Surgical Management of Acute Epidural Hematomas

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 E. 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 for Surgery

- An epidural hematoma (EDH) greater than 30 cm^3 should be surgically evacuated regardless of the patient's Glasgow Coma Scale (GCS) score.
- An EDH less than 30 cm^3 *and* with less than a 15-mm thickness *and* with less than a 5-mm midline shift (MLS) in patients with a GCS score greater than 8 *without* focal deficit can be managed nonoperatively with serial computed tomographic (CT) scanning and close neurological observation in a neurosurgical center.

Timing

- It is strongly recommended that patients with an acute EDH in coma (GCS score < 9) with anisocoria undergo surgical evacuation as soon as possible.

Methods

- There are insufficient data to support one surgical treatment method. However, craniotomy provides a more complete evacuation of the hematoma.

KEY WORDS: Coma, Computed tomographic parameters, Craniotomy, Epidural, Head injury, Hematoma, Surgical technique, Timing of surgery, Traumatic brain injury

Neurosurgery 58:S2-7-S2-15, 2006 DOI: 10.1227/01.NEU.0000210363.91172.A8 www.neurosurgery-online.com

OVERVIEW

Incidence

Since the introduction of CT scanning as the imaging study of choice to detect intracranial lesions after trauma, the incidence of surgical and nonsurgical EDH among traumatic brain injury (TBI) patients has been reported to be in the range of 2.7 to 4% (8, 11, 25, 41). Among patients in coma, up to 9% harbored an EDH requiring craniotomy (10, 35). The peak incidence of EDH is in the second decade, and the mean age of patients with EDH is between 20 and 30 years of age (3, 8, 9, 13, 16–18, 20, 22, 26, 29, 32, 37, 39). EDH are a rare entity in patients older than 50 to 60 years of age. In pediatric patients, the mean age of patients harboring EDH is between 6 and 10 years (21, 34), and EDH is less frequent in very young children and neonates (27, 30).

Pathogenesis

Traffic-related accidents, falls, and assaults account for 53% (range, 30–73%), 30% (range, 7–52%), and 8% (range, 1–19%), respectively, of all EDH (3, 8, 20, 22, 26, 27, 36, 40). In pediatric patients, falls are the leading cause of EDH in 49% of cases (range, 25–59%) and traffic-related accidents are responsible for 34% (range, 25–41%) of all EDH (21, 25–27, 30, 34). EDH can result from injury to the middle meningeal artery, the middle meningeal vein, the diploic veins, or the venous sinuses. Historically, bleeding from the middle meningeal artery has been considered the main source for EDH. In a recent report on EDH in 102 pediatric patients and 387 adults, arterial bleeding was identified as the source of the EDH in 36% of the adults and only in 18% of the children (27). In 31% of the pediatric patients, a bleeding source could not be identified and venous bleeding accounted for approximately 32% of EDH in both age groups.

Location

In surgical series, EDH are more frequently located in the temporoparietal and temporal regions as compared with other locations (3, 6, 25, 27, 29, 32). In 2 to 5% of patients, bilateral EDH are found (11, 18, 40), and there seems to be a slight predominance of right-sided EDH over left-sided lesions (6, 40).

Clinical Presentation

In patients with EDH, 22 to 56% are comatose on admission or immediately before surgery (3, 17, 20, 22, 25, 32). The classically described "lucid interval," i.e., a patient who is initially unconscious, then wakes up and secondarily deteriorates, was observed in a total of 456 of 963 patients (47%) undergoing surgery for EDH in seven studies (3, 8, 18, 22, 28, 31, 39). Between 12 and 42% of patients remained conscious throughout the time between trauma and surgery (3, 8, 17, 22). Pupillary abnormalities are observed in between 18 and 44% of patients, and up to 27% (3–27%) of patients are neurologically intact. Other presenting symptoms include focal deficits, such as hemiparesis, decerebration, and seizures. Early seizures are noted in 8% of pediatric patients presenting with EDH (21).

Mortality

The mortality in patients in all age groups and GCS scores undergoing surgery for evacuation of EDH is approximately 10% (range, 7–12.5%) (7, 8, 14, 17, 18, 20, 22, 28, 31, 32). Mortality in comparable pediatric case series is approximately 5% (25, 30).

Determinants of Outcome in Patients Undergoing Surgical Evacuation of an EDH

GCS, age, pupillary abnormalities, associated intracranial lesions, time between neurological deterioration and surgery, and intracranial pressure (ICP) have been identified as important factors determining outcome from EDH.

Age and GCS

The influence of age on outcome in the subgroup of patients with EDH is not as pronounced as it is in TBI patients overall. Three studies using multiple regression analysis found that GCS was a better predictor of outcome than age in patients undergoing surgery for EDH (20, 22, 38). In a retrospective analysis of 98 patients of all age groups with EDH undergoing craniotomy, van den Brink et al. (39) investigated determinants of outcome at 6 months. They identified GCS, age, and the CT diagnosis of subarachnoid hemorrhage as significant factors correlated with outcome, using multivariate analysis. Admission GCS or GCS before surgery is the single most important predictor of outcome in patients with EDH undergoing surgery (3, 10, 20, 22, 24, 38, 39). In three studies using multivariate analysis in a total of 284 patients, the admission GCS score was identified as the most significant factor determining outcome at 6 months (20, 38, 39). In one study with 200 patients undergoing craniotomy, admission and preoperative GCS both correlated with functional outcome at 1 year (22). Gennarelli et al. (10) analyzed the relationship between type of lesion, GCS score on admission, and 3-months outcome in 1107 comatose patients with TBI. The highest mortality was found in patients with a subdural hemorrhage and a GCS between 3 and 5 (74%). Patients with an EDH and a GCS of 3 to 5 had a mortality of 36%, and patients with an EDH and a GCS of 6 to 8 had a mortality of only 9%.

Pupils

Pupillary abnormalities, such as pupillary asymmetry or fixed and dilated pupils occur in approximately 20 to 30% of patients with EDH undergoing surgery (3, 16, 20, 40) and in 62% of patients who are comatose on admission (32). One study showed that ipsilateral mydriasis was not associated with adverse outcome and was reversible when operated on within 70 minutes after pupillary dilation (6). Bilateral mydriasis, however, is associated with a high mortality (3, 6, 8, 24, 32, 39). Mydriasis contralateral to the hematoma is also associated with high mortality (24, 32). Van den Brink et al. (39), in a multivariate model evaluating the relative prognostic value of predictive parameters, found that, in patients in all age groups and GCS scores, pupillary abnormalities were significantly related to unfavorable outcome. Adverse outcome was observed in 30% of normal pupillary responses, in 35% of unilateral fixed pupils, and in 50% of bilateral fixed pupils. Bricolo and Pasut (3) achieved a good outcome in 100% of patients who presented with anisocoria and in 90% of patients who presented with anisocoria and hemiparesis. The only patient with bilateral mydriasis in their case series died.

Associated Lesions

Associated intracranial lesions are found in between 30 and 50% of adult patients with surgically evacuated EDH (3, 8, 13, 16, 20, 22, 23, 27, 29, 31, 32, 35). These are predominantly contusions and intracerebral hemorrhage followed by subdural hematoma (SDH) and diffuse brain swelling (8, 16, 29, 32, 35). The incidence of associated lesions is less in the pediatric age group (25, 27, 30). SDH and/or parenchymal lesions in association with EDH lower the chance of a good outcome. In two studies with a total of 315 patients operated on for evacuation of an EDH, the frequency of associated intracranial lesions was 33% (20, 22). In both studies, a significant relationship was found between the presence of other lesions in addition to the EDH and an adverse outcome. Lee et al. (22) identified associated brain lesions as one of four independent predictors of unfavorable outcome after surgery for EDH and this has been confirmed by several others (8, 13, 16, 23, 32). Cranial fractures are present in between 70 and 95% of cases (15, 17, 20, 25, 30, 37). The impact of fractures on outcome is controversial. Kuday et al. (20) observed a significant relationship between cranial factures and adverse outcome in 115 patients undergoing surgery for EDH. Lee et al. (22) did not see this relationship in a series of 200 patients managed similarly, and Rivas et al. (32) actually reported a significantly lower mortality rate in patients with cranial fractures. Significant extracranial injury is present in 7 to 23% of patients operated on for an EDH (8, 13, 17, 24, 27). Lobato et al. (24)

found extracranial injury in 20% of their patients, and the mortality rate in this subgroup was lower than the overall mortality (7.6% versus 28%). No data were found on the association of hypotension and outcome in patients with an acute EDH.

ICP

There is only one study available in which postoperative ICP and its relationship to outcome 6 months after trauma was studied. Lobato et al. (24) monitored ICP in 54 (83%) of 64 comatose patients after removal of an EDH. Elevated ICP (>15 mm Hg) was found in 67% of cases, and ICP greater than 35 mm Hg was significantly associated with a higher mortality.

PROCESS

A MEDLINE computer search using the following keywords for the years 1975 to 2001 was performed: "traumatic brain injury" or "head injury" and "epidural" or "extradural" and "hematoma" or "hematoma" or "hemorrhage." The search was narrowed by including the keywords "surgical treatment" or "surgery" or "operation" or "craniotomy" or "craniectomy" or "craniostomy" or "burr holes" and excluding "spinal." These searches combined yielded 168 articles. The reference lists of these publications were reviewed and an additional 22 articles were selected for analysis. Case reports, publications in books, and publications regarding penetrating brain injuries on spinal EDH and on exploratory burr holes without a preoperative CT scan were not included. Articles were excluded if the diagnosis of EDH was not based on CT scanning, or if subgroups of patients who did not undergo CT scanning were not clearly identified. Publications with fewer than 10 patients or publications that did not include information on outcome were excluded. Of these 190 articles, 18 were selected for analysis.

SCIENTIFIC FOUNDATION

Indication for Surgery

The decision to operate on an acute EDH is based on the patient's GCS score, pupillary exam, comorbidities, CT findings, age, and, in delayed decisions, the patient's ICP. Neurological deterioration over time is also an important factor influencing the decision to operate. Trauma patients presenting to the emergency room with altered mental status, pupillary asymmetry, and abnormal flexion or extension are at high risk for either an SDH and/or EDH compressing the brain and brainstem.

CT Characteristics and Outcome

CT is the imaging study of choice for the diagnosis of an EDH. CT scanning is recommended in patients at risk for harboring an acute EDH. It allows not only diagnosis of the primary lesion but also identification of additional features that affect outcome, such as MLS, traumatic subarachnoid hemorrhage, obliteration of the basal cisterns, thickness of the blood clot, and hematoma volume.

In a series of 200 patients who were treated surgically for EDH, Lee et al. (22) found that a hematoma volume greater than 50 cm^3 was significantly related to higher mortality and unfavorable functional outcome. Unfavorable functional recovery was observed in 6.2% of patients with a hematoma volume less than 50 cm^3, and in 24% of patients with a hematoma volume greater than 50 cm^3. Mixed density of the blood clot, indicating acute bleeding, was observed in 32% of their patients and correlated with unfavorable outcome but not with mortality. Patients with an MLS greater than 10 mm showed a higher mortality and more unfavorable outcome when compared with those with less displacement. Partial or total obliteration of the basal cisterns was observed in 59% of their patients and correlated with both mortality and functional outcome. Multivariate analysis identified only hematoma volume as an independent predictor of unfavorable outcome.

In contrast, in 98 patients with EDH who underwent surgery, van den Brink et al. (39) found that the status of the basal cisterns, MLS, and hematoma volume were not related to outcome. The authors only identified the presence of traumatic subarachnoid hemorrhage to be significantly associated with unfavorable outcome. Patients with favorable outcome had a hematoma volume of 56 ± 30 cm^3 and, with unfavorable outcome, the hematoma volume was 77 ± 63 cm^3, but this difference was not significant.

Rivas et al. (32) found that hematoma volume and severity of MLS were related to preoperative coma in patients with EDH. In comatose patients, a hematoma volume greater than 150 cm^3 and an MLS greater than 12 mm were associated with increased mortality. Mixed-density blood clots were observed in 62% of their patients and were related to poor outcome. Location of the lesion did not influence outcome. Seelig et al. (35) did not find a relationship between location of blood clot, MLS, and outcome in 51 comatose patients undergoing surgery for EDH.

In summary, most authors could not detect a relationship between blood clot location and outcome. However, it is likely that hematoma volume, MLS, mixed density of the blood clot, and traumatic subarachnoid hemorrhage are related to outcome, but more studies are needed to clarify this issue.

Surgery and Nonoperative Treatment

Prospective, randomized trials comparing surgical treatment with nonoperative management are not available. Some studies compared patients who were treated either surgically or nonoperatively, and used logistic regression analysis and multivariate analysis models to determine factors that were associated with either treatment (36, 37). Some investigators looked at patient series that were initially all treated nonoperatively and analyzed the factors associated with subsequent, delayed surgery (2, 7, 19, 37). There are no studies on nonoperative treatment of comatose patients with EDH.

What are the factors leading to surgery? The following studies compared characteristics between patients who were treated with either surgery or were managed nonoperatively. The value of such analyses is doubtful because it merely documents the criteria used to select patients for surgery.

Servadei et al. (36) conducted a prospective study including 158 consecutive patients with GCS 14 and 15 with EDH who were admitted to three neurosurgical units. A treatment protocol was not defined for these hospitals. One hundred-sixteen patients underwent surgery and 42 patients were managed nonoperatively. Ninety-three percent of patients with an MLS greater than 5 mm, and 91% of patients with a hematoma thickness greater than 15 mm underwent surgery. A logistic regression analysis identified hematoma thickness and MLS as the factors associated with surgery. Location and the presence of associated lesions did not reach significance. Outcome was good in all patients. Similar results were obtained in 33 pediatric patients, 20 of whom were treated surgically (1). Both groups did not differ in terms of age, GCS, and outcome. Multivariate logistic regression analysis revealed that MLS, hematoma thickness, and volume, as well as temporal location of the blood clot were related to surgery. Hematoma volume and MLS were 41 cm^3 and 8 cm^3, and 4 mm and 0.5 mm, for the surgical and nonsurgical groups, respectively.

A review of 30 patients who were treated with craniotomy and 18 patients treated nonoperatively revealed that patients managed with surgery had lower GCS scores, were more likely to present with pupillary abnormalities and hemiparesis, and had larger blood clots and more MLS (12). Temporal location of the hematoma and the presence and location of a fracture were not related to surgery.

Factors Determining Delayed Surgery

Bezircioglu et al. (2) conducted a prospective study on the nonoperative management of 80 patients with EDH and GCS scores between 9 and 15. Patients with a GCS score greater than 8, an EDH volume less than 30 ml, a hematoma thickness less than 2 cm, and without neurological deficit were treated nonoperatively. Five patients deteriorated and underwent craniotomy. One of these patients died, the others had good outcomes. The only factor significantly associated with delayed surgery was a temporal location of the hematoma, which was observed in all five surgical patients but only in 24% of the 75 patients treated without operation.

In a study of 74 patients with initially asymptomatic EDH managed nonoperatively, 14 required delayed surgery because of neurological deterioration or increase in the size of the hematoma (5). The authors found that a hematoma volume greater than 30 cm^3, a hematoma thickness greater than 15 mm, and an MLS greater than 5 mm were significantly more frequent in patients requiring surgery. A hematoma volume greater than 30 cm^3, an EDH thickness greater than 15 mm, and an MLS greater than 5 mm were observed in 5%, 27%, and 28% of patients managed without surgery, and in 57%, 71%, and 79% of patients who had surgery, respectively. The authors used the "ellipsoid" or "ABC/2" method to estimate the volume of EDHs (see *Appendix I*). Hematoma location, bone fractures, and time-to-initial CT scan were not related to outcome. In a small study on 22 patients, 7 of whom required later surgery, a time interval of less than 6 hours after injury to the first CT scan and a cranial fracture that crossed a major vessel were significantly related to surgery (19).

Studies Describing Successful Nonsurgical Management

Bullock et al. (4) treated 12 of 123 patients presenting with EDH nonsurgically. All patients were conscious (GCS 12–15) with a hematoma volume between 12 and 38 cm^3 (mean, 26.8 cm^3) and an MLS less than 10 mm on the initial CT scan. None of the hematomas were in the temporal region. All patients made a good outcome. Cucciniello reported on 57 patients with EDH who were treated nonoperatively (9). Initial GCS was between 10 and 15. Five hematomas were in the temporal region. The maximum hematoma thickness ranged between 6 and 12 mm. Only one patient had an MLS. All patients made a good recovery.

Timing of Surgery

Time between Injury and Surgery

The effect of surgical timing on outcome from EDH is relevant for a subgroup of patients in whom the EDH causes compression of brain structures that, with time, could cause poor outcome. This subgroup is usually categorized as having pupillary abnormalities and/or a GCS score less than 9 (coma). Generally, studies of EDH reveal that only 21 to 34% of patients present to the hospital with a GCS score less than 8 or 9 (3, 20, 22, 25). Studies do not find a relationship between surgical timing and outcome if patients of all GCS scores are included. In 200 patients with EDH that were surgically evacuated, Lee et al. (22) failed to demonstrate a significant relationship between surgery within 4 hours of trauma or surgery within 2 hours of admission and outcome, using multivariate analysis. However, a significant correlation was observed between the duration of brain herniation, as evidenced by anisocoria, and the outcome. The time lapse between the onset of pupillary abnormalities and surgery is related to outcome. Cohen et al. (6) studied 21 patients with EDH and GCS score less than 9 who underwent surgery. Ten of these patients developed anisocoria after admission. All 5 patients with anisocoria for longer than 70 minutes before surgical evacuation of the EDH died. Patients with anisocoria for shorter than 70 minutes achieved a good outcome. Haselsberger et al. (13) studied 60 patients with EDH, and 34 patients developed coma before surgery. They found that patients treated within 2 hours after loss of consciousness exhibited a mortality rate of 17% and good recovery in 67%, compared with a mortality rate of 56% and good results in 13% in patients operated on later. Sakas et al. (33) found that all patients with either SDH or EDH with fixed and dilated pupils for longer than 6 hour died.

Patient Transfer and Timing of Surgery

The question of whether a patient with acute EDH should be treated at the nearest hospital or transferred to a specialized trauma center has been debated but poorly documented in studies. This is an important timing issue and is significant in the group of patients who are deteriorating. Another issue is the surgical evacuation of EDH by nonneurosurgeons with subsequent transfer to a neurosurgical center. Obviously, these studies are uncontrolled with regard to the efficacy of surgery and the type of patients included in both arms. In the above timing of surgery, the group of patients in a coma and with pupillary abnormalities can be expected to do worse the longer the interval to evacuation of the EDH. Thus, because of the delay, transferred patients would have longer interval times to surgery.

Wester (40) studied 83 patients with acute EDH that underwent craniotomy. Twenty-eight patients were transferred from other hospitals and 11 of these underwent emergency surgery at those outside institutions. Patients who underwent surgery outside the parent institution by nonneurosurgeons had a significantly worse outcome at 3 months as compared with patients who were directly admitted to the study hospital. This was mainly attributed to the technical inadequacy of the primary operation at the outside institution. The authors interpreted this as support for the strategy of directly transferring patients to an adequate trauma center, but they did not control for other confounding variables, such as admission GCS and pupillary exam.

Another study analyzed 107 patients operated on for EDH (3). The majority (67%) of these patients were transferred from outlying hospitals. The authors noted that only 6% of the direct admissions experienced a poor outcome, as compared with 18% of patients who were transferred after undergoing CT scanning at an outside institution. This difference failed to reach statistical significance. Poon and Li (31) studied 71 patients with EDH managed surgically primarily at a neurosurgical hospital and 33 patients transferred from an outside institution. Time delay from neurological deterioration to surgery was 0.7 ± 1 hour and 3.2 ± 0.5 hours for the direct versus indirect transferred group, respectively. Six-months outcome was significantly better in patients who were directly admitted with a minimal delay from deterioration in neurological exam to surgery.

SUMMARY

In patients with an acute EDH, clot thickness, hematoma volume, and MLS on the preoperative CT scan are related to outcome. In studies analyzing CT parameters that may be predictive for delayed surgery in patients undergoing initial nonoperative management, a hematoma volume greater than 30 cm^3, an MLS greater than 5 mm, and a clot thickness greater than 15 mm on the initial CT scan emerged as significant. Therefore, patients who were not comatose, without focal neurological deficits, and with an acute EDH with a thickness of less than 15 mm, an MLS less than 5 mm, and a hematoma volume less than 30 cm^3 may be managed nonoperatively with serial CT scanning and close neurological evaluation in a neurosurgical center (see *Appendix II* for measurement techniques). The first follow-up CT scan in nonoperative patients should be obtained within 6 to 8 hours after TBI. Temporal location of an EDH is associated with failure of nonoperative management and should lower the threshold for surgery. No studies are available comparing operative and nonoperative management in comatose patients. The literature supports the theory that patients with a GCS less than 9 and an EDH greater than 30 cm^3 should undergo surgical evacuation of the lesion. Combined with the above recommendation, it follows that all patients, regardless of GCS, should undergo surgery if the volume of their EDH exceeds 30 cm^3. Patients with an EDH less than 30 should be considered for surgery but may be managed successfully without surgery in selected cases.

Time from neurological deterioration, as defined by onset of coma, pupillary abnormalities, or neurological deterioration to surgery, is more important than time between trauma and surgery. In these patients, surgical evacuation should be performed as soon as possible because every hour delay in surgery is associated with progressively worse outcome.

KEY ISSUES FOR FUTURE INVESTIGATION

- Effect of transfer versus direct admission to a trauma center on timing of surgery and outcome from EDH.
- Identification of subgroups that do not benefit from surgery: old patients with low GCS scores, pupillary abnormalities, and associated intracerebral lesions.
- Surgical technique.

REFERENCES

1. Bejjani G, Donahue D, Rusin J, Broemeling L: Radiological and clinical criteria for the management of epidural hematomas in children. **Pediatr Neurosurg** 25:302–308, 1996.
2. Bezircioglu H, Ersahin Y, Demircivi F, Yurt I, Donertas K, Tektas S: Nonoperative treatment of acute extradural hematomas: Analysis of 80 cases. **J Trauma** 41:696–698, 1996.
3. Bricolo A, Pasut L: Extradural hematoma: toward zero mortality. A prospective study. **Neurosurgery** 14:8–12, 1984.
4. Bullock R, Smith R, van Dellen JR: Nonoperative management of extradural hematoma. **Neurosurgery** 16:602–606, 1985.
5. Chen T, Wong C, Chang C, Lui T, Cheng W, Tsai M, Lin T: The expectant treatment of "asymptomatic" supratentorial epidural hematomas. **Neurosurgery** 32: 176–179, 1993.
6. Cohen J, Montero A, Israel Z: Prognosis and clinical relevance of anisocoria-craniotomy latency for epidural hematoma in comatose patients. **J Trauma** 41:120–122, 1996.
7. Cook R, Dorsch N, Fearnside M, Chaseling R: Outcome prediction in extradural haematomas. **Acta Neurochir (Wien)** 95:90–94, 1988.
8. Cordobes F, Lobato R, Rivas J, Munoz M, Chillon D, Portillo J, Lamas E: Observations on 82 patients with extradural hematoma. Comparison of results before and after the advent of computerized tomography. **J Neurosurg** 54:179–186, 1981.
9. Cucciniello B, Martellotta N, Nigro D, Citro E: Conservative management of extradural haematomas. **Acta Neurochir (Wien)** 120:47–52, 1993.

10. Gennarelli T, Spielman G, Langfitt T, Gildenberg P, Harrington T, Jane J, Marshall L, Miller J, Pitts L: Influence of the type of intracranial lesion on outcome from severe head injury. **J Neurosurg** 56:26–32, 1982.
11. Gupta S, Tandon S, Mohanty S, Asthana S, Sharma S: Bilateral traumatic extradural haematomas: Report of 12 cases with a review of the literature. **Clin Neurol Neurosurg** 94:127–131, 1992.
12. Hamilton M, Wallace C: Nonoperative management of acute epidural hematoma diagnosed by CT: The neuroradiologist's role. **AJNR Am J Neuroradiol** 13:853–859, 1992.
13. Haselsberger K, Pucher R, Auer L: Prognosis after acute subdural or epidural haemorrhage. **Acta Neurochir (Wien)** 90:111–116, 1988.
14. Heinzelmann M, Platz A, Imhof H: Outcome after acute extradural haematoma, influence of additional injuries and neurological complications in the ICU. **Injury** 27:345–349, 1996.
15. Hunt J, Hill D, Besser M, West R, Roncal S: Outcome of patients with neurotrauma: The effect of a regionalized trauma system. **Aust N Z J Surg** 65:83–86, 1995.
16. Jamjoom A: The influence of concomitant intradural pathology on the presentation and outcome of patients with acute traumatic extradural haematoma. **Acta Neurochir (Wien)** 115:86–89, 1992.
17. Jamjoom A: The difference in the outcome of surgery for traumatic extradural hematoma between patients who are admitted directly to the neurosurgical unit and those referred from another hospital. **Neurosurg Rev** 20:227–230, 1997.
18. Jones N, Molloy C, Kloeden C, North J, Simpson D: Extradural haematoma: Trends in outcome over 35 years. **Br J Neurosurg** 7:465–471, 1993.
19. Knuckey N, Gelbard S, Epstein M: The management of "asymptomatic" epidural hematomas. A prospective study. **J Neurosurg** 70:392–396, 1989.
20. Kuday C, Uzan M, Hanci M: Statistical analysis of the factors affecting the outcome of extradural haematomas: 115 cases. **Acta Neurochir (Wien)** 131: 203–206, 1994.
21. Lahat E, Sheinman G, Feldman Z, Barzilai A, Harel R, Barzilay Z, Paret G: Metabolic and clinical markers of prognosis in the era of CT imaging in children with acute epidural hematomas. **Pediatr Neurosurg** 33:70–75, 2000.
22. Lee E, Hung Y, Wang L, Chung K, Chen H: Factors influencing the functional outcome of patients with acute epidural hematomas: Analysis of 200 patients undergoing surgery. **J Trauma** 45:946–952, 1998.
23. Lobato R, Cordobes F, Rivas J, de la Fuente M, Montero, A, Barcena A, Perez C, Cabrera A, Lamas E: Outcome from severe head injury related to the type of intracranial lesion. A computerized tomography study. **J Neurosurg** 59:762–774, 1983.
24. Lobato R, Rivas J, Cordobes F, Alted E, Perez C, Sarabia R, Cabrera A, Diez I, Gomez P, Lamas E: Acute epidural hematoma: An analysis of factors influencing the outcome of patients undergoing surgery in coma. **J Neurosurg** 68:48–57, 1988.
25. Maggi G, Aliberti F, Petrone G, Ruggiero C: Extradural hematomas in children. **J Neurosurg Sci** 42:95–99, 1998.
26. Meier U, Heinitz A, Kintzel D: Surgical outcome after severe craniocerebral trauma in childhood and adulthood. A comparative study [in German]. **Unfallchirurg** 97:406–409, 1994.
27. Mohanty A, Kolluri V, Subbakrishna D, Satish S, Mouli B, Das B: Prognosis of extradural haematomas in children. **Pediatr Neurosurg** 23:57–63, 1995.
28. Otsuka S, Nakatsu S, Matsumoto S, Sato S, Motozaki T, Ban S, Yamamoto T: Study on cases with posterior fossa epidural hematoma—Clinical features and indications for operation. **Neurol Med Chir (Tokyo)** 30:24–28, 1990.
29. Paterniti S, Fiore P, Macri E, Marra G, Cambria M, Falcone F, Cambria S: Extradural haematoma. Report of 37 consecutive cases with survival. **Acta Neurochir (Wien)** 131:207–210, 1994.
30. Pillay R, Peter J: Extradural haematomas in children. **S Afr Med J** 85:672–674, 1995.
31. Poon W, Li A: Comparison of management outcome of primary and secondary referred patients with traumatic extradural haematoma in a neurosurgical unit. **Injury** 22:323–325, 1991.
32. Rivas J, Lobato R, Sarabia R, Cordobes F, Cabrera A, Gomez P: Extradural hematoma: Analysis of factors influencing the courses of 161 patients. **Neurosurgery** 23:44–51, 1988.
33. Sakas D, Bullock M, Teasdale G: One-year outcome following craniotomy for traumatic hematoma in patients with fixed dilated pupils. **J Neurosurg** 82:961–965, 1995.
34. Schutzman S, Barnes P, Mantello M, Scott R: Epidural hematomas in children. **Ann Emerg Med** 22:535–541, 1993.
35. Seelig J, Marshall L, Toutant S, Toole B, Klauber M, Bowers S, Varnell J: Traumatic acute epidural hematoma: Unrecognized high lethality in comatose patients. **Neurosurgery** 15:617–620, 1984.
36. Servadei F, Faccani G, Roccella P, Seracchioli A, Godano U, Ghadirpour R, Naddeo M, Piazza G, Carrieri P, Taggi F, Pagni CA: Asymptomatic extradural haematomas. Results of a multicenter study of 158 cases in minor head injury. **Acta Neurochir (Wien)** 96:39–45, 1989.
37. Sullivan T, Jarvik J, Cohen W: Follow-up of conservatively managed epidural hematomas: Implications for timing of repeat CT. **AJNR Am J Neuroradiol** 20:107–113, 1999.
38. Uzan M, Yentur E, Hanci M, Kaynar MY, Kafadar A, Sarioglu AC, Bahar M, Kuday C: Is it possible to recover from uncal herniation? Analysis of 71 head injured cases. **J Neurosurg Sci** 42:89–94, 1998.
39. van den Brink WA, Zwienenberg M, Zandee SM, van der Meer L, Maas AI, Avezaat CJ: The prognostic importance of the volume of traumatic epidural and subdural haematomas revisited. **Acta Neurochir (Wien)** 141:509–514, 1999.
40. Wester K: Decompressive surgery for "pure" epidural hematomas: Does neurosurgical expertise improve the outcome? **Neurosurgery** 44:495–500, 1999.
41. Wu J, Hsu C, Liao S, Wong Y: Surgical outcome of traumatic intracranial hematoma at a regional hospital in Taiwan. **J Trauma** 47:39–43, 1999.

EVIDENTIARY TABLE

TABLE 1. Surgical management of acute epidural hematomas[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>Bejjani et al. (1)</td><td>33</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>Discharge</td><td>Retrospective analysis of factors affecting the decision to operate in 33 pediatric patients with EDH. 13 patients underwent operative treatment.</td><td>Mass effect, temporal location of blood clot, MLS, thickness of clot, and volume were independently related to surgery. Other clinical factors, such as age, GCS, and associated fractures were not. Outcome was good in >90% of patients.
<table>
<tr><th>EDH</th><th>Operative treatment</th><th>Nonoperative treatment</th></tr>
<tr><td>Thickness (mm)</td><td>20</td><td>9</td></tr>
<tr><td>Volume (cm^3)</td><td>41</td><td>8</td></tr>
<tr><td>MLS (mm)</td><td>4</td><td>0.5</td></tr>
</table></td></tr>
<tr><td>Bezircioglu et al. (2)</td><td>80</td><td>III</td><td>GCS > 8</td><td>Surgery and nonsurgical</td><td>GOS at 2 mo</td><td>Prospective study on nonoperative management of patients with EDH. Patients with a EDH volume <30 ml, thickness <2 cm, GCS > 8, no neurological deficit, and admitted within 24 h of TBI were treated nonoperatively.</td><td>Of 80 patients who were treated nonoperatively, 5 deteriorated and needed surgery. One died, and 4 had a good outcome. Temporal lobe EDH was related to delayed surgery.</td></tr>
<tr><td>Bricolo and Pasut (3)</td><td>107</td><td>III</td><td>All GCS</td><td>All surgery</td><td>GOS at 6 mo</td><td></td><td>
<table>
<tr><th>Neurological signs on admission</th><th>No. of patients</th><th>Good outcome (%)</th></tr>
<tr><td>None</td><td>17</td><td>100</td></tr>
<tr><td>One dilated pupil</td><td>8</td><td>100</td></tr>
<tr><td>Hemiparesis only</td><td>23</td><td>91</td></tr>
<tr><td>Hemiparesis and one dilated pupil</td><td>10</td><td>90</td></tr>
<tr><td>Decortication</td><td>9</td><td>44</td></tr>
<tr><td>Decerebration</td><td>4</td><td>25</td></tr>
<tr><td>Both pupils fixed</td><td>1</td><td>0</td></tr>
</table>
<table>
<tr><th>GCS on admission</th><th>No. of patients</th><th>GR/MD (%)</th><th>SD/VS (%)</th><th>Dead (%)</th></tr>
<tr><td>3–4</td><td>4</td><td>25</td><td>25</td><td>50</td></tr>
<tr><td>5–7</td><td>32</td><td>78</td><td>13</td><td>9</td></tr>
<tr><td>8–15</td><td>71</td><td>97</td><td>3</td><td>0</td></tr>
</table></td></tr>
<tr><td>Bullock et al. (4)</td><td>12</td><td>III</td><td>GCS 12–15</td><td>Nonsurgical</td><td>Discharge</td><td>Retrospective analysis of the nonoperative treatment of 12 patients with EDH.</td><td>All patients made a good recovery. No temporal EDH patients were included, and basal cisterns were open or only partially effaced in all patients. MLS was <10 mm in all patients. Mean volume of the EDH was 26.8 cm^3.</td></tr>
<tr><td>Chen et al. (5)</td><td>74</td><td>III</td><td>GCS > 12</td><td>Surgery and nonsurgical</td><td>GOS at 1 mo</td><td>Retrospective analysis of 111 of 465 patients with EDH who underwent initial nonoperative treatment. All nonoperative cases had a GCS > 12, and 14 patients underwent delayed surgery because of neurodeterioration or increase in the size of the EDH. 37 patients were excluded because of incomplete CT data.</td><td>All patients achieved a good GOS. Patients requiring delayed surgery presented more frequently with an EDH volume >30 cm^3, clot thickness >15 mm, or MLS > 5 mm on the initial CT scan.
<table>
<tr><th></th><th>Operative treatment</th><th>Nonoperative treatment</th><th>P value</th></tr>
<tr><td>No. of patients</td><td>14</td><td>97</td><td></td></tr>
<tr><td>Temporal/ frontotemporal location of EDH</td><td>42.8%</td><td>36.6%</td><td>n.s.</td></tr>
<tr><td>EDH > 30 cm^3</td><td>8</td><td>3</td><td>$P < 0.001$</td></tr>
<tr><td>MLS > 5 mm</td><td>11</td><td>17</td><td>$P < 0.001$</td></tr>
<tr><td>EDH > 15 mm thickness</td><td>10</td><td>16</td><td>$P < 0.01$</td></tr>
</table></td></tr>
</table>

(*Table continues*)

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Cohen et al. (6)	21	III	GCS < 8	All surgery	Not documented	Prospective data collection on 21 adult patients admitted during 3 yr with acute EDH and GCS < 8, who underwent surgery. 10 patients developed new anisocoria after admission. Only 14 patients had CT scans. 3 patients had emergency craniotomy without radiographic studies.	Anisocria for more than 70 min was associated with 100% mortality, and for less than 70 min with GOS 4 and 5. **Time from anisocoria to craniotomy** / **No. of patients** / **GR/MD (%)** / **Dead (%)** <71 min / 5 / 100 / 0 >89 min / 5 / 0 / 100
Cucciniello et al. (9)	57	III	GCS 10–15	Nonsurgical	Not documented	Retrospective analysis of a case series of 57 patients out of 144 with EDH who were managed nonoperatively.	All patients had good outcome. Only one patient demonstrated MLS and maximum hematoma thickness was between 6 and 12 mm.
Hamilton and Wallace (12)	48	III	All GCS	Surgery and nonsurgical	Discharge	Retrospective analysis of patients who underwent surgical and nonoperative treatment for EDH.	Patients who underwent surgical treatment had lower GCS scores, more pupillary abnormalities, larger EDH, greater MLS, and were more likely to show uncal herniation on CT.
Haselsberger et al. (13)	60	III	All GCS	All surgery	Not documented	A review of 171 patients who presented with either subdural (111 patients) or epidural (60 patients) hematoma. The influence of surgical timing on mortality and functional recovery was analyzed.	Patients with an acute subdural or epidural hematoma had a lower mortality and improved functional recovery when operated on <2 h after onset of coma. **Time from coma onset to surgery** / **No. of patients** / **GR/MD (%)** / **SD/VS (%)** / **D (%)** <2 h / 18 / 67 / 16 / 17 >2 h / 16 / 13 / 31 / 56
Knuckey et al. (19)	22	III	All GCS	Surgery and nonsurgical	Not documented	Retrospective analysis of 22 patients of all age groups who were initially treated nonoperatively. 7 patients needed subsequent craniotomy.	Early CT scan <6 h after trauma and cranial fractures crossing big vessels or the middle meningeal artery were associated with deterioration. Initial GCS, age, and size of the EDH were not.
Kuday et al. (20)	115	III	All GCS	All surgery	GOS at 6 mo	Retrospective analysis of prospectively collected data on 115 patients of all age groups undergoing surgery for "signs of herniation."	GCS is the parameter correlating most closely with outcome. The presence of a cranial fracture and "long" interval between onset of symptoms and intervention also affect outcome.
Lee et al. (22)	200	III	All GCS	All surgery	GOS at 1 yr	A retrospective study of 200 patients with epidural hematomas requiring operation. Analysis of factors leading to a poor outcome.	Functional outcome correlated with decreased length of herniation time, no posturing, normal pupils, and a high GCS score. Unfavorable radiological signs were associated brain injury, MLS >1 cm, obliterated basal cisterns, and size and density of the blood clot. **Interval between anisocoria and decompression (h)** / **No. of patients** / **SD/VS/D (%)** No / 126 / 7.9 <1.5 / 18 / 22.2 1.5–2.5 / 27 / 25.9 2.5–3.5 / 13 / 30.8 3.5–4.5 / 13 / 53.8 >4.5 / 3 / 66.7 **Hematoma volume (ml)** / **No. of patients** / **SD/VS/D (%)** <50 / 81 / 6.2 51–100 / 81 / 14.8 101–150 / 31 / 38.7 >150 / 7 / 71.4 **MLS (mm)** / **No. of patients** / **SD/VS/D (%)** <5 / 85 / 9.4 6–10 / 69 / 8.7 11–15 / 35 / 37.1 >15 / 11 / 63.6

(*Table continues*)

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>Poon and Li (31)</td><td>104</td><td>III</td><td>All GCS</td><td>All surgery</td><td>GOS at 6 mo</td><td>A prospective study of 104 patients of all age groups with isolated EDH. One-third of the patients were transferred from an outside hospital.</td><td>A significant increase in mortality and morbidity was related to increased time from neurological deterioration to surgery.
<table>
<tr><th>No. of patients</th><th>Time between deterioration of conscious level and surgery (h)</th><th>D (%)</th><th>VS/SD/MD (%)</th><th>GR (%)</th></tr>
<tr><td>71</td><td>0.7 ± 1</td><td>4</td><td>10</td><td>86</td></tr>
<tr><td>33</td><td>3.2 ± 0.5</td><td>24</td><td>27</td><td>49</td></tr>
</table></td></tr>
<tr><td>Sakas et al. (33)</td><td>11</td><td>III</td><td>“Comatose”</td><td>All surgery</td><td>GOS at 1 yr</td><td>Analysis of 40 severe TBI patients who underwent craniotomy after developing bilateral fixed and dilated pupils.</td><td>Patients with SDH had a significant increase in mortality (64%) compared with those with EDH (18%). Patients who underwent delayed (>3 h) surgery had a worse outcome.
<table>
<tr><th>Time from pupillary nonreactivity to surgery</th><th>No. of patients</th><th>GR/MD (%)</th><th>SD (%)</th><th>VS/D (%)</th></tr>
<tr><td><3 h</td><td>20</td><td>30</td><td>30</td><td>40</td></tr>
<tr><td>>3 h</td><td>16</td><td>25</td><td>12</td><td>63</td></tr>
</table></td></tr>
<tr><td>Seelig et al. (35)</td><td>51</td><td>III</td><td>“Comatose”</td><td>All surgery</td><td>GOS at 3 mo–2 yr</td><td>Prospective multicenter database analyzed retrospectively, looking at the factors influencing outcome after surgery for EDH.</td><td>The most powerful indicator of outcome was motor score before surgery.
<table>
<tr><th>Motor score</th><th>No. of patients</th><th>GR/MD/SD (%)</th><th>VS/D (%)</th></tr>
<tr><td>1–3</td><td>19</td><td>32</td><td>68</td></tr>
<tr><td>4–6</td><td>32</td><td>69</td><td>31</td></tr>
</table></td></tr>
<tr><td>Servadei et al. (36)</td><td>158</td><td>III</td><td>GCS 14/15</td><td>Surgery and nonsurgical</td><td>GOS at 6 mo</td><td>Prospective study of 158 consecutive patients with minor TBI (GCS 14/15) admitted to 3 neurosurgical units. No treatment protocol was specified and a logistic regression analysis was conducted to identify the factors leading to surgery.</td><td>116 patients underwent surgery and 42 patients were managed nonoperatively. Of all factors analyzed, only thickness of hematoma and MLS were related to the decision to operate. Outcome was the same in both groups.
<table>
<tr><th>MLS (mm)</th><th>No. of patients</th><th>Craniotomy (%)</th><th>Nonoperative management (%)</th></tr>
<tr><td>0–5</td><td>130</td><td>70</td><td>30</td></tr>
<tr><td>6–10</td><td>19</td><td>89.5</td><td>10.5</td></tr>
<tr><td>>10</td><td>8</td><td>100</td><td>0</td></tr>
</table></td></tr>
<tr><td>van den Brink et al. (39)</td><td>98</td><td>III</td><td>All GCS</td><td>All surgery</td><td>GOS at 6 mo</td><td>Retrospective analysis of CT parameters and outcome in 98 patients of all age groups with acute EDH.</td><td>Volume of the EDH did not correlate with outcome. Subarachnoid blood and pupillary dysfunction, age >20 yr, and GCS on admission were parameters correlating with outcome.
<table>
<tr><th>Age (yr)</th><th>SD/VS/D (%)</th></tr>
<tr><td><20</td><td>6</td></tr>
<tr><td>21–40</td><td>17</td></tr>
<tr><td>41–60</td><td>31</td></tr>
<tr><td>>60</td><td>50</td></tr>
<tr><th>Motor score</th><th>SD/VS/D(%)</th></tr>
<tr><td>1–3</td><td>50</td></tr>
<tr><td>4–6</td><td>7</td></tr>
<tr><th>Pupils</th><th>SD/VS/D(%)</th></tr>
<tr><td>Normal</td><td>3</td></tr>
<tr><td>Unilateral fixed and dilated</td><td>35</td></tr>
<tr><td>Bilateral fixed and dilated</td><td>50</td></tr>
</table></td></tr>
<tr><td>Wester (40)</td><td>83</td><td>III</td><td>All GCS</td><td>All surgery</td><td>GOS at 3 mo</td><td>Retrospective study of the management of pure EDH in patients of all age groups in Norway. Information on their initial neurological exam is limited.</td><td>The outcome of 11 patients treated at the primary hospital was worse than the outcome of patients that were admitted directly. The authors conclude that patients should be transferred directly for neurosurgical management.</td></tr>
</table>

[a] GCS, Glasgow Coma Scale; EDH, epidural hematoma; MLS, midline shift; GOS, Glasgow outcome score; TBI, traumatic brain injury; GR, good recovery; MD, moderate disability; SD, severe disability; VS, vegetative state; D, death; CT, computed tomographic scan; n.s., not significant.