Development of the Chronic Subdural Hematoma Grading System to Predict Postoperative Recurrence

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Abstract

Objective Assessing the risk of postoperative recurrence of chronic subdural hematoma (CSDH) is a clinical focus. To screen the main factors associated with the perioperative hematoma recurrence. We also propose a new prognostic grading system and compare it with previous grading systems to deliver a quick and effective system.

Methods We included 242 unilateral patients with CSDH as the training group for modeling. Factors predicting postoperative recurrence requiring reoperation (RrR) were determined using univariate and multivariate regression analyses. The cut-off value for the brain re-expansion rate was determined through receiver operating characteristic curve analysis. Based on these, we developed a new prognostic scoring system and conducted preliminary verification. A verification group including 119 patients with unilateral CSDH was used to verify the predictive performance of the new and other grading systems.

Results The key factors for predicting unilateral CSDH recurrence were cerebral re-expansion rate ($\leq 40\%$) at postoperative days 7 – 9 and the preoperative computed tomography density classification (isodense or hyperdense, or separated or laminar types). Cerebral atrophy played a key role in brain re-expansion. The CSDH prognostic grading system ranged from 0 to 3. An increased score was associated with a more accurate progressive increase in the RrR rate. Our grading system demonstrated the best predictive performance compared with other systems (area under the curve = 0.856).

Conclusions Our prognostic grading system could quickly and effectively screen high-risk RrR patients with unilateral CSDH. However, increased attention should be paid to brain re-expansion rate after surgery in patients with CSDH.

Introduction

Chronic subdural hematoma (CSDH) is a common neurological disease in the elderly. The incidence among people over 65 years of age is 80.1/100,000/year¹³, and the average age of onset is 76.8 years²⁶. Currently, surgery is the chief mode of treatment along with the use of drugs as a supplement. Minimally invasive surgery can quickly and effectively remove the hematoma, relieve the pressure on the brain tissue, and improve the clinical symptoms of the patient. Improved surgical skills and perioperative management have significantly reduced the postoperative recurrence requiring reoperation (RrR) rate. Nonetheless, the recurrence rate after surgery remains at 10.9% – 26.3%^{1,30}.

Assessment of the risk of postoperative recurrence in CSDH has been proven challenging in clinical research. The risk factors of recurrence reported so far mainly include the general clinical characteristics of the patient and the surgical methods, perioperative management methods, and imaging characteristics used^{5,17,21,22,28}. Among them, imaging characteristics play a very important role.

The changes in perioperative imaging in CSDH include the following: the volume and maximum width of the hematoma, the volume and maximum width of the effusion, the distance of the midline shift, the

volume of gas, the computed tomography (CT) density of the hematoma, and the effusion or signal manifestation of the MRI image of the hematoma and effusion. CT is routinely used for perioperative examination because of the ease of simple operation and the relatively low costs involved. This study retrospectively analyzed the general clinical characteristics and CT imaging parameters of patients with CSDH to determine the factors related to postoperative recurrence. The key factors were selected to establish a recurrence risk model grading system, which was compared with other previously published grading systems^{8,29,32}. The aim of this study is to develop a convenient and effective recurrence grading model system for clinical use.

Methods

Patients

A retrospective review of 242 patients with unilateral CSDH who were treated via surgical evacuation between July 2017 and October 2020 at The First Hospital of Jilin University was conducted. All patients were evaluated for appropriateness of surgical intervention using CT. The patients underwent burr-hole irrigation with saline under general anesthesia, following which a catheter attached to a closed-system drainage was constructed. The drainage tube was usually removed 24 h after the surgery.

The following clinical and demographic data were recorded: sex, age, atrophy, history of trauma, smoking, alcohol abuse, comorbidities (hypertension, diabetes mellitus, heart disease, and cerebral infarction), anticoagulant and antiplatelet use, coagulation evaluation (platelet count, INR, and APTT), and complication (epilepsy).

CT scanning was performed once preoperatively and twice postoperatively (before drainage tube removal on postoperative day 1 and patient discharge on postoperative days 7–9).

A picture archiving and communication system was used to gather preoperative and postoperative radiographic data, which included the preoperative hematoma characteristics (volume, density characteristics²³, and maximal thickness), postoperative effusion characteristics (volume, density characteristics, and maximal thickness), postoperative residual air volume, pre- and postoperative midline shift, and cerebral re-expansion rate (which was calculated using the equation: $\text{preoperative hematoma volume} - \text{postoperative effusion volume} / \text{preoperative hematoma volume} \times 100\%$) from the CT scans of the head. Quantitative imaging characteristics were analyzed using the Philips IntelliSpace Discovery 3.0 software (ISD3.0, Philips, US). For quantitative volumetric analysis, the hematoma, effusion, and residual air margins were traced for each axial slice, and the volumes were calculated using the software. The quantitative image analysis was performed by a neuroradiologist who was blinded to the CSDH recurrence.

The recurrence measure was reoperation after the first surgery due to hematoma reaccumulation by CT scan and reappearance of neurological deficits with 6 months (exclude postoperative acute subdural

hematoma).

All patients underwent a six-month follow-up. Ethical approval for this study was obtained from the Institutional Review Board of The First Hospital of Jilin University (IRB00008484). The requirement to obtain informed consent from the patients for the use of the materials was waived based on the retrospective nature of the study under the approval of the IRB.

Statistical Analyses

Research data were described using categorical variables (percentage of patients) and continuous variables (mean $\pm$ standard deviation). The risk factors of recurrence were first performed by univariate analysis. The χ^2 test or Fisher's exact test was used for categorical variables, and the Student's *t*-test or Man–Whitney *U* test was used for continuous variables. Subsequently, a logistical regression model was used for multivariate analysis, and variable selection was based on a *p* value of < 0.01 . Regression coefficients were scaled and rounded off to obtain the weighting of variables. The ability of predicting the postoperative recurrence of CSDH was determined using the receiver operating characteristic (ROC) curve. The cut-off value was defined as the highest sum of sensitivity and specificity calculated based on the Youden index. Finally, the scoring system for predicting the recurrence of CSDH was internally verified, and the ROC curve was used to compare different scoring systems. All data were analyzed using the SPSS version 22.0 software (IBM, Armonk, New York) and the MedCalc version 19.0 software (MedCalc Software, Ostend, Belgium). A two-tailed *p* < 0.05 was considered statistically significant.

Results

Clinical Characteristics of the Patients

Of the 242 patients who underwent surgery for unilateral CSDH, 211 were males and 31 were females (age range, 21–91 years; mean age, 64.7 ± 14.4 years). Patient demographic and clinical data are shown in Tables 1. Reoperation was performed on 14 patients (5.8%) (Supplemental Table 4).

Risk Factors for RrR of CSDH

Associations between various individual variables and reoperation are shown in Tables 1. Univariate analyses showed that age > 65 years, atrophy, preoperative CT classification based on the density of the hematoma, and postoperative radiographic factors (effusion volume, cerebral re-expansion rate, maximal effusion thickness [> 20 mm], and midline shift [> 5 mm]) were associated with a significantly higher RrR (Table 1). Furthermore, effusion volume, cerebral re-expansion rate, maximal effusion thickness, and midline shift demonstrated more sensitivity on days 7–9 than on day 1 (Supplemental Table 1 and Fig. 1). Multivariate analysis showed that isodense/hyperdense or separated/laminar types of CT images and cerebral re-expansion rate were independent risk factors for potential CSDH recurrence at postoperative days 7–9 (Tables 1).

Predicting the Formula of Cerebral Re-expansion

In previous studies, the hematoma clearance rate was determined by calculating the change in the maximum thickness or volume of hematoma before and after surgery (Supplemental Table 2). We found that this formula could indirectly reflect the re-expansion rate in cerebral tissues. In addition, we proposed that the midline shift could reflect the cerebral re-expansion rate before and after surgery. ROC curve analysis was used to compare the abilities of three cerebral re-expansion formulas to predict RrR. Pairwise comparisons of the AUCs of the three cerebral expansion formulas did not show any statistically significant differences (Supplemental Table 5 and Fig. 2). Moreover, the maximum thickness re-expansion rate was clinically easy to calculate and did not require any other software. The cerebral re-expansion rate was used based on the maximum thickness for the analysis of the clinical data in this study.

Risk Factors for Cerebral Re-expansion

The factors that affected the cerebral re-expansion rate were evaluated. ROC curve analysis was used to determine the cut-off point (41.18%). Re-expansion rates of $> 40\%$ and $\leq 40\%$ were considered good re-expansion and partial re-expansion, respectively (Fig. 2). Univariate analysis showed that the cerebral re-expansion rate was significantly related to cerebral atrophy. Age (> 65 years) and brain trauma (> 30 days) were associated with cerebral re-expansion (Table 2). Multivariate analysis showed that cerebral atrophy was the only factor related to the cerebral re-expansion rate (Table 2).

RrR Grading System of CSDH

The preoperative hematoma density on CT according to the classification described by Nakaguchi et al.²³ and re-expansion at postoperative days 7–9 were identified as independent recurrent factors in unilateral CSDH patients (Table 3). These results of the regression modeling were the basis for the development of the new CSDH classification system. Risk factors related to RrR were used in a statistical selection test to identify and create the most effective model for a scoring system based on high-risk patient groups for RrR. The new grading system developed in this study consisted of the preoperative hematoma density on CT and the re-expansion at postoperative days 7–9, and scores were assigned based on the strength and regression coefficients associated with RrR. The CSDH prognostic grading system ranged from 0 to 3 (Table 4). An increase in the score was associated with a more accurate progressive increase in the RrR rate (Nagelkerke $R^2 = 0.504$; $p < 0.001$).

Internal Validation and Comparison of the RrR Model

Internal validation with the other cohorts ($n = 119$, Supplemental Table 3) was performed to examine the predictive power. Furthermore, the Changchun model was compared with different grading models to predict the RrR (Supplemental Table 6)^{8,27,29}. The results showed that the Changchun model was more accurate than the different models in its ability to predict the RrR ($p < 0.001$). Likewise, the ROC curve analysis revealed that the Changchun model was better at predicting the recurrence (AUC = 0.856; Fig. 3 and Table 5).

Discussion

Several factors affect the recurrence of CSDH after surgery, including the general clinical characteristics of the patient, surgical skills, perioperative management, and imaging characteristics, which are closely related to the recurrence^{5,17,21,22,28}. Owing to advancements in research, clinicians can reduce surgical complications by improving the surgical skills and strengthening perioperative management, yet cases of postoperative recurrence continue to be reported. This may be attributed to the structural characteristics of the brain tissue and the pathological characteristics of the hematoma.

The brain tissue is similar to an elastic sponge. A high-quality sponge has good resilience and can re-expand quickly after decompression, whereas poor quality sponges rebound slowly after compression and have poor recruitment effects⁹. The cord separation of the hematoma cavity is likely to cause poor drainage. Furthermore, the presence of fresh blood in the hematoma fluid indicates that the disease is in the active phase and might be associated with postoperative recurrence^{6,21}. These characteristics can be observed by analyzing the imaging parameters during the perioperative period.

The clinical factors related to RrR were retrospectively analyzed in this study. As reported previously, age (> 65 years) was related to recurrence^{3,12}. The imaging characteristics during the perioperative period play an important role in the assessment of the RrR. The univariate analysis shows that the preoperative CT classification, volume of effusion, midline shift, effusion thickness, and cerebral re-expansion rate after surgery were related to recurrence. These results are consistent with those reported previously^{2,9,24,28}.

Cerebral re-expansion rate is calculated as the change in brain tissue volume before and after surgery. Under the condition of a fixed cranial cavity volume, the effusion and volume change of a hematoma before and after surgery can indirectly reflect the cerebral re-expansion rate^{11,15}. However, some studies defined brain re-expansion rate as the change in the maximal thickness of the hematoma and the maximal thickness of the effusion before and after surgery^{19,20,25} (Supplemental Table 2). The volumes of the hematoma and the effusion in the formula for the brain re-expansion rate need to be calculated using software, which is not convenient for clinical application. In this study, three formulas were compared based on the volume, maximal thickness, and midline shift ratios. The formulas demonstrated similar predictive effects, especially the ones based on the maximal thickness ratio and the volume ratio (AUC difference = 0.002; $p = 0.983$; Supplemental Table 5 and Fig. 2). The calculation of the maximal thickness of the hematoma and effusion does not require software assistance and can be conveniently applied in the clinical setting. Therefore, we use the formula based on the maximal thickness ratio as that for the cerebral re-expansion rate in the grading system.

Cerebral atrophy was found to affect the re-expansion of the brain tissue ($p = 0.002$). In addition, age (> 65 years) and injury time (> 30 days) had a tendency to influence the re-expansion ($p = 0.091$ and $p = 0.057$). Multivariate analysis revealed that atrophy was the only factor that affected the re-expansion rate ($p = 0.015$). Previous studies have found that cerebral atrophy, long injury time (> 30 days), and old age are high-risk factors for CSDH recurrence, and these factors are related to the cerebral re-expansion

rate^{19,20,25}. This means that the cerebral re-expansion rate is a hub in the collection of the above risk factors.

The pathological characteristics of CSDH are closely related to the characteristics of the CT imaging²³. The density of the images on the CT scan is closely related to hematoma recurrence¹⁸. The homogeneous type includes three subtypes (hypodense, isodense, and hyperdense). The separated type is defined as a higher density component under a lower density component, and there is a clear boundary between them. If two components are mixed without a boundary, it is called the gradation type. The laminar type is defined as a hematoma that presents with a dense layer running along the inner membrane. The trabecular type is defined as a hematoma with a low iso-density component and a high-density septum that separates the inner and outer membranes. In the pathophysiology of CSDH, the hypodense and gradation subtypes are considered to have a moderate tendency to re-bleed, and the trabecular type is considered to be the regression stage of these lesions²³. The isodense, hyperdense, laminar, and separated types have a high-risk of recurrence²⁸. Conversely, the hypodense, gradation, and trabecular types have a low risk of recurrence.

The data of 242 patients were used to establish a model scoring system to assess the recurrence of CSDH following which another group (119 patients, June 2015 to July 2016) was used to verify the grading system. The factors predicting postoperative recurrence were screened out, and those that met the criteria were incorporated into the multiple regression analysis model. It was concluded that the cerebral re-expansion rate and preoperative CT imaging classification were important independent predictors of RrR. According to the ROC curve analysis, the critical threshold of the postoperative cerebral re-expansion rate (cut-off point, 40%) was determined. According to the intensity and regression coefficients associated with RrR to assign scores to establish a grading system. The prediction performance of the new model was compared with those of the previously published models in the validation group, and the new model had a better evaluation effect (AUC = 0.856). The main parameters of the model were easy to collect clinically and could quickly screen the RrR high-risk patients, thereby providing a reference for guiding the treatment.

Past studies have established models to evaluate high-risk patients for RrR. They have good clinical application values but are associated with some shortcomings. The Alberta grading system only includes preoperative clinical and imaging parameters without the postoperative factors and cannot fully reflect the perioperative imaging changes⁸. In the Oslo grading system, the preoperative hematoma volume cut-off point is 130 mL, and the postoperative residual cavity volume cut-off points are 80 and 120 mL²⁹. In the Xining grading system, the thresholds for the volume of the hematoma before the operation and the volume of the postoperative residual cavity are 121 and 72 mL, respectively³³. However, it is not suitable for different races to use the same fixed volume parameter threshold due to limitations in clinical application. The Xining grading system adopts the Nomogram Model, which is a relatively innovative method, but the outcome of predicting the recurrence is binary. The proportion of postoperative gas accumulation in the Wuhu grading system is an important factor²⁷. However, with improvements in

surgical skills, the amount of postoperative gas produced is reduced and does not affect the patient's prognosis⁷. On the contrary, the cerebral re-expansion rate can more accurately reflect the changes in the patient's perioperative imaging.

Comparisons of the relationship between bilateral CSDH and cerebral re-expansion rate indicated that the postoperative re-expansion ability of bilateral CSDH was weaker ($p = 0.028$; Supplemental Table 3). This result was consistent with those reported in previous studies¹⁵. Consequently, the unilateral grading system cannot be applied to patients with bilateral CSDH. We need develop a model to predict the recurrence of bilateral CSDH³².

The parameters of postoperative day 1 were mostly used in some studies^{29,32}. In the current study, the imaging parameters of postoperative day 1 were compared with those of days 7–9. The 7–9th day parameters demonstrated better predictive abilities of the recurrence of CSDH (Supplemental Table 1 and Fig. 1). The re-expansion is greatest during the first week after surgery and slows down considerably after that⁹.

Cerebral re-expansion is very important to reduce recurrence. The current methods used to increase the re-expansion rate of the brain tissue include the following: intraoperative aspiration of pneumocephalus via a subdural drain following evacuation⁴, neuroendoscopic removal of the residual septa and trabecula structures to promote brain expansion¹⁴, postoperatively performed supervised Valsalva maneuver (SVM)³¹, administration of at least 2000 mL per 3 days¹⁰, and early mobilization¹⁶. These methods reduce potential subdural space and promote cerebral expansion, thereby decreasing RrR.

One of the limitations of this study is that it is a single-center study. Hence, further verifications using multicenter studies are warranted.

Conclusions

In this study, cerebral re-expansion was found to play an important role in the RrR of CSDH. On the basis of the preoperative CT imaging classification and cerebral re-expansion rate, a grading model system for assessing recurrence was established. This model was validated and compared with previously used models, and it was found to be the most effective. These findings suggest that the postoperative recurrence of CSDH can be reduced by increasing the cerebral re-expansion rate.

Declarations

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Conflicts of interest/Competing interests The authors declare no competing interests.

Availability of data and material The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the First Hospital of Jilin University (IRB00008484).

Consent to participate Not applicable.

Consent for publication Not applicable.

Authors' contributions Li Bie contributed to the study conception and design. Also, all authors were involved in material preparation and data collection. Data analysis was performed by Shuai Han. The first draft of the manuscript was written by Li Bie, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

References

1. Almenawer SA, Farrokhyar F, Hong C, Alhazzani W, Manoranjan B, Yarascavitch B et al (2014) Chronic subdural hematoma management: a systematic review and meta-analysis of 34,829 patients. *Ann Surg* 259:449–457
2. Andersen-Ranberg NC, Debrabant B, Poulsen FR, Bergholt B, Hundsholt T, Fugleholm K (2019) The Danish chronic subdural hematoma study-predicting recurrence of chronic subdural hematoma. *Acta Neurochir (Wien)* 161:885–894
3. Bartek J Jr, Sjavik K, Dhawan S, Sagberg LM, Kristiansson H, Stahl F et al (2019) Clinical Course in Chronic Subdural Hematoma Patients Aged 18–49 Compared to Patients 50 Years and Above: A Multicenter Study and Meta-Analysis. *Front Neurol* 10:311
4. Chavakula V, Yan SC, Huang KT, Liu J, Bi WL, Rozman P et al (2020) Subdural Pneumocephalus Aspiration Reduces Recurrence of Chronic Subdural Hematoma. *Oper Neurosurg (Hagerstown)* 18:391–397
5. Gazzeri R, Laszlo A, Faiola A, Colangeli M, Comberiati A, Bolognini A et al (2020) Clinical investigation of chronic subdural hematoma: Relationship between surgical approach, drainage location, use of antithrombotic drugs and postoperative recurrence. *Clin Neurol Neurosurg* 191:105705
6. Goto H, Ishikawa O, Nomura M, Tanaka K, Nomura S, Maeda K (2015) Magnetic resonance imaging findings predict the recurrence of chronic subdural hematoma. *Neurol Med Chir (Tokyo)* 55:173–178
7. Huang GH, Li XC, Ren L, Dai RX, Sun ZL, Jiang XF et al (2020) Take it seriously or not: postoperative pneumocephalus in CSDH patients? *Br J Neurosurg* 34:284–289
8. Jack A, O'Kelly C, McDougall C, Findlay JM (2015) Predicting recurrence after chronic subdural haematoma drainage. *Can J Neurol Sci* 42:34–39
9. Jang KM, Choi HH, Mun HY, Nam TK, Park YS, Kwon JT (2020) Critical Depressed Brain Volume Influences the Recurrence of Chronic Subdural Hematoma after Surgical Evacuation. *Sci Rep*

10. Janowski M, Kunert P (2012) Intravenous fluid administration may improve post-operative course of patients with chronic subdural hematoma: a retrospective study. *PLoS One* 7:e35634
11. Jeong SI, Kim SO, Won YS, Kwon YJ, Choi CS (2014) Clinical Analysis of Risk Factors for Recurrence in Patients with Chronic Subdural Hematoma Undergoing Burr Hole Trephination. *Korean J Neurotrauma* 10:15–21
12. Kanazawa T, Takahashi S, Minami Y, Jinzaki M, Toda M, Yoshida K (2020) Prediction of postoperative recurrence of chronic subdural hematoma using quantitative volumetric analysis in conjunction with computed tomography texture analysis. *J Clin Neurosci* 72:270–276
13. Karibe H, Kameyama M, Kawase M, Hirano T, Kawaguchi T, Tominaga T (2011) [Epidemiology of chronic subdural hematomas]. *No Shinkei Geka* 39:1149–1153
14. Kayaci S, Kanat A, Koksall V, Ozdemir B (2014) Effect of inner membrane tearing in the treatment of adult chronic subdural hematoma: a comparative study. *Neurol Med Chir (Tokyo)* 54:363–373
15. Kung WM, Hung KS, Chiu WT, Tsai SH, Lin JW, Wang YC et al (2012) Quantitative assessment of impaired postevacuation brain re-expansion in bilateral chronic subdural haematoma: possible mechanism of the higher recurrence rate. *Injury* 43:598–602
16. Kurabe S, Ozawa T, Watanabe T, Aiba T (2010) Efficacy and safety of postoperative early mobilization for chronic subdural hematoma in elderly patients. *Acta Neurochir (Wien)* 152:1171–1174
17. Miah IP, Herklots M, Roks G, Peul WC, Walchenbach R, Dammers R et al (2020) Dexamethasone Therapy in Symptomatic Chronic Subdural Hematoma (DECSA-R): A Retrospective Evaluation of Initial Corticosteroid Therapy versus Primary Surgery. *J Neurotrauma* 37:366–372
18. Miah IP, Tank Y, Rosendaal FR, Peul WC, Dammers R, Lingsma HF et al (2021) Radiological prognostic factors of chronic subdural hematoma recurrence: a systematic review and meta-analysis. *Neuroradiology* 63:27–40
19. Mori K, Maeda M (2003) Risk factors for the occurrence of chronic subdural haematomas after neurosurgical procedures. *Acta Neurochir* 145:533–540
20. Mori K, Maeda M (2001) Surgical treatment of chronic subdural hematoma in 500 consecutive cases: clinical characteristics, surgical outcome, complications, and recurrence rate. *Neurol Med Chir (Tokyo)* 41:371–381
21. Motiei-Langroudi R, Stippler M, Shi S, Adeeb N, Gupta R, Griessenauer CJ et al (2018) Factors predicting reoperation of chronic subdural hematoma following primary surgical evacuation. *J Neurosurg* 129:1143–1150
22. Motoie R, Karashima S, Otsuji R, Ren N, Nagaoka S, Maeda K et al: Recurrence in 787 Patients with Chronic Subdural Hematoma: Retrospective Cohort Investigation of Associated Factors Including Direct Oral Anticoagulant Use. **World Neurosurg** 118:e87-e91, 2018
23. Nakaguchi H, Tanishima T, Yoshimasu N (2001) Factors in the natural history of chronic subdural hematomas that influence their postoperative recurrence. *J Neurosurg* 95:256–262

24. Ohba S, Kinoshita Y, Nakagawa T, Murakami H: The risk factors for recurrence of chronic subdural hematoma. *Neurosurg Rev* 36:145–149; discussion 149–150, 2013
25. Ro HW, Park SK, Jang DK, Yoon WS, Jang KS, Han YM (2016) Preoperative predictive factors for surgical and functional outcomes in chronic subdural hematoma. *Acta Neurochir (Wien)* 158:135–139
26. Santarius T, Kirkpatrick PJ, Ganesan D, Chia HL, Jalloh I, Smielewski P et al (2009) Use of drains versus no drains after burr-hole evacuation of chronic subdural haematoma: a randomised controlled trial. *Lancet* 374:1067–1073
27. Shen J, Xin W, Li Q, Gao Y, Zhang J (2019) A Grading System For The Prediction Of Unilateral Chronic Subdural Hematoma Recurrence After Initial Single Burr Hole Evacuation. *Risk Manag Healthc Policy* 12:179–188
28. Stanisic M, Hald J, Rasmussen IA, Pripp AH, Ivanovic 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)* 155:323–333; discussion 333, 2013
29. Stanisic M, Pripp AH (2017) A Reliable Grading System for Prediction of Chronic Subdural Hematoma Recurrence Requiring Reoperation After Initial Burr-Hole Surgery. *Neurosurgery* 81:752–760
30. Toi H, Kinoshita K, Hirai S, Takai H, Hara K, Matsushita N et al (2018) Present epidemiology of chronic subdural hematoma in Japan: analysis of 63,358 cases recorded in a national administrative database. *J Neurosurg* 128:222–228
31. Won SY, Dubinski D, Behmanesh B, Bernstock J, Keil F, Freiman T et al: Supervised Valsalva Maneuver after Burr Hole Evacuation of Chronic Subdural Hematomas: a Prospective Cohort Study. **J Neurotrauma**, 2020
32. Won SY, Dubinski D, Eibach M, Gessler F, Herrmann E, Keil F et al: External validation and modification of the Oslo grading system for prediction of postoperative recurrence of chronic subdural hematoma. **Neurosurg Rev**, 2020
33. Yan C, Yang MF, Huang YW (2018) A Reliable Nomogram Model to Predict the Recurrence of Chronic Subdural Hematoma After Burr Hole Surgery. *World Neurosurg* 118:e356–e366

Tables

Table 1. Clinical and Imaging characteristics of patients with CSDH (n = 242)

Factors	Number of Patients (%)		Univariable analysis <i>p</i> value	Multivariable analysis value	<i>p</i>	Multivariable analysis OR (95% CI)
	No Recurrence	Recurrence				
Clinical characteristics						
Total	228 (94.2)	14 (5.8)				
Sex(male)	198 (86.8)	13 (92.9)	0.513			
Age > 65 years	124 (54.4)	13 (92.9)	0.005*	0.227		4.04 (0.42-39.02)
Atrophy	67 (29.4)	8 (57.1)	0.029*	0.100		3.42 (0.79-14.76)
History of Trauma	147 (64.8)	11 (78.6)	0.291			
Smoking	105 (46.1)	9 (64.3)	0.185			
Alcohol abuse	55 (24.1)	5 (35.7)	0.333			
Hypertension	59 (25.9)	5 (35.7)	0.418			
Diabetes mellitus (DM)	48 (21.1)	5 (35.7)	0.198			
Heart disease	43 (18.7)	5 (35.7)	0.125			
Cerebral infarction	26 (11.4)	3 (21.4)	0.262			
Anticoagulant medication	6 (2.6)	0 (0)	0.593			
Antiplatelet medication	14 (6.1)	2 (14.3)	0.234			
Platelet count < 140× 10 ³ /μL	15 (6.6)	0 (0)	0.322			
INR > 1.2	3 (1.3)	1 (7.1)	0.213			
APTT > 40 sec	8 (3.5)	0 (0)	0.476			
Postoperative epilepsy	11 (4.8)	2 (14.3)	0.128			
Preoperative MGS score			0.418			
0-1	169 (74.1)	9 (64.3)				
2-3	59 (25.9)	5 (35.7)				
4	0 (0)	0 (0)				
Postoperative MGS score at 1 day			0.356			
0-1	211 (92.5)	12 (85.7)				
2-3	17 (7.5)	2 (14.3)				
4	0 (0)	0 (0)				
Postoperative MGS score at 7 - 9 day			0.196			
0-1	215 (94.3)	12 (85.7)				
2-3	12 (5.7)	2 (14.3)				
4	0 (0)	0 (0)				
Preoperative CT						
Hematoma volume (ml)	98.96 ± 40.55	119.19 ± 42.26	0.113			
Mean hematoma density (HU)	37.29 ± 7.13	40.43 ± 6.32	0.118			
Maximal hematoma thickness (> 30mm)	99 (43.4)	8 (57.1)	0.316			
Midline shift (> 10mm)	68 (29.8)	6 (42.9)	0.304			
Hematoma density changes based on CT ^a			0.044*	0.022*		14.06 (1.47-134.52)
Isodense or hyperdense subtypes and laminar or separated types	153 (67.1)	13 (92.9)				
Hypodense or gradation subtypes	75 (32.9)	1 (7.1)				

and trabecular type

Postoperative CT at 1st day					
Effusion volume (ml)	38.72 ± 24.80	64.29 ± 40.11	0.034*		
Cerebral re-expansion rate ^b (%)	60.30 ± 20.52	47.11 ± 26.17	0.022*		
Mean effusion density (HU)	18.63 ± 7.94	15.29 ± 5.43	0.122		
Maximal effusion thickness (> 20mm)	42 (18.4)	7 (50.0)	0.004*		
Midline shift (> 5mm)	48 (21.1)	7 (50.0)	0.012*		
Gas volume (> 10ml)	44 (19.3)	4 (28.6)	0.398		
Postoperative CT at 7 - 9th day					
Effusion volume (ml)	39.19 ± 24.31	76.57 ± 39.54	0.001*		
Cerebral re-expansion rate ^b (%)	59.78 ± 21.76	33.03 ± 17.41	0.001*	0.014*	0.96 (0.92-0.99)
Mean effusion density (HU)	19.68 ± 6.33	21.79 ± 8.04	0.236		
Maximal effusion thickness (> 20mm)	37 (16.2)	7 (50.0)	0.001*	0.104	3.30 (0.78-13.90)
Midline shift (> 5mm)	31 (13.6)	6 (42.9)	0.003*	0.084	3.49 (0.84-14.40)
Gas volume (> 10ml)	20 (8.8)	1 (7.1)	0.834		

CSDH: chronic subdural hematoma, OR: odds ratio, CI: confidence interval, INR: International normalized ratio, APTT: activated partial thromboplastin time, MGS: Markwalder grading scale.

^aNakaguchi classification of chronic subdural hematoma, ^bCerebral re-expansion rate = (preoperative hematoma volume-postoperative effusion volume)/preoperative hematoma volume × 100%

* $p < 0.05$.

Table 2. Univariate analysis and Multivariable analysis of factors predicting cerebral re-expansion (n = 242)

Factors	Cerebral re-expansion		Univariable analysis <i>p</i> value	Multivariable analysis <i>p</i> value	Multivariable analysis OR (95% CI)
	Good (%)	Partial (%)			
Total	188 (77.7)	54 (22.3)			
Sex (male)	166 (88.3)	45 (83.3)	0.336		
Age > 65 years	101 (53.7)	36 (66.7)	0.091	0.626	1.20 (0.58 - 2.50)
Atrophy	49 (26.1)	26 (48.1)	0.002*	0.015*	2.44 (1.19 - 4.97)
Trauma > 30 days	77 (41.0)	30 (55.6)	0.057	0.057	1.84 (0.98 - 3.43)
Smoking	90 (47.9)	24 (44.4)	0.656		
Alcohol abuse	44 (23.4)	16 (29.6)	0.350		
Hypertension	48 (25.5)	16 (29.6)	0.547		
Diabetes	37 (19.7)	16 (29.6)	0.119		
Heart disease	38 (20.2)	10 (18.5)	0.783		
Cerebral infarction	21 (11.2)	8 (14.8)	0.467		
Anticoagulant medication	5 (2.7)	1 (1.9)	0.737		
Antiplatelet medication	13 (6.9)	3 (5.6)	0.723		
Platelet count < 140× 10 ³ /μL	11 (5.9)	4 (7.4)	0.676		
INR > 1.2	3 (1.6)	1 (1.9)	0.896		
APTT > 40 sec	8 (4.3)	0 (0.0)	0.123		
Postoperative epilepsy	10 (5.3)	3 (5.6)	0.946		
Postoperative intracranial hemorrhage	11 (5.9)	3 (5.6)	0.935		
Postoperative blood glucose abnormality	3 (1.6)	1 (1.9)	0.896		
Preoperative hematoma volume (> 100 ml)	90 (47.9)	26 (48.1)	0.971		
Preoperative Midline shift (> 10 mm)	56 (29.8)	18 (33.3)	0.618		
Preoperative Mean hematoma density (HU)			0.831		
< 25	7 (3.7)	3 (5.6)			
25 - 35	62 (33.0)	17 (31.5)			
> 35	119 (63.3)	34 (62.9)			
Preoperative hematoma density on CT			0.510		
Isodense or hyperdense subtypes and laminar or separated types	131 (69.7)	35 (64.8)	0.497		
Hypodense or gradation subtypes and trabecular type	57 (30.3)	19 (35.2)			
Postoperative air volume (> 10 ml)	11	2 (3.7)	0.537		

	(5.9)	
Postoperative mean hematoma density (HU)	0.167	
< 25	156 (83.0)	39 (72.2)
25 - 35	28 (14.9)	14 (25.9)
> 35	4 (2.1)	1 (1.9)

INR: International normalized ratio, APTT: Activated partial thromboplastin time.

* $p < 0.05$

Table 3. Univariate and Multivariate analysis of factors related to CSDH recurrence (n = 242)

Factors	Univariate analysis			Multivariable analysis		
	OR	95%CI	p value	OR	95%CI	p value
Age > 65 years	10.90	1.40-84.74	0.005*	7.51	0.74-76.44	0.089
Atrophy	3.20	1.07-9.59	0.029*	4.05	0.89-18.52	0.071
Density: isodense or hyperdense or separated or laminar types	6.37	0.82-49.63	0.044*	10.25	1.81-127.20	0.015*
Maximal effusion thickness at postoperative 7-9th day (> 20mm)	5.16	1.71-15.59	0.001*	2.09	0.43-10.09	0.359
Midline shift at postoperative 7-9th day (> 5mm)	3.97	1.22-12.92	0.003*	2.80	0.62-12.68	0.182
Thickness re-expansion at postoperative 7 - 9th day ($\leq 40\%$)	26.57	5.73-123.20	0.001*	25.90	4.56-147.05	0.001*

OR, odds ratio, CI confidence interval.

* $p < 0.05$, Nagelkerke $R^2 = 0.504$

Table 4. Changchun CSDH grading system for prediction of RrR

				Score points
Components of the grading system (Unilateral)				
Preoperative hematoma density on CT				
Hypodense or gradation subtypes and trabecular type				0
Isodense or hyperdense subtypes and laminar or separated types				1
Thickness re-expansion at postoperative 7 - 9th day				
> 40%				0
≤ 40%				2
Total score				0 - 3
Total score points	No recurrence	Recurrence	Rate of Recurrence (95% CI) (%)	<i>p</i> value
0	57	0	0 (0.0 - 6.3)	0.001*
1	129	2	1.5 (0.2 - 5.4)	
2	18	1	5.3 (0.1 - 26.0)	
3	24	11	31.4 (16.9 - 49.3)	

* $p < 0.05$

Table 5. Comparison of the different grading systems (n = 119)

Grading systems	AUC	95% CI
Olso grading system (post 1st day)	0.630	0.537 - 0.717
Olso grading system (post 7 - 9th day)	0.716	0.626 - 0.795
Alberta grading system (pre)	0.544	0.451 - 0.636
Wuhu grading system (post 1st day)	0.550	0.457 - 0.642
Xining grading system (post 1st day)	0.571	0.477 - 0.662
Changchun grading system (post 1st day)	0.695	0.604 - 0.776
Changchun grading system (post 7 - 9th day)	0.856	0.780 - 0.914

pre: preoperative; post: postoperative, AUC: the areas under the curve, CI, confidence interval.

* $p \leq 0.05$

Figures

Figure 1

Receiver operating characteristic curve analysis for postoperative radiological characteristics at different times

Figure 2

Receiver operating characteristic curve analysis for postoperative brain re-expansion to predict CSDH recurrence

Figure 3

Receiver operating characteristic curve analysis for different grading systems

Supplementary Files

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- [SupplementalTable4.docx](#)
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