CLINICAL ARTICLE
Korean J Neurotrauma 2015;11(2):112-117

pISSN 2234-8999 / eISSN 2288-2243
http://dx.doi.org/10.13004/kjnt.2015.11.2.112

Clinical Analysis of Delayed Surgical Epidural Hematoma

Jiin Kang, MD, Soonki Hong, MD, PhD, Chul Hu, MD, PhD, Jinsoo Pyen, MD, PhD, Kum Whang, MD, PhD, Sungmin Cho, MD, PhD, Jongyeon Kim, MD, Sohyun Kim, MD, and Jiwoong Oh, MD

Department of Neurosurgery, Wonju College of Medicine, Yonsei University, Wonju, Korea

Objective: A small epidural hematoma (EDH) that has been diagnosed to be nonsurgical by initial brain computed tomography (CT) can increase in size and need surgical removal, resulting in a poor prognosis. However, there have been few studies, which focused delayed operated EDH. Therefore, we analyzed the clinical factors to determine the predicting factors of delayed operated EDH.

Methods: Between January 2011 and January 2014, 90 patients, who were admitted due to EDH, were enrolled in this study. None of the patients were indicated for operation initially. Based on the presence of surgery, we classified the patients into a delayed-surgery group (DG) and a non-surgical group (NG). Additionally, we analyzed them according to the following: time interval between the trauma and the initial CT, gender, age, medical history, drinking, change of mean arterial pressure (MAP), volume of EDH and other traumatic brain lesion.

Results: Among the 90 patients, the DG was 19 patients. Compared with NG, the DG revealed increased MAP, less presence of drinking, and a short time interval (DG vs. NG: +9.684 mm Hg vs. -0.428 mm Hg, 5.26% vs. 29.58%, 1.802 hours vs. 5.707 hours, respectively, $p<0.05$). Analyzing the time interval with receiver operating characteristic, there was 88.2% sensitivity and 68.3% specificity at the 2.05-hour cut-off value (area under the curve=0.854).

Conclusion: According to our results, the time interval between the trauma and the initial CT along with blood pressure change are potential predicting factors in the cases of delayed operation of EDH.

(Korean J Neurotrauma 2015;11(2):112-117)

KEY WORDS: Hematoma, epidural, cranial · Craniocerebral trauma · Tomography, X-ray computed · Neurosurgery.

Introduction

Acute epidural hematoma (EDH) accounts for 2.7% to 11% of traumatic brain injuries (TBIs), and if the size is large, the disease leads to devastating results.[1,7,12] Generally, a small EDH does not cause neurological deficits, and it has a good prognosis. However, if an initially small EDH suddenly expands, the patient's condition may deteriorate quickly.[2,8,13] This may cause death or a serious neurological disorder in a patient, and thus, it always requires attention and quick action. EDH expansion is a significant concern in patient care.

So far, much of the literature has reported on the expansion of acute EDH, and most types have been analyzed, including asymptomatic hematoma expansion found in the follow-up of computed tomography (CT).[5,11,17,19] The change of the hematoma in EDH treatment–not only the change of radiologic imaging size but also the degree of expansion of the hematoma leading to operation–is important. Thus, we investigated the early predictors and risk factors of hematoma expansion in patients who underwent delayed surgery when their neurological condition worsened due to the expansion of the hematoma during the conservative treatment of EDH.

Materials and Methods

This was a retrospective study of 151 patients who opt-

Received: August 2, 2015 / **Revised:** September 16, 2015
Accepted: October 12, 2015
Address for correspondence: Jiwoong Oh, MD
Department of Neurosurgery, Wonju College of Medicine, Yonsei University, 20 Ilsan-ro, Wonju 26426, Korea
Tel: +82-33-741-0592, Fax: +82-33-746-2287
E-mail: nsojw@yonsei.ac.kr

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ed for conservative treatment during initial hospitalization among patients who presented with traumatic EDH from January 2011 to January 2014.

Of the 151 patients, 61 patients were excluded; eight patients were excluded for surgery because of hematoma size increases without significant neurological symptoms or signs. Four patients who underwent emergency surgery because of severe neurological deficits without follow-up CT were excluded. Ten patients were excluded due to hemorrhagic diseases, such as hepatic cirrhosis, hematologic malignancy, and end-stage renal disease with hemodialysis. Two patients with diffuse axonal injury and 19 patients with other severe accompanying TBIs (e.g., subdural hematoma, intracerebral hemorrhage) were excluded. Eighteen patients with Abbreviated Injury Scale (AIS)[6] scores of more than 3 with traumatic multi-organ injury were excluded. Accompanying head injuries included skull fracture, contusional hemorrhage of less than 5 mL, and traumatic subarachnoid hemorrhage of less than a Fisher Grade 3.

A total of 90 patients were enrolled in this study and divided into a delayed-surgery group (DG) and a non-surgical group (NG). The DG was the group that received surgery due to changes in symptoms and hematoma growth in the course of the conservative treatment period. In other words, the DG was a group of patients, who were not indicated for operation initially, that underwent surgery later due to EDH growth with neurological deterioration. Members of this group had to have shown neurological change and hematoma increase in the follow-up CT and to have undergone surgery (Figure 1). The NG was the group that proceeded with conservative treatment. The follow-up CT of the NG was performed within 6 to 12 hours. The routine brain CT was also performed within 6 hours in both groups.

The gender, age, initial Glasgow Coma Scale (GCS), presence of drinking at trauma attack, and medical history (hypertension, diabetes, anticoagulant use) of all patients were investigated. The laboratory studies–including platelet counts, prothrombin time (PT), and partial thromboplastin time (PTT)–were also investigated. In addition, the initial amounts and changes in EDH amounts (mL), changes in mean arterial pressure (MAP, mm Hg), accompanying head injury, and time interval between trauma and initial CT time (hours) were collected. The prognostic outcome of both groups was evaluated with the Glasgow Outcome Scale. Only in the DG, we also analyzed the relationship between the prognosis of patients and the GCS of both initial and later time points, where the same patients went through neurological aggravation.

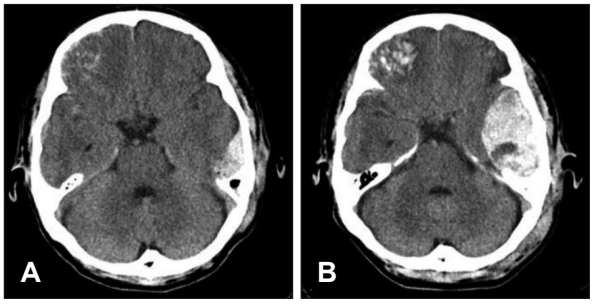

FIGURE 1. One case of delayed-surgery group. Computed tomography of 61-year-old male who visited our institution due to a pedestrian traffic accident. A: First plan of our treatment was only conservative management. B: From 3 hours from admission, the pat.

The ABC/2 method was used to measure the amount of EDH.[9] The indications for EDH surgery were defined as a volume of more than 30 mL, a thickness of more than 10 mm, or a mid-line shift of more than 15 mm. MAP change was defined as the difference between the first time MAP was measured in the Emergency Room and just before the follow-up CT. Whether platelet counts were normal was determined based on a range from 165,000 to 360,000. Additionally, normal PT and PTT were determined based on 9.5 to 12.8 seconds and 27.9 to 37.8 seconds, respectively.

Each factor was examined with univariate analysis and multivariate analysis. The Statistical Package for the Social Sciences (SPSS) version 18.0 for Windows (SPSS Inc., Chicago, IL, USA) was used as the analysis program. In the univariate analysis, an independent *t*-test was conducted for continuous variables, and a chi-square test was conducted for nominal variables. A logistic regression test was performed for the multivariate test. All analyses were statistically significant at p-value <0.05.

Results

Of the 90 patients, 19 were DG patients. The 71 NG patients continued with conservative management. The average amounts of change in the hematomas of the DG and the NG were 33.02 ± 31.02 mL and 2.415 ± 6.272 mL, respectively ($p<0.001$) (Figure 2).

Independent variables of the DG and NG are shown in Table 1. In the univariate study, the presence of drinking, MAP change, and time interval between trauma and initial CT were statistically significant. In the NG, 20 patients with drinking (29.58%) were reported to be higher than one patient (5.26%) in the DG ($p=0.0345$). The MAP change of the NG showed a decrease of 0.428 mm Hg, while the DG showed an increase of 9.684 mm Hg ($p=0.031$). The time interval between trauma and initial CT time was 5.707 ± 6.963 hours for the NG and 1.802 ± 1.565 hours for the DG. Initial

brain CT was performed more quickly in the DG than the NG (p=0.0001). Other factors–including age, anticoagulant use, medical history, and accompanying head injury–were not statistically significant.

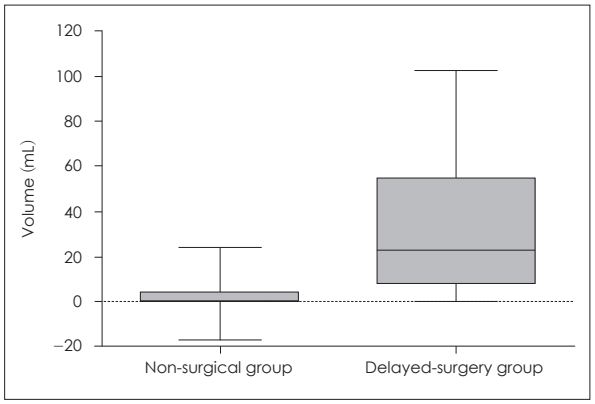

FIGURE 2. Expansion volume of epidural hematoma in both groups. The changes in hematomas of delayed-surgery group and non-surgical group were 33.02±31.02 mL and 2.415±6.272 mL, respectively (p=0.001).

In the multivariate study, only the time interval between trauma and initial CT was statistically significant (p=0.0135) (Table 2). According to the presence of surgery, the receiver operating characteristic (ROC) curve for the time interval between trauma and initial CT time was drawn at the cut-off value of 2.08 hours. A specificity of 88.2% and sensitivity of 68.3% are shown in Figure 3 (area under the curve=0.854). In comparison with the NG, the DG revealed a relatively poor outcome; however, this difference between the two groups was not statistically significant (p=0.0673) (Table 3). On the other hand, the GCS checked at later time points, where the patients were neurologically aggravated, statistically significantly affected the prognosis (p=0.020). Nonetheless, the initial GCS and the degree of change in GCS score were not statistically influential (Table 4).

Discussion

This study examined the risk factors and predictors of ex-

TABLE 1. Comparison of characteristics of non-surgical group and delayed-surgery group (univariate analysis)

Clinical factors	Presence of surgery		p-value
	No operation (n=71)	Delayed operation (n=19)	
Gender (male/female)	62/9	13/6	0.078
Age (mean, years)	41.15±22.49	39.47±20.96	0.7699
Initial GCS (mean)	12.83±2.81	13.44±2.45	0.43
Presence of drinking	20 (29.58%)	1 (5.26%)	0.0345*
Hypertension	32 (45.08%)	6 (31.59%)	1.000
Diabetes mellitus	16 (22.52%)	4 (21.05%)	1.000
Abnormal PLT count	15 (21.13%)	4 (21.05%)	1.000
Abnormal PT/PTT	38 (53.5%)	12 (63.1%)	0.4528
Anticoagulant use	3 (3.33%)	0 (0.00%)	1.000
Initial volume of EDH (mL)	10.756±9.956	11.152±7.897	0.8732
MAP change (mm Hg)	−0.428±18.405	9.684±14.442	0.031*
Accompanying head injury	51 (71.83%)	14 (73.68%)	0.872
Interval time between initial CT and trauma attack (hours)	5.707±6.963	1.802±1.565	0.0001*

*p<0.05. GCS: Glasgow Coma Scale, PLT: platelet, PT: prothrombin time, PTT: partial thromboplastin time, EDH: epidural hematoma, MAP: mean arterial pressure, CT: computed tomography

TABLE 2. Comparison of characteristics of non-surgical group and delayed-surgery group (multivariate analysis)

Clinical factors	Presence of surgery		p-value	95% Wald Confidence Limits	
	No operation (n=71)	Delayed operation (n=19)			
Gender (male/female)	62/9	13/6	0.56	0.246	13.271
Age (mean, years)	41.15±22.49	39.47±20.96	0.54	0.971	1.058
Presence of drinking	20 (29.58%)	1/19 (5.26%)	0.07	0.001	1.316
Abnormal PT/PTT	38 (53.5%)	12 (63.1%)	0.9597	0.057	1.771
Initial volume of EDH (mL)	10.756±9.956	11.152±7.897	0.097	0.983	1.237
MAP change (mm Hg)	−0.428±18.405	9.684±14.442	0.1771	0.192	0.827
Accompanying head injury	51 (71.83%)	14 (73.68%)	0.1369	0.598	42.368
Interval time between initial CT and trauma attack (hours)	5.707±6.963	1.802±1.565	0.0135*	0.983	1.100

*p<0.05. PT: prothrombin time, PTT: partial thromboplastin time, EDH: epidural hematoma, MAP: mean arterial pressure, CT: computed tomography

pansion of EDH for surgery from the clinical rather than radiologic perspective of initial EDH, which is not indicated for surgery. Anatomically, the surgical approach of EDH is relatively easy and does not require proficiency. Therefore, in a clinical situation, methods of surgical management alone cannot be the problem. A problem in the clinical situation occurs when conservative treatment is determined to be sufficient for early acute EDH, but it suddenly expands in size, leading to neurological disorders. In other words, due to the relatively small acute EDH in the initial, clear state of consciousness, the patient can suddenly worsen. At that time, if surgery is required due to EDH expansion on the CT, there is no rapid response in the process, and several problems can occur. The authors tried to find predictors or risk factors associated with this process.

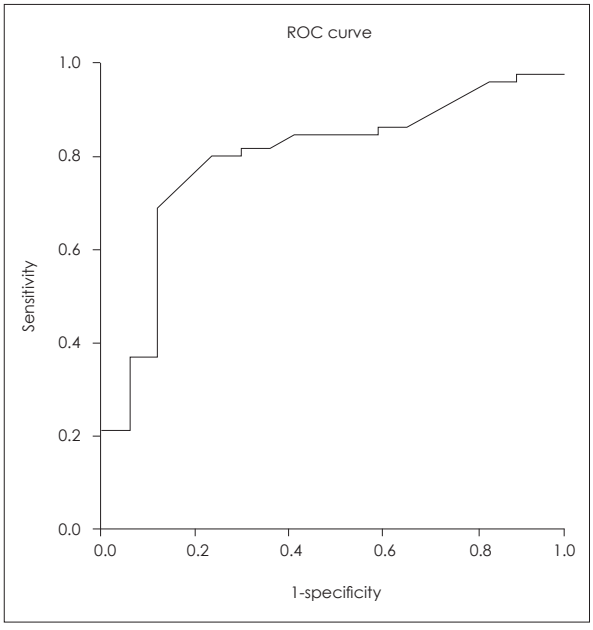

FIGURE 3. Receiver operating characteristic curve with computed tomography interval time from trauma attack and presence of surgery. If we set the cut-off value as 2.08 hours, the sensitivity and specificity of this curve was 88.2% and 68.3%. ROC: receiver operating characteristic.

Several vectors associated with EDH progression from existing reports have already been revealed. However, the majority involved asymptomatic radiologic change and did not focus on changes in the clinical status of patients that needed operations.[5,7,19] Therefore, we evaluated risk factors for surgery, using only cases of expanded EDH for which surgery was necessary. Thus, the patients of this study were selected initially for conservative treatment, and the DG was defined as the group that received surgery due to changes in symptoms and hematoma growth in the follow-up CT during conservative treatment.

In this study's univariate analysis and multivariate analysis results, the most significant factor was the time interval between the trauma and the initial CT. We considered the main reason to be that CT was undergone during hematoma expansion.[2,4,17] Based on the results of this study and a review of previous literature, the time interval between head trauma and CT was shorter. In that time, EDH had a high probability of expansion. According to Oertel et al.,[15] the time between the initial injury and the first CT of the EDH-enlarged group was 1.3 hours, while the time of the non-enlarged group was 2.3 hours. In the study by Bezircioğlu et al.,[3] they recommended that CT be taken within 6 hours in the follow-up of EDH.

Therefore, our research also considered time interval between trauma and initial CT time as a definite risk factor, and the ROC curve was calculated. At the 2.08-hour cut-off value, specificity of 88.2% and sensitivity of 68.3% were confirmed. Additionally, this result requires re-evaluation and reinforcement from large-scale studies, and we should note that it is more important to obtain a cut-off value of high

TABLE 3. Comparison of prognostic outcomes in patients according to presence of surgery

Presence of surgery	Prognosis		*p*-value
	Good (GOS 3–5)	Poor (GOS 1, 2)	
No operation (n=71)	8 (11.27%)	63 (88.73%)	0.0673
Delayed operation (n=19)	6 (31.58%)	13 (68.42%)	

GOS: Glasgow Outcome Scale

TABLE 4. Comparison of prognostic outcomes of patients according to initial GCS, GCS at time of neurological aggravation, and degree of change in GCS scores in delayed surgery group

	Prognosis		*p*-value
	Good (GOS 3–5, n=6)	Poor (GOS 1, 2, n=13)	
Initial GCS	13.75±0.95	14.3±0.82	0.300
GCS at time of neurological aggravation	8.5±1.73	12.1±0.87	0.020*
Degree of change in GCS scores (mean)	5.25±2.21	2.20±0.42	0.070

*$p<0.05$. GOS: Glasgow Outcome Scale, GCS: Glasgow Coma Scale

sensitivity than that of specificity for the prediction of EDH expansion and faster operation. Ultimately, this study aimed to evaluate and analyze the variable factors that may serve as prognostic parameters in both groups of patients. The parameters with statistical significance were strongly considered for the risk factors of delayed operation in the aggravating of EDH. Of the factors discussed, the interval time between trauma onset and initial CT, which was statistically presented with time-dependent sensitivity and specificity, was found to have predictive potential in the diagnosis of disease progression.

In addition to the time interval between trauma and initial CT, changes in MAP and the presence of drinking were also statistically significant. Neurological change is a clinically important factor for predicting prognoses in TBIs; therefore, intracranial pressure changes during the expansion of the EDH were also thought to be accompanied by MAP change, and MAP was set up as an independent variable. It was found that the average MAP change of the DG was increased by about 10 mm Hg more than that of the NG. However, a 10 mm Hg change of MAP is not clinically meaningful. The increase of MAP can be seen as a change in systolic MAP due to Cushing's reaction, pain, or external factors, and as variance due to the difference between observers. Different MAP measurement times for each group can be a confounding factor. This means that MAP was measured before follow-up CT in the NG as a routine check-up, but in the DG, MAP was measured after neurological deterioration or severe headache. Additionally, pain controllers, inotropes, or antihypertensive agents can be confounding factors for MAP.

Additionally, the authors excluded the patients who presented with AIS values of 3 or over and injuries to other organs, as these factors can act as confounding variables.

Drinking alcohol was another aspect the authors considered an important, independent factor influencing the initial GCS and the severity of EDH in the DG. Drinking was reported in only one of 20 patients of the DG, which was thought to reflect a selection bias due to the small sample. This also means further study is required to reveal the correlation between drinking and the prognosis for EDH expansion. This has been found to have meaning in the literature; however, whether accompanied by brain injury, such as a fractured skull, or anticoagulants, no statistically significance correlation was found in the present study.[7,10,12,16,18] However, this is also thought to be because it was conducted at a single institution. The relatively small sample size and different inclusion criteria compared with other studies could have caused conflicting results. Additionally, in EDH, factors of age are known to affect the dural adhesion to the skull.[14] We subsequently carried out a statistical analysis on the effect of age; however, it was not found to be statistically significant (p=0.078).

We hypothesized that gender differences may also lead to variable states of dural adhesion and cause diverse types of trauma as well as affect the severity of the disease progression. However, these independent factors were concluded to be not statistically significant.

In this study, the prognostic outcome of the patients in the DG were poor compared to those in the NG, but we were not able to prove this statistically. We understand that this may be due to the retrospective nature of the study and the small pool of patients. When focusing only on the patients in the DG, the mechanical damage made by the hematoma expansion itself was statistically more influential in determining the prognostic outcome than the degree of clinical changes in the patients. Obviously, it is logical to assume that larger changes in GCS scores mean poorer prognostic outcomes for patients, and this was clinically witnessed in our patients. However, our investigation was not able to prove this phenomenon statistically.

Thus, the small number of patients and retrospective nature of the study are the greatest limitations of this study. There is also a possibility of selection bias. For instance, the patients who arrived at our Emergency Department during the process of hematoma expansion were included in our study. However, if the hematoma was already large enough to be considered an end-point of hematoma expansion, requiring an emergency operation, they were excluded from our study. In order to overcome this limitation, a well-organized time-matched study will be required in the future.

In reality, the time interval between trauma and initial CT is a non-modifiable factor that can be applied in the clinical situation. The statistics have shown that the parameters–such as changes in MAP, presence of drinking, and time interval between trauma and initial CT–are statistically significant to support our hypothesis. Nonetheless, they are unfortunately non-modifiable clinical factors, which cannot be used in treatment guidelines. However, this particular study has proven that these factors have critical implications as predictive risk factors of progressive EDH requiring surgery.

Conclusion

In summary, our data revealed a sensitivity of 68.3% and a specificity of 88.2% at a 2.08-hour time interval between trauma and initial CT. This present finding indicated that if the time interval between trauma and initial CT was shorter in acute EDH, the probability of the patient suffering subse-

quent neurological deterioration following a delayed operation increased. Since the time interval between trauma and initial CT is a non-modifiable factor, if it is shorter, the neurosurgeons should be alerted to the possible neurological deterioration of the patients due to the growing hematoma and promptly respond with appropriate treatments.

■ The authors have no financial conflicts of interest.

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