Original Article doi: 10.2176/nmc.oa.2016-0228

Neurol Med Chir (Tokyo) 57, 210–216, 2017 Online March 30, 2017

The Effect of Irrigation Solutions on Recurrence of Chronic Subdural Hematoma: A Consecutive Cohort Study of 234 Patients

Masashi KUWABARA,[1] Takashi SADATOMO,[1] Kiyoshi YUKI,[1] Keisuke MIGITA,[1] Yasutaka IMADA,[1] Kiyoharu SHIMIZU,[1] Takeshi HARA,[1] Hideo OBA,[1] and Kaoru KURISU[2]

[1]*Department of Neurosurgery, Higashihiroshima Medical Center, Higashihiroshima, Hiroshima, Japan;*
[2]*Department of Neurosurgery, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima, Hiroshima, Japan*

Abstract

Chronic subdural hematomas (CSDHs) occur often in elderly persons and can occur with mild head trauma. With burr-hole irrigation as standard treatment, symptoms usually improve and can be cured, and outcomes are good, but postoperative recurrences are a common problem. This study investigated the effectiveness and recurrence rates when using artificial cerebrospinal fluid (ACF) instead of normal saline (NS) as an irrigation solution for burr-hole irrigation in patients with CSDH. This prospective study included 234 consecutive patients who underwent initial surgical treatment by burr-hole irrigation for a CSDH between April 2008 and June 2015. The irrigation solution used was changed from NS to ACF in June 2011. Factors examined with regard to recurrence included age, sex, unilateral or bilateral surgery, computed tomography (CT) findings, antiplatelet or anticoagulant drug use, past history, and irrigation solution (NS or ACF). These were analyzed by univariate and multivariate analyses. Univariate analyses (chi-square test) with a significance level <5% showed that recurrence rates were significantly lower in the ACF group than in the NS group ($P = 0.003$). Multivariate analysis (multiple logistic regression analysis) showed that the risk of recurrence was reduced 3.14-fold in the ACF group compared to the NS group (odds ratio, 3.143; 95% confidence interval, 0.1504–0.6733; $P = 0.0028$). None of the other factors were significantly different. In burr-hole irrigation for CSDH, the use of ACF instead of NS as an irrigation solution significantly reduces recurrence rates.

Key words: artificial cerebrospinal fluid, chronic subdural hematoma, recurrence

Introduction

Chronic subdural hematomas (CSDHs) occur often in elderly persons and can occur with mild head trauma. CSDHs are commonly encountered in neurosurgical clinical practice, but the mechanism of onset and enlargement has not been fully elucidated, and much still remains unknown. With burr-hole irrigation as standard treatment, symptoms usually improve and can be cured, and outcomes are good, but postoperative recurrences are a common problem. The rate of postoperative recurrences varies among medical institutions, and the rates of 4.0–26.5% have been reported.[1–14] Factors involved in CSDH recurrence include differences in surgical techniques, age, hematoma volume, computed tomography (CT) findings, and the types of drugs used, but these vary and still remain unclear.[6,13,15–19] In addition to a variety of comorbidities in older patients, there are differences in these various factors, and this may account for differences in statistical analysis results. On the other hand, burr-hole irrigation, which is standard treatment in CSDH, is a relatively straightforward procedure that is done under local anesthesia. Therefore, if surgical techniques and postoperative management are uniform, with little variation among neurosurgeons, the prospective analysis of treatment outcomes would not be difficult.

Recently, artificial cerebrospinal fluid (ACF), with a composition close to normal cerebrospinal fluid (CSF), has been used for irrigation and perfusion in neurosurgery. This has been reported to reduce adverse events such as seizures and have a hemostatic effect

Received August 24, 2016; Accepted December 11, 2016

on minor bleeding from the brain surface.[20,21] Normal saline (NS) has conventionally been used as an irrigation solution in burr-hole irrigation for CSDH, but the use of ACF may improve treatment effectiveness.

Therefore, a prospective study of 234 consecutive patients with CSDH who underwent burr-hole irrigation at our hospital was conducted. Various factors, including the type of irrigation solution (NS or ACF), were analyzed by univariate and multivariate analyses to investigate whether they contributed to CSDH recurrence rates.

Patients and Methods

This study included 234 consecutive patients with CSDH who underwent burr-hole irrigation as the initial surgery by our Department of Neurosurgery at Higashihiroshima Medical Center (Higashihiroshima, Hiroshima Prefecture, Japan) between April 2008 and June 2015. Simultaneous bilateral surgery for a bilateral hematoma was regarded as one surgical operation. There were 157 men (67.1%) and 77 women (32.9%), with a mean age of 75.2 years (range: 21–96 years).

Surgery was performed as soon as possible after a confirmed diagnosis in all patients. Surgery was performed under local anesthesia, and a single burr hole was placed at the thickest point of the hematoma. The hematoma was aspirated as much as possible, the hematoma cavity was irrigated with NS through a silicone catheter, and then the burr hole was closed without inserting a drain. The scalp was closed in two layers. Residual air after closing was removed as much as possible, and this was replaced with NS. However, in June 2011, we started using ACF instead of NS as the irrigation solution. Patients received antibiotics by infusion for 3 days after surgery and were discharged from the hospital in about a week after surgery. They were followed-up for at least 3 months after discharge. Recurrence was defined by symptom exacerbation on the same side and within 3 months after initial surgery that again required surgery. Since the surgical procedure was uniform during this period, and all of the surgery was performed under the supervision of experienced neurosurgeons, it seems to be no significant difference by the operator. Before the surgery, written, informed consent was obtained from all patients and/or family members. The study protocol was approved by the ethics committee of our center.

Factors that were prospectively examined with regard to recurrence included age, sex, unilateral or bilateral surgery, CT findings (hematoma density, midline shift, septal wall, hematoma thickness), antiplatelet or anticoagulant drug use, past history (diabetes, ischemic heart disease, cerebrovascular disease, liver dysfunction, renal dysfunction), and irrigation solution (NS or ACF). Hematoma thickness was measured by drawing a line perpendicular to the longest diameter of the hematoma and the measuring thickness from the slice with maximum thickness.

In patients who were taking antiplatelet or anticoagulant drugs, surgery was usually performed under the same schedule, except that these drugs were discontinued before surgery. Hematoma density was classified into 4 categories as low, high, mixed (low and high), or isodense.

All analyses were performed using SPSS software (version 22.0, SPSS Inc.). In the recurrence and non-recurrence groups, patient characteristics were regarded as independent factors, and these were compared between groups using Pearson's chi-squared test. Multiple logistic regression analysis was also performed with recurrence as the dependent variable and patient characteristics as the explanatory variables. However, the number of patients with ischemic heart disease and renal dysfunction was disproportionate between the recurrence and non-recurrence groups. Therefore, these were excluded as factors from the multiple logistic regression model. The level of statistical significance was $P < 0.05$.

Results

Burr-hole irrigation was successfully performed in all 234 consecutive patients. There were no serious neurological complications or deaths. Table 1 summarizes the patient characteristics. There were no significant differences in age, sex, hematoma right-left side difference, CT findings, the use of antiplatelet or anticoagulant drugs, or past history between the NS group and the ACF group (Table 1).

Among the 234 patients overall who underwent surgery, 36 (15.4%) had a recurrent CSDH within 3 months. Among the 101 patients in whom the irrigation solution was NS, 24 (23.8%) had a recurrence. In contrast, only 12 of 133 (9.0%) of patients in whom the irrigation solution was ACF had a recurrence. Prospective univariate analyses and multivariate analysis of the recurrence rates with regard to the irrigation solution showed that the use of ACF was a significant factor in reducing CSDH recurrence.

The 36 patients with recurrence included 25 men and 11 women, with a mean age of 75.6 years (range: 59–90 years). One patient had used an anticoagulant drug, eight had used antiplatelet drugs, seven had diabetes mellitus, two had cerebrovascular disease, one had ischemic heart disease, three had liver dysfunction, and one had renal dysfunction.

Table 2 shows the results of univariate and multivariate analyses of factors in the 36 patients with

Table 1 Baseline patient characteristics, clinical findings and the results of univariate analysis

	All patients	ACF	NS	*P* value
	n = 234 (%)	*n* = 133 (%)	*n* = 101 (%)	
Age				0.6778
< 75	97 (41.5)	59 (44.4)	38 (37.6)	
≧ 75	137 (58.5)	74 (55.6)	63 (62.4)	
Sex				0.5756
Male	157 (67.1)	87 (65.4)	70 (69.3)	
Female	77 (32.9)	46 (34.6)	31 (30.7)	
Operation side				0.2361
Right	99 (42.3)	61 (45.9)	38 (37.6)	
Left	98 (41.9)	49 (36.8)	49 (48.5)	
Both	37 (15.8)	23 (17.3)	14 (13.9)	
CT findings				
Density				0.9096
High	24 (8.8)	14 (9.0)	10 (8.6)	
Low	41 (15.1)	24 (15.4)	17 (14.7)	
Iso	123 (45.2)	70 (44.9)	53 (45.7)	
Mix	84 (30.9)	48 (30.8)	36 (31.0)	
Midline shift (mm)	7.53 ± 3.81	7.32 ± 3.53	7.82 ± 4.10	0.0627
Septal wall				0.4246
Yes	76 (27.9)	41 (26.3)	35 (30.2)	
No	196 (72.1)	115 (73.7)	81 (69.8)	
Hematoma thickness (mm)	21.3 ± 8.21	21.5 ± 6.16	21.1 ± 6.09	0.6397
Drug history				
Anticoagulant	19 (8.1)	15 (11.3)	4 (4.0)	0.0531
Antiplatelet	34 (14.5)	18 (13.5)	16 (15.8)	0.7088
Past history				
Diabetes mellitus	40 (17.1)	26 (19.5)	14 (13.9)	0.2949
Ischemic heart disease	10 (4.3)	8 (6.0)	2 (2.0)	0.1939
Cerebrovascular disease	16 (6.8)	10 (7.5)	6 (5.9)	0.7952
Liver dysfunction	13 (5.6)	7 (5.3)	6 (5.9)	0.8227
Renal dysfunction	4 (1.7)	3 (2.3)	1 (1.0)	0.6359

ACF: artificial cerebrospinal fluid, NS: normal saline, CT: computed tomography, values are means ± SD.

recurrence and the 198 patients without recurrence. The results of univariate analysis, as described previously, showed a significant difference based on the type of irrigation solution. The recurrence rate was significantly lower in the ACF group than in the NS group (P = 0.003). None of the other factors, including age, sex, unilateral or bilateral surgery, CT findings (hematoma density, midline shift, septal wall, hematoma thickness), antiplatelet or anticoagulant drug use, and past history (diabetes mellitus, ischemic heart disease, cerebrovascular disease, liver dysfunction, renal dysfunction) had a significant effect on the recurrence rate. The results of multivariate analysis showed the risk of recurrence was reduced 3.14-fold in the ACF group compared to the NS group (odds ratio, 3.143; 95% confidence interval, 0.1504–0.6733; P = 0.0028). None of the other factors, including age, sex, unilateral or bilateral surgery, CT findings (hematoma density, midline shift, septal wall, hematoma thickness), antiplatelet or anticoagulant drug use, and past history (diabetes mellitus, cerebrovascular disease, liver dysfunction) was significantly different with respect to CSDH recurrence (Table 2).

Discussion

CSDHs are relatively easy to treat by burr-hole irrigation under local anesthesia. However, the mechanisms by which CSDHs occur and enlarge, and the mechanisms by which CSDHs decrease and heal with irrigation, are not completely understood. With burr-hole irrigation, which is standard treatment for a CSDH, symptoms improve and can be cured, and outcomes are generally good. However, postoperative recurrences are a common problem.

Factors reportedly involved in recurrent CSDH include age, sex, hematoma thickness, use of antiplatelet and anticoagulant drugs, and past medical

Table 2 Results of univariate and multivariate analyses of chronic subdural hematoma recurrence

Factor	Univariate analysis				Multivariate analysis		
	No recurrence (%)	Recurrence (%)	Recurrence rate	*P* value	OR	95% CI	*P* value
Total	198 (84.6)	36 (15.4)	15.4%				
Age				0.4704	0.99	0.96–1.02	0.5024
<75	97 (49.0)	15 (41.7)	13.4%				
≧75	101 (51.0)	21 (58.3)	17.2%				
Sex				0.8481	1.14	0.53–2.45	0.7443
Male	132 (66.7)	25 (69.4)	15.9%				
Female	66 (33.3)	11 (30.6)	14.3%				
Operation side				0.6495	1.60	0.53–4.82	0.4043
Right	85 (42.9)	14 (38.9)	37.6%				
Left	80 (40.4)	18 (50.0)	18.4%				
Both	33 (16.7)	4 (11.1)	10.8%				
CT findings							
Density				0.3776	1.20	0.57–2.51	0.6286
High	17 (7.4)	7 (16.7)	29.2%				
Low	33 (14.3)	8 (19.0)	19.5%				
Iso	107 (46.6)	16 (38.1)	13.0%				
Mix	73 (31.7)	11 (26.2)	13.1%				
Midline shift (mm)	6.68 ± 4.10	8.42 ± 4.24		0.1052	0.94	0.86–1.03	0.1875
Septal wall				0.9338	0.73	0.32–1.65	0.4498
Yes	65 (28.3)	11 (26.2)	14.5%				
No	165 (71.7)	31 (73.8)	15.8%				
Hematoma thickness (mm)	21.1 ± 5.94	22.4 ± 6.13		0.2291	0.95	0.90–1.01	0.1026
Intraoperative irrigation solution				0.003*	3.14	0.15–0.67	0.0028*
NS	77 (38.9)	24 (66.7)	23.8%				
ACF	121 (61.1)	12 (33.3)	9.0%				
Drug history							
Anticoagulant	18 (40.9)	1 (11.1)		0.3219	0.29	0.04–2.21	0.2301
Antiplatelet	26 (59.1)	8 (88.9)		0.1954	1.89	0.78–4.49	0.1597
Past history							
Diabetes mellitus	29 (43.3)	7 (50.0)		0.4561	1.48	0.62–3.55	0.3765
Ischemic heart disease	8 (11.9)	2 (14.3)		0.6543			
Cerebrovascular disease	16 (23.9)	1 (7.1)		0.1417	1.40	0.28–6.86	0.6806
Liver dysfunction	10 (14.9)	3 (21.4)		0.4283	1.71	0.45–6.54	0.4338
Renal dysfunction	4 (6.0)	1 (7.1)		0.3897			

ACF: artificial cerebrospinal fluid, NS: normal saline, CT: computed tomography, values are means ± SD, OR: odds ratio, CI: confidence interval, $^{*}P < 0.05$.

history.[6,13,15–19] Recurrences related to surgical technique have also been frequently reported. However, few reports have compared recurrence rates with a focus on the type of irrigation solution used during surgery. Therefore, the present study focused on the composition of the ACF used as the irrigation solution during surgery and whether this would affect CSDH recurrence.

The rate of postoperative recurrent CSDH reported in the literature varies from 4.0% to 26.5%.[1–14] The overall recurrence rate with our surgical procedure was 15.4%, which roughly corresponds with previously reported rates. However, the recurrence rate was 23.8% in patients in whom normal saline (NS) was used as the irrigation solution, but only 9.0% in those in whom ACF was used as the irrigation solution.

The present study was a prospective clinical study, and considering that most of the patients were elderly and had a variety of baseline characteristics, careful statistical analysis was necessary. On the other hand, surgical techniques and postoperative management in CSDH are relatively straightforward, so that there was not much room for variation in treatment. Therefore, we surmised that if statistical analysis were properly performed, results with a high level of evidence could be obtained. Various factors for recurrent CSDH were examined by both univariate and multivariate analyses. Both analyses showed similar results, namely, that using ACF as the irrigation solution significantly reduced the recurrence rate.

ACFs have recently been developed as solutions with a composition similar to normal CSF for the purpose of using a more physiologic irrigation solution during neurosurgical procedures. NS contains Na^+ and Cl^- and has a pH of 6.3. In contrast, ACF, in addition to Na^+ and Cl^-, includes electrolytes such as Ca^{2+}, K^+, and HCO_{3}^-, as well as glucose, which are not present in NS. Moreover, ACF is adjusted to a more physiologic pH of 7.3 (Table 3).

Table 3 Composition of irrigation solutions and CSF

Component	NS	ACF	Normal rat CSF	Normal human CSF
Na^+ (mEq/L)	154	145	150–152	145.5
K^+ (mEq/L)	–	2.8	3.5–6.2	2.8
Mg^{2+} (mEq/L)	–	2.2	2.6–4.8	2.2
Ca^{2+} (mEq/L)	–	2.3	3.0–5.0	2.3
Cl^- (mEq/L)	154	129	132–136	111.9
HCO_{3}^- (mEq/L)	–	23.1	24–26	23.1
P (mM/L)	–	1.1	n.a.	1.1
$Lactate^-$ (mEq/L)	–	–	n.a.	n.a.
Glucose (g/L)	–	0.61	0.72–1.8	0.61
Osmolality ratio	about 0.9	about 1	n.a.	about 1
pH	about 6.7	about 7.3	n.a.	7.307

NS: nomal saline, ACF: artifical cerebrospinal fluid, CSF: cerebrospinal fluid, n.a.: no data available.

The composition of CSF has been examined in basic research studies. In an *in vivo* study in a rat model with induced injury to the cerebral cortex, and in which NS and ACF were used to irrigate the brain surface, edema was less with ACF than with NS.

In another study, Nishimura et al.[22] cultured astrocytes that were isolated from human fetal brains, and these were used to compare how irrigation and perfusion solutions affected brain cell function. They found that ACF had a significantly lower adverse effect on astrocyte function than did NS.

Another study compared histological changes in outer hematoma membranes after irrigation with NS or ACF in burr-hole irrigation of CSDHs.[23] In outer hematoma membranes irrigated with NS, there was decreased extracellular matrix (ECM), cytoplasmic contraction, nuclear condensation, and eosinophilic infiltration. In contrast, in outer hematoma membranes irrigated with ACF, these findings were reduced, and chromatin structure was preserved.

These results demonstrated that in burr-hole irrigation in CSDHs damage of hematoma membranes is significantly less with exposure to ACF than NS. And therefore it is presumed that oozing from hematoma membranes is significantly less with exposure to ACF than NS.

This suggests that ACF is effective as an irrigation and perfusion solution in burr-hole surgery for CSDHs.

In another model of irrigation of bleeding on the mouse brain surface, ACF was more effective than NS for hemostasis, and the presumed mechanism involved the addition of Ca^{2+} and K^+.[4,14] Therefore ACF acts on new blood vessels on the outer hematoma membrane, and may promote hemostasis of the outer hematoma membrane.

In a study comparing NS and ACF as a ventricular perfusate during endoneurosurgery, ACF was associated with a lower incidence of headache, fever, and nuchal rigidity. The presumed reason was that ACF caused less of an inflammatory reaction due to chemical irritation than NS.[21,24]

In burr-hole irrigation in CSDH, for the reasons mentioned previously, the use of pH-adjusted ACF as an irrigation solution, which differs from mildly acidic NS, can also reduce damage of the hematoma membrane, thus decreasing CSDH recurrence rates. In addition, ACF acts on new blood vessels on the outer hematoma membrane, and by controlling vasoconstriction and blood clotting/fibrinolysis, ACF may promote hemostasis of the outer hematoma membrane.

Of particular note in the present study is the fact that a preoperative bleeding diathesis (liver dysfunction, renal dysfunction, the use of anticoagulant or antiplatelet drugs) did not significantly affect the CSDH recurrence rate. Previous reports have suggested that preoperative anticoagulant and antithrombotic therapy increases the risk of recurrence.[25,26] Moreover, with the increase in the elderly population, the number of patients with a bleeding diathesis (e.g., liver dysfunction, renal dysfunction) is increasing, and this bleeding diathesis has been reported as a factor in recurrence.[16,27] However, other studies have reported findings similar to the present study, namely, that the use of anticoagulant and antiplatelet drugs has no effect on CSDH recurrence rates.[6,13]

Ko et al.[16] reported that hematoma density was another important risk factor for CSDH recurrence, and that surgery should be delayed in high-density and mixed-density hematomas. Oishi et al.[18] also reported a higher recurrence rate with high-density hematomas. On the other hand, Yoshii et al.[19] reported a higher recurrence rate and that surgery should be delayed with low-density CT findings. Thus, there are differing opinions in the neurosurgical literature. The present statistical analysis showed that CT findings (hematoma density, hematoma thickness, midline shift, a septal wall, and unilateral or bilateral) had no significant effect on CSDH recurrence rates. Future studies with a larger number of patients may provide more accurate results.

Conclusions

A prospective study of 234 consecutive patients who underwent initial burr-hole irrigation for CSDH was conducted, and factors related to recurrence were evaluated by univariate and multivariate analyses. Both sets of analyses showed similar results, namely, that ACF as an irrigation solution significantly reduced CSDH recurrence. None of the other factors examined had a significant effect on the recurrence rate.

Conflicts of Interest Disclosure

The authors have declared that no conflict of interest exists.

References

1) Amirjamshidi A, Abouzari M, Eftekhar B, Rashidi A, Rezaii J, Esfandiari K, Shirani A, Asadollahi M, Aleali H: Outcomes and recurrence rates in chronic subdural hematoma. *Br J Neurosurg* 21: 272–275, 2007
2) Baechli H, Nordmann A, Bucher HC, Gratzl O: Demographics and prevalent risk factors of chronic subdural hematoma: results of a large single-center cohort study. *Neurosurg Rev* 27: 263–266, 2004
3) El-Kadi H, Miele VJ, Kaufman HH: Prognosis of chronic subdural hematomas. *Neurosurg Clin N Am* 11: 553–567, 2000
4) Ernestus RI, Beldzinski P, Lanfermann H, Klug N: Chronic subdural hematoma: surgical treatment and outcome in 104 patients. *Surg Neurol* 48: 220–225, 1997
5) Foelholm R, Waltimo O: Epidemiology of chronic subdural haematoma. *Acta Neurochir* (*Wien*) 32: 247–250, 1975
6) Fujita Y, Doi K, Harada D, Kamikawa S: Modulation of physiological hemostasis by irrigation solution: Comparison of various irrigation solutions using a mouse brain surface bleeding model. *J Neurosurg* 112: 824–828, 2010
7) Hamilton MG, Frizzell JB, Tranmer BI: Chronic subdural hematoma: the role for craniotomy reevaluated. *Neurosurgery* 33: 67–72, 1993
8) Markwalder TM: Chronic subdural hematomas: a review. *J Neurosurg* 54: 637–645, 1981
9) Mori K, Maeda M: 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, 2001
10) Nakaguchi H, Tanishima T, Yoshimasu N: Factors in the natural history of chronic subdural hematomas that influence their postoperative recurrence. *J Neurosurg* 95: 256–262, 2001
11) Robinson RG: Chronic subdural hematoma: surgical management in 133 patients. *J Neurosurg* 61: 263–268, 1984
12) Sambasivan M: An overview of chronic subdural hematoma: experience with 2300 cases. *Surg Neurol* 47: 418–422, 1997
13) 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* 63: 1125–1129, 2008
14) van Havenbergh T, van Calenbergh F, Goffin J, Plets C: Outcome of chronic subdural hematoma: analysis of prognostic factors. *Br J Neurosurg* 10: 35–39, 1996
15) Janowski M, Kunert P: Intravenous fluid administration may improve post-operative course of patients with chronic subdural hematoma: a retrospective study. *PLoS One* 7: e35634, 2012
16) Ko BS, Lee JK, Seo BR, Moon SJ, Kim JH, Kim SH: Clinical analysis of risk factors related to recurrent

chronic subdural hematoma. *J Korean Neurosurg Soc* 42: 11–15, 2008
17) Kristof RA, Grimm JM, Stoffel-Wagner B: Cerebrospinal fluid leakage into the subdural space: possible influence on the pathogenesis and recurrence frequency of chronic subdural hematoma and subdural hygroma. *J Neurosurg* 108: 275–280, 2008
18) Oishi M, Toyama M, Tamatani S, Kitazawa T, Saito M: Clinical factors of recurrent chronic subdural hematoma. *Neurol Med Chir* (*Tokyo*) 41: 382–386, 2001
19) Yoshii K, Seki Y, Aiba T: Causative factors of recurrence of chronic subdural hematoma. *Neurological Surgery* 15: 1065–1071, 1987
20) Berghauser Pont LM, Dammers R, Schouten JW, Lingsma HF, Dirven CM: Clinical factors associated with outcome in chronic subdural hematoma: a retrospective cohort study of patients on preoperative corticosteroid therapy. *Neurosurgery* 70: 873–880, 2012
21) Oka K, Yamamoto M, Nonaka T, Tomonaga M: The significance of artificial cerebrospinal fluid as perfusate and endoneurosurgery. *Neurosurgery* 38: 733–736, 1996
22) Nishimura M, Doi K, Enomono R, Lee E, Naito S, Yamauchi A: ARTCEREB® irrigation and perfusion solution for cerebrospinal surgery: pharmacological assessment using human astrocytes exposed to test solutions. *Yakugaku Zasshi* 129: 1121–1126, 2009 (Japanese)
23) Adachi A, Higuchi Y, Fujikawa A, Machida T, Sueyoshi S, Harigaya K, Ono J, Saeki N: Risk factors in chronic subdural hematoma: comparison of irrigation with artificial cerebrospinal fluid and normal saline in a cohort analysis. *PLoS One* 9: e103703, 2014
24) Elliott KAC, Jasper HH: Physiological salt solutions for brain surgery. *J Neurosurg* 6: 140–152, 1949
25) Lindvall P, Koskinen LD: Anticoagulants and antiplatelet agents and the risk of development and recurrence of chronic subdural hematomas. *J Clin Neurosci* 16: 1287–1290, 2009
26) Rust T, Kiemer N, Erasmus A: Chronic subdural hematomas and anticoagulation or anti-thrombotic therapy. *J Clin Neurosci* 13: 823–827, 2006
27) Yamada T, Natori Y: Risk factors associated with recurrence after burr hole evacuation for chronic subdural hematoma. *Jpn J Neurosurg* (*Tokyo*) 22: 125–132, 2013
28) Doi K, Kawano T, Morioka Y: Various irrigation solutions affect postoperative brain edema and cellular damage during experimental neurosurgery in rats. *Surg Neurol* 66: 565–572, 2006
29) Koizumi S, Hayasaka T, Goto-Inoue N, Doi K, Setou M, Namba H: Imaging mass spectrometry evaluation of the effects of various irrigation fluid in a rat model of postoperative cerebral edema. *World Neurosurg* 77: 153–159, 2012

Address reprint requests to: Masashi Kuwabara, MD, Department of Neurosurgery, Higashihiroshima Medical Center, Jike 513 Saijyo, Higashihiroshima, Hiroshima 739-0041, Japan.
e-mail: m214028@gmail.com