Surgical Management of Acute Subdural Hematomas

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RECOMMENDATIONS
(see *Methodology*)

Indications for Surgery

- An acute subdural hematoma (SDH) with a thickness greater than 10 mm *or* a midline shift greater than 5 mm on computed tomographic (CT) scan should be surgically evacuated, regardless of the patient's Glasgow Coma Scale (GCS) score.
- All patients with acute SDH in coma (GCS score less than 9) should undergo intracranial pressure (ICP) monitoring.
- A comatose patient (GCS score less than 9) with an SDH less than 10-mm thick and a midline shift less than 5 mm should undergo surgical evacuation of the lesion if the GCS score decreased between the time of injury and hospital admission by 2 or more points on the GCS and/or the patient presents with asymmetric or fixed and dilated pupils and/or the ICP exceeds 20 mm Hg.

Timing

- In patients with acute SDH and indications for surgery, surgical evacuation should be performed as soon as possible.

Methods

- If surgical evacuation of an acute SDH in a comatose patient (GCS $<$ 9) is indicated, it should be performed using a craniotomy with or without bone flap removal and duraplasty.

KEY WORDS: Coma, Computed tomographic parameters, Craniotomy, Decompressive craniectomy, Head injury, Hematoma, Intracranial pressure monitoring, Salvageability, Subdural, Surgical technique, Timing of surgery, Traumatic brain injury

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OVERVIEW

SDH represents one type of intracranial mass lesion, and surgical management attempts to define the subset of patients who would benefit from surgical evacuation of an acute SDH. SDH are diagnosed on a CT scan as extracranial, hyperdense, crescentic collections between the dura and the brain parenchyma. They can be divided into acute and chronic lesions. Herein, "acute SDH" is defined as an SDH diagnosed within 14 days of traumatic brain injury (TBI).

Incidence

Studies conducted after the introduction of CT scanning report an incidence of acute SDH between 12 and 29% in patients admitted with severe TBI. Combining several publications, acute SDH was diagnosed in 21% of 2870 patients (8, 26, 27, 36). When including mild, moderate, and severe head injuries, 11% (360 of 3397 patients) present with SDH (21, 28). The mean age for this combined group is between 31 and 47 years, with the vast majority of patients being men (6, 11, 17, 21).

Mechanism

The mechanism of injury responsible for the development of an SDH differs between age groups. Most SDH are caused by motor vehicle-related accidents (MVA), falls, and assaults. In one study, 56% of SDH in the younger group (18–40 yr) were caused by MVA and only 12% were caused by falls, whereas, in the older groups (>65 yr), these mechanisms were responsible for 22% and 56% of SDH, respectively (15). Falls have been identified as the main cause of traumatic SDH in two studies looking specifically at patients older than 75 and 80 years (3, 16). Studies with comatose patients describe MVA as the mechanism of injury in 53 to 75% of SDH. This indicates that MVA causes more severe injury, possibly because of high-velocity accidents and diffuse axonal injury (18, 26, 36).

Clinical Presentation

Between 37 and 80% of patients with acute SDH present with initial GCS scores of 8 or less (4, 6, 21, 28, 33). A lucid interval has been described in 12 to 38% of patients before admission but there is no conclusive evidence that this correlates with outcome (1, 9, 31, 34, 36). The definition of lucid interval is vague. Authors interpret the lucid interval differently and analysis of its frequency requires documentation during the prehospital phase. Pupillary abnormalities are observed in 30 to 50% of patients on admission or before surgery (6, 10, 28, 33).

Mortality

Studies looking at patients from all age groups with GCS scores between 3 and 15 with SDH requiring surgery quote mortality rates between 40 and 60% (10, 11, 13, 14, 17, 27, 39). Mortality among patients presenting to the hospital in coma with subsequent surgical evacuation is between 57 and 68% (7, 12, 18, 20, 26, 36).

Associated Injuries

Only 30 to 40% of SDH requiring surgery are isolated lesions (21, 28). In the majority of cases, the SDH is associated with other intracranial and extracranial injuries. Contusions and intracerebral hematomas are the most frequently associated intracranial abnormalities. Associated intracranial and extracranial lesions have been reported in larger series to occur in 47 to 57% of patients presenting with GCS scores between 3 and 15 (4, 11, 15, 28) and in 65 to 82% of patients with GCS scores less than 10 (18, 26). In patients with SDH, contusions and fractures are frequent associated injuries (16, 19, 25, 31, 36, 37). An associated subarachnoid hemorrhage has been observed in 14 to 25% of patients with SDH (4, 28) and epidural hematomas are observed in 6 to 14% of patients (4, 28). Significant extracranial injuries are observed in 18 to 51% of patients and the majority of these cases include facial fractures, extremity fractures, and thoracic and abdominal trauma (5, 6, 11, 28, 31). Because of the frequent association of SDH with parenchymal injury, surgical management decisions should take into consideration the recommendations for both lesion types.

PROCESS

A MEDLINE computer search using the following keywords for the years 1975 to 2001 was performed: "traumatic brain injury" or "head injury" and "subdural" or "intradural" and "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 "chronic" and "spinal." These searches combined yielded 161 articles. The reference lists of these publications were reviewed and an additional 18 articles were selected for analysis. Case reports, publications in books, and publications regarding penetrating brain injuries, or spinal or chronic SDH were not included. Chronic SDH was defined as an SDH occurring or diagnosed more than 14 days after trauma. Articles were excluded if the diagnosis of SDH 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 179 articles, 21 were selected for analysis.

SCIENTIFIC FOUNDATION

Indications for Surgery

The decision to operate on an SDH is based on the patient's GCS score, pupillary exam, comorbidities, CT findings, age, and, in delayed decisions, 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 an epidural hematoma compressing the brain and brainstem.

CT Parameters

Many investigators have tried to define a relationship between CT parameters, such as hematoma volume, clot thickness, midline shift (MLS), and patency of the basal cisterns, and outcome. Two studies using multivariate analysis to identify factors affecting outcome from SDH found contradictory results. Howard et al. (15) reported on 67 patients, with GCS scores between 3 and 15, who were undergoing surgery, and found a significant correlation between poor outcome and the volume of the SDH and the MLS. The volume of the SDH, the MLS, and mortality were significantly greater in older patients. van den Brink et al. (33) found no difference in hematoma volumes, MLS or status of the basal cisterns when comparing surgical patients, who had a GCS of 3 to 15, and favorable versus unfavorable outcome. Zumkeller et al. (39) investigated CT scan parameters in 174 patients with SDH and a GCS between 3 and 15 undergoing surgery. The findings revealed a 10% mortality rate in patients with a clot thickness of less than 10 mm, and a 90% mortality for patients with clots thicker than 30 mm. For an MLS greater than 20 mm, there was a steep increase in mortality. Both parameters correlated well with the Glasgow outcome score (GOS). In a mixed group of patients treated with or without surgery, Servadei et al. (28) also found a correlation between outcome and clot thickness, MLS, and status of the basilar cisterns. Kotwica and Brzezinski (18) found a significant relationship between MLS and outcome in 200 patients with GCS scores lower than 10, who were undergoing surgery for SDH. In summary, there seems to be a relationship between CT parameters and outcome, but it is difficult to determine specific threshold values.

Surgical Versus Nonoperative Treatment of SDH

The decision for nonoperative versus surgical management of SDH is influenced by the GCS score; CT parameters, such as MLS, SDH clot thickness and volume, and patency of the basal cisterns; and the salvageability of the patient (i.e., whether the primary injury is so extensive that evacuation of the SDH will not make a difference in outcome). On the basis of the reviewed literature, a clot thickness greater than 10 mm or a MLS greater than 5 mm are suggested as critical parameters for surgical evacuation of an acute SDH, regardless of the GCS.

Wong (37) tried to identify parameters that would predict the failure of initial nonoperative management. No treatment protocol was defined. Six of 31 patients with GCS scores between 6 and 15 who were initially treated without surgery required a later craniotomy because of neurological deterioration (performed within 3 d). The authors found that an MLS greater than 5 mm in patients with a GCS score of lower than 15 on the initial CT scan was significantly related to the failure of nonoperative treatment. Hematoma volume and thickness of the hematoma were not predictive. Good outcome was achieved in all patients.

Matthew et al. (22) reviewed the data on 23 patients with GCS scores between 13 and 15 who were initially treated nonoperatively. No criteria were defined for nonoperative management. All patients had an isolated SDH and all were observed in the neurosurgical intensive care unit. Six patients required delayed (mean, 14 d) evacuation of their SDH. Significant differences in clot thickness and hematoma volume were found between the operative and the nonoperative groups. In addition, all patients with an initial hematoma thickness greater than 10 mm required surgery. Finally, Servadei et al. (27) developed a protocol to select comatose patients with SDH for nonoperative management. The criteria used to select comatose patients for nonoperative treatment were clinical stability or improvement during the time from injury to evaluation at the hospital, hematoma thickness less than 10 mm and MLS less than 5 mm on the initial CT scan, and ICP monitoring in the neurosurgical intensive care unit. Surgery was performed if the ICP exceeded 20 mm Hg. Fifteen of 65 comatose patients with SDH were treated nonoperatively. Of these, two patients were identified that required delayed surgery based on increasing ICP and the development of intracerebral hematomas. Good outcome was achieved in 23% of the patients in the surgery group and 67% of the patients in the nonoperative group. The authors concluded that nonoperative treatment can be safely used for a defined group of comatose patients with SDH.

Age and Salvageability

Increasing age is a strong independent factor in prognosis from severe TBI, with a significant increase in poor outcome in patients older than 60 years of age (2). Among patients with acute SDH, there is also a tendency for older patients to have a poorer outcome, especially those patients presenting with low GCS scores (3, 16, 18, 19, 36). In comatose patients with GCS scores less than 9 who underwent craniotomy for SDH, Wilberger et al. (36) found that age older than 65 years was statistically correlated with poorer outcome. In patients with GCS scores less than 10 undergoing surgery for SDH, Kotwica and Brzezinski (18) found that there was a statistically significant difference in 3-months outcome between younger patients (18–30 yr of age, 25% mortality) and older patients (>50 yr, 75% mortality). Three smaller studies looked specifically at patients between 70 and 100 years of age with an admission GCS (one study) or preoperative GCS (two studies) equal to or less than 9. The 49 patients from these three studies all underwent surgery. Forty-eight patients died and one had a poor outcome (severely disabled or vegetative) (3, 16, 19). No patient older than the age of 75 years who preoperatively was extensor posturing, flaccid to pain, or had unilateral or bilateral fixed and dilated pupils made a good recovery (GOS, 3–5) (16). In 23 comatose patients aged 66 years and older who presented with an acute SDH, Howard et al. (15) found that 17 died and the others survived in a vegetative state or with severe disabilities.

Functional outcomes in older patients with low GCS scores have also been reported. However, these articles did not document whether patients showed signs of cerebral herniation. Hatashita et al. (14) reported 9 deaths in 12 patients older than 65 years who presented with GCS scores between 4 and 6 and underwent surgery for SDH, as compared with 34% for those aged 19 to 40 years. Two older patients survived with a GOS of 4 or 5. In another publication, 1 of 28 comatose patients older than 65 years made a functional recovery after craniotomy for SDH (36). Although some studies that included patients with all GCS scores undergoing surgery for SDH found a relationship between age and outcome (15, 21, 28), other authors failed to describe such a relationship (13, 17, 26, 33, 39). Three studies using multivariate analysis in patients operated on for SDH did not identify age as an independent predictor of outcome (15, 26, 33). In summary, there is a relationship between poor outcome and age, low GCS, and signs of herniation, but it is not possible to predict death on the basis of old age and poor GCS with certainty.

Timing of Surgery

The time from injury to entering the operating room is one of the few factors that can be affected by intervention. Unfortunately, the relationship between time from injury to operation and outcome is difficult to study because patients who are operated on soon after TBI tend to have more severe injuries than those who undergo delayed surgery. Therefore, outcome in patients operated on a short time after injury is frequently worse when compared with patients undergoing delayed surgery. Furthermore, time from TBI to surgery may not be as important as time from clinical deterioration or onset of cerebral herniation to surgery. The literature supports the statement that the length of time from clinical deterioration to operative treatment of an SDH is significantly related to outcome. Haselsberger et al. (13) studied the time interval from onset of coma to surgery in 111 patients with SDH. Thirty-four patients were operated on within 2 hours after onset of coma. Of those patients, 47% died and 32% recovered with good outcome or moderate disability. However, 54 patients who underwent surgery longer than 2 hours after the onset of coma had a mortality of 80% and only 4% had a favorable outcome. These differences were statistically significant.

Seelig et al. (26) studied the delay to surgery in 82 patients with SDH who were all comatose on admission. They found a 30% mortality rate in patients operated on within 4 hours after injury and a 90% mortality in patients who had surgery more than 4 hours after injury. The mean time for evacuation was 390 ± 39 minutes in patients who died and 170 ± 18 minutes in patients who made a functional recovery. Multivariate analysis identified time to surgery as one of the factors determining outcome from SDH. The weaknesses of this study are that a proportion of patients did not undergo CT scanning and that SDH was diagnosed using air ventriculography. In comatose patients undergoing surgery for SDH, Wilberger et al. (36) found that the time interval from TBI to surgery was 374 ± 31 minutes for patients who died and 280 ± 26 minutes for patients who made a functional recovery. Mortality in patients undergoing surgery within 4 hours of injury was 59% versus 69% in patients operated on after 4 hours. A statistically significant difference could only be found in patients who underwent surgery after 12 hours, in which case, mortality rose to 82%.

Sakas et al. (24) looked at outcome from surgery for intracerebral hematoma, epidural hematoma, and SDH in 40 patients who developed bilateral pupillary abnormalities during their hospital course. The authors found a significant relationship between the time from onset of bilateral pupillary abnormalities and 6-months outcome. Patients who had surgery more than 3 hours after herniation had a higher morbidity and mortality than those undergoing surgery earlier (mortality, 63% versus 30%).

Most studies focusing on the time between injury and surgery did not find a correlation with outcome (15, 17, 18, 21, 28, 32). Some investigators even reported that early surgery was associated with worse results than delayed surgery (6, 14, 29). As mentioned, this may be related to the fact that most investigators do not control for other variables affecting outcome, such as prehospital hypotension, hypoxia, GCS score, and associated intracranial lesions. In 82 patients undergoing surgery for SDH, Dent et al. (6) found that time to surgery of less than 4 hours was associated with a significantly lower rate of functional outcome when compared with surgery delayed for longer than 4 hours (24% versus 51%). Mortality was approximately 30% in both groups. The authors also found that patients who underwent surgery within 4 hours were more likely to have obliterated basal cisterns and showed a tendency for lower GCS scores and more associated intracranial injuries, suggesting a more severe TBI.

The only large study with patients with low GCS scores (GCS < 10) that did not find a relationship between early surgery and better outcome was the study by Kotwica and Brzezinski (18). In that study, mortality was approximately 60% in all patients, regardless of whether they had surgery within 4 hours or between 4 and 16 hours after TBI. A detailed analysis reveals that although GCS scores were the same, almost 90% of patients undergoing early surgery had associated intracranial lesions. Associated lesions were found in 78% and 64% of patients surviving the first 5 and 12 hours, respectively. This indicates that patients with early surgery had more severe injuries. In summary, there is evidence that patients who undergo surgery within 2 to 4 hours after clinical deterioration have a better outcome than those who undergo delayed surgery.

Surgical Technique

Different surgical techniques have been advocated for the evacuation of an SDH. The most commonly used techniques are:

- Twist drill trephination/craniostomy procedures.
- Burr hole trephination.
- Craniotomy with or without dural grafting.
- Subtemporal decompressive craniectomy.
- Large decompressive hemicraniectomy, with or without dural grafting.

Most investigators do not specify the type of surgical treatment used for evacuation of the SDH and, if they do, they usually do not address the effectiveness of the procedure. Except for two studies (14, 30) no papers were found looking at the impact of procedure type on outcome. The choice of operative technique is influenced by the surgeon's expertise, training, and evaluation of the particular situation. Some centers treat all SDH with decompressive craniectomies (18, 23), whereas other centers used solely osteoplastic craniotomies (36). Most studies report a mixture of procedures depending on the clinical and radiographic evaluation (13–15, 17, 38), or combined approaches in the same patient, i.e., subtemporal decompression plus subsequent craniotomy (26) or craniotomies with contralateral decompressive craniectomies in some children (31). One study evaluated decompressive hemicraniectomies for the treatment of selected patients with SDH (30).

Only two investigators addressed the effect of the operative technique on outcome from SDH. Hatashita et al. (14) looked at 3-months GOS in 60 patients with GCS scores between 3 and 15 admitted for SDH evacuation. All patients underwent surgery. The authors performed 24 burr holes, 25 craniotomies, 8 craniotomies with dural grafting, and 3 decompressive craniectomies. In patients with GCS scores between 4 and 6, the authors found a statistically significant increased mortality and reduced functional recovery rate in patients undergoing burr hole trephination versus craniotomy. Koc et al. (17) compared craniotomy, craniotomy with dural grafting, and decompressive craniectomy in 113 patients with GCS scores between 3 and 15 undergoing SDH evacuation. Seventeen patients underwent decompressive craniectomy and all died. No other significant differences were found between treatment groups. The results of all of these studies have to be viewed with caution because groups undergoing different types of surgical treatment were not comparable.

SUMMARY

In patients with an acute SDH, clot thickness or volume and the MLS on the preoperative CT correlate with outcome. In studies analyzing CT parameters that may be predictive for delayed surgery in patients undergoing initial nonoperative management, an MLS greater than 5 mm or a clot thickness greater than 10 mm on the initial CT scan emerged as significant prognostic factors (see *Appendices* for measurement techniques). Therefore, patients with SDH presenting with a clot thickness greater than 10 mm or an MLS greater than 5 mm should undergo surgical evacuation, regardless of their GCS. Patients who present in a coma (GCS < 9) but with an SDH with a thickness less than 10 mm and an MLS less than 5 mm can be treated nonoperatively, providing that they undergo ICP monitoring, they are neurologically stable since the injury, they have no pupillary abnormalities, and they have no intracranial hypertension (ICP > 20 mm Hg). Because of the frequent association of SDH with parenchymal injury, surgical management decisions should take into consideration the recommendations for both lesion types.

KEY ISSUES FOR FUTURE INVESTIGATION

- Craniotomy versus decompressive craniectomy and dural grafting for the initial evacuation of SDH. Effect of different prehospital ambulance systems on timing of surgery and outcome from SDH.
- Incidence and impact of prehospital hypotension and hypoxia on outcome from SDH.
- Identification of subgroups that do not benefit from surgery: older patients with low GCS scores, pupillary abnormalities, and associated intracerebral lesions.
- Prospective evaluation of the treatment option for comatose patients (GCS < 9) presented above: does operating on all comatose patients, regardless of their hematoma thickness and MLS lead to a better outcome than following the treatment option presented above.

REFERENCES

1. Bowers S, Marshall L: Outcome in 200 consecutive cases of severe head injury treated in San Diego County: A prospective analysis. **Neurosurgery** 6:237–242, 1980.
2. Brain Trauma Foundation: Early indicators of prognosis in severe traumatic brain injury. **J Neurotrauma** 17:535–627, 2000.
3. Cagetti B, Cossu M, Pau A, Rivano C, Viale G: The outcome from acute subdural and epidural intracranial haematomas in very elderly patients. **Br J Neurosurg** 6:227–231, 1992.
4. 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.
5. Croce M, Dent D, Menke P, Robertson J, Hinson M, Young B, Donovan T, Pritchard F, Minard G, Kudsk K, Fabian TC: Acute subdural hematoma: Nonsurgical management of selected patients. **J Trauma** 36:820–826, 1994.
6. Dent D, Croce M, Menke P, Young B, Hinson M, Kudsk K, Minard G, Pritchard F, Robertson J, Fabian T: Prognostic factors after acute subdural hematoma. **J Trauma** 39:36–42, 1995.
7. Domenicucci M, Strzelecki J, Delfini R: Acute posttraumatic subdural hematomas: "Intradural" computed tomographic appearance as a favorable prognostic factor. **Neurosurgery** 42:51–55, 1998.
8. Ersahin Y, Mutluer S: Posterior fossa extradural hematomas in children. **Pediatr Neurosurg** 19:31–33, 1993.
9. Espersen J, Petersen O: Computerized tomography (CT) in patients with head injuries. Relation between CT scans and clinical findings in 96 patients. **Acta Neurochir (Wien)** 56:201–217, 1981.
10. Fell D, Fitzgerald S, Moiel R, Caram P: Acute subdural hematomas. Review of 144 cases. **J Neurosurg** 42:37–42, 1975.
11. Gabl M, Mohsenipour I, Benedetto K: Acute posttraumatic subdural hematoma in advanced age [in German]. **Unfallchirurgie** 15:273–278, 1989.
12. 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.
13. Haselsberger K, Pucher R, Auer L: Prognosis after acute subdural or epidural haemorrhage. **Acta Neurochir (Wien)** 90:111–116, 1988.
14. Hatashita S, Koga N, Hosaka Y, Takagi S: Acute subdural hematoma: Severity of injury, surgical intervention, and mortality. **Neurol Med Chir (Tokyo)** 33:13–18, 1993.
15. Howard MA 3rd, Gross AS, Dacey RJ Jr, Winn HR: Acute subdural hematomas: An age-dependent clinical entity. **J Neurosurg** 71:858–863, 1989.
16. Jamjoom A: Justification for evacuating acute subdural haematomas in patients above the age of 75 years. **Injury** 23:518–520, 1992.
17. Koc R, Akdemir H, Oktem I, Meral M, Menku A: Acute subdural hematoma: Outcome and outcome prediction. **Neurosurg Rev** 20:239–244, 1997.
18. Kotwica Z, Brzezinski J: Acute subdural haematoma in adults: An analysis of outcome in comatose patients. **Acta Neurochir (Wien)** 121:95–99, 1993.
19. Kotwica Z, Jakubowski J: Acute head injuries in the elderly. An analysis of 136 consecutive patients. **Acta Neurochir (Wien)** 118:98–102, 1992.
20. 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.
21. Massaro F, Lanotte M, Faccani G, Triolo C: One hundred and twenty-seven cases of acute subdural haematoma operated on. Correlation between CT scan findings and outcome. **Acta Neurochir (Wien)** 138:185–191, 1996.
22. Mathew P, Oluoch-Olunya D, Condon B, Bullock R: Acute subdural haematoma in the conscious patient: Outcome with initial nonoperative management. **Acta Neurochir (Wien)** 121:100–108, 1993.
23. 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.
24. 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.
25. Schecter W, Peper E, Tuatoo V: Can general surgery improve the outcome of the head-injury victim in rural America? A review of the experience in American Samoa. **Arch Surg** 120:1163–1166, 1985.
26. Seelig J, Becker D, Miller J, Greenberg R, Ward J, Choi S: Traumatic acute subdural hematoma: Major mortality reduction in comatose patients treated within four hours. **N Engl J Med** 304:1511–1518, 1981.
27. Servadei F, Nasi M, Cremonini A, Giuliani G, Cenni P, Nanni A: Importance of a reliable admission Glasgow Coma Scale score for determining the need for evacuation of posttraumatic subdural hematomas: A prospective study of 65 patients. **J Trauma** 44:868–873, 1998.

28. Servadei F, Nasi M, Giuliani G, Cremonini A, Cenni P, Zappi D, Taylor G: CT prognostic factors in acute subdural haematomas: The value of the 'worst' CT scan. **Br J Neurosurg** 14:110–116, 2000.
29. Shenkin H: Acute subdural hematoma. Review of 39 consecutive cases with high incidence of cortical artery rupture. **J Neurosurg** 57:254–257, 1982.
30. Shigemori M, Syojima K, Nakayama K, Kojima T, Ogata T, Watanabe M, Kuramoto S: The outcome from acute subdural haematoma following decompressive hemicraniectomy. **Acta Neurochir (Wien)** 54:61–69, 1980.
31. Spanu G, Pezzotta S, Silvani V, Leone V: Outcome following acute supratentorial subdural hematoma in pediatric age. **J Neurosurg Sci** 29:31–35, 1985.
32. 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.
33. 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.
34. van den Heever CM, van der Merwe DJ: Management of depressed skull fractures. Selective conservative management of nonmissile injuries. **J Neurosurg** 71:186–190, 1989.
35. Wilberger JJ, Harris M, Diamond D: Acute subdural hematoma: Morbidity and mortality related to timing of operative intervention. **J Trauma** 30:733–736, 1990.
36. Wilberger JJ, Harris M, Diamond D: Acute subdural hematoma: Morbidity, mortality, and operative timing. **J Neurosurg** 74:212–218, 1991.
37. Wong CW: Criteria for conservative treatment of supratentorial acute subdural haematomas. **Acta Neurochir (Wien)** 135:38–43, 1995.
38. Yanaka K, Kamezaki T, Yamada T, Takano S, Meguro K, Nose T: Acute subdural hematoma—Prediction of outcome with a linear discriminant function. **Neurol Med Chir (Tokyo)** 33:552–558, 1993.
39. Zumkeller M, Behrmann R, Heissler H, Dietz H: Computed tomographic criteria and survival rate for patients with acute subdural hematoma. **Neurosurgery** 39:708–712, 1996.

TABLE 1. Surgical management of acute subdural hematomas[a]

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion				
Cagetti et al. (3)	26	III	All GCS	All surgery	Early mortality	Retrospective study of 28 patients between 80 and 100 yr of age. 2 patients had an EDH and 26 patients had a SDH.	Patients older than 80 yr had a 88% mortality. All 19 patients with a GCS between 3 and 9 died.				
							GCS	**No. of patients**	**Died**	**Survived**	
							13–15	4	2	2	
							10–12	5	4	1	
							3–9	19	19	0	
Dent et al. (6)	211	III	All GCS	Surgery and nonsurgical	GOS at a mean of 253 d	Retrospective analysis of factors affecting outcome in 211 patients with SDH. 83 patients underwent surgery and 128 did not. A treatment protocol was not specified.	Admission GCS, injury severity score, and pupillary reactivity were independent predictors of outcome in the entire patient population.				
								<4 h from TBI to surgery (%)	**>4 h (%)**	***P* value**	
							GR/MD	24	51	0.02	
							SD/VS	48	19		
							D	28	30	n.s.	
							Open cisterns	5	19	0.0004	
							Effaced cisterns	76	53	0.002	
							GCS	7.0 points	8.4 points	n.s.	
Haselsberger et al. (13)	111	III	All GCS	All surgery	GOS at 9 mo	A retrospective review of 171 patients who presented with either a subdural (111 patients) or an epidural (60 patients) hematoma. The influence of surgical timing was analyzed in relation to mortality and functional recovery.	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	34	32	21	47
							>2 h	55	4	16	80
Hatashita et al. (14)	60	III	All GCS	All surgery	GOS at 3 mo	Retrospective analysis of 60 patients and the influence of surgical timing on the outcome from SDH.	Patients operated on within 4 h of injury had a higher mortality compared with those operated on after 4 h. Patients with a GCS between 4 and 6 who underwent a craniotomy had a significantly better outcome compared with those who were treated with burr holes.				
							GOS	**<4 h from TBI to surgery, n = 43 (%)**	**4–10 h, n = 17 (%)**		
							GR/MD	26	41		
							D	63	35		
Howard et al. (15)	67	III	All GCS	All surgery	GOS at 2 mo	Retrospective analysis of 2 age groups (18–40 yr and >65 yr) of patients with acute SDH.	Age >65 yr, size of the hematoma, and MLS were related to outcome, but not independently. Size of the hematoma and MLS were greater in the older patient group. Mortality in the older patient group was 74%, in the younger group, it was 18% ($P < 0.001$).				
Jamjoom (16)	27	III	All GCS	All surgery	GOS at 6 mo	A review of 27 patients aged 75 yr or older who required operation for an acute SDH.	No patient older than 75 yr who preoperatively was extensor posturing, flaccid to pain, or had unilateral or bilateral fixed and dilated pupils made a good recovery (GOS 3–5). Evacuation of acute subdural hematoma is not recommended in this subgroup of patients.				
								No. of patients	**GR/MD (%)**	**SD/V (%)**	**D (%)**
							Preoperative deterioration to GCS < 8	13		8	92
							Pupils reactive	15	27	27	46
							Uni/bilateral unreactive pupils	12			100
							Admission GCS > 4	19	21	16	63
							Admission GCS < 5	8		13	87

TABLE 1. Continued

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Koc et al. (17)	113	III	All GCS	All surgery	GOS at 3 mo	Review of 113 consecutive patients of all age groups operated on for acute SDH.	Preoperative GCS and pupillary exam correlated with functional outcome. Associated intracerebral hematoma, cerebral contusion, and SAH were also related to poorer outcome. Time from injury to surgery did not affect mortality.

	No. of patients	GR (no.)	MD (no.)	SD (no.)	D (no.)
GCS 3–4	37	2			35^{b}
GCS 5–6	28	4	2		22^{b}
GCS 7–8	25	2	1	11	25
GCS 9–12	11	10	1		
GCS 13–15	12	11		1	
Bilateral present light reflex	63	37	3	2	21
Unilateral absent light reflex	11	1	1		9^{c}
Bilateral absent light reflex	39		1		38^{c}

$^{b}P < 0.05$, $^{c}P < 0.01$

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Kotwica and Brzezinski (18)	200	III	GCS < 10	All surgery	GOS at 3 mo	Retrospective analysis of 200 adult patients who underwent surgical evacuation of an acute SDH.	A GCS between 3 and 6, age >50 yr, and MLS > 1.5 cm were associated with poor outcome. There was no difference in outcome between early (less than 4 h) and late surgical evacuation.

	No. of patients	GR (no.)	MD (no.)	SD (no.)	VS (no.)	D (no.)
GCS 3–6	166	29	6	25	7	99
GCS 7–9	34	5	6	2	6	15
MLS < 1.5 cm	41	15	2	6	2	16
MLS 1.5–3 cm	96	18	6	12	10	50
MLS > 3 cm	63	1	4	9	1	4
Age 18–40 yr	70	16	5	12	8	29
Age 50–65 yr	70	3	4	7	3	53

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Kotwica and Jakubowski (19)	27	III	All GCS	All surgery	Not documented	Retrospective analysis of 27 patients >70 yr with SDH undergoing surgery.	Old age is associated with a high mortality from SDH. All 17 patients with a GCS < 9 died.
Massaro et al. (21)	127	III	All GCS	All surgery	GOS at 18 mo	Retrospective analysis of 127 patients undergoing surgery for SDH.	GCS is the most important predictor of outcome.

	No. of patients	GR/MD (%)	SD (%)	D (%)
GCS > 12	8	100		
GCS 9–12	35	34	20	46
GCS < 9	84	11	21	68

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Mathew et al. (22)	23	III	GCS 13–15	Surgery and nonsurgical	GOS at 3–8 mo	Retrospective analysis of 23 patients with SDH who were initially managed nonoperatively.	6 patients underwent delayed surgery. All patients had a good outcome at 3–8 mo. All patients with a clot >10 mm thick on initial CT scan required surgery.
Sakas et al. (24)	22	III	Comatose	All surgery	GOS at 1 yr	Analysis of 40 severe TBI patients who underwent craniotomy after developing bilateral fixed and dilated pupils.	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.

Time from pupillary nonreactivity to surgery	No. of patients	GR/MD (%)	SD (%)	VS/D (%)
<3 h	20	30	30	40
>3 h	16	25	12	63

Authors (ref. no.)	No. of patients	Class	Inclusion GCS	Treatment	Outcome	Description	Conclusion
Servadei et al. (27)	65	III	GCS < 9	Surgery and nonsurgical	GOS at 6 mo	Retrospective analysis of comatose patients with SDH who were treated nonoperatively according to predefined criteria.	15 of 65 comatose patients with SDH were treated nonoperatively and 2 patients required delayed surgery because of increasing ICP and intracerebral hematomas. The authors concluded that nonoperative treatment can be safely used for selected comatose patients with SDH.
Servadei et al. (28)	206	III	All GCS	Surgery and nonsurgical	GOS at 6 mo	Prospective analysis of 206 patients of all age groups presenting with an acute SDH of at least 5 mm thickness. 148 patients underwent operative treatment.	The initial CT scan identifies patients at risk for unfavorable outcome. Hematoma thickness, MLS, status of basal cisterns, and presence of SAH in all patients (surgical and nonsurgical) are related to outcome.
Shigemori et al. (30)	15	III	GCS < 9	All surgery	GOS at 6 mo	Retrospective analysis of 15 patients with SDH undergoing decompressive hemicraniectomy because of rapid neurological deterioration.	10 patients died and 2 patients made a good recovery. Good recovery was only seen in patients with low postoperative ICP. The patients who made a good recovery were both 9 yr old.

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>Uzan et al. (32)</td><td>18</td><td>III</td><td>Comatose</td><td>All surgery</td><td>GOS at 6 mo</td><td>Prospective study of 71 patients with EDH, SDH, and intracerebral hemorrhage, of all age groups operated on for signs of uncal herniation.</td><td>Timing of surgery did not affect outcome. GCS correlated with GOS.</td></tr>
<tr><td>van den Brink et al. (33)</td><td>91</td><td>III</td><td>All GCS</td><td>All surgery</td><td>GOS at 6 mo</td><td>Retrospective analysis of the CT scan parameters in 91 patients with acute SDH.</td><td>Volume of the subdural blood did not correlate with outcome. Subarachnoid blood and pupillary dysfunction were the only significant parameters correlating with a poor outcome.
<table>
<tr><th></th><th>SD/VS/D (%)</th></tr>
<tr><td>Bilateral abnormal pupils</td><td>89</td></tr>
<tr><td>GCS motor score < 4</td><td>80</td></tr>
<tr><td>GCS motor score > 3</td><td>52</td></tr>
</table></td></tr>
<tr><td>Wilberger et al. (35)</td><td>101</td><td>III</td><td>GCS < 9</td><td>All surgery</td><td>GOS after 18 mo</td><td>Retrospective analysis of 101 comatose patients of all age groups with acute SDH.</td><td>A significant increase in mortality was associated with GCS 3 or 4, age greater than 65 yr, ICP greater than 45 mm Hg and evacuation of hematoma >12 h after injury.
<table>
<tr><th></th><th>No. of patients</th><th>GR/MD</th><th>D</th><th>P value</th></tr>
<tr><td>Time from injury to operation</td><td>101</td><td>280 ± 26 min</td><td>374 ± 31 min</td><td>n.s.</td></tr>
<tr><th>Age (yr)</th><th>No. of patients</th><th>GR/MD (%)</th><th>D (%)</th><th>P value</th></tr>
<tr><td><35</td><td>35</td><td>31.4</td><td>54.3</td><td>n.s.</td></tr>
<tr><td>35–50</td><td>21</td><td>23.8</td><td>61.9</td><td>n.s.</td></tr>
<tr><td>51–65</td><td>17</td><td>11.8</td><td>70.6</td><td>n.s.</td></tr>
<tr><td>65</td><td>28</td><td>3.6</td><td>82.1</td><td>$P < 0.01$</td></tr>
<tr><th>GCS</th><th>No. of patients</th><th>% GR/MD</th><th>% D</th><th>P value</th></tr>
<tr><td>3</td><td>19</td><td>5</td><td>90</td><td>$P < 0.05$</td></tr>
<tr><td>4</td><td>32</td><td>10</td><td>76</td><td>$P < 0.05$</td></tr>
<tr><td>5</td><td>27</td><td>18</td><td>62</td><td>n.s.</td></tr>
<tr><td>6–7</td><td>23</td><td>44</td><td>51</td><td>n.s.</td></tr>
</table></td></tr>
<tr><td>Wong (37)</td><td>31</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>GCS at 2 wk to 5 yr</td><td>Retrospective analysis of 31 adult patients (1 child) of 300 patients with SDH who were initially treated nonoperatively. 6 patients required delayed surgery for neurological deterioration. No difference was found in outcome.</td><td>MLS > 5 mm (only in patients with GCS < 15) and thickness of the hematoma >10 mm on the initial CT scan are significantly related to the failure of nonoperative treatment. Hematoma volume was not predictive.</td></tr>
<tr><td>Yanaka et al. (38)</td><td>170</td><td>III</td><td>All GCS</td><td>Surgery and nonsurgical</td><td>GOS at 3 mo</td><td>A retrospective study on 170 patients of all age groups with SDH admitted during 7 yr, treated either surgically or nonsurgically. A strict protocol was followed and patients with MLS > 5 mm underwent surgery.</td><td>77 patients underwent surgery. Prognostic indicators of outcome for the whole group of patients were: GCS, pupils, age, hematoma size, MLS, clot thickness, associated contusions, SAH, status of basal cisterns, and ICP.</td></tr>
<tr><td>Zumkeller et al. (39)</td><td>174</td><td>III</td><td>All GCS</td><td>All surgery</td><td>Postoperative mortality</td><td>Retrospective analysis of 174 patients operated on for acute SDH.</td><td>SDH thickness of less than 1 cm or midline shift less than 12 mm are well tolerated, with high survival rates. Mortality climbs steeply when MLS surpasses clot thickness.</td></tr>
</table>

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