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OUTCOME PREDICTORS AFTER SUBDURAL HEMATOMA WITH MIDLINE SHIFTS GREATER THAN 10 *MM*

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Abstract

This study aims to clarify some variables associated with an improved outcome in acute and chronic subdural hematomas with major midline shifts (extreme subdural hematomas).

A retrospective review of 814 patients, who were admitted to a Level 1 trauma center with the diagnosis of subdural hematoma, was performed. Out of those patients 77 were included in the overall statistical analysis. Both groups were assessed in regard to 33 different variables, including mechanism of injury (spontaneous, fall, other trauma), time of injury, presence of prior brain lesion (e.g. stroke, tumor), coagulation profile at the time of admission, etc. The Glasgow Coma Scale at the time of admission, Glasgow Outcome Scale at discharge, the amount of brain displacement, and the presence of hydrocephalus, herniation, or new infarcts were also recorded. Additionally, 8 radiographic variables were evaluated using computed tomography investigation to assess the degree of shift and location of extra-axial fluid collections as well as the degree of midline shift following therapeutic intervention and at the time of discharge.

The study included 26 patients with acute subdural hematoma and 51 patients with chronic subdural hematoma. In patients with acute subdural hematoma and extreme midline shift, unfavorable outcomes were significantly associated with coagulopathy, delayed intervention and failure to achieve reduction of midline shift to <10 mm during the hospital stay.

In patients with chronic subdural hematoma and extreme midline shift, unfavorable outcome is associated with lower Glasgow Coma Scale at the time of admission, midline shifts ≥20 mm and failure to reduce midline shift to less than 10 mm during the hospitalization.

The ratio of reduction in midline shift measured at discharge was statistically higher with the usage of a drain (p=0.027). Finally, mechanism of injury did not show any statistically significant effect on treatment outcomes.

A relatively small group of patients with major extra-axial fluid collections was reviewed showing the possibility of a good recovery among a substantial patient cohort. Thus, cases of large subdural effusions with massive shifts are not necessarily associated with bad outcomes and a substantial subgroup of patients will have favorable recovery when appropriately treated.

Keywords: *subdural hematoma, midline shift, outcome, outcome predictors, extreme midline shift.*

Introduction

Subdural hematoma is the most common neurosurgical pathology, and it affects all ages of the population. As the world becomes technologically more advanced and population becomes progressively older, the overall incidence of traumatic intracranial hematoma is increasing [*Uno M et al., 2017*]. The amount of research that has been carried out on this direction is extraordinary. However, many issues are unsolved and there are a wide variety of treatment algorithms and guidelines across countries.

One of the objective reasons for the observed difficulty of uniform treatment algorithm is the wide variety of traumatic brain injuries and even traumatic hematomas. Intracranial pressure following the traumatic intracranial bleeding can be

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elevated due to increasing mass effect from hematomas and contusions, diffuse brain swelling or hydrocephalus. Intracranial hypertension can lead to ischemia due to reduction of the cerebral perfusion pressure. Substantial evidence from large cohort studies points to the fact that intracranial hypertension is associated with excess mortality following traumatic brain injury [*Kolias A et al., 2016*].

Acute subdural hematomas (ASDH) are one of the conditions most strongly associated with traumatic brain injury with a frequency of 12%-29%. Because of ASDH complex pathophysiology, its mortality of remains high, in spite of advances in emergency medical systems. It mainly affects younger population and is therefore a serious socio-economical issue.

Despite the abundance of subdural hematomas and their common devastating outcome, a review of the literature revealed a relative shortage and discrepancies in outcome prediction. Some but not all of the risk factors for poor outcome include co-existing intracranial lesions, including a variety of diffuse injuries, contusional hematomas, and edemas. In addition, it is also modified by subsequent phenomena such as both global and focal ischemia beneath hematoma, reactive hyperemia or hyperperfusion, coagulopathy, delayed hematomas, and so on [*Karibe H et al., 2014*].

Several studies have attempted to determine factors affecting the outcome of acute and chronic subdural hematomas [*Iantosca M, Simon R, 2000; D'Amato L et al., 2007; Li L et al., 2012; Bacigaluppi S et al., 2017; Uno M et al., 2017; Vilcinis R et al., 2017; Moussa W et al., 2018*]. Currently a multicenter randomized clinical trial RESCUE-ASDH is under way to assess the role of decompressive craniectomy in improving the outcome [*Kolias A et al., 2016*]. There is also an increasing interest in investigating the age, mechanism of injury, time to treatment, etc [*Fakhry S et al., 2004; Leung G et al., 2012; Katsigiannis S et al., 2017*]. One common shortfall in all the mentioned studies is that acute subdural hematomas are considered in whole as one pathologic entity. However, there are multiple other prognostic factors which are investigated less thoroughly or are not considered at all.

One of such factors, which is commonly used to prognosticate the outcome in family discussions, is the size of the hematoma. Despite being an objective measurement on a routine non-contrast CT scan, the thickness of the hematoma does not always correlate with the severity of injury and most importantly, with the outcome of the disease, as there is a wide variation in pericortical subarachnoid space volume secondary to brain atrophy and age related replacement hydrocephalus. Therefore, a more reliable prognostic factor could be the extent of the midline shift, which directly correlates with the cerebral tissue damage, edema and altered cerebral perfusion. A thorough literature review showed that there are no articles which specifically studied subdural hematomas resulting in critical midline shifts greater than 10*mm*, so called extreme subdural hematomas. These include both acute and subdural hematomas, as in term of prognosis the extent of the midline shift is thought to be a greater determinant than the acuity.

This study aims to clarify some variables associated with the outcome in acute and chronic subdural hematomas with major midline shifts, as well as correlation of the midline shift to many other variables, including but not limited to the mechanism of injury (spontaneous, fall, other trauma), time of injury, presence of prior brain lesion (e.g. stroke, tumor) and coagulation profile at the time of admission.

Material and methods

A retrospective review of hospital charts from 814 consecutive patients, who were admitted to the Level I Trauma Center from January 2010 and September 2016 with a diagnosis of extra-axial fluid collection, was performed. Patients were classified into two groups depending on the acuity of the hematoma. The acute subdural hematoma (ASDH) group included patients who had trauma within 3 days or hyper-intensity on a CT/MRI. The rest of the patients, who had history of trauma for more than 3 days, iso-, hypo- and mixed- intensity on CT/MRI, were included in the chronic subdural hematoma (CSDH) group.

Twenty-six patients with ASDH and 51 patients with CSDH fulfilled the inclusion criteria of midline shifts greater than 10 *mm*. Additionally, 19 patients (18 ASDH and 1 CSDH with extreme midline shifts) who were seen in the Emergency Department with clinical signs of brain death were excluded from the current study as

there is a general agreement regarding the futility of treatment in these patients. Thus, 77 patients were included in the overall statistical analysis. Both groups were assessed in regard to 33 different variables, including age, gender, race, mechanism of injury (spontaneous, fall, other traumas), time of injury, presence of prior brain lesion (e.g. stroke, tumor), coagulation profile at the time of admission, etc. The Glasgow Coma Scale (GCS) at time of admission, Glasgow Outcome Scale (GOS) at discharge, the amount of brain displacement, and the presence of hydrocephalus, herniation, or new infarcts were also recorded. Additionally, 8 radiographic variables were evaluated using CT investigation to assess the degree of shift and location of extra-axial fluid collections as well as the degree of midline shift following therapeutic intervention and at the time of discharge (Figure).

The surgical intervention of choice for ASDH was craniectomy and evacuation of hematoma whereas options for chronic and subacute subdural hematomas included craniotomy, burr hole evacuation of hematoma or subdural evacuating portal system drain.

The primary endpoint of this study was the Glasgow Outcome Score at discharge, regardless of clinical status upon admission. A GOS of 1-3 was considered an unfavorable outcome, and a GOS of 4-5 was recorded as a good outcome.

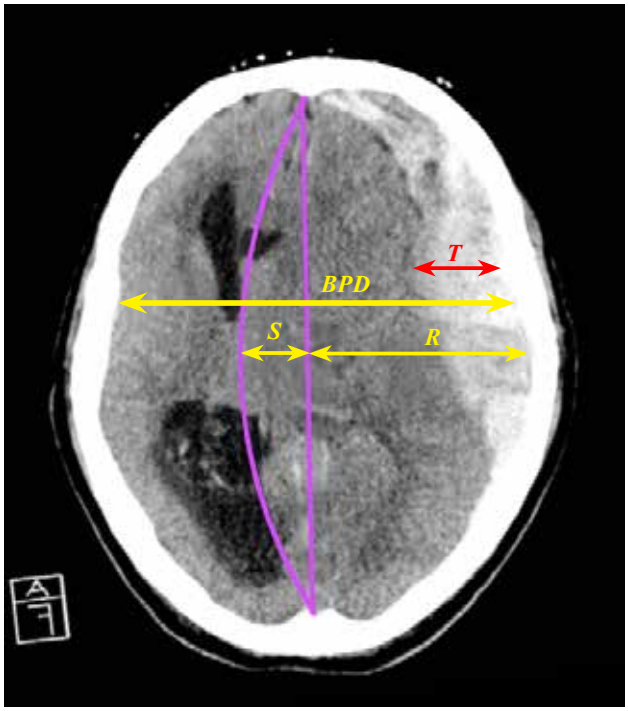

FIGURE. *Radiographic variables of CT assessment*
NOTES: ***BPD*** *- Inner biparietal diameter,* ***0.5BPD*** *- Radius,* ***S*** *- Midline shift,* ***T*** *- Hematoma thickness*

Statistical analysis was performed using SPSS 17 software (SPSS Inc., 2008). Analysis of variables (ANOVA) with the Bonferroni method was performed in order to analyze the statistical impacts of the collected variables.

RESULTS

Among the cohort of 77 patients with midline shift of 10 *mm* or greater, 26 suffered from ASDH and 51 from CSDH. The mean age of presentation in the ASDH group was 31 (16-79 years old) and 45 in the CSDH group (39-85 years old). Both groups showed marked male predominance.

From all patients included in the ASDH group, 27 developed the hematoma after considerable head trauma and 9 after minor head trauma. In the CSDH group only 4 patients recalled a considerable head trauma. Other patients developed CSDH either spontaneously or after a mild fall. Patients with ASDH had higher mortality rates than those with CSDH (23.1% vs. 4.4% respectively, $p=0.011$). This data excludes patients presenting initially with brain death. However, survivors of ASDH in this patient cohort showed better clinical and neurological improvement than those with CSDH (GOS of 4-5: 53.8% vs. 37.8% respectively, $p=0.024$). Further statistical analysis revealed several other common variables which similarly affected the outcomes of both ASDH and CSDH groups.

Patients who improved were younger than those who died (mean age difference – 10.2 years, $p=0.012$) or clinically worsened (mean age difference – 7.2 years, $p=0.001$). The presence of past brain lesions, e.g. stroke, was associated with worse outcomes compared to previously intact patients (66.2% vs. 33.7%, $p=0.037$). Severe neurological compromise at the time of admission was associated with a poor outcome (altered mental status ($p<0.001$), speech difficulty ($p=0.001$), non-reactive pupillary reflex ($p=0.014$), and radiographic evidence of brain herniation ($p=0.015$)).

Early operative intervention in both groups resulted in improved outcomes. However, due to a small number of patients, this difference did not reach statistical significance.

Variables affecting the outcome of acute subdural hematomas. Review of data with statistical analysis revealed only 3 variables which had statistically significant impact on the treatment outcome of patients suffering from ASDH. Unfavorable outcomes were significantly associated with having coagulopathy on admission (p=0.009), delayed intervention after arrival to the hospital (>3 hours vs. <3 hours p=0.019), and failure to achieve reduction of midline shift to <10 *mm* during patient stay in the postoperative period (p=0.049).

Additionally, risk factors for brain death on arrival included being of the female sex (p=0.005) and hematoma thickness (not midline shift) of more than 25 *mm* (p=0.042). Nevertheless, 38% of patients with hematoma thickness of more than 25 *mm* recovered.

Variables affecting the outcome of chronic subdural hematomas. Unfavorable outcomes in patients with CSDH were significantly associated with having lower GCS on admission (p=0.0004), midline shifts ≥20 *mm* (p=0.023) and failure to reduce midline shift to less than 10 *mm* during the patient's stay in the hospital (p=0.001).

Regarding the clinical status at the time of discharge, 22 were discharged without any neurological deficits, 9 patients died during or soon after discharge, and the remaining 20 patients were discharged with variable degrees of neurological deficits.

Treatment of CSDH with subdural evacuating portal system drain or burr hole were associated with worse clinical outcomes when compared to conservative treatment (p=0.006) or craniotomy (p<0.001). However, patients who received conservative treatment (withholding surgery) and craniotomy had lower GCS scores on admission. Therefore, after multivariate analysis with the exclusion of confounding factors, the difference was not statistically significant.

The ratio of reduction in midline shift measured at discharge was statistically higher with the usage of a drain (p=0.027). Finally, mechanism of injury did not show any statistically significant effect on treatment outcomes.

Discussion

Outcome predictors of subdural hematomas have been a subject for research even before the first CT scanners were introduced into clinical practice. Cerebral angiography has been the only feasible modality to select appropriate surgical candidates and perform surgical evacuation [*van der Werf A, 1975*]. With the advances of current imaging technologies, a tremendous amount of work has been done in this direction. Until now, predictors of outcome in a subgroup of patients with large subdural effusions and significant midline shift were largely unknown and not well investigated.

Many prognostic factors have been proposed to predict the outcome of treatment in patients suffering from subdural hematomas. Some of the most referred factors are advanced age [*Iantosca M, Simon R, 2000; Petridis A et al., 2009; Katsigiannis S et al., 2017; Wasfie T et al., 2017; Uno M et al., 2017*], method of surgical treatment [*Huang Q et al., 2003; Chen S et al., 2011; Vilcinis R et al., 2017*], multidisciplinary approach [*Fakhry S et al., 2004; Leung G et al., 2012; Katsigiannis S et al., 2017*] and preoperative neurological status [*Katsigiannis S et al., 2017*]. However, to the best of our knowledge, only one publication has specifically evaluated the degree of midline shift as an outcome measure of ASDH and no publications were found of similar evaluation for CSDH [*Moussa W et al., 2018*].

In current study we aimed to reveal the detailed prognostic variables specifically affecting the outcome in large subdural hematomas resulting in extreme midline shifts.

In a study by W. Moussa and co-authors (2018) hematoma to midline shift ratio was found to be an important prognostic factor for treatment outcomes. They found that the ratio of 0.79 or less is correlated with a low postoperative GCS and GOS. Since values less than 1 indicate intrinsic cerebral injury and edema, this was thought to be the reason for such correlation [*Moussa W et al., 2018*]. However, in our cohort of patients this variable showed no statistically significant correlation with the outcome. We assume that once the threshold of 10 *mm* of midline shift is passed, the role of hematoma to midline shift ratio loses its prognostic significance.

Advanced age is one of the most commonly cited negative predictive factors for both ASDH and CSDH [*Evans J et al., 2015; Raj R et al., 2016; Bacigaluppi S et al., 2017; Won S et al., 2017*]. Our results are in agreement with this finding, but also

indicate that comorbidities and anticoagulation status are the most likely responsible factors for such discrepancy, neutralizing the hypothetical advantage of increased subarachnoid space due to cerebral atrophy. Altered coagulation profile has been found to be a negative prognostic factor in a number of other publications [*Bacigaluppi S et al., 2017; Abboud T et al., 2018*], especially in elderly patients [*Uno M et al,* 2017].

One of the most controversial aspects of the management of acute subdural hematomas is the method of operative intervention. A recent multicenter randomized clinical trial, RESCUEicp, failed to show the benefit of routine decompressive craniectomy in patients with severe traumatic brain injuries without intracranial hematomas as compared to medical management alone [*Hutchinson P et al., 2016*]. Another randomized trial is currently recruiting patients to evaluate the role of routine decompressive craniectomy after evacuation of acute subdural hematoma [*Kolias A et al., 2016*]. Many earlier studies have attempted to evaluate craniotomy versus craniectomy as the best therapeutic intervention; however, no Level I evidence is available to date [*Huang Q et al., 2003; Bullock M et al., 2006; Chen S et al., 2011; Karibe H et al., 2014; Vilcinis R et al., 2017*]. All these studies uniformly show no added benefit of decompressive craniectomy to simple evacuation of subdural hematoma. In our study, failure to reduce the midline shift to less than 10 *mm* in the postoperative period was a statistically significant prognostic factor for poor outcomes of CSDH. This may indicate that decompressive craniectomy has advantages for a subgroup of patients with large subdural hematomas and midline shift of greater than 10 *mm*. However, the advantage is not statistically significant.

Thus, comparing our results with literature data, it becomes apparent that extreme subdural effusions with midline shift of more than 10 *mm* are somewhat unique pathological entities and do not correlate with the same outcome predictors as all subdural hematomas in general.

CONCLUSION

A relatively small group of patients with major extra-axial fluid collections and a midline shift of >10 *mm* was reviewed showing the possibility of a good recovery among a substantial patient cohort. In patients with acute subdural hematomas and extreme midline shift, unfavorable outcomes were significantly associated with coagulopathy, delayed intervention (>3 hours) and failure to achieve reduction of midline shift to <10 *mm* during the hospital stay.

In patients with chronic subdural hematomas and extreme midline shift, unfavorable outcome is associated with lower GCS at the time of admission, midline shifts ≥20 *mm* and failure to reduce midline shift to less than 10 *mm* during the hospitalization.

Thus, cases of large subdural effusions with massive shifts are not necessarily associated with bad outcomes and a substantial subgroup of patients will have favorable recovery when appropriately treated.

Based on the results of our retrospective analysis, we will conduct a long-term prospective study to better understand the constellation of factors affecting the outcome after extreme intracranial hematomas.

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