

# Predictive Factors for Recurrence after Burr-Hole Craniostomy of Chronic Subdural Hematoma

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**Objective :** Chronic subdural hematoma is a common and relatively benign disease. However, recurrence is common after surgical treatment, and the recurrence rate varies from 5% to 33%. The aim of this study was to investigate the predictive factors for recurrence of chronic subdural hematoma.

**Methods :** We analyzed data from 248 patients with chronic subdural hematoma who were treated by burr-hole craniostomy with a closed drainage system for hematoma evacuation in this five-year retrospective study.

**Results :** Thirty-one (12.6%) patients underwent re-operation for recurrence of chronic subdural hematoma. Univariate analysis revealed that anticoagulation ( $p=0.0279$ ), headache ( $p=0.0323$ ), and preoperative midline shifting ( $p=0.0321$ ) showed significant differences with respect to recurrent chronic subdural hematoma. We performed a multivariate logistic regression analysis and found that diabetes mellitus (odds ratio [OR], 2.618; 95% confidence interval [CI], 1.0899–6.2898;  $p=0.0314$ ), anticoagulation (OR, 6.739; 95% CI, 1.1287–40.2369;  $p=0.0364$ ), headache (OR, 2.951; 95% CI, 1.1464–7.5964;  $p=0.0249$ ), and preoperative midline shifting (OR, 1.0838; 95% CI, 1.0040–1.1699;  $p=0.0391$ ) were independent predictive factors for recurrence of chronic subdural hematoma.

**Conclusion :** We showed that diabetes mellitus, anticoagulation, headache, and preoperative midline shifting were independent predictors of recurrence of chronic subdural hematoma.

**Key Words :** Recurrence · Hematoma, Subdural, Chronic · Multivariate analysis.

## INTRODUCTION

Chronic subdural hematoma (CSDH) is a common and relatively benign pathological disease in neurosurgical practice and it is particularly common in elderly patients<sup>26,27</sup>. The estimated annual incidence of CSDH has been reported to be as high as 13.3 cases per 100000 persons and, it has increased

markedly in the elderly population<sup>5</sup>.

Although there are many surgical techniques to treat CSDH, there is no consensus regarding the best surgical technique to treat CSDH. The strategies include surgical techniques such as twist-drill trephination, one or two burr-hole craniostomy with or without drainage and craniotomy<sup>6,9,14,19,20</sup>. Burr-hole craniostomy with a closed drainage sys-

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tem is the most popular surgical technique<sup>21,30</sup>. Burr-hole craniostomy with a closed drainage system under general anesthesia has been the treatment of choice for patients with CSDH at our institution.

Despite the fact that most CSDHs resolve after a simple burr-hole craniostomy, recurrence of CSDH remains a difficult problem. Some reports presented that the rate of recurrence after CSDH operation ranged approximately from 5% to 33%<sup>11,14,41</sup>. A previous report mainly analyzed the significant factors for clinical outcome after burr-hole craniostomy, but few reports have focused on the predictive factors for recurrence in both clinical and radiological aspects preoperatively<sup>31</sup>.

The aim of this study is to investigate the predictive factors for recurrence of CSDH after burr-hole craniostomy.

## MATERIALS AND METHODS

Institutional review board approval was received, and all patients were recruited from a single institution. We retrospectively reviewed all patients who were operated on for CSDH at our institution between January 2010 and December 2015. All cases of CSDH were confirmed on the basis of a computed tomography (CT) scan. Patients who underwent surgery for CSDH were included.

Information regarding patient age, sex, duration from symptoms to operation, type of symptoms (headache, hemiparesis, loss of consciousness, speech disturbance, gait disturbance and memory impairment), initial Glasgow coma scale (GCS), repeated head trauma, cause of CSDH and comorbidities such as hypertension (HBP), diabetes mellitus (DM), liver disease, renal disease, coronary heart disease (CHD), cerebrovascular disease (CVD), malignancy and history of anticoagulant or antiplatelet medication was obtained from the medical charts. The following laboratory data were investigated: platelet count, prothrombin time percentage, international normalized rate (INR). The initial CT findings were investigated: location of CSDH (unilateral or bilateral), distance of midline shift, initial maximal thickness of subdural hematoma, degree of brain atrophy, density of subdural hematoma and presence of membrane septation. Brain atrophy was classified into four stages: no, mild, moderate and severe atrophy using visual rating of the brain atrophy scale<sup>15</sup>. The density of subdural he-

matoma was classified into four groups; low density (<25 Hounsfield unit [HU]), isodensity (25–35 HU), hyper density (>35 HU), and mixed type on the basis of CT scans.

All patients were treated with single or double burr-hole drainage under general anesthesia. Selection of the procedure was dependent on the surgeon's preference. All patients received a closed system using a silastic drain tube for several days, depending on the amount of drainage. Perioperative surgical management from the operative records was investigated.

We defined recurrence as a case of reoperation due to an increase in hematoma volume in the ipsilateral subdural space seen on CT within 6 months post operatively. Reoperation was performed in the patients who had a radiologically increasing hematoma with neurological deficits due to the hematoma.

## Statistical analysis

Data are presented as the mean±standard deviation, or median (interquartile range) for continuous variables, and number (percentage) for categorical variables. A univariate analysis was performed with Pearson's chi-square test or Fisher's exact test and Mann-Whitney U test to examine the presence of an association between the study variables and CSDH recurrence. The Mann-Whitney U test was used for non-categorical variables (age, platelet, INR, PT percentage, midline shifting, and thickness of hematoma). Variables with  $p < 0.2$  in univariate analysis were selected for multivariate analysis. A multivariate analysis was performed using a logistic regression model to determine the independent association of recurrence with factors. Variables in the final model were selected according to a backward method. The relationship between each factor and recurrence of CSDH is presented in terms of an odds ratio (OR) and a 95% confidence interval (CI). A  $p$  value  $< 0.05$  was considered statistically significant. Statistical analysis was performed using the MedCalc ver. 16.2.0 software package (MedCalc Software, Mariakerke, Belgium).

## RESULTS

Between January 2010 and December 2015, we treated 248 consecutive patients diagnosed with CSDH. Perioperative mortality was observed in 2 patients (0.8%) due to myocardial

infarction and leukemia. Of the remaining 246 patients, we performed reoperation in 31 patients due to recurrent CSDH.

The baseline characteristics are described in Table 1. The mean age was 68.59±12.23 (29–90) years. There were 173 men and 73 women in the study. Male predominance was observed in our study. History of HBP, DM, liver disease, kidney disease, CHD, CVD, and malignancy was present in 117 (47.5%), 69 (28%), 19 (7.7%), 7 (2.8%), 10 (4.0%), 11 (4.4%), and 22 (8.9%) patients, respectively. Prior medication history included history of anticoagulation in 6 patients (2.4%) and history of antiplatelet drugs in 53 patients (21.5%). The most common cause of CSDH was history of head trauma (187 patients, 76.0%). History of repeated head trauma was noted in 13 patients (5.2%) and symptom duration was 22.7±23.50 days. Initial GCS score of 15 was noted in 205 patients (83.3%). Forty-one patients (16.7%) had an initial GCS score below 14 points. The most common symptom was headache (147 patients, 59.7%). Bilateral CSDH was observed in 63 patients (25.6%), whereas unilateral CSDH was observed in 183 patients (74.3%). The most common hematoma density on CT was mixed density (109 patients, 44.3%). Midline shifting was 7.23 ±5.47 mm (range, 0–21 mm). Initial hematoma thickness was 20.01±6.99 mm (range, 5–40 mm).

Summary of the baseline characteristics and hematoma recurrence in 246 patients with CSDH are described in Table 2. Two groups were compared, the non-recurrence group (NRG) and the recurrence group (RG), to determine the statistical significance. Thirty-one patients (12.6%) experienced recurrence, whereas 215 patients (87.4%) did not experience recurrence. There were no significant differences between age and recurrence of CSDH and between comorbidities and recurrence of CSDH. Patients with CSDH recurrence tended to have a history of malignancy. Prior anticoagulation medication was significantly related to recurrence of CSDH ( $p=0.0279$ ). Initial symptoms such as headache were significantly related to recurrence CSDH ( $p=0.0323$ ). In terms of radiologic findings, midline shifting was significantly related to recurrence of CSDH ( $p=0.0321$ ). Patients with CSDH recurrence tended to have a radiologic finding of difference in hematoma density ( $p=0.0778$ ) and degree of brain atrophy ( $p=0.1003$ ) on brain CT.

We performed univariate and multivariate logistic regression analyses. Summary of independent factors of recurrence in 246 patients with CSDH is described in Table 3. Prior anti-

**Table 1.** Summary of baseline characteristics

	Value
Age (year)	68.59±12.23 (29–90)
Sex, men : women	173 : 73 (70.3% : 30.7%)
Comorbidities	
Hypertension	117 (47.5)
DM	69 (28)
Liver disease	19 (7.7)
Kidney disease	7 (2.8)
CHD	10 (4.0)
CVD	11 (4.4)
Malignancy	22 (8.9)
Prior medication	
Anticoagulation	6 (2.4)
Antiplatelet agent	53 (21.5)
History and Initial symptoms	
Cause of CSDH	
Trauma	187 (76.0)
Previous craniotomy history	4 (1.6)
Spontaneous or unknown	55 (22.3)
Repeated trauma history	13 (5.2)
Symptom duration (days)	22.7±23.50 (0–90)
Headache	147 (59.7)
Hemiparesis	105 (42.6)
LOC	10 (4.0)
Speech disturbance	27 (10.9)
Gait disturbance	58 (23.5)
Memory impairment	12 (4.8)
Objective finding	
Initial GCS	
15	205 (83.3)
13–14	13 (5.2)
8–12	22 (8.9)
3–7	6 (2.4)
Laboratory investigation	
Platelet	238951±79949 (52000–619000)
INR	1.0837±0.27 (0.89–4.53)
PT percentage (%)	91.38±16.53 (16–135)
Radiologic finding	
Hematoma (unilateral : bilateral)	183 : 63 (74.3% : 25.7%)
Hematoma density on CT	
Low density	44 (17.8)
Iso density	76 (31.3)
Hyperdensity	17 (6.9)
Mixed density	109 (44.3)
Midline shifting (mm)	7.23±5.47 (0–21)
Membrane septation	97 (39.4)
Hematoma thickness (mm)	20.01±6.99 (5–40)
Brain atrophy	
Normal	73 (29.6)
Mild	85 (34.5)
Moderate	63 (25.6)
Severe	25 (10.1)

Values are presented as mean±standard deviation (range) or number (%) unless otherwise indicated. DM : diabetes mellitus, CHD : coronary heart disease, CVD : cerebral vascular disease, CSDH : chronic subdural hematoma, LOC : loss of consciousness, GCS : Glasgow coma scale, INR : international ratio, PT : prothrombin time, CT : computed tomography

**Table 2.** Summary of baseline characteristics in no recurrence group and recurrence group in 246 patients with CSDH

	NRG	RG	p-value
Total number	215 (87.4)	31 (12.6)	
Age (years)	71.5 (63.00–77.00)	68.0 (59.25–74.75)	0.0960*
Male/female	149/66	24/7	0.3560*
Comorbidities			
Hypertension	102/215 (47.4)	15/31 (48.4)	0.0917 <sup>†</sup>
DM	57/215 (26.5)	12/31 (38.7)	0.1584 <sup>†</sup>
Liver disease	15/215 (7.0)	4/31 (12.9)	0.2739 <sup>§</sup>
Kidney disease	6/215 (2.8)	1/31 (3.2)	1.0000 <sup>§</sup>
CHD	9/215 (4.2)	1/31 (3.2)	1.0000 <sup>§</sup>
CVD	10/215 (4.7)	1/31 (3.2)	1.0000 <sup>§</sup>
Malignancy	22/215 (10.2)	0/31 (0)	0.0865 <sup>§</sup>
Prior medication			
Anticoagulation	3/215 (1.4)	3/31 (9.7)	0.0279 <sup>§</sup>
Antiplatelet agent	46/216 (21.4)	7/31 (22.6)	0.8810 <sup>†</sup>
History and Initial symptoms			
Cause of CSDH			0.7655 <sup>†</sup>
Trauma	162/215 (74.5)	25/31 (80.6)	
Previous craniotomy history	4/215 (2.0)	0/31 (0)	
spontaneous	49/215 (23.5)	6/31 (19.4)	
Repeated trauma history	10/215 (4.7)	3/31 (9.7)	0.2432 <sup>§</sup>
Symptom duration (days)	14 (4–30)	20 (4.75–30.00)	0.4898*
Headache	123/215 (57.2)	24/31 (77.4)	0.0323 <sup>†</sup>
Hemiparesis	93/215 (43.3)	12/31 (38.7)	0.6330 <sup>†</sup>
LOC	9/215 (4.2)	1/31 (3.2)	1.0000 <sup>§</sup>
Speech disturbance	25/215 (11.6)	2/31 (6.5)	0.5455 <sup>§</sup>
Gait disturbance	49/215 (22.8)	9/31 (29.0)	0.4450 <sup>†</sup>
Memory impairment	10/215 (4.7)	2/31 (6.5)	0.6520 <sup>§</sup>
Objective finding			
Initial GCS			0.8856 <sup>‡</sup>
15	180/215 (83.7)	25/31 (80.6)	
13–14	11/215 (5.1)	2/31 (6.5)	
8–12	18/215 (8.4)	4/31 (12.9)	
3–7	6/215 (2.8)	0/31 (0)	
Laboratory investigation			
Platelet	235000 (187000–279750)	233000 (187500–297500)	0.8364*
INR	1.04 (0.99–1.10)	1.0500 (1.01–1.08)	0.5750*
PT percentage (%)	93 (84.00–101.75)	91 (83.00–97.75)	0.4225*
Radiologic finding			
Hematoma (unilateral, bilateral)	56/215 (26.0)	7/31 (22.6)	0.6800 <sup>†</sup>
Hematoma density on CT			0.0778 <sup>‡</sup>
Low density	40/215 (18.6)	4/31 (12.9)	
Iso density	70/215 (32.6)	6/31 (19.4)	
Hyperdensity	14/215 (6.5)	3/31 (9.7)	
Mixed density	91/215 (42.3)	18/31 (58.1)	
Midline shifting (per mm)	6.7 (2.00–10.71)	9.0 (5.25–14.63)	0.0321*
Membrane septation	132/215 (61.4)	17/31 (54.8)	0.4859 <sup>†</sup>
Hematoma thickness (per mm)	20.0 (14.42–24.67)	20.6 (15.00–24.75)	0.6855*
Brain atrophy			0.1003 <sup>‡</sup>
No	61/215 (28.4)	12/31 (38.7)	
Mild	71/215 (33.0)	11/31 (35.5)	
Moderate	56/215 (26.0)	7/31 (22.6)	
Severe	24/215 (11.1)	1/31 (3.2)	

Values are presented as median (interquartile range) or number (%) unless otherwise indicated. \*Mann-Whitney analysis. <sup>†</sup>Chi-square analysis. <sup>‡</sup>Chi-square analysis for trend. <sup>§</sup>Fisher's exact test. NRG : no recurrence group, RG : recurrence group, DM : diabetes mellitus, CHD : coronary heart disease, CVD : cerebral vascular disease, CSDH : chronic subdural hematoma, LOC : loss of consciousness, GCS : Glasgow coma scale, INR : international ratio, PT : prothrombin time, CT : computed tomography

coagulation medication ( $p=0.0161$ ), headache ( $p=0.0368$ ), and midline shifting ( $p=0.0238$ ) were significant risk factors for recurrence of CSDH in univariate logistic regression analysis. A statistical tendency towards a higher rate of recurrence of CSDH was present for age ( $p=0.0728$ ), DM ( $p=0.1613$ ), and

INR ( $p=0.0791$ ). On multivariate logistic regression analysis, we found that DM (OR 2.61, 95% CI 1.09–6.29,  $p=0.0314$ ), anticoagulation (OR 6.74, 95% CI 1.13–40.23,  $p=0.0364$ ), headache (OR 2.95, 95% CI 1.15–7.60,  $p=0.0249$ ), and midline shifting (OR 1.08, 95% CI 1.00–1.17,  $p=0.0391$ ) were signifi-

**Table 3.** Univariate and multivariate logistic regression analysis of predictive factors for recurrence of CSDH

Variables	Univariate analysis			Multivariate analysis		
	OR	95% CI	p-value	OR	95% CI	p-value
Age (per year)	0.9742	0.9468–1.0024	0.0728	0.9731	0.9424–1.0047	0.0949
Male	0.6585	0.2703–1.6041	0.3577			
Comorbidities						
Hypertension	1.0386	0.4889–2.2066	0.9215			
DM	1.7507	0.7996–3.8329	0.1613	2.6182	1.0899–6.2898	0.0314
Liver disease	1.9753	0.6107–6.3892	0.2557			
Kidney disease	1.1611	0.1351–9.9814	0.8917			
CHD	0.7630	0.0933–6.2381	0.8008			
CVD	0.6833	0.0844–5.5306	0.7212			
Prior medication						
Anticoagulation	7.5714	1.4568–39.3513	0.0161	6.7390	1.1287–40.2369	0.0364
Antiplatelet agent	1.0716	0.4344–2.6431	0.8807			
History and Initial symptoms						
Repeated trauma history	2.1964	0.5698–8.4667	0.2531			
Symptom duration (days)	1.0035	0.9882–1.0191	0.6532			
Initial GCS per point	0.9994	0.8326–1.1996	0.9952			
Headache	2.5645	1.0592–6.2088	0.0368	2.9510	1.1464–7.5964	0.0249
Hemiparesis	1.2070	0.5580–2.6105	0.6327			
LOC	0.7630	0.0933–6.2381	0.8008			
Speech disturbance	0.5241	0.1178–2.3312	0.3962			
Gait disturbance	1.3859	0.5992–3.2053	0.4455			
Memory impairment	1.4138	0.2950–6.7767	0.6650			
Laboratory investigation						
Platelet	1.0019	0.9974–1.0064	0.4085			
INR	2.8537	0.8853–9.1982	0.0791			
PT percentage (%)	0.9885	0.9679–1.0095	0.2818			
Radiologic finding						
Hematoma (unilateral, bilateral)	0.8281	0.3383–2.0274	0.6797			
Hematoma density on CT						
Low density	Ref					
Iso density	0.8571	0.2282–3.2198	0.8194			
Hyperdensity	2.1429	0.4258–10.7845	0.3553			
Mixed density	1.9780	0.6292–6.2187	0.2432			
Midline shifting (per mm)	1.0824	1.0106–1.1593	0.0238	1.0838	1.0040–1.1699	0.0391
Membrane septation	1.3097	0.6132–2.7971	0.4859			
Hematoma thickness (per mm)	1.0151	0.9621–1.0711	0.5840			
Brain atrophy						
Normal	Ref					
Mild	0.7656	0.3117–1.8320	0.5352			
Moderate	0.6354	0.2337–1.7277	0.3742			
Severe	0.2675	0.0326–2.1936	0.2194			

Hosmer & Lemeshow test, Chi squared 3.2980,  $p=0.8561$ . CSDH : chronic subdural hematoma, OR : odds ratio, CI : confidence interval, Ref : reference, DM : diabetes mellitus, CHD : coronary heart disease, CVD : cerebral vascular disease, GCS : Glasgow coma scale, LOC : loss of consciousness, INR : international ratio, PT : prothrombin time, CT : computed tomography

cantly associated with recurrence of CSDH.

## DISCUSSION

When the veins that bridge the subdural space are excessively stretched, they rupture, and venous blood escapes into the subdural space<sup>40</sup>. Chronic subdural hematomas begin with hemorrhage into the subdural space. The blood becomes encapsulated by a membrane of neovascularization at the inner surface of dura mater. This fragile membrane is caused by an inflammatory reaction to a chemical mediator in the subdural fluid collection. The sinusoidal channels in the neomembrane lead to frequent micro bleeding. Eventually, it causes encapsulation of unclotted and liquefacted hematoma by splitting of the neomembrane<sup>36</sup>.

Many risk factors for the development of CSDH have been described in the literature<sup>4,22</sup>. In the previous study, a few factors for recurrence of CSDH have been reported, such as advanced age, anticoagulant, antiplatelet medication, DM, brain atrophy, bilateral hematoma, postoperative subdural air accumulation and technical differences in surgery<sup>10,23,39</sup>. But, there is a lack of advanced studies on the predictive factors for CSDH recurrence related to clinical history, radiologic findings such as laterality of hematoma, membrane septation, brain atrophy, midline shifting, hematoma thickness and hematoma density on CT through multivariable regression analysis. Therefore, we analyzed the predictive factors for recurrence of CSDH in this study.

We found that the presence of initial symptoms such as headache, DM, prior anticoagulant medication, and postoperative midline shifting are independent predictors for recurrence of CSDH.

### Clinical finding

Consistent with previous reports, we found that clinical data (age, sex, hypertension, DM, liver disease, kidney disease, CHD, CVD, and malignancy) were not associated with hematoma recurrence<sup>35,37</sup>. Although there was no significant association of age and DM with hematoma recurrence in univariate analysis, age had a tendency for association with hematoma recurrence ( $p=0.0949$ ) and DM was the important predictive factor for hematoma recurrence in multivariate logistic regression analysis ( $p=0.0314$ ).

Previous reports showed the result of a significant association between brain atrophy and recurrence of CSDH<sup>2,26,32</sup>. In general, brain atrophy is closely related to the aging process. Then, age is expected to have clinical significance in recurrence of CSDH, but our finding was not in accordance with this expectation. We speculate that the reason for this difference is as follows : in terms of age, the mean age was 68.59 years in our study. There were 27 patients who were less than 50 years of age. The recurrence rate in this younger group (5 out of 27 patients, 18.5%) was higher than that in all age groups (31 out of 246 patients, 12.6%). The frequency of spontaneous CSDH in the younger group (7 out of 27 patients, 25.9%) was higher than that in all age groups (55 out of 246, 22.3%). CSDH in the younger group is generally uncommon. We speculate that this younger group had underlying conditions related with defect of coagulation capacity which was responsible for recurrence of CSDH. Hence, we suggest that the age factor did not have a significant association with recurrent CSDH.

In this study, DM was an independent predictive factor for recurrence of CSDH. DM may play a role in decreasing the risk of rebleeding in patients with CSDH due to increased platelet aggregation of high osmotic pressure<sup>39</sup>. Torihashi et al.<sup>37</sup> suggested that DM may play a role in increasing the recurrence rate of CSDH. Tugcu et al.<sup>38</sup> speculated that exudation due to capillary vasculopathy caused by DM plays an important role in re-expansion of the CSDH cavity. Hyperviscosity of the subdural blood is expected to draw more water into the hematoma and to increase the risk of recurrence<sup>1</sup>. On the other hand, we suggest that the cause of higher recurrence in patients with DM after operation for CSDH may be well-developed neovascularization of the neomembrane which is a bleeding source of CSDH. In case of diabetic retinopathy, hyperglycemia instigates retinal vascular endothelial dysfunction and thus retinal<sup>7</sup>. We speculate that the neomembrane of patients with DM and CSDH may be like that in diabetic retinopathy. Well-developed neovascularization of the neomembrane can be still bleed after hematoma evacuation. Generally, patients with DM usually take various medications, such as antiplatelet agents, antihypertensive drugs, and so on. Such various medications may exert a negative influence on coagulation capacity of CSDH after operation.

We found that prior anticoagulation medication is an independent predictive factor for recurrence of CSDH. Recently,

the number of elderly patients who are being treated with anticoagulant or antiplatelet agents is increasing<sup>13,22</sup>. The typical anticoagulant, warfarin, interferes with vitamin K metabolism and results in impaired synthesis of coagulation factors II, VII, IX, and X, as well as the regulatory factor protein C, S, and Z<sup>3</sup>. Aspirin irreversibly inhibits the enzyme cyclooxygenase. Clopidogrel affects the adenosine diphosphate dependent activation of IIb/IIIa complex<sup>29</sup>. Postoperative bleeding after burr-hole craniostomy may be due to impairment of coagulation capacity after prior use of anticoagulant or antiplatelet medications. The hemostatic mechanism differs between anticoagulant and antiplatelet agents, but we cannot suggest that this is the cause of the statistically significant difference. Among the 246 patients, there were only 6 patients with a history of anticoagulant use while there were 53 patients with a history of antiplatelet agent use. We suppose that these 6 patients with a history of anticoagulant use had been treated more intensively before the diagnosis of CSDH in terms of lowering the coagulation capacity compared to patients with a history of antiplatelet agent use. A larger proportion is needed to make a reliable decision between anticoagulant and antiplatelet agents.

The symptoms of CSDH usually present as three types. The first is the symptom of increased intracranial pressure (IICP). The second is the change of mental status. The third is dementia related symptoms<sup>34</sup>. The incidence of headache was significantly higher in patients with recurrent CSDH in our study. Headache is regarded as an early symptom of IICP or due to cortical irritation from CSDH. IICP and cortical irritation from CSDH are thought to play important roles in recurrence of CSDH. Higher IICP interrupts brain expansion after the operation for CSDH, and CSDH is likely to collect in the remaining space of non-brain expansion compared with that in the patients who have full brain expansion after the operation<sup>17,31</sup>. Elastance of the compressed brain due to a higher IICP is low; hence, brain expansion after the operation will not occur very rapidly. We speculated that the severity of headache had a connection with the degree of IICP. The absence of the headache symptom reflects non-IICP and this indicates the possibility of rapid brain expansion after the operation for CSDH.

### Radiologic finding

We found that preoperative midline shifting is an indepen-

dent predictive factor for recurrence of CSDH. Nakaguchi et al.<sup>24</sup> suggested that postoperative midline shifting may cause impaired adhesion between the inner and outer neomembrane and thus facilitate recurrence of CSDH after the operation. We suggest that preoperative midline shifting also plays an important role in recurrence of CSDH on the basis of impaired adhesion between inner and outer neomembrane and brain elastance. Prolonged brain compression due to a subdural hematoma may cause severe degree of midline shifting, and it may affect brain expansion after the operation for some time. Degree of brain expansion in the early postoperative period is known to be a very important factor for recurrence of CSDH<sup>12,18,31</sup>. In cases of bilateral CSDH, there tends to be mild midline shifting. We think that CSDH compresses the brain parenchyma bilaterally, and thus the midline septum of the brain may maintain its balance. However, even if bilateral CSDH has a tendency for a mild degree of midline shift, we should not state that the incidence of recurrence of bilateral CSDH is low compared with that of unilateral CSDH because midline shifting cannot reflect the degree of compressed brain due to bilateral CSDH. Various imaging studies are needed to estimate the degree of the compressed brain due to bilateral CSDH in the future. We suggest that a coronal section image of brain MRI may be helpful to estimate the degree of the compressed brain.

There was no significant relationship between laterality of CSDH (unilateral vs. bilateral CSDH) and recurrence in our study. Unlike the previous report, the recurrence rate of bilateral CSDH in this study was not significantly different from that of unilateral CSDH<sup>16,37</sup>. Several risk factors for bilateral CSDH have been identified, and they include old age, coagulopathy, use of antiplatelet or anticoagulation medications, and hemodialysis<sup>34</sup>. Previous reports revealed that poor brain re-expansion has been shown to be correlated with recurrence of CSDH, and thus this abnormality leads to the potential for recurrence of CSDH, especially in bilateral CSDH<sup>16</sup>. However, our finding was not significantly different between recurrence rates of unilateral CSDH and bilateral CSDH in Table 2 (26% vs. 22.6%). We presume that the recurrence rate would have been the same if there was no difference in the bleeding tendency between unilateral and bilateral CSDH.

There was no significant relationship between hematoma thickness of CSDH and recurrence in our study. In general, CSDH is particularly common in elderly patients who show

brain atrophy and brain atrophy provides a potential space for hematoma expansion. We can infer the possibility of satisfactory evacuation of hematoma due to hematoma constituent of liquefaction hematoma rather than solid hematoma in the majority of cases regardless of hematoma thickness<sup>25,33</sup>.

There was no significant relationship between hematoma density of CSDH and recurrence in our study, however high density or mixed type density of hematoma have the tendency of higher recurrence rate. Mixed density of hematoma has been reported to be involved in the high recurrence rate<sup>8,28</sup>. The cause of different results between our reports and other literatures seems to be the difference of analysis method. We sorted hematoma density into four groups (low density, iso density, hyperdensity, and mixed density) through Chi-square analysis for trend whereas the cited papers sorted it to only two groups (low density and mixed density) through Chi-square analysis for two groups. These categorizations may cause the different results of hematoma densities. However, the higher tendency of recurrence rate in mixed type of hematoma is applicable to our results. These findings in recurrence rate of mixed hematoma between NRG and RG presented in Table 2 (9.7% vs. 58.1%).

The present study was a retrospective study and is therefore subject to potential sources of bias and variation. A prospective study with a larger number of cases is needed.

## CONCLUSION

We suggest that diabetes mellitus, anticoagulation, headache, and preoperative midline shifting are independent preoperative predictors of recurrence of chronic subdural hematoma.

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