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Original Article

The Optimal Operative Timing of Traumatic Intracranial Acute Subdural Hematoma Correlated with Outcome

Abstract

Objective: Acute subdural hematoma (ASDH) has been associated with mortality in traumatic brain injury. The timing of surgical evacuation for ASDH has still been controversial. The object of this study was to determine the temporal and clinical factors associated with outcome following surgery for ASDH. **Materials and Methods:** The study retrospectively viewed medical records and neuroimaging studies of ASDH patients who underwent surgical evacuation. Surgical outcomes were dichotomized into favorable and unfavorable outcomes, and operative times compared between the groups. **Results:** The records of 145 ASDH patients who underwent surgery were reviewed. Almost two-thirds of the patients were admitted for surgical evacuation, of whom 71% underwent a decompressive operation. The temporal variables were as follows: mean time from scene of accident to emergency department (ED) was 70 (Standard deviation [SD] 256.0) min, mean time from ED to obtaining CT of the brain was 45.6 (SD 38.9) min, mean time from brain computed tomographic to operating room arrival was 68.6 (SD 50.0) min, and mean time from ED arrival to skin incision was 160.1 (SD 88.1) min. The mean time from ED arrival to skin incision was significantly shorter in the unfavorable outcome group. Because of this reverse association between time from ED to surgery, multivariate analysis was applied to adjust the timing factors with other clinical factors, and the results indicated that temporal factors were not associated with functional outcome, as features such as increased intracranial pressure due to obliterated basal cistern and brain herniation were significantly associated with functional outcome. **Conclusions:** The optimal times for surgical evacuation of ASDH are challenging to estimate because compressed brainstem signs are more important than time factors. ASDH patients with compressed brainstem should have surgery as soon as possible.

Keywords: *Acute subdural hematoma, subdural hematoma, the timing of surgery*

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Introduction

Accidents are one of the top three causes of death in Thailand, especially in road traffic accidents. The traffic accident mortality rate between 2010 and 2013 in Thailand was 21.61–23.16 per 100,000 people. Previous studies have reported that 15.8%–29% of trauma patients in the emergency department (ED) had head injuries and the most common intracranial injury was subdural hematoma.[1-3]

Acute subdural hematoma (ASDH) has correlated with mortality in traumatic brain injury.[4,5] Indications for surgical evacuation in patients with ASDH are the thickness of ASDH >10 mm or midline shift more significant than 5 mm on computed tomographic (CT) scan. All patients who have a Glasgow Coma Scale (GCS) score <9 with ASDH <10 mm thick and a midline shift <5 mm should undergo surgical evacuation if the GCS score decreases by 2 or more points and/or the pupils become asymmetric or fixed and/or the intracranial pressure increases to 20 mmHg.[6]

However, the timing following the initial appearance of the patient at the ED for surgical evacuation is still controversial. Seelig *et al*. found that surgical evacuation within 4 h after the patient's injury was associated with favorable outcome while Haselsberger *et al*. reported that patients who went into the coma from the ASDH should be operated on within 2 h after neurological deterioration.[7,8] Conversely, Hatashita *et al*. found that the timing of surgery in ASDH patients associated with neither mortality or outcome, and Kotwica and Brzeziński studied 200 patients and found that a shorter time to surgery was not a predictive factor associated with

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mortality or functional outcome.[4,9] In addition, Walcott *et al*. found patients with ASDH who underwent surgery within 4 h of ED presentation had a higher mortality rate than patients whose surgery was performed later than 4 h after presentation.[10]

In this study, we aimed to explore what association if any there was between the timing of surgical evacuation in ASDH patients and the functional outcome. A secondary objective was to determine prognostic factors associated with poor outcome in ASDH patients.

Materials and Methods

Study population

The study was a retrospective cohort review of electronic medical records from our institutional trauma registry. We enrolled consecutive traumatic brain injury patients admitted to the Level I Trauma Center of Songklanagarind Hospital, the major tertiary care institution, and a teaching hospital, between 2007 and 2016. Patients who had an ASDH and subsequently underwent surgical evacuation were included in the study, while patients with failure of initial conservative treatment, penetrating mechanism of injury, and/or persistent unstable vital signs were excluded from the study.

Demographic data, mechanism of injury, physical and neurological examination results, neuroimaging findings, the thickness of ASDH, associated intracranial lesions, treatment, and type of surgery were gathered from the computer-based trauma registry. The patients were categorized into three groups according to their GCS score: Mild head injury (GCS 13–15), moderate head injury (GCS 9–12), and severe head injury (GCS 3–8).

At the time of hospital discharge, the patients were categorized into five groups according to the Glasgow Outcome Scale (GOS): (1) death, (2) persistent vegetative state, (3) severe disability, (4) moderate disability, and (5) good recovery.[11] Finally, the GOS scores were dichotomized into favorable (GOS 4 and 5) and unfavorable categories (GOS 1–3).[12] The study was performed with the approval of the Ethics Committee of the Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University.

Timing factors

The timing factors that we used in this study were calculated using various starting-ending points collected from our hospital computer-based trauma registry. The time from scene-of-accident to ED arrival (StED) and time from ED arrival to CT of the brain (EDtCT) was the time as documented by the emergency medical service team. Operating room (OR) arrival time was documented by the OR nurses to determine the duration of CT of the brain to surgery (CT-brain to OR arrival [CTtOR]) and ED to surgery (EDtSx) timing was duration from ED arrival to skin incision time which documented by an anesthesiologist in anesthetic records.

Statistical analyses

The clinical factors were analyzed using descriptive statistics presented as proportions, mean, and standard deviation (SD). Means between two groups were compared by independent *t*-test, while analysis of the association between various factors and functional outcomes was performed using binary logistic regression. Clinical factors were analyzed in univariable analyses, and candidate factors for the multivariable analyses were any variables with a univariable value of $P < 0.1$. In multivariable analyses, variables were eliminated from the model one at a time based on the Akaike Information Criterion. The statistical analyses were performed using the R version 3.4.0 software (R Foundation, Vienna, Austria).

Results

Clinical characteristics

The baseline characteristics of the study population are presented in Table 1. The study involved 145 individuals enrolled according to the inclusion criteria, and more than two-thirds of them were road traffic injuries, especially involving motorcycle accidents. The mean age of the study population was 49.8 (SD 19.7) years. The percentage of male patients was 77.2% of the study population. Concerning severity, 63.4% of the cases had severe head injuries, while 17.9% had mild head injuries. The mean injury severity score was 25.5 (SD 5.7), and the low abbreviated injury scale score of the head was 4.7 (SD 0.4). The posttraumatic seizure was observed in 2.1% of the patients. The most common associated injury was the maxillofacial fracture in 13.8% of the patients, as shown in Table 2.

The mean subdural hematoma thickness was 13.2 (SD 6.0) mm, and 31% of the ASDHs were located in the frontal lobe. More than two-thirds of the cases had an obliterated basal cistern and midline shift more than 5 mm was found in 87.6% of the patients. All patients underwent surgical evacuation, with decompressive craniectomy with clot removal performed in 71.7% of the patients, as shown in Table 3.

The mean of length of hospital stay for the ASDH patients was 31.5 (SD 53) days. At hospital discharge, 34.5% had died in hospital, with the discharge outcomes being good recovery (31.0%), moderate disability (20.0%), severe disability (10.3%), and vegetative state (4.1%). The mean follow-up time was 182.3 (SD 42) days, and the final recorded outcomes were good recovery (47.4%), moderate disability (30.5%), severe disability (15.8%), persistent vegetative state (6.3%), and no further deaths.

The patients who underwent decompressive surgery had significantly more serious factors such as fixed

Table 1: Baseline characteristics (*n*=145)

Factor	*n* (%)
Sex	
Male	112 (77.2)
Female	33 (22.8)
Age (years)	
<60	95 (65.5)
≥60	50 (34.5)
Mechanism	
Motorcycle accident	90 (62.1)
Fall at ground level	18 (12.4)
Fall from height	15 (10.3)
Assault	10 (6.9)
Pedestrian injuries	8 (5.5)
Car accidents	4 (2.8)
Underlying disease	
Heart disease	18 (12.4)
Prior head injury	3 (2.1)
Chronic lung disease	2 (1.4)
Renal insufficiency	1 (0.7)
Liver	1 (0.7)
Medication before injury	
Antiplatelet usage	7 (4.8)
Anticoagulant usage	3 (2.1)
Event at emergency department	
Hypotension episode	6 (4.1)
Bradycardia episode	3 (2.1)
Fever episode	1 (0.7)
Tachypnea episode	6 (4.1)
Pulse oximetry (O_2sat <90 mmHg)	7 (4.8)
Arterial blood gas (PaO_2 <60 mmHg)	6 (4.1)
GCS score	
15-13	26 (17.9)
12-9	27 (18.6)
8-3	92 (63.4)
Pupil reactivity	
React both eyes	74 (51.0)
Fixed dilated both eyes	41 (28.3)
Fixed dilated one eye	29 (20.0)
Could not evaluate	1 (0.7)
Hemiparesis	7 (4.8)
Seizure	3 (2.1)
Associated injury	
Maxillofacial	20 (13.8)
Musculoskeletal injury	14 (9.7)
Pneumothorax	11 (7.6)
Lung contusion	5 (3.4)
Cervical spine	4 (2.8)
Rib fracture	4 (2.8)
Liver injury	1 (0.7)
Other injury	5 (3.4)

GCS – Glasgow coma scale

pupils (Chi-square test, P = 0.001), GCS 8-3 (P < 0.001), and/or obliterated basal cistern (P = 0.001) than patients who underwent craniotomy with clot evacuation. Patients with unfavorable outcome had significantly higher severity injuries as indicated by GCS 8–3 (Chi-square test, P < 0.04) or obliterated basal cistern (P = 0.014) than patients with a favorable outcome.

Table 2: Characteristics of intracranial lesions

Factor	*n* (%)
Subdural hematoma thickness (mm)	
<10	36 (24.8)
≥10	109 (87.6)
Mean of subdural hematoma thickness (SD) (mm)	13.2 (6.0)
Location of subdural hematoma	
Frontal	45 (31.0)
Parietal	25 (17.2)
Temporal	15 (10.3)
Occipital	4 (2.8)
Subdural site	
Unilateral	
Left side	63 (43.4)
Right side	61 (42.1)
Bilateral	
Left side domination	15 (10.3)
Right side domination	6 (4.1)
Midline shift (mm)	
<5	18 (12.4)
≥5	127 (87.6)
Basal cistern	
Patent	50 (34.5)
Obliterated	95 (65.5)
Associated intracranial injury	
Traumatic subarachnoid hemorrhage	127 (87.6)
Cerebral Contusion	76 (52.4)
Calvarial fracture	70 (49.0)
Basilar skull fracture	48 (33.1)
Intraventricular hemorrhage	5 (3.4)

SD – Standard deviation

Timing factors

For the timing factors, the means of StED, EDtCT, CTtOR, and EDtSx times were 70.5 (SD 256), 45.6 (SD 38.9), 68.6 (SD 50.0), and 160.1 (SD 88.1) min, respectively. The functional outcomes were divided into favorable and unfavorable outcome subgroups, and the timing factors then analyzed according to these subgroups as shown in Figure 1. Comparing the means between the favorable and unfavorable subgroups, the EDtSx in the unfavorable group was significantly shorter than in the favorable group (*t*-test, P = 0.01).

Factors associated with unfavorable outcome

Table 4 shows the results of the univariable analysis. Initially, the significant factors associated with unfavorable outcome were fixed pupil in at least one eye, obliterated basal cistern, decompressive craniectomy, and duration from EDtSx 4 h or less.

From univariable analyses, candidate factors for the multivariable analysis were any variable with a univariable value of $P < 0.1$. However, type of surgery was removed because this factor was confounded by severity of the injury as indicated by low GCS score and/or obliterated basal cistern.

The results of the multivariable analysis that followed the backward selection procedure are presented in Table 4. Two variables were independently ($P < 0.05$) associated with poor outcome, the fixed pupil in at least one eye (OR 2.5, 95% CI 1.03–0.2), and obliterated basal cistern (OR 3.2, 95% CI 1.3–7.8), while duration from EDtSx was found to be not significant. We repeated the regression analysis using the forward selection procedure and obtained the same results. Because no correction for the collinearity of data was necessary, the variance inflation factor for each covariate was <10.

Table 3: Treatments and outcomes

Factor	*n* (%)
Type of surgery	
Craniotomy with clot removal	41 (28.3)
Decompressive craniectomy	104 (71.7)
Length of hospital stay (SD) (days)	31.5 (53.0)
GCS at discharge	
Good recovery	15 (10.3)
Moderate disability	21 (14.5)
Severe disability	40 (27.6)
Vegetative stage	19 (14.5)
Death	50 (34.5)
GCS at last follow-up (*n*=95)	
Good recovery	45 (47.4)
Moderate disability	29 (30.5)
Severe disability	15 (15.8)
Persistent vegetative stage	6 (6.3)

SD – Standard deviation; GCS – Glasgow Coma Scale

Discussion

This paper examined the optimal timing of surgery in patients with ASDH. There is controversy concerning this topic, as, for example, Haselsberger *et al*. reported that ASDH patients had a better outcome when operated on within 2 h after neurological deterioration, while a study by Seelig *et al*. found that an operating time within 4 h was associated with a favorable outcome.[7,8] Moreover, several other studies have reported that surgical evacuation within 4 h was not associated with either improved functional outcome nor survival rate but was associated with a higher rate of poor outcome.[4,9-11]

This present study found somewhat contradictory effects of the relationships of various timing factors. Initial analysis indicated that an operating timing within 4 h was

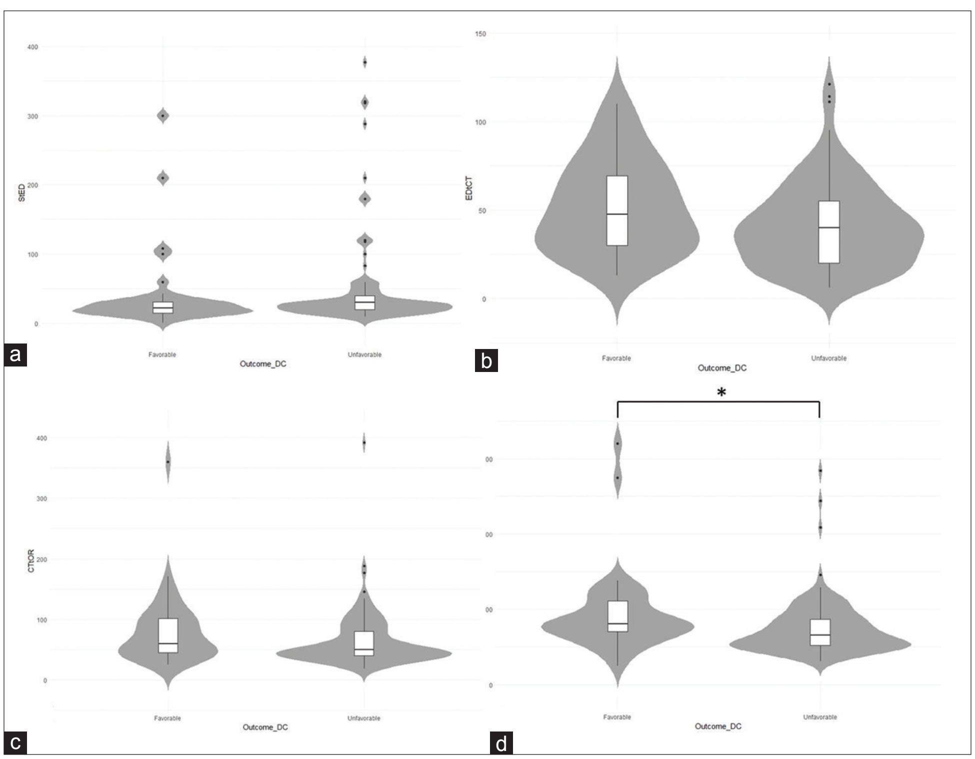

Figure 1: Violin plots demonstrate the means of the timing factors compared by functional outcome groups. (a) Mean times of patient transferals from scene to emergency department arrival of favorable and unfavorable groups were 40.6 (+58.0) and 80.3 (+293.1) minutes. (b) Mean times from emergency department arrival to computed tomographic brain of favorable and unfavorable subgroups were 60.3 (+64.6) and 40.8 (+24.0) min. (c) Mean times from computed tomographic brain to operating room arrival between favorable and unfavorable groups were 82.0 (+60.0) and 64.1 (+45.6) min. (d) Mean times from department arrival to surgery of favorable and unfavorable groups were 190.3 (+113.1) and 150.2 (+76.1) min that were significantly different (*t*-test, *P* = 0.01, asterisk)

Table 4: Logistic regression for unfavorable outcome

Factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Sex				
Male	Reference	0.92		
Female	1.04 (0.4-2.5)			
Age (years)				
<60	Reference			
>60	1.80 (0.7-4.2)	0.17		
Mechanism				
Motorcycle accident	Reference			
Car accident	1.45 (0.3-5.6)	0.58		
Falling from height	2.90 (0.6-13.6)	0.17		
Falling at ground	0.36 (0.9-1.3)	0.13		
Assault	1.0 (0.2-5.7)	0.91		
Pedestrian injury	1.0 (0.2-5.3)	0.95		
ISS score				
<25	Reference			
>25	2.08 (0.8-5.0)	0.10		
Bradycardia				
No	Reference			
Yes	0.66 (0.05-7.5)	0.73		
Hypoxia/hypotension				
No	Reference			
Yes	1.68 (0.1-14.8)	0.64		
Neurological deterioration				
No	Reference			
Yes	1.58 (0.4-5.0)	0.43		
Hemiparesis				
No	Reference			
Yes	1.13 (0.2-6.1)	0.88		
Seizure				
No	Reference			
Yes	0.65 (0.05-7.4)	0.73		
Epidural hematoma				
No	Reference			
Yes	0.31 (0.06-1.6)	0.16		
Cerebral Contusion				
No	Reference			
Yes	1.13 (0.5-2.4)	0.73		
Intraventricular hemorrhage				
No	Reference			
Yes	1.33 (0.1-12.3)	0.80		
Subarachnoid hemorrhage				
No	Reference			
Yes	2.82 (1.0-7.8)	0.04		
Calvarial skull fracture				
No	Reference			
Yes	2.01 (0.9-3.7)	0.07		
Basal skull fracture				
No	Reference			
Yes	1.7 (0.7-4.0)	0.21		
Midline shift (mm)				
<5	Reference			
>5	1.19 (0.3-3.6)	0.75		

Contd...

Table 4: Contd...

Factor	Univariable analysis		Multivariable analysis	
	OR (95% CI)	*P*	OR (95% CI)	*P*
SDH thickness (mm)				
<10	Reference			
>10	1.22 (0.5-2.8)	0.63		
Pupil reactivity				
Reaction BE	Reference		Reference	
Fixed pupil at least on one eye	3.39 (1.4-7.9)	0.05	2.5 (1.03-6.2)	0.04
Basal cistern obliteration				
Patent	Reference		Reference	
Obliteration	4.5 (2.0-10.0)	<0.01	3.2 (1.3-7.8)	0.007
GCS score (as above)				
Mild	Reference			
Moderate	0.90 (0.2-2.7)	0.85		
Severe	2.33 (0.8-6)	0.08		
Type of surgery				
Craniotomy	Reference			
Decompressive cramniectomy	3.6 (1.7-7.3)	<0.01		
Duration from ED to surgery (h)				
>4	Reference		Reference	
<4	3.43 (1.03-11.4)	0.04	2.4 (0.6-9.1)	0.17

OR – Odds ratio; CI – Confidence interval; SDH – Subdural hematoma; GCS – Glasgow Coma Scale; ED – Emergency department; ISS – Injury severity score; BE – Both eyes

significantly related to poor outcome, and faster surgical evacuation was related to poorer outcomes in univariable analysis. However, when using multivariable analysis to control confounders, the final model indicated that fixed pupil at least on one eye and basal cistern obliteration were significantly associated with the poor outcomes.

Therefore, patients presenting with compressed brainstem signs such as fixed pupils and/or obliterated basal cistern should receive prompt surgical evacuation as soon as possible, as also suggested by Bullock *et al*.[6]

Typically, the neuronal pathway of the pupillary light reflex is positioned in the intrinsic brainstem. Light reflex is led by optical tract fibers, which synapse in the pretectal area. The pretectal neurons synapse to the Edinger–Westphal complex. Finally, the ciliary nerve serves pupillary constrictor responses. Pupillary dilatation with no response to light is caused by a compressed ipsilateral oculomotor nerve and brainstem ischemia.[13] Several studies have reported that bilateral fixed dilated pupils are a significant predictor of unfavorable outcome,[1,14-17] while we found that fixed pupil at least on one eye that directly related to the poor outcome from brainstem injuries.

In the same way, the obliterated mesencephalic cistern indicates that the supratentorial brain parenchyma is compressing the brainstem that a significant prognostic factor associated with poor outcome and death.[12,18-21]

Finally, certain limitations of the present study should be acknowledged. The retrospective design may have led to bias and an inability to control confounding factors.[22] However, we tried to tackle these limitations by employing multivariable analyses. However, the strength of our study is that this is the first paper to suggest an explanation for the reverse correlation between time interval to surgery and functional outcome, based on the adjustment of several clinical factors.

Conclusions

The optimal times for surgical evacuation of ASDH are challenging to estimate because compressed brainstem signs are more important than time factors. Compressed brainstem signs are strong prognostic factors in predicting functional outcome in ASDH patient who undergo surgery.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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