th>No. of patients</th><th>D (%)</th></tr>
<tr><td>Diffuse edema, no focal lesion</td><td>16</td><td>12.5</td></tr>
</table></td></tr>
<tr><td>Soloniuk et al. (58)</td><td>35</td><td>III</td><td>GCS ≤ 8 or $>$ 8</td><td>Surgery</td><td>GOS 6 mo</td><td>Retrospective review of 35 patients undergoing craniotomy for evacuation of ICH to evaluate characteristics of timing of appearance of ICH and factors related to outcome. ICH defined as homogeneous coalescent area of high attenuation measuring 2 cm or greater.</td><td>• Only 26% of ICH requiring evacuation are present on CT within 6 h of injury.
• 49% overall 1-yr mortality; 71% with GCS ≤ 8.
• Mortality varies with location, with panhemispheric, temporal, and frontal rates of 80%, 57%, and 37%, respectively.<table>
<tr><th></th><th>No. of patients</th><th>D (%)</th></tr>
<tr><td>ICH, operated</td><td>35</td><td>49</td></tr>
</table></td></tr>
<tr><td>Sprick et al. (59)</td><td>34</td><td>III</td><td>GCS 3 to $>$ 7</td><td>Surgery and nonsurgical</td><td>GOS, not specified</td><td>Retrospective series of 34 patients with DTICH of at least 2.5-cm diameter in previously normal area on initial CT to evaluate outcome and clinical characteristics.</td><td>• 53% DTICH developed within 24 h after admission and 79% within 48 h<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>Disabled (%)</th><th>D (%)</th></tr>
<tr><td>All</td><td>34</td><td>17.6</td><td>55.9</td><td>26.5</td></tr>
<tr><td>Operated</td><td>7</td><td>14.3</td><td>42.9</td><td>42.9</td></tr>
</table></td></tr>
<tr><td>Statham et al. (60)</td><td>18</td><td>III</td><td>GCS 5–14</td><td>Surgery (n = 1) and nonsurgical</td><td>GOS 6 mo</td><td>Retrospective review of 18 patients with primary CT diagnosis of frontal contusion, defined as regions of mixed high and low or low attenuation in the frontal lobes, to attempt to determine factors that may lead to neurological deterioration and worse outcome.</td><td>• Good outcome was achieved in 72% of patients with frontal contusion.
• Both cases of deterioration were associated with extensive bilateral injury (no statistics).<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Unilateral contusion</td><td>10</td><td>90</td><td>0</td><td>0</td><td>0</td><td>10</td></tr>
<tr><td>Limited bilateral contusions</td><td>5</td><td>40</td><td>40</td><td>20</td><td>0</td><td>0</td></tr>
<tr><td>Extensive bilateral contusions</td><td>3</td><td>67</td><td>0</td><td>0</td><td>0</td><td>33</td></tr>
<tr><td>Frontal contusions, total</td><td>18</td><td>72.2</td><td>11.1</td><td>5.6</td><td>0</td><td>11.1</td></tr>
</table></td></tr>
<tr><td>Taylor et al. (61)</td><td>27</td><td>II</td><td>GCS 4–11</td><td>Decompressive bitemporal craniectomy and nonsurgical</td><td>GOS 6 mo;Health State Utility Index 6 mo</td><td>Prospective, randomized, controlled trial of 27 children with TBI and sustained intracranial hypertension to evaluate effect of early decompressive bitemporal craniectomy on outcome and on control of ICP.</td><td>• Trend towards greater decrease in ICP in decompression group ($P = 0.057$).
• Trend towards shorter ICU stay in decompression group ($P = 0.12$).
• Trend towards improved outcome in decompression group ($P = 0.046$ [$P < 0.0221$ required for significance]).<table>
<tr><th></th><th>No. of patients</th><th>Favorable (%)</th><th>Unfavorable (%)</th></tr>
<tr><td>Decompression</td><td>13</td><td>53.8[q]</td><td>46.1</td></tr>
<tr><td>Control</td><td>14</td><td>14.3</td><td>85.7</td></tr>
</table>[q] $P = 0.046$ ($P < 0.0221$ required for significance). Favorable: normal or functionally normal but requiring medication or medical supervision. Unfavorable: moderate disability, dependent, severely disabled/vegetative, or dead.</td></tr>
<tr><td>Teasdale et al. (62)</td><td>37</td><td>III</td><td>GCS 3–8</td><td>Nonsurgical</td><td>GOS 6 mo</td><td>Retrospective series of 37 patients diagnosed with severe diffuse head injury (without midline shift of $>$5 mm) to determine the relationship between compression of basal cisterns/3rd ventricle and elevated ICP.</td><td>• Highly significant relationship between status of basal cisterns/III ventricle and level of ICP.
• Presence versus absence of cisterns/III ventricle seemed to correlate with outcome within GCS groups (no statistics).<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD (%)</th><th>VS/D (%)</th></tr>
<tr><td>GCS 3–5, absent cisterns/3rd ventricle</td><td>11</td><td>9.1</td><td>0</td><td>90.9</td></tr>
<tr><td>GCS 3–5, present cisterns/3rd ventricle</td><td>5</td><td>20</td><td>20</td><td>60</td></tr>
<tr><td>GCS 6–8, absent cisterns/3rd ventricle</td><td>8</td><td>37.5</td><td>25</td><td>37.5</td></tr>
<tr><td>GCS 6–8, present cisterns/3rd ventricle</td><td>13</td><td>61.5</td><td>15.4</td><td>23.1</td></tr>
</table></td></tr>
</table>

TABLE 1. Continued

<table>
<tr><th>Authors (ref. no.)</th><th>No. of patients</th><th>Class</th><th>Inclusion GCS</th><th>Treatment</th><th>Outcome</th><th>Description</th><th>Conclusion</th></tr>
<tr><td>Tseng (63)</td><td>32</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>GOS 1 yr</td><td>Retrospective series of 32 patients with DTICH to evaluate clinical and radiologic factors affecting outcome.</td><td>

- Hematoma volume, cisternal effacement, timing of detection, occurrence of clinical deterioration, and GCS at time of follow-up CT were related significantly to outcome.
- 16% overall mortality.

<table>
<tr><th></th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS/D (%)</th></tr>
<tr><td>GCS 3–7 at follow-up CT[r]</td><td>12</td><td>33</td><td>67</td></tr>
<tr><td>GCS 8–12 at follow-up CT</td><td>16</td><td>100</td><td>0</td></tr>
<tr><td>GCS 13–15 at follow-up CT</td><td>4</td><td>100</td><td>0</td></tr>
<tr><td>Cistern effacement[s]</td><td>5</td><td>0</td><td>100</td></tr>
<tr><td>No cistern effacement</td><td>27</td><td>88.9</td><td>11.1</td></tr>
</table>

[r] $P < 0.005$, [s] $P < 0.001$.
</td></tr>
<tr><td>Tseng (64)</td><td>32</td><td>III</td><td>GCS 5–7</td><td>Craniotomy ± manual temporal lobe reduction</td><td>GOS 3 mo</td><td>Retrospective study of 32 patients with GCS 5–7, CT evidence for uncal herniation, anisocoria, and hemiparesis treated either with standard surgical procedure (i.e., craniotomy with hematoma evacuation and contusion resection) or with standard procedure plus manual reduction of herniated temporal lobe. GOS measured at ≥3 mo postop to compare outcome between groups.Reduction procedure described as gentle elevation of temporal lobe until tentorium is visualized and CSF egress is noted.</td><td>

- Addition of temporal lobe reduction to the standard surgical procedure seemed to result in better outcome (no statistics; selection bias).

<table>
<tr><th></th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>Craniectomy + contusion + reduction</td><td>10</td><td>20</td><td>70</td><td>0</td><td>0</td><td>10</td></tr>
<tr><td>Craniectomy + contusion, no reduction</td><td>22</td><td>0</td><td>27</td><td>9</td><td>9</td><td>55</td></tr>
</table>
</td></tr>
<tr><td>Uzzell et al. (65)</td><td>117</td><td>III</td><td>GCS 4–6</td><td>Nonsurgical</td><td>GOS 6 mo; neuro-psychological mean 4.8 mo (n = 30)</td><td>Retrospective series of 117 patients with DAI, diffuse swelling, or focal injury by CT to characterize differential outcome. Neuropsychological testing was performed in a subset of 30 patients to characterize differential neuropsychological sequelae based on lesion type. Patients with SDH, EDH, SAH, or development of a second major lesion were excluded. DAI defined as "midline hemorrhages or multiple small hemorrhages at gray-white matter interfaces"; diffuse swelling defined as "narrowing or obliteration of ventricles or basilar cisterns"; focal injuries defined as "unilateral intracerebral hemorrhages or contusions."</td><td>

- Patients with DAI had significantly higher mortality and significantly less "good recovery" than other groups.
- Memory and learning score but not intelligence or visuomotor speed score significantly differed among CT groups.
- Levels of memory, learning, and visuomotor speed were higher after diffuse swelling injuries, but improvement was less over time.
- Patients with DAI had greater improvement over time of memory, learning, and visuomotor speed.
- Patients with focal injuries had improvement over time in visuomotor speed, but not recall or learning.
- Diagnostic groups did not differ significantly in age, years of education, GCS, timing of neuropsychological testing, sex, handedness, or GOS at 6 mo.

<table>
<tr><th>CT group[t]</th><th>No. of patients</th><th>GR (%)</th><th>MD (%)</th><th>SD (%)</th><th>VS (%)</th><th>D (%)</th></tr>
<tr><td>DAI</td><td>33</td><td>18</td><td>15</td><td>15</td><td>12</td><td>40</td></tr>
<tr><td>Diffuse swelling</td><td>34</td><td>62</td><td>17</td><td>6</td><td>0</td><td>15</td></tr>
<tr><td>Focal injury</td><td>50</td><td>48</td><td>15</td><td>14</td><td>0</td><td>22</td></tr>
</table>

[t] $P < 0.01$.
</td></tr>
<tr><td>Vollmer et al. (66)</td><td>321</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>GOS 6 mo</td><td>Prospective study from 1984–1987 of patients with GCS 3–15 to evaluate effect of age on outcome in different populations, including patients with large (>15 cm^3) ICH requiring evacuation (n = 54) and patients with <15 cm^3 ICH (n = 267).</td><td>

- Presence of ICH and of large ICH (>15 cm^3) increased significantly with age.
- Increasing age was independently predictive of poor outcome in large and small ICH subgroups.

<table>
<tr><th></th><th>No. of patients</th><th>VS/D (%)</th></tr>
<tr><td>ICH <15 cm^3[u]</td><td>267</td><td></td></tr>
<tr><td>Age 16–25 yr</td><td></td><td>31.8</td></tr>
<tr><td>Age 26–35 yr</td><td></td><td>27.7</td></tr>
<tr><td>Age 36–45 yr</td><td></td><td>42.4</td></tr>
<tr><td>Age 46–55 yr</td><td></td><td>62.2</td></tr>
<tr><td>Age >56 yr</td><td></td><td>82.2</td></tr>
</table>

[u] $P < 0.001$
</td></tr>
</table>

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Whitfield et al. (67)	26	III	GCS 3–13	Bifrontal decompressive craniectomy	GOS 6 mo	Retrospective review of outcome for 26 patients undergoing bifrontal decompressive craniectomy for refractory intracranial hypertension (ICP > 30 mm Hg with CPP < 70 mm Hg; or ICP > 35 mm Hg irrespective of CPP) managed using a standardized ICP/CPP treatment algorithm. Continuous ICP, ABP, and CPP data were analyzed for 8 patients to examine effect of bifrontal decompressive craniectomy on these variables. Surgical technique described.	● 61% of severe TBI subgroup had favorable outcome (GOS 4–5). ● ICP was significantly reduced from 37.5 to 18.1 mm Hg ($P = 0.003$). ● CPP differences were not significant. ● Amplitude of ICP waveform, amplitude of slow waves, and RAP coefficient (reflecting increased compensatory reserve) were significantly reduced by surgery in a subgroup of eight patients. ● Timing of surgery was not predictive of outcome. **No. of patients / GR/MD (%) / SD (%) / VS (%) / D (%)** All 26 / 69 / 8 / 0 / 23 Age<16 6 / 83.3 / 0 / 0 / 16.7 GCS 3–8 18 / 61.1 / 11.1 / 0 / 27.8 GCS 9–12 5 / 100 / 0 / 0 / 0 GCS 13 3 / 66.7 / 0 / 0 / 33.3 **Timing of surgery / No. of patients / Favorable (%) / Unfavorable (%)** OR <48 h after injury 20 / 60 / 40 OR >48 h after injury 6 / 100 / 0
Wu et al. (68)	35	III	All GCS	Surgery	GOS 6 mo	Retrospective series of 489 patients treated surgically for intracranial hematomas to assess prognostic factors related to GOS at 6 mo. A subgroup of 35 patients with ICH is included.	● Postresuscitation GCS, preoperative change in pupillary size, No. of operations, No. of hematomas, and type of lesion were significantly related to surgical outcome. ● Good outcome: single, evacuated EDH > ICH > SDH. **No. of patients / GR (%) / MD (%) / SD (%) / VS (%) / D (%)** Acute ICH, evacuated 35 / 60 / 22.9 / 8.6 / 2.8 / 5.7
Yamaki et al. (69)	48	III	Unknown	Surgery and nonsurgical	GOS; time of maximal hematoma diameter	Retrospective review of 48 patients with traumatic ICH > 3-cm diameter whose first CT occurred within 6 h of injury to evaluate the timing of hematoma evolution and to assess outcome. CT scans of 32 nonoperated patients were used to assess natural history of hematoma evolution.	● All ICH >3-cm diameter developed within 24 h of injury. ● Only 56% of ICH >3-cm diameter developed within 6 h of injury. ● ICH reached maximal size in 84% of patients within 12 h. **No. of patients / GR (%) / MD (%) / SD (%) / VS (%) / D (%)** ICH, total 58 / 53 / 14 / 2 / 3 / 28 ICH, operated 26 / 35 / 8 / 4 / 7 / 46 **No. of patients / GR (%)** Nonoperated 32 / 13 Operated 26 / 46 Admitted immediately after TBI 16 / 31 Admitted >6 h after TBI 10 / 70
Young et al. (72)	15	III	Grady Coma Scale 1–5	Surgery	Modified GOS, not specified	Retrospective series after introduction of CT of 15 patients treated surgically for DTICH to examine clinical and radiologic correlates, and to relate clinical status to outcome.	● Morbidity/mortality associated with coma score on admission (no statistics). ● 80% occipital/parietooccipital impact; contrecoup frontotemporal lesions. ● Definition of DTICH: develops in area of previous contusion. **No. of patients / Intact (%) / Mild disability (%) / Significant disability (%) / D (%)** Grady 1–2 6 / 83.3 / 16.7 / 0 / 0 Grady 3–4 9 / 0 / 0 / 22.2 / 77.8 DTICH, total 15 / 33.3 / 6.7 / 13.3 / 46.7
Zumkeller et al. (73)	53	III	GCS <5 to 11–15	Surgery and nonsurgical	Poor versus good, not specified	Retrospective series of 104 patients with ICH, 53 of whom presented with traumatic ICH, comparing operative versus nonoperative treatment with outcome.	● No statistical difference in outcome was found between operated and nonoperated groups. **No. of patients / Good (%) / Poor (%)** Operated 31 / 71 / 29 Nonoperated 22 / 40.9 / 59.1 Single lobe, operated 17 / 70.6 / 29.4 Single lobe, non-operated 8 / 75 / 25 P = n.s.

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[a] GCS, Glasgow Coma Scale; GOS, Glasgow outcome score; ICH, intracerebral hemorrhage; ICP, intracranial pressure; CT, computed tomographic; GR, good recovery; MD, moderate disability; VS, vegetative state; D, death; SD, severe disability; DTICH, delayed traumatic intracerebral hematoma; SDH, subdural hematoma; n.s., not significant; FIM, functional independence measure; EDH, epidural hematoma; LOC, loss of consciousness; TCDB, Traumatic Coma Data Bank; SEP, somatosensory evoked potential; CPP, cerebral perfusion pressure; AEP, acoustic evoked potential; STD, subtemporal decompression; TL, temporal lobectomy; MUC, multiple unilateral contusion; GBS, generalized brain swelling; DAI, diffuse axonal injury; TBI, traumatic brain injury; SAH, subarachnoid hemorrhage; IVH, intraventricular hemorrhage; ABP, arterial blood pressure; RAP, renal artery pressure; ICU, intensive care unit; OR, operation.