



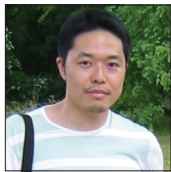
Original Article

Intraoperative hematoma volume can predict chronic subdural hematoma recurrence

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Received : 01 February 2021

Accepted : 20 April 2021

Published : 25 May 2021

DOI

10.25259/SNI_97_2021

Quick Response Code:



ABSTRACT

Background: We routinely measured the exact chronic subdural hematoma (CSDH) volume during single burr hole surgery. To date, several risk factors have been reported for CSDH recurrence, including sex, hematoma volume and degree of midline shift calculated from computed tomography, use of anticoagulants or antiplatelet medications, and alcohol consumption habits. The aim of this study was to clarify whether hematoma volume, in conjunction with other factors, can predict recurrence.

Methods: We retrospectively reviewed the clinical data of 194 consecutive patients with CSDH who underwent single burr hole surgery. The risk factors for recurrence were analyzed based on patients' sex, age, bilaterality, existence of apparent trauma history, exact intraoperative hematoma volume, and various clinical factors, including preoperative anticoagulant/antiplatelet intake.

Results: Recurrence occurred in 22 patients (11.3%). Multivariate logistic regression analysis revealed that intraoperative hematoma volume was an independent risk factor for CSDH recurrence (odds ratio [OR], 1.01; 95% confidence interval [CI], 1.01–1.02, $P < 0.001$), in addition to sex (male) (OR 9.25; 95% CI, 1.00–84.8; $P = 0.049$) and diabetes mellitus (DM) (OR: 3.97, 95% CI, 1.34–11.7, $P = 0.013$). Based on receiver operating characteristics analysis, the cutoff value of the hematoma volume predicting CSDH recurrence was 150 ml (sensitivity and specificity of 72.7% and 72.1%, respectively; area under the curve: 0.7664, 95% CI: 0.654–0.879, $P < 0.001$). Of these, a hematoma volume ≥ 150 mL was the strongest independent risk factor for recurrence according to multiple regression (OR: 8.98, 95% CI: 2.73–29.6, $P < 0.001$) and Cox regression analysis (hazard ratio: 3.05, 95% CI: 1.18–7.87, log-rank $P = 0.0046$, $P = 0.021$). Follow-up periods after surgery were significantly longer for cases with recurrence than for non-recurrence cases (24.8 ± 11.5 vs. 15.9 ± 9.7 days), and the recurrence prediction cutoff value was 17 days, with a sensitivity and specificity of 83.1% and 68.2%, respectively (AUC: 0.7707, 95% CI: 0.6695–0.8720, $P < 0.001$).

Conclusion: Intraoperative hematoma volume could be a predictive value for CSDH recurrence.

Keywords: Chronic subdural hematoma, Hematoma volume, Recurrence, Risk factors

INTRODUCTION

Chronic subdural hematoma (CSDH) is one of the most frequent diseases encountered by neurosurgeons.^[2,11,13,16,18-20,22,23,25,33] Recently, with the growing proportion of elderly people in the population, CSDH is projected to become the most common neurosurgical disease by the year 2030.^[3,31] Furthermore, long-term outcomes of elderly patients with CSDH are poorer and worse than expected.^[31] Therefore, less-invasive surgery using a single burr hole or twist drill

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under local anesthesia with drainage tube insertion has been recommended.^[2,11,13,18-20,23-25,32,33] Recently, no irrigation of the hematoma cavity has been reported as an effective strategy, which has resulted in reduction of surgery time without an increase in recurrence.^[9,30] However, no report has mentioned the exact evacuated hematoma volume, and most reports predict CSDH recurrence by calculating hematoma volume, shape, density, degree of midline shift, or post-surgical residual air and/or hematoma space using computed tomography (CT) and/or magnetic resonance imaging (MRI).^[2,3,10,12,26,28,30] Furthermore, CSDH recurrence is also influenced by anticoagulants/antiplatelet medications (AC/AT), headache, diabetes mellitus (DM), aphasia, the no-drainage method, male sex, malignancy, bilateral disease hyper density on CT, and hematoma thickness.^[3,6,7,15,34] On the other hand, atorvastatin, steroids, the angiotensin converting enzyme (ACE) inhibitor, tranexamic acid, and Chinese herb Gorei-san have been found to reduce recurrence.^[15,17,21,30]

The aims of this study were to identify preoperative predictive factors for recurrence, and we hypothesized that intraoperative hematoma volume was also associated with CSDH recurrence and could be included as a risk factor. If possible, we also studied the exact postsurgical drainage times and volumes of patients, to clarify the appropriate drainage duration.

This study was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the Shunan Memorial Hospital Institutional Review Board. The review board approved that the need for informed consent was waived, given the retrospective nature of the study.

MATERIALS AND METHODS

Surgical techniques

All patients underwent single burr-hole surgery, and closed system drainage was performed under local anesthesia. The hematoma was evacuated as follows. Just after cutting the outer membrane of the hematoma, the stand-by aspirator vacuumed the hematoma as much as possible. When voluntary hematoma flow was confirmed to have stopped, the aspirated hematoma volume was measured using a commercial surgical bucket. A drainage tube was then inserted posteroinferiorly into the hematoma cavity. At the extent of insertion, manual aspiration was performed gently using an injection tube. Aspirated hematoma volume was calculated as the total volume of the hematoma. In cases of bilateral disease, the hematoma volume was calculated by combining both sides. Irrigation was seldom performed.^[9,30] After evacuation of the hematoma, the drainage tube was placed in the frontal position. The tube was removed the day after confirmation of the absence of surgical complication

by CT. Ambulation was allowed after drain removal, and the patients were discharged 3–7 days after surgery.

Subjects and methods

We retrospectively analyzed the clinical records of patients who were treated over a period of 8 years (January 1, 2013, to December 31, 2020). Age, sex, and medical history, including medication use, alcohol intake, and smoking habits, were recorded. Recurrence was defined as the reappearance of neurological signs and/or symptoms with CT evidence of increased hematoma cavity volume, which was re-treated with burr hole surgery and was counted as a case. Postoperative follow-up termination was based on radiological and clinical findings.

Statistical analysis

Data are presented as mean \pm standard deviation for continuous variables and number (percentage) for categorical variables. Univariate analysis was performed using the Mann–Whitney U-test, while either Pearson's Chi-square test or Fisher's exact test was used 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 (i.e., age, hematoma volume, drainage volume, and hours). Factors associated with recurrence in the univariate analysis ($P < 0.20$) were entered into a multivariate logistic regression analysis. Two-tailed $P < 0.05$ was considered statistically significant. Odds ratios (ORs) were estimated for magnitude of effect with 95% confidence intervals (CIs). The Kaplan–Meier survival curve was plotted, and the log-rank test was conducted to compare the time to recurrence. Statistical analyses were performed using BellCurve for Excel (Social Survey Research Information Co., Ltd., Tokyo, Japan).

RESULTS

The results are summarized in [Tables 1-3]. The data on 194 patients (mean age, 79.6 ± 9.2 years; range, 55–97 years), consisting of 50 women (25.8%) and 144 men, were retrospectively reviewed [Table 1]. These patients collectively presented 88 left side, 58 right side, and 48 bilateral hematomas. A total of 136 patients (70.1%) experienced apparent traumatic head injury episodes; 43 patients (22.2%) underwent AC/AT; and 22 patients experienced recurrence [11.3%; Table 2]. In the recurrence cases, a larger hematoma volume was recorded than in non-recurrence cases (196.91 ± 84.1 vs. 123.57 ± 68.5 mL, $P < 0.001$). Univariate analysis revealed that sex, DM, and hematoma volume were significant risk factors for recurrence, while alcohol consumption habits and bilateral disease were correlated with recurrence [Tables 1 and 2].

Table 1: Baseline characteristics of patients with no-recurrence versus recurrence of CSDH.

Characteristic	No-recur (n=172)	Recur (n=22)	P-value
Mean age (SD), years	79.6 (9.4)	81.9 (6.3)	0.227
Sex			0.016
Female	49 (28)	1 (5)	
Male	123 (72)	21 (95)	
Poor preoperative mRS (3–5)	70 (41)	9 (41)	0.985
Alcohol intake	49 (28)	10 (45)	0.103
Ever smoker	17 (10)	2 (9)	0.906
Hypertension	95 (55)	12 (55)	0.951
Diabetes	37 (22)	9 (41)	0.044
Hyperlipidemia	42 (24)	4 (18)	0.517
Anticoagulants	37 (22)	6 (27)	0.540
Trauma history	123 (72)	13 (59)	0.231
Bilateral disease	38 (22)	8 (36)	0.138
Liver disease	10 (6)	2 (9)	0.548
Hematoma volume (SD)	123 (69)	197 (84)	<0.001
Hematoma volume 150 ml≤	47 (27)	16 (73)	<0.001
Observation after surgery, days (SD)	16 (10)	25 (16)	<0.001
Poor postoperative mRS (3–6)	68 (40)	9 (41)	0.901

Data are presented as number (%) unless otherwise indicated. Boldface type indicates statistical significance. mRS; modified Rankin Scale

Table 3: Comparison between patients with hematoma volume <150 ml and 150 ml ≤.

Characteristic	<150 ml (n=131)	150 ml ≤ (n=63)	P-value
Mean age (SD), yrs	79.0 (9.8)	81.0 (7.6)	0.20
Sex			0.43
Female	36 (27)	14 (22)	
Male	95 (73)	28 (78)	
Poor preoperative mRS (3–5)	51 (39)	9 (14)	0.46
Alcohol intake	45 (34)	14 (22)	0.086
Ever smoker	17 (13)	2 (3)	0.032
Hypertension	72 (55)	35 (56)	0.940
Diabetes	30 (23)	16 (26)	0.702
Hyperlipidemia	33 (25)	13 (21)	0.485
Anticoagulants	29 (22)	14 (23)	0.989
Trauma history	97 (74)	39 (64)	0.084
Bilateral disease	13 (10)	33 (54)	<0.001
Liver disease	10 (8)	2 (3)	0.227
Recurrence	6 (5)	16 (26)	<0.001
Hematoma volume (SD)	92 (33)	214 (67)	<0.001
Observation after surgery, days (SD)	15.8 (10)	19.3 (11)	<0.001
Poor postoperative mRS (3–6)	48 (37)	29 (48)	0.211

Data are presented as number (%) unless otherwise indicated. Boldface type indicates statistical significance

Table 2: Univariate analysis for odds of CSDH recurrence.

Variable	Univariate analysis		
	OR	95% CI	P-value
Demographics			
Mean age, years	1.03	0.98-1.09	0.23
Male	8.37	1.10-63.9	0.02
Medical history/comorbidity			
Poor preoperative mRS (3–5)	1.01	0.41-2.49	0.98
Alcohol intake	2.09	0.85-5.16	0.10
Ever smoker	0.91	0.20-4.24	0.91
Hypertension	0.97	0.40-2.37	0.95
Diabetes	2.53	1.00-6.37	0.04
Hyperlipidemia	0.69	0.22-2.15	0.52
Anticoagulants	1.37	0.50-3.74	0.54
Trauma history	0.58	0.23-1.43	0.23
Bilateral disease	2.02	0.79-5.16	0.14
Liver disease	1.62	0.33-7.93	0.55
Poor postoperative mRS (3–6)	1.06	0.43-2.61	0.90
Hematoma volume	1.01	1.01-1.02	<0.001
Hematoma volume 150 ml ≤	7.09	2.62-19.2	<0.001

Boldface type indicates statistical significance

According to the receiver operating characteristics (ROC) analysis, 150 mL was the predictive value for recurrence [sensitivity and specificity of 72.7% and 72.1%, respectively; area under the curve [AUC]: 0.7664, 95% CI: 0.654–0.879, $P < 0.001$, Figure 1a].

[Table 3] compares the hematoma volume between under 150 and over 150 mL groups. The results showed a higher incidence of bilateral disease, recurrence, and longer observation periods in the latter groups, whereas the age, sex, and number of diabetic patients did not significantly differ between the groups. Multiple logistic regression analyses showed that a hematoma volume over 150 mL was the only independent recurrence factor [Table 2 and Figure 1b]. Conversely, age, history of hypertension and hyperlipidemia, anticoagulant/antiplatelet intake, smoking habits, and pre- and post-operative modified Rankin scale did not affect CSDH recurrence [Tables 1 and 2].

Recurrence cases had longer observation periods than non-recurrence cases (24.8 ± 11.5 vs. 15.9 ± 9.7 d, respectively, $P < 0.001$), and ROC analysis revealed that the recurrence predictive cutoff value of follow-up periods was 17 days, with a sensitivity and specificity of 83.1% and 68.2%, respectively [AUC: 0.7707, 95% CI: 0.6695–0.8720, $P < 0.001$, Figure 2]. [Table 4] displays the results of a multivariable Cox regression analysis evaluating interaction in recurrence hazard, where hematoma volume > 150 mL was the only significant risk factor [hazard ratio [HR]: 3.05, 95% CI: 1.18–7.87, log-rank $P = 0.0046$, $P = 0.021$, Table 4]. The mean drainage hour and volume after surgery were 21.1 ± 8.3 h (7–48 h) and 126.7 ± 114.2 mL (0–600 mL), respectively, although these data were obtained since mid-2016 and there have been no significant differences between the non-recurrence and recurrence

Table 4: Cox regression analysis of CSDH recurrence hazard evaluating the interaction between hematoma volume, sex difference, and diabetes.

Characteristic	HR (95% CI)	Log-rank P value	P-value
Sex (male)	5.75 (0.76–43.6)	0.018	0.091
Diabetes	1.55 (0.65–3.68)	0.11	0.320
Hematoma volume ≥ 150 ml	3.05 (1.18–7.87)	0.0046	0.021

Boldface type indicates statistical significance

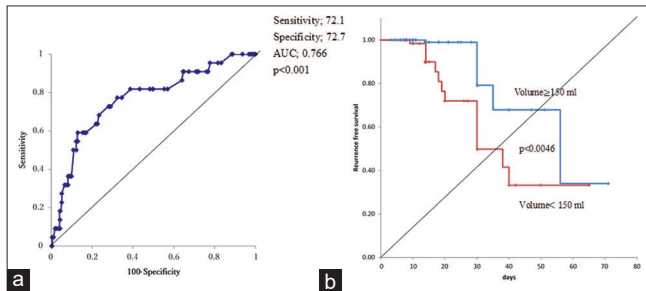


Figure 1: Hematoma volume and recurrence. (a) Receiver operating characteristic curve analysis for recurrence after burr hole surgery of chronic subdural hematoma reveals cut-off value of intraoperative hematoma volume. (b) Kaplan–Meier curves of recurrence-free survival after burr hole surgery for intraoperative hematoma volume >150 ml shows higher recurrence rate.

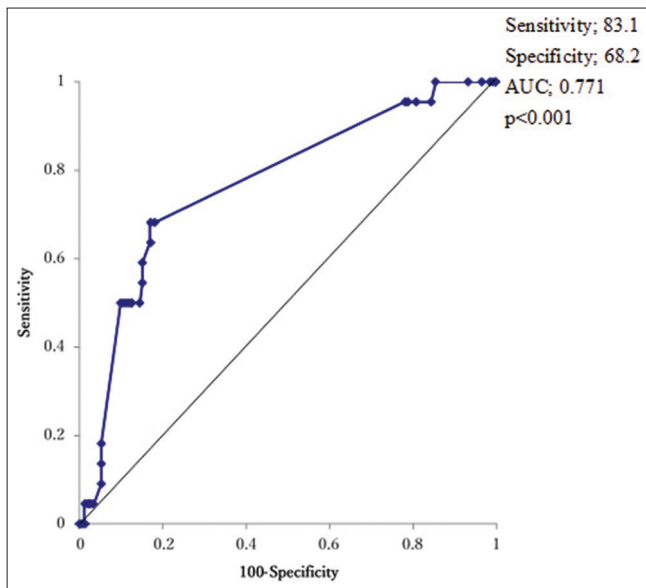


Figure 2: Receiver operating characteristic curve analysis for recurrence after burr hole surgery of chronic subdural hematoma reveals cutoff value of follow-up duration.

groups (20.7 ± 7.9 vs. 23.7 ± 10.7 h and 124.3 ± 110.7 vs. 143.5 ± 139.0 mL, respectively).

DISCUSSION

The annual incidence of CSDH is 3.4–20.6/100,000, but this increases to 7.35–127.1/100,000 in the elderly group (over 65 years or 80 years of age).^[7,15,16,20–22,25,31] Postsurgical recurrence of CSDH has been reported to occur in 0.36%–33% of the cases reported in the literature.^[5,7,18,21,22,31] The results of the current study fall within this range.

The predictive factors for recurrence were categorized as (1) Clinically: male sex, age, alcohol intake, coagulation abnormality (including anticoagulant/antiplatelet intake, liver diseases, and malignancy), DM; (2) Radiologically: hyper density hematoma on CT, bilateral disease, brain atrophy, midline shift, hematoma thickness, large hematoma volume, air, and/or residual hematoma volume after surgery; (3) symptomatically: aphasia, long symptom duration, and residual headache after surgery; and (4) methodologically: no drainage and irrigation or non-irrigation.^[3,6,7,11,15,18,19,22,23,25,34]

In the current study, we found that intraoperative hematoma volume is the strongest predictive factor of recurrence, followed by sex (male) and DM history, which agrees with the reported predictive factors.

Most previous studies have estimated hematoma volume by CT and/or MRI.^[3,12,27,28] We confirmed that the cutoff volume of recurrence is ≥ 150 mL, which is similar to the results of a recently reported series (≥ 160 mL, as measured by CT/MRI).^[30] We believe that most neurosurgeons simply discard evacuated hematoma, either directly or by diluting and washing away with irrigation. The no-irrigation method is critical for evaluating the exact hematoma volume and preventing the influx of foreign fluid into the hematoma cavity (normal saline or artificial cerebrospinal fluid) and arachnoid tear, which also results in cerebrospinal fluid leakage.^[9,28] Thickness, midline shift, or post-surgical subdural space are theoretically and physically associated with the hematoma volume itself.^[3,34] Thus, intraoperative hematoma volume measurement is an easy and simple way to record the nature of CSDH and should be officially recorded. However, further accumulation of records may be needed to assess its necessity.

To simplify the calculation of hematoma volume, we counted cases on an individual basis, unified the volume of both sides in bilateral disease and omitted complicated counts on the case and sides. Most volumetric studies using CT/MRI are one-dimensional (width) or two-dimensional studies, while three-dimensional analysis before surgery is a time-consuming method from the perspective of emergency medicine. Further development of computational analysis will solve these issues, but still be a virtual reality method.^[15] From the pathophysiologic perspective, hematoma volume and recurrence can be explained by repeated microbleeds from outer membrane and blood influxes into the persistent subdural cavity and macrophages

and inflammatory cytokines also interact the formation of hematoma.^[4,8,12,17,31] Thus, sufficient subdural space is the key factor for hematoma development and larger hematoma may more contain these cascading molecules.^[8,17] As a result, residual spaces (due to insufficient drainage) after surgery leads to refractory recurrence and introduction of middle meningeal artery embolization may be another choice of treatment theoretically.^[4,8]

CSDH is an apparently male-dominant disease, which was reflected in the results of this study; several hypotheses for this have been proposed, including that males are more likely to experience trauma and complications and a theoretical estrogen protective effect on microcapillary development on the hematoma membrane in females.^[6] The mean age and sex ratio obtained in our cohort are similar to that of national data.^[31] Recently, the incidence of CSDH has been reported to have increased; thus, age might not affect recurrence in the present case.^[31] Even under these circumstances, male sex is still an independent powerful predictive factor for CSDH recurrence and should be considered in conjunction with other predictive factors.

We reached the consensus that DM is a strong predictive factor for CSDH recurrence, as previously reported.^[1,15,29] In CSDH formation, exudation due to capillary vasculopathy caused by DM plays an important role in re-expansion of the CSDH cavity, and hyper viscosity due to DM of the subdural blood is expected to draw more water into the hematoma and increase the risk of recurrence.^[15,29] Similar to diabetic retinopathy, well-developed neovascularization of the neomembrane could still result in bleeding after surgery.^[1,15] Hyperdense CSDH due to repeat microhemorrhages from the immature capillary network favors recurrence, which may be related to the diabetic status of blood glucose level, and could be observed as hyper density on CT, although we did not check hematoma density in conjunction with DM history in this study.^[5] DM patients also take various medications because of complex complications and these may interact and have a negative influence on coagulopathy in CSDH patients.^[15] Therefore, appropriate blood glucose control may reduce recurrence. Further studies are needed to clarify the preventive effects of DM control.

Bilateral disease and alcohol consumption habits were associated with recurrence, although without statistical significance, but the former would physically increase hematoma volume with poor brain re-expansion compared to unilateral disease, and the latter leads to liver dysfunction and results in a poor anticoagulation status in the human body, which may explain this recurrence tendency.^[3,5,6,30]

Whether AC/AT is a risk factor for CSDH recurrence is controversial, as is the matter of discontinuation and resumption, or constant administration of these drugs during CSDH surgery.^[27,28,31] In this protocol, we discontinued AC/

AT, and only resumed administration after confirmation of no recurrence on CT. However, there have been many people who take these drugs, and more people will take them as society continues to age. We, therefore, suggest that these should not be routinely discontinued and that the possibility of permanent ischemic attack should be taken into consideration to decide on a case-by-case basis.^[28,31]

There is no consensus yet on an optimal follow-up imaging protocol, although several efforts have been made to ensure the surveillance of recurrence.^[12,31] CT for asymptomatic patients or routine repeated daily scanning seems less beneficial and may be unnecessary.^[10] The decision to conduct follow-up postoperative CT scans is based on the clinical status rather than routine scanning.^[12] We usually perform brain CT within 24 h, 1 week, and 2 weeks after surgery. CT at 2 weeks after surgery is equivalent to 1 week after discharge CT on outpatient visit. We continued to follow the cases if they had apparent or suspicious recurrence, including suggestive findings on CT, such as poor expansion of intrinsic brain parenchyma or subdural fluid collection, which were also considered as recurrence factors.^[1,3,6,12,15,20,27,28,30,31,34] As a result, follow-up days theoretically obtain longer recurrence-favor cases in our study. We believe that additional scans should be performed in selected patient groups considering socioeconomic costs and irradiation influence.

The use of saline irrigation of the hematoma cavity is dependent on the surgeon's preference, and whether irrigation is a risk factor for recurrence is also controversial.^[6-8,30] To reduce surgery time, we chose the no-irrigation method, and this was not a risk factor in the present study. As mentioned above, irrigation prevents foreign material influx into the cranium, but the rising effect on the hematoma cavity has also been reported.^[6] This controversy may continue in the future.

CSDH will become the most common neurosurgical disease in 10 years, and long-term outcomes of elderly patients with CSDH are poorer than expected, and we therefore do not recognize this disease as a benign disease in the senile developing world. CSDH is an important cause of morbidity and mortality and is associated with reduced long-term survival.^[5,31] Therefore, it is important to reduce the number of required surgeries, bed rest, and hospital stays and visits. Early elevation of the head and mobilization should be employed to prevent pneumonia and deep venous thrombosis.^[29] From the perspective of invasiveness, local anesthesia is preferred,^[2,20,22-25] while reduced or omitted irrigation helps shorten the operation time and increases patients' comfort during local anesthesia.^[8,30,33] Finally, a short drainage duration decreases bed rest and hospital stay.

Most reports regarding CSDH surgery seldom mentioned the actual drainage time and volume, only mentioning whether it was "overnight," "1-day," "2-days," or "48-h."^[1,9,14,17,27,28,30] The

drain was removed when no more drainage fluid appeared, or when the target volume according to the institution or physician was reached.^[3,28,30] To the best of our knowledge, we are the first to mention the exact postsurgery drainage time. The mean drainage hours were 21.1 ± 8.3 h (7–48 h), and there were no statistical differences between recurrent and non-recurrent cases. Considering the recurrence rate of 11.3% in this study, ~20 h should be sufficient for postsurgical drainage, which must be performed overnight (from midday to next morning). This protocol also reduces bed-rest time and patients could resume daily life as early as possible in the aging case increase of CSDH.^[31] Prolonged placement also leads to a rise in the infection rate, and early mobilization is recommended to avoid complications related to prolonged recumbence.^[17] The mean drainage volume in our study was 126.7 ± 114.2 ml (0–600 ml) and there were no statistical differences between recurrent and non-recurrent cases. The drainage volume includes irrigation saline or CSF, which leads to bias in the prediction of recurrence.^[10] In cases of bilateral disease, enlargement of non-operated hematoma due to high pressure in the hematoma cavity of the non-operated site was detected, and additional operation for non-operated hematomas (cut-off 44 cm³ or greater) led to rehospitalization and deterioration of activities of daily life.^[26] Therefore, we recommend simultaneous burr hole surgery on both sides, if possible. The primary goal is to relieve intracranial pressure and to prevent the angiogenic and inflammatory process and complete drainage is not necessary.^[27]

Atorvastatin, steroids, the ACE inhibitor, tranexamic acid, or Chinese herb Gorei-san use has been recommended to reduce recurrence.^[15,17,21,30,31] These drugs may act as an inflammation inhibitor alone or in conjunction.^[21] Although the hypertension and hyperlipidemia patients who took these medicines had no relationship with CSDH recurrence in this study, we routinely prescribe Gorei-san after surgery.^[15,30,31] Further studies are needed to clarify the role of these medicines in CSDH treatment.

As a result, we recommend the following methods for CSDH surgery: (1) single burr-hole surgery, (2) under local anesthesia, (3) recording intraoperative hematoma volume, (4) around 20 h drainage without irrigation (5) early discharge followed by CT examination after 1 week, and (6) with protective Gorei-san subscription.

This study has several limitations. The first was the lack of precise CT assessments of recurrence before and after surgery. Second, this study only followed a relatively small number of patients. Third, this was a retrospective study conducted at a single center. Fourth, all patients underwent the same surgery and anesthesia protocol (single burr hole under local anesthesia); thus, there was no comparison with other methods. Finally, the follow-up CT scans were evaluated

according to predetermined protocols, and the termination of follow-up was based on the physician's decision.

CONCLUSION

This study showed that intraoperative hematoma volume measurement could be a predictive value for CSDH recurrence. The patients followed up for more than 17 days and with hematoma volume > 150 mL should be carefully observed for recurrence, in addition to male patients and DM patients. Further prospective multicenter studies are required to evaluate these findings.

Author contributions to the study and manuscript preparation include the following: conception and design: Honda. Acquisition of data: Honda. Analysis and interpretation of data: Honda. Drafting the article: Honda. Critically revising the article: All authors. Reviewed submitted version of the manuscript: All authors. Statistical analysis: Honda.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Abouzari M, Rashidi A, Rezaii J, Esfandiari K, Asadollahi M, Aleali H. The role of postoperative patient posture in the recurrence of traumatic chronic subdural hematoma after burr-hole surgery. *Neurosurgery* 2007;61:794-7; discussion 797.
2. Adachi A, Higuchi Y, Fujikawa A, Machida T, Sueyoshi S, Harigaya K, *et al.* Risk factors in chronic subdural hematoma: Comprehension of irrigation with artificial cerebrospinal fluid and normal saline in a cohort analysis. *PLoS One* 2014;9:e103703.
3. Altaf I, Shams S, Vohra AH. Radiological predictors of recurrence of chronic subdural hematoma. *Pak J Med Sci* 2018;34:194-7.
4. Ban SP, Hwang G, Byoun HS, Kim T, Lee SU, Bang JS, *et al.* Middle meningeal artery embolization for chronic subdural hematoma. *Radiology* 2018;286:992-9.
5. Basler D, Farooq S, Mehmood T, Reyes M, Samadani U. Actual and projected incidence rates for chronic subdural hematomas in United States Veterans administration and civilian populations. *J Neurosurg* 2015;123:1209-15.
6. Chen FM, Wang K, Xu KL, Wang L, Zhan TX, Cheng F, *et al.* Predictors of acute intracranial hemorrhage and recurrence of chronic subdural hematoma following burr hole drainage.

- BMC Neurol 2020;20:92.
7. Hammer A, Tregubow A, Kerry G, Schrey M, Hammer C, Steiner HH. Predictors for recurrence of chronic subdural hematoma. *Turk Neurosurg* 2017;27:756-62.
 8. Hashimoto T, Ohashi T, Watanabe D, Koyama S, Namatame H, Izawa H, *et al.* Usefulness of embolization of the middle meningeal artery for refractory chronic subdural hematomas. *Surg Neurol Int* 2014;4:104.
 9. Honda M, Maeda H. Chronic subdural hematoma; necessity of irrigation and preventive factors of recurrence. *Int J Curr Med Pharm Res* 2017;3:2389-91.
 10. Huang YH. Volume of chronic subdural haematoma: Is it one of the radiographic factors related to recurrence? *Injury* 2014;45:1327-31.
 11. Ivamoto H, Lemos H Jr., Atallah A. Surgical treatment for Chronic subdural hematomas: A comprehensive systemic review. *World Neurosurg* 2016;86:399-418.
 12. Jang KM, Choi HH, Mun HY, Nam TK, Park YS, Kwon JT. Critical depressed brain volume influences the recurrence of chronic subdural hematoma after surgical evacuation. *Sci Rep* 2010;10:1145.
 13. Javadi SA, Naderi F, Javadi AM. The optimal surgical approach for treatment of chronic subdural hematoma: Questionnaire assessment of practice in Iran and review of the literature. *Acta Med Iran* 2015;53:617-21.
 14. Kim J, Moon J, Kim T, Ahn S, Hwang G, Bang J, *et al.* Risk factor analysis for the recurrence of chronic subdural hematoma: A review of 368 consecutive surgical cases. *Korean J Neurotrauma* 2015;11:63-9.
 15. Kim SU, Lee DH, Kim YI, Yang SH, Sung JH, Cho CB. Predictive factors for recurrence after burr-hole craniostomy of chronic subdural hematoma. *J Korean Neurosurg Soc* 2017;60:701-9.
 16. Kudo H, Kuwamura K, Izawa I, Sawa H, Tamaki N. Chronic subdural hematoma in elderly people: Present status on Awaji Island and epidemiological prospect. *Neurol Med Chir (Tokyo)* 1992;32:207-9.
 17. Lee KS. How to treat chronic subdural hematoma? Past and now. *J Korean Neurosurg Soc* 2019;62:144-52.
 18. Liu W, Bakker NA, Groen JM. Chronic subdural hematoma: A systemic review and meta-analysis of surgical procedures. *J Neurosurg* 2014;121:665-73.
 19. Neto JF, Araujo JLV, Ferraz VR, Haddad L, Veiga JC. Chronic subdural hematoma: Epidemiological and prognostic analysis of 176 cases. *Rev Col Bras Cir* 2015;42:283-7.
 20. Okada Y, Akai T, Okamoto K, Iida T, Takata H, Iizuka H. A comparative study of the treatment of chronic subdural hematoma--burr hole drainage versus burr hole irrigation. *Surg Neurol* 2002;57:405-9; discussion 410.
 21. Qiu S, Zhuo W, Sun C, Su Z, Yan A, Shen L. Effects of atorvastatin on chronic subdural hematoma: A systematic review. *Medicine* 2017;96:e7290.
 22. Ro HW, Park SK, Jang DK, Yoon WS, Jang KS, Han YM. Preoperative predictive factors for surgical and functional outcomes in chronic subdural hematoma. *Acta Neurochir (Wien)* 2016;158:135-9.
 23. Rovlias A, Theodoropoulos S, Papoutsakis D. Chronic subdural hematoma: surgical management and outcome in 986 cases: A classification and regression tree approach. *Surg Neurol Int* 2015;6:127.
 24. Santarius T, Kirkpatrick PJ, Ganesan D, Chia HL, Jalloh I, Smielewski P, *et al.* Use of drains versus no drains after burr-hole evacuation of chronic subdural haematoma: A randomised controlled trial. *Lancet* 2009;374:1067-73.
 25. Schwarz F, Loos F, Dünisch P, Sakr Y, Safatli DA, Kalff R, *et al.* Risk factors for reoperation after initial burr hole trephination in chronic subdural hematomas. *Clin Neurol Neurosurg* 2015;138:66-71.
 26. Stanišić M, Hald J, Rasmussen IA, Pripp AH, Ivanović J, Kolstad F, *et al.* Volume and densities of chronic subdural haematoma obtained from CT imaging as predictors of postoperative recurrence: A prospective study of 107 operated patients. *Acta Neurochir (Wien)* 2013;155:323-33.
 27. Stavrinou P, Katsigiannis S, Lee JH, Hamisch C, Kriscsek B, Mpotsaris A, *et al.* Risk factors for chronic subdural hematoma recurrence identified using quantitative computed tomography analysis of hematoma volume and density. *World Neurosurg* 2017;99:465-70.
 28. Takahashi S, Yamauchi T, Yamamura T, Ogishima T, Arai T. Proposal of treatment strategies for bilateral chronic subdural hematoma based on laterality of treated hematoma. *Asian J Neurosurg* 2018;13:1134-9.
 29. Torihashi K, Sadamasa N, Yoshida K, Narumi O, Chin M, Yamagata S. Independent predictors for recurrence of chronic subdural hematoma: A review of 343 consecutive surgical cases. *Neurosurgery* 2008;63:1125-9.
 30. Uda H, Nagm A, Ichinose T, Onishi Y, Yoshimura M, Tsuruno T, *et al.* Burr hole drainage without irrigation for chronic subdural hematoma. *Surg Neurol Int* 2020;11:89.
 31. Uno M, Toi H, Hirai S. Chronic subdural hematoma in elderly patients: Is this disease benign? *Neurol Med Chir (Tokyo)* 2017;57:402-9.
 32. Weigel R, Schmiedek P, Krauss JK. Outcome of contemporary surgery for chronic subdural haematoma: Evidence-based review. *J Neurol Neurosurg Psychiatry* 2003;74:937-43.
 33. Xu C, Chen S, Yuan L, Jing Y. Burr-hole irrigation with closed-system drainage for the treatment of chronic subdural hematoma: A meta-analysis. *Neurol Med Chir (Tokyo)* 2016;56:62-8.
 34. Yamamoto H, Hirashima Y, Hamada H, Hayashi N, Origasa H, Endo S. Independent predictors of recurrence of chronic subdural hematoma: Results of multivariate analysis performed using a logistic regression model. *J Neurosurg* 2003;98:1217-21.

How to cite this article: Honda M, Maeda H. Intraoperative hematoma volume can predict chronic subdural hematoma recurrence. *Surg Neurol Int* 2021;12:232.