Predictive factors for recurrence and clinical outcomes in patients with chronic subdural hematoma

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OBJECTIVE Chronic subdural hematoma (CSDH) is a common type of intracranial hemorrhage in elderly patients. Many studies have suggested various factors that may be associated with the recurrence of CSDH. However, the results are inconsistent. The purpose of this study was to determine the associations among patient factors, recurrence, and clinical outcomes of CSDH after bur hole surgery performed during an 11-year period at twin hospitals.

METHODS Kaplan-Meier analysis was performed to evaluate the risk factors for CSDH recurrence. Univariate and multivariate Cox proportional hazards regression analyses were used to calculate hazard ratios with 95% CIs for CSDH recurrence based on many variables. One-way repeated-measures ANOVA was used to assess the differences in the mean modified Rankin Scale score between categories for each risk factor during each admission and at the last follow-up.

RESULTS This study was a retrospective analysis of 756 consecutive patients with CSDH who underwent bur hole surgery at the Hanyang University Medical Center (Seoul and Guri) between January 1, 2004, and December 31, 2014. During the 6-month follow-up, 104 patients (13.8%) with recurrence after surgery for CSDH were identified. Independent risk factors for recurrence were as follows: age > 75 years (HR 1.72, 95% CI 1.03–2.88; $p = 0.039$), obesity (body mass index ≥ 25.0 kg/m²), and a bilateral operation.

CONCLUSIONS This study determined the risk factors for recurrence of CSDH and their effects on outcomes. Further studies are needed to account for these observations and to determine their underlying mechanisms.

<https://thejns.org/doi/abs/10.3171/2016.8.JNS16867>

KEY WORDS body mass index; chronic subdural hematoma; recurrence; modified Rankin Scale; trauma; vascular disorders

CHRONIC subdural hematoma (CSDH) is a common type of intracranial hemorrhage in elderly patients, with a recurrence rate after bur hole surgery ranging from 9.2% to 26.5%.³⁵ Numerous studies have reported various potential risk factors for CSDH recurrence, although their results are inconsistent.^{1,2,6,9,12,15,21–24,31,35,37} Cerebral atrophy is a well-known risk factor for occurrence and/or recurrence of CSDH.^{18,38,39} Despite the fact that many studies have reported an association between body mass index (BMI) and brain atrophy, there have been no studies regarding the association between BMI and recurrence or clinical outcomes of CSDH.^{5,7,8,10,16,20,25,28,34} We hypothesized that the cerebral atrophy associated with higher BMI may influence CSDH recurrence.

The purpose of the present study was to determine the associations among patient factors, recurrence, and clinical

outcomes of CSDH after bur hole surgery performed during an 11-year period at twin hospitals.

Methods

Patients and Definition of CSDH Recurrence

Initially, we collected data on 794 patients with CSDH from the Traumatic Brain Injury registry at our twin hospitals (Seoul, $n = 439$; Guri, $n = 355$). We then excluded 38 patients (21 for missing data, 13 for postoperative acute intracranial bleeding that required surgery, and 4 for sudden cardiac arrest). Finally, we retrospectively analyzed the cases of 756 consecutive patients with CSDH who underwent bur hole surgery at the Hanyang University Medical Center (Seoul and Guri) between January 1, 2004, and December 31, 2014. Diagnosis was confirmed by head CT

ABBREVIATIONS BMI = body mass index; CSDH = chronic subdural hematoma; mRS = modified Rankin Scale.

SUBMITTED April 5, 2016. **ACCEPTED** August 25, 2016.

INCLUDE WHEN CITING Published online December 16, 2016; DOI: 10.3171/2016.8.JNS16867.

scan or MR image in all patients. After we obtained data in patients with CSDH from the registry, all medical records (including operative records) were reviewed by 2 specialized research teams using an electronic medical records system database.

We defined recurrence as a radiologically confirmed CSDH, which developed in the ipsilateral subdural space within 6 months of the initial surgery and produced neurological deficits that required reoperation.⁴

This study was approved by the institutional review boards of Hanyang University Medical Center in both Seoul and Guri.

Surgical Procedures and General Management

A standard 1- or 2-bur hole craniostomy was performed in all cases with or without saline irrigation under local or general anesthesia in both hospitals. All patients who had bilateral CSDH surgery received each bur hole craniostomy in a single operation. We treated each bilateral hematoma as 1 case and performed the same procedure on both sides. We inserted closed-system drainage in all cases and placed the drain approximately 30–50 cm below head level. In most cases, the drain was removed within 3 days. We performed repeat surgery with the same procedure in the recurrent patient group. We did not use preoperative dexamethasone in any cases.

Antiplatelet or anticoagulant agents were discontinued before surgery in all cases. In patients with elevation of the international normalized ratio on admission, we routinely administered intravenous vitamin K before surgery. Antiplatelet or anticoagulant agents were usually restarted 1 month from the day of surgery.

Routine follow-up CT scans were acquired immediately and 1 week after surgery. Patients without complications were generally discharged within 10 days.

BMI Measurement and Classification

Body weight and height were measured and recorded by the nurse on admission. If this was not possible, we used the most recent weight measurements obtained from the patients or their relatives. BMI was calculated as weight/(height × height) and expressed in kg/m². Based on the West Pacific-Asian criteria of obesity,³⁶ we divided all patients into 4 groups based on BMI: < 18.5 kg/m² (underweight), 18.5–22.9 kg/m² (normal), 23.0–24.9 kg/m² (overweight), and ≥ 25.0 kg/m² (obese). In addition, we divided obese patients (≥ 25.0 kg/m²) into groups of 25.0–27.4 and ≥ 27.5 kg/m² to more specifically investigate the association between recurrence and BMI in obese patients (data shown in the Supplemental Material). A recent study supports the use of this specific BMI classification for the Asian population.¹⁴

Clinical Patient Factors

Hypertension and diabetes were defined as previous use of antihypertensive/antidiabetic medication, medical records indicating a history of hypertension/diabetes, or patient/guardian self-reporting. These methods were also used to determine other medical history. We defined malignancy as any cancer in any part of the body, including

the CNS, lymph nodes, soft tissue, bone marrow, and so on. We defined a history of cerebrovascular disease based on medical history and review of neuroimaging. A history of smoking was defined to include current smokers, and a history of drinking was classified into 3 groups: never or less than once a month, moderate (once a month to less than once a week), and frequent (weekly or more). We also investigated the use of antithrombotic medications, including antiplatelet agents (aspirin and/or clopidogrel), anticoagulants (warfarin), and combined use, in all patients.

Radiological Variables

All CT scans and MR images of 756 patients with CSDH were assessed by 2 senior neurosurgeons (H.J.Y. in Seoul and J.H.C. in Guri). We measured the width of the hematoma and the midline shift immediately before surgery and evaluated the side of the operation after surgery. We also evaluated encephalomalacic changes that may have indicated a previous brain hemorrhage or ischemic damage and classified these as cerebrovascular disease.

Outcome Measures

We assessed the 6-month recurrence rate after surgery for CSDH in both hospitals. Fifty-five patients did not return for the 6-month follow-up examination, yielding a completion rate of 92.7%. We also investigated the modified Rankin Scale (mRS) score of all patients at admission and at the last follow-up.

Statistical Analysis

Baseline characteristics of patient data are presented as the mean ± SD or the median (interquartile ranges). Discrete variables are expressed as count (percentage). The χ^2 test for dichotomous variables and the Student t-test for continuous variables were used to assess clinical differences between patients with and without recurrence.

Time-to-event (recurrence) analysis was performed to evaluate risk factors for CSDH recurrence using Kaplan-Meier curves, with censoring of patients who died or were lost to follow-up. We used univariate Cox proportional hazards regression analyses to calculate hazard ratios with 95% CIs for CSDH recurrence based on several variables. Subsequently, sex, age, and covariates that were significant at $p < 0.20$ in univariate analysis were included in multivariate analysis to test for an independent association with CSDH recurrence.³³ We also presented the multivariate HRs adjusted for the 5 categorical groups of BMI in Table 1 in the Supplemental Material.

The mRS score is presented for each admission and the last follow-up as the mean ± SD based on the risk factors for CSDH recurrence. A paired t-test was used to compare the differences between the mean mRS score at admission and the last follow-up. We used 1-way repeated-measures ANOVA to assess the differences in the mean mRS score between categories of each risk factor at each admission and last follow-up. Multiple comparison Tukey-adjusted p values were reported.

Statistical analyses were performed using R version 3.1.2 and SPSS for Windows, version 22.0 software (IBM Corp.).

TABLE 1. Characteristics of patients with CSDH included in the study

Variable	No Recurrence	Recurrence	Total	p Value
No. (%)	652 (86.2)	104 (13.8)	756 (100)	
Follow-up in mos, mean $\pm$ SD	12.1 $\pm$ 6.3	13.6 $\pm$ 5.5	12.3 $\pm$ 6.3	0.019
Sex, M, no. (%)	491 (75.3)	83 (79.8)	574 (75.9)	0.382
Age in yrs, mean $\pm$ SD	67.8 $\pm$ 8.2	68.6 $\pm$ 8.5	67.9 $\pm$ 8.3	0.314
Age group, yrs, no. (%)				0.033
<65	220 (33.7)	27 (26.0)	247 (32.7)	
65–74	292 (44.8)	43 (41.3)	335 (44.3)	
≥ 75	140 (21.5)	34 (32.7)	174 (23.0)	
Height in cm, mean $\pm$ SD	165.6 $\pm$ 7.1	165.4 $\pm$ 7.5	165.6 $\pm$ 7.2	0.781
Weight in kg, mean $\pm$ SD	61.8 $\pm$ 11.8	62.8 $\pm$ 12.6	61.9 $\pm$ 11.9	0.407
BMI in kg/m ² , median (IQR)	22.7 (20.3–24.9)	23.3 (19.7–25.7)	22.9 (20.3–25.0)	0.282
BMI classification, no. (%)				0.128
<18.5 kg/m ² , underweight	94 (14.4)	17 (16.3)	111 (14.7)	
18.5–22.9 kg/m ² , normal	248 (38.0)	28 (26.9)	276 (36.5)	
23.0–24.9 kg/m ² , overweight	156 (23.9)	26 (25.0)	182 (24.1)	
≥ 25.0 kg/m ² , obese	154 (23.6)	33 (31.7)	187 (24.7)	
Medical history, no. (%)				
Hypertension	279 (42.8)	40 (38.5)	319 (42.2)	0.469
Diabetes	172 (26.4)	35 (33.7)	207 (27.4)	0.154
Heart disease	112 (17.2)	20 (19.2)	132 (17.5)	0.709
Liver disease	66 (10.1)	15 (14.4)	81 (10.7)	0.252
Renal disease	49 (7.5)	9 (8.7)	58 (7.7)	0.836
Malignancy	57 (8.7)	8 (7.7)	65 (8.6)	0.868
Cerebrovascular disease	84 (12.9)	19 (18.3)	103 (13.6)	0.183
Alcohol use, no. (%)				0.432
<1 time/mo	392 (60.1)	56 (53.8)	448 (59.3)	
1 time/mo to <1 time/wk	139 (21.3)	24 (23.1)	163 (21.6)	
≥ 1 time/wk	121 (18.6)	24 (23.1)	145 (19.2)	
Smoking, no. (%)	194 (29.8)	31 (29.8)	225 (29.8)	1.000
Antithrombotic use, no. (%)				0.429
No	380 (58.3)	56 (53.8)	436 (57.7)	
Antiplatelet	191 (29.3)	29 (27.9)	220 (29.1)	
Warfarin	66 (10.1)	15 (14.4)	81 (10.7)	
Both	15 (2.3)	4 (3.8)	19 (2.5)	
Radiological findings, no. (%)				
Preop hematoma width >20 mm	287 (44.0)	51 (49.0)	338 (44.7)	0.342
Preop midline shift >10 mm	242 (37.1)	44 (42.3)	286 (37.8)	0.328
Surgical details				
Anesthesia, no. (%)				1.000
General	179 (27.5)	28 (26.9)	207 (27.4)	
Local	473 (72.5)	76 (73.1)	549 (72.6)	
Side of op, no. (%)				0.025
Unilat	564 (86.5)	81 (77.9)	645 (85.3)	
Bilat	88 (13.5)	23 (22.1)	111 (14.7)	
No. of bur holes, no. (%)				0.441
1	590 (90.5)	91 (87.5)	681 (90.1)	
2	62 (9.5)	13 (12.5)	75 (9.9)	
Saline irrigation, no. (%)	84 (12.9)	13 (12.5)	97 (12.8)	1.000

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TABLE 1. Characteristics of patients with CSDH included in the study

Variable	No Recurrence	Recurrence	Total	p Value
Surgical details (<i>continued</i>)				
Drain insertion, no. (%)	652 (100)	104 (100)	756 (100)	
No. of days until drain removal, mean $\pm$ SD	2.7 $\pm$ 0.9	2.7 $\pm$ 0.8	2.7 $\pm$ 0.9	0.998

IQR = interquartile range.

Results

Clinical Characteristics

We included 756 consecutive patients who underwent surgery for CSDH between January 1, 2004, and December 31, 2014, in one of the twin hospitals. The average

age of the patients was 67.9 years, and 75.9% were men. The mean follow-up was 12.3 $\pm$ 6.3 months (median 11.5 months, interquartile range 9.0–14.5 months).

During the 6-month follow-up, we identified 104 patients (13.8%) with recurrence after surgery for CSDH. Thirty-four patients (32.7%) were 75 years or older, and

TABLE 2. Univariate and multivariate analyses of the association between CSDH recurrence and various variables

Variable	Univariate Analysis		Multivariate Analysis	
	HR (95% CI)	p Value	HR (95% CI)	p Value
Sex, M (vs F)	1.26 (0.78–2.03)	0.346	1.30 (0.80–2.11)	0.285
Age, yrs				
<65	Reference			
65–74	1.20 (0.74–1.95)	0.453	1.12 (0.69–1.82)	0.647
≥ 75	1.89 (1.14–3.13)	0.013	1.72 (1.03–2.88)	0.039
BMI, kg/m ²				
18.5–22.9, normal	Reference			
<18.5, underweight	1.56 (0.86–2.85)	0.147	1.61 (0.87–2.95)	0.128
23.0–24.9, overweight	1.44 (0.84–2.45)	0.185	1.41 (0.83–2.41)	0.207
≥ 25.0 , obese	1.81 (1.09–3.00)	0.021	1.73 (1.03–2.93)	0.040
Hypertension	0.86 (0.58–1.27)	0.444		
Diabetes	1.38 (0.92–2.07)	0.123	1.25 (0.82–1.89)	0.300
Heart disease	1.12 (0.69–1.83)	0.639		
Liver disease	1.47 (0.85–2.54)	0.169	1.58 (0.91–2.73)	0.103
Renal disease	1.20 (0.61–2.37)	0.605		
Malignancy	0.87 (0.42–1.79)	0.706		
Cerebrovascular disease	1.50 (0.91–2.46)	0.112	1.47 (0.89–2.43)	0.130
Alcohol drinking				
<1 time/mo	Reference			
1 time/mo to <1 time/wk	1.20 (0.75–1.94)	0.448		
≥ 1 time/wk	1.36 (0.85–2.20)	0.205		
Smoking	1.01 (0.67–1.54)	0.955		
Antithrombotic				
No	Reference			
Antiplatelet	1.03 (0.66–1.61)	0.898		
Warfarin	1.44 (0.82–2.55)	0.209		
Antiplatelet + warfarin	1.69 (0.61–4.66)	0.311		
Preop hematoma width ≥ 20 mm (vs <20 mm)	1.21 (0.82–1.78)	0.333		
Preop midline shift ≥ 10 mm (vs <10 mm)	1.23 (0.83–1.81)	0.298		
Anesthesia (general vs local)	0.99 (0.64–1.53)	0.977		
Side of op (bilat vs unilat)	1.73 (1.09–2.75)	0.020	1.80 (1.13–2.88)	0.014
No. of bur holes (2 vs 1)	1.28 (0.72–2.29)	0.408		
Saline irrigation	0.95 (0.53–1.70)	0.868

FIG. 1. A Kaplan-Meier curve with a log-rank test showing the recurrence-free proportion of patients 6 months after bur hole surgery based on the following risk factors for recurrence of CSDH: all patients (A), age group (B), BMI (C), and side of operation (D). Figure is available in color online only.

there were 33 patients (31.7%) with a BMI ≥ 25.0 kg/m² in the recurrence group. Twenty-three patients (22.1%) in the recurrence group underwent bilateral operation. Further descriptive data are shown in Table 1.

Risk Factors for Recurrence of CSDH

We estimated the HRs for clinical, radiological, and surgical factors associated with recurrence after CSDH surgery. In a multivariate Cox regression analysis, which included sex, age group, BMI group, diabetes, liver disease, cerebrovascular disease, alcohol drinking, preoperative hematoma width, and side of operation, independent risk factors for recurrence were as follows: ≥ 75 years age group (HR 1.72, 95% CI 1.03–2.88; $p = 0.039$), obese group (BMI ≥ 25.0 kg/m²) (HR 1.73, 95% CI 1.03–2.93; $p = 0.040$), and bilateral operation group (HR 1.80, 95% CI 1.13–2.88; $p = 0.014$) (Table 2). There were no interactions between BMI and age ($p = 0.075$), BMI and bilateral

operation group ($p = 0.246$), or bilateral operation group and age ($p = 0.956$).

The Kaplan-Meier curve, with log-rank tests showing the recurrence-free proportion of patients within 6 months after surgery for CSDH based on age group, BMI classification, and the side of operation is presented. The overall 6-month recurrence-free proportion of patients reached a plateau near 86% (Fig. 1A). Older patients (≥ 75 years) had a greater risk of recurrence of CSDH (Fig. 1B). High BMI groups tended to have a higher recurrence rate (Fig. 1C). Patients with bilateral CSDH also had a greater risk of recurrence of CSDH (Fig. 1D). The multivariate hazard ratios adjusted for the 5 BMI groups are presented in Supplemental Table I. A Kaplan-Meier curve based on these BMI groups is shown in Supplemental Fig. I. Although there was a tendency toward a higher recurrence rate in patients with a BMI ≥ 27.5 kg/m², this was not statistically significant. However, the small number of patients with BMI ≥ 27.5 kg/m² might have lowered the statistical power.

TABLE 3. Admission and last follow-up mRS scores based on risk factors for recurrence of CSDH

Characteristic	mRS Score*		p Value
	Admission	Last Follow-Up	
All patients	2.22 ± 0.95	1.06 ± 1.09	<0.001
Age, yrs			
<65	2.10 ± 0.90	0.87 ± 0.96	<0.001
65–74	2.21 ± 0.94	0.96 ± 0.95	<0.001
≥75	2.40 ± 1.02	1.49 ± 1.38	<0.001
BMI classification, kg/m ²			
<18.5	2.26 ± 0.93	0.89 ± 0.86	<0.001
18.5–22.9	2.11 ± 0.93	0.82 ± 0.86	<0.001
23.0–24.9	2.25 ± 0.99	0.97 ± 0.99	<0.001
≥25.0	2.33 ± 0.96	1.59 ± 1.34	<0.001
Side of op			
Unilat	2.19 ± 0.99	1.01 ± 1.11	<0.001
Bilat	2.41 ± 0.71	1.30 ± 0.98	<0.001

* Values presented as the mean ± SD.

Clinical Outcomes of the Risk Factors for Recurrence

The mean mRS score at admission and last follow-up was 2.22 and 1.06 in all patients, respectively, and the difference between the admission and the last follow-up mean mRS score was statistically significant in all patients and subgroups (Table 3). We found relatively higher last follow-up mean mRS scores in the older age group (≥ 75 years, mean 1.49, SD 1.38), the higher BMI group (≥ 25.0 kg/m², mean 1.59, SD 1.34), and the bilateral operation group (mean 1.30, SD 0.98). There was a higher mean mRS score on admission in overweight (BMI 23.0–24.9 kg/m²; $p = 0.043$) and obese (BMI ≥ 25.0 kg/m²; $p = 0.036$) groups compared with the normal weight group (BMI 18.5–22.9 kg/m²) (Fig. 2).

In addition, we observed a significantly higher average mRS score on admission in the 65–74 years age group ($p = 0.049$) and the ≥ 75 years age group ($p < 0.001$) relative to the < 65 years age group. This association was also observed in the bilateral operation group ($p = 0.026$) compared with the unilateral group. At the last follow-up, obese patients ($p < 0.001$), those ≥ 75 years old ($p < 0.001$), and patients who required a bilateral operation ($p = 0.011$) showed higher average mRS scores compared with the admission mRS scores of the same reference categories. The mean mRS scores with SDs at admission and at the last follow-up, stratified by the 5 BMI groups, are presented in Supplemental Figure II.

Discussion

We observed an overall recurrence rate of 13.8% in patients with CSDH during a 6-month follow-up after bur hole surgery performed between January 1, 2004, and December 31, 2014, in 2 hospitals. Older patients (≥ 75 years), obese patients (BMI ≥ 25.0 kg/m²), and patients who required a bilateral operation had a 1.72-fold, 1.73-fold, and 1.80-fold higher recurrence rate, respectively, after adjusting for all relevant variables. These risk factors for recur-

rence also influenced clinical outcomes. Our study showed that older age, higher BMI, and bilateral operations were also associated with higher admission and follow-up mRS scores.

Our study showed that patients with factors associated with brain atrophy leading to poor reexpansion showed a higher recurrence rate. To the best of our knowledge, our study is the first to evaluate the association between the recurrence of CSDH and BMI. It is unclear whether higher BMI is related to the higher CSDH occurrence. However, our study showed that higher BMI was associated with recurrence of CSDH. The underlying pathophysiology is not clear. However, Raji et al. reported that a higher BMI was associated with lower brain volumes in overweight and obese elderly subjects, even when controlling for potential confounders such as age, sex, and race.²⁸

In addition, Cherbuin et al. found that being overweight was associated with hippocampal atrophy.⁵ Other studies regarding BMI-associated brain atrophy support this finding.^{10,16,25,34} Possible mechanisms include cortisol elevation, lack of exercise, and Type 2 diabetes.^{7,8,20} Fukuhara et al. reported that advanced age, brain atrophy, large hematomas, and prolonged compressed parenchyma influenced brain elasticity.⁹ Brains with high elasticity tend to reexpand poorly, and poor brain reexpansion is correlated with the recurrence of CSDH.^{21,35}

Therefore, we hypothesized that brain atrophy and its association with high BMI might play a role in the underexpansion of the brain after surgery for CSDH, which subsequently increased the likelihood of CSDH recurrence. Although there was no statistical significance between CSDH recurrence and the underweight group, there were more recurrences in the underweight group compared with the normal BMI patient group. A recent study in Korea reported that being underweight was associated with low socioeconomic status and all-cause mortality.¹⁷ In addition, Silventoinen et al. found that being underweight is associated with a low social position, marginalization, and poor health behaviors.³² These factors may influence the higher recurrence rate to some extent in underweight patients relative to the patients with normal BMI in our study.

We observed a higher recurrence rate in the older age group. Previous studies reported that age was associated with poor brain expansion and recurrence of CSDH.^{9,11,21,26,29,30} Ro et al. reported findings similar to ours,²⁹ showing that there were more recurrences of CSDH in patients with no brain expansion or brain underexpansion after surgery for CSDH, and that this was associated with age and the duration of symptoms.

Bilateral hematoma was also associated with CSDH recurrence in our study. There have been several studies demonstrating bilateral hematoma to be a risk factor for the recurrence of CSDH.^{27,30,35} A study in Japan found that patients with bilateral CSDH tended to have previous brain atrophy, which led to poor brain reexpansion after operation. Poor brain reexpansion is thought to create the potential for the reaccumulation of a hematoma. Huang et al. reported that the recurrence rate of up to 28% observed for bilateral CSDH was higher than the 10% rate observed for unilateral CSDH.¹³

FIG. 2. Bar graphs with error bars showing the differences between the mRS score at admission and at the last follow-up based on the following risk factors for recurrence of CSDH: all patients (A), BMI (B), age group (C), and side of operation (D). Figure is available in color online only.

Lee found that the key determinant for development of CSDH is sufficient subdural space, in other words, cerebral atrophy.¹⁸ Yang et al. suggested that cerebral atrophy leads to tearing of the bridging veins between the rigidly fixed dura mater and the mobile arachnoid layer.³⁹ A study using microscopy of postmortem material demonstrates that the subdural portion of the bridging veins has thinner vessel walls with less collagen, resulting in greater fragility than the subarachnoid portion. Therefore, these studies support the hypothesis that with greater cerebral atrophy, there is an increased likelihood of subsequent CSDH development.

Risk factors for CSDH recurrence also influenced clinical outcomes in the present study. A recent study in Korea demonstrated that older patients (≥ 75 years) and patients with recurrent CSDH tended to have poorer mRS grades at 3 months.²⁹ Previous studies demonstrated that an age threshold of 75 years was associated with unfavorable functional outcomes.^{3,19} Consequently, we hypothesized

that patients with CSDH with previous brain atrophy have a higher recurrence rate, which is associated with poor brain reexpansion; this might result in less favorable clinical outcomes.

There were several limitations to our study. Due to the retrospective nature of the study, the findings may not be as accurate as those of a planned prospective study. We included only Korean patients in this study, which makes the generalizability of the results of this study limited. Our study population is leaner (that is, lower BMI) than those in most Western countries. Therefore, genetic variation and other underlying differences that exist between Asian and Western populations may confound the findings of this study.

The statistically significant effect of the bilateral operation group on recurrence might have some effect on the nonsignificant association between midline shift and CSDH recurrence. Therefore, further studies that include larger numbers of patients with unilateral CSDH are re-

quired to more clearly investigate the association between CSDH recurrence and preoperative midline shift.

Reoperation was performed based on residual or recurrent CSDH on CT and persistent neurological deficits. However, the decision to reoperate was not strictly standardized due to the retrospective nature of the study. There was some variation in the period between admission and last follow-up in this study. Therefore, it is possible that higher mRS scores were observed in the short-term follow-up group compared with the long-term follow-up group.

Conclusions

We found significant associations between recurrence of CSDH and older age, higher BMI, and bilateral hematoma among patients who underwent burr hole surgery during the 11-year study period in twin hospitals. In addition, risk factors for recurrence of CSDH also influenced clinical outcomes. We expect these findings to be helpful for predicting prognosis for patients who undergo surgical treatment of CSDH. In addition, further prospective multicenter studies will be required to evaluate these findings.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ryu. Acquisition of data: Han. Analysis and interpretation of data: Han. Drafting the article: Han. Critically revising the article: CH Kim, JM Kim, Cheong, Yi. Reviewed submitted version of manuscript: CH Kim, JM Kim, Cheong, Yi. Statistical analysis: Han. Radiologic confirmation: Cheong, Yi.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Material. <https://thejns.org/doi/suppl/10.3171/2016.8.JNS16867>.

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