



Extensive postoperative subdural fluid volume affects the onset of chronic subdural hematoma after unruptured aneurysmal clipping surgery



Toshiharu Murakami, Ichiro Nakagawa*, Hun Soo Park, Masashi Kotsugi, Yoshiaki Takamura, Yasuhiro Takeshima, Ryosuke Matsuda, Fumihiko Nishimura, Shuichi Yamada, Yasushi Motoyama, Young Su Park, Hiroyuki Nakase

Departments of Neurosurgery, Nara Medical University, 840 Shijo-cho, Kashihara, Nara 634-8522, Japan

ARTICLE INFO

Keywords:

Chronic subdural hematoma
Aneurysmal clipping surgery
Subdural fluid volume
Arachnoid-plasty procedure

ABSTRACT

Objective: To evaluate risk factors associated with chronic subdural hematoma (CSDH) onset after clipping surgery for unruptured intracranial aneurysm, and determine whether intraoperative conventional arachnoid-plasty (ARP) can suppress the CSDH onset by reducing subdural fluid volume.

Patients and Methods: We retrospectively evaluated 217 patients who underwent surgical clipping at our institution from 2012 to 2018. Risk and predictive factors for symptomatic CSDH development including clinical characteristics, postoperative subdural fluid volume, Hounsfield unit (HU) value of subdural fluid density evaluated by CT and the effect of conventional ARP were compared between CSDH and non-CSDH groups.

Results: Of 217 patients who underwent surgical clipping for anterior circulation aneurysm, 209 were included in this study. Among whom, postoperative CSDH, required burr irrigation, occurred in 12 (5.7%). Mean age was significantly higher in the CSDH group (70 ± 8 years) than in the non-CSDH group (64 ± 11 years, $p = 0.03$). Subdural fluid volumes on postoperative day (POD)1, POD8 and POD30 were significantly larger in the CSDH group than in the non-CSDH group (38.4 ± 33.5 cm³, 54.8 ± 36.3 cm³, 77.2 ± 36.1 cm³ vs 10.0 ± 7.7 cm³, 16.1 ± 12.8 cm³, 14.0 ± 17.5 cm³, $p < 0.001$, respectively). However, intraoperative conventional ARP did not reduce postoperative subdural fluid volume nor suppress onset of CSDH. Multivariate logistic regression analysis revealed extensive subdural fluid volume as the only risk factor independently associated with CSDH development.

Conclusions: In this study, postoperative large subdural fluid volume represented an independent risk factor associated with the incidence of CSDH after unruptured aneurysmal clipping. Reducing subdural fluid volume strategy could suppress the onset of CSDH after surgery.

1. Introduction

Chronic subdural hematoma (CSDH) is an uncommon complication after clipping surgery for unruptured aneurysms. Some reports have described CSDH occurring at a frequency of about 1.7–5.1% after clipping surgery [1–8]. Gender difference and increases in age and postoperative subdural fluid volume have been reported as factors associated with CSDH after aneurysmal clipping surgery. [4,5,7–11], Recent studies have suggested that CSDH after unruptured aneurysmal clipping is associated with increased postoperative subdural fluid volume [10,12–14] and the arachnoid-plasty (ARP) procedure could help prevent the onset of CSDH [6,12]. However, whether a conventional ARP procedure can prevent the onset of CSDH by reducing the subdural fluid space after aneurysmal clipping surgery is unclear. The present

study examined whether subdural fluid volume change and conventional ARP procedure are associated with the onset of CSDH after unruptured aneurysmal clipping surgery.

2. Patients and methods

This retrospective observational study was based on criteria of the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement and was approved by the institutional review board at Nara Medical University (Approval no. 2046). All patients were provided with a document explaining all aneurysmal clipping procedures and burr-hole irrigation procedures and all provided written, informed consent to the use of their medical records for research purposes.

* Corresponding author.

E-mail address: nakagawa@naramed-u.ac.jp (I. Nakagawa).

<https://doi.org/10.1016/j.clineuro.2019.105533>

Received 14 July 2019; Received in revised form 14 September 2019; Accepted 21 September 2019

Available online 28 September 2019

0303-8467/ © 2019 Elsevier B.V. All rights reserved.

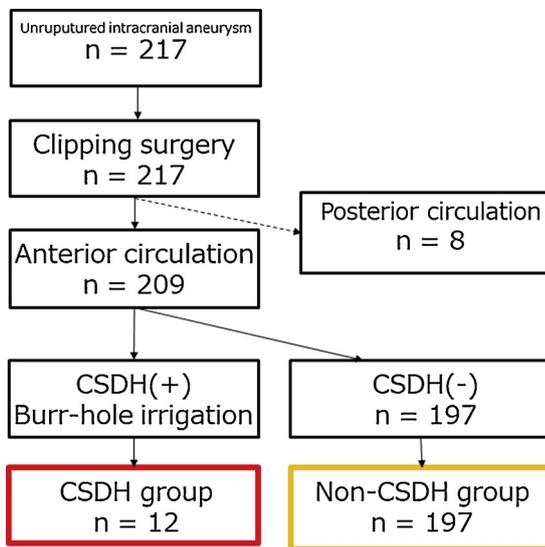


Fig. 1. Patient selection algorithm. We collected data from 217 consecutive patients with unruptured intracranial aneurysm who underwent clipping surgery between January 2012 and May 2018. Of these, 8 were excluded due to posterior circulation aneurysm. Twenty (5.7%) of those who underwent clipping surgery suffered ipsilateral CSDH recurrence.

2.1. Study population

Data from 217 consecutive patients who underwent surgical clipping of unruptured intracranial aneurysms of the anterior circulation from January 2012 to May 2018 at Nara Medical University were retrospectively extracted into a database. Unruptured intracranial aneurysms were diagnosed on brain computed tomography (CT) angiography or brain magnetic resonance angiography. Among the 217 patients, a total of 209 patients who underwent surgical clipping for anterior circulation aneurysm were included in this study (Fig. 1). Posterior circulation aneurysms were excluded. All clipping surgeries were performed by certified experienced neurosurgeons. The data included the patient characteristics of age, gender, risk factors including smoking and alcohol habits, hypertension, diabetes mellitus, hyperlipidemia, use of antithrombotic medication with or without conventional ARP and clinical outcomes thereafter. As a simple, easy procedure, conventional ARP was performed in about half of cases in the present study. After clipping, conventional ARP was performed by reconstructing the opened cistern. Saline was slowly infused into the open subarachnoid space into the cistern. The cistern was covered by fibrin glue-soaked absorbable hemostat (Surgicel; Johnson and Johnson Tokyo, Japan). Background characteristics of these patients are listed in Table 1. Mean age of the 209 patients was 62.0 ± 10 years, and 63 patients (29%) were male. The incidence of CSDH after clipping surgery was calculated based on the number of symptomatic cases who required burr-hole irrigation and drainage treatment.

2.2. Radiologic evaluation

Postoperative radiologic data were examined using a CT scanner (SOMATOM Definition Flash; Siemens Healthineers, Tokyo, Japan). These volumetry studies were performed using the CT scans taken on the axial planes with a section thickness of 5 mm, with PiViewSTAR (INFINITY, Tokyo, Japan), a picture archiving and communication system (PACS). After clipping surgery, patients were followed with periodic CT scanning. Postoperative CT data were reviewed the day after the clipping surgery, and on postoperative day (POD)8 and POD30. According to a previous study, the XYZ/2 method was used to conveniently and precisely evaluate the subdural fluid volume [13]. Briefly, three components of x, y and z of the axial image from head CT

Table 1
Clinical characteristics between groups.

Variable	CSDH group (n = 12)	non-CSDH group (n = 197)	p value
General characteristics			
Mean age	70 \pm 8	64 \pm 11	0.034*
Females	6 (50%)	148 (75%)	0.114
Aneurysm location			
MCA	10 (83%)	106 (54%)	0.136
ACA	1 (8%)	46 (23%)	
ICA	1 (8%)	45 (23%)	
Risk factors			
Hypertension	8 (67%)	129 (72%)	0.819
Diabetes	2 (17%)	14 (7%)	0.516
Hyperlipidemia	3 (25%)	60 (30%)	0.939
Current smoker	1 (8%)	60 (30%)	0.190
Medications			
Statins	3 (25%)	46 (23%)	0.826
ARBs	5 (42%)	78 (40%)	0.872
Antithrombotics	2 (17%)	15 (8%)	0.596

* $p < 0.05$, CSDH; Chronic subdural hematoma, MCA; middle cerebral artery, ACA; anterior cerebral artery, ICA; internal cerebral artery, ARBs; angiotensin II receptor blockers.

were set and measured and approximated the volume of the subdural fluid volume by the XYZ/2 method. Furthermore, we evaluated chronological changes in subdural fluid volume, Hounsfield unit (HU) values, and the end results of subdural fluid volume in serial CT scans. We measured the most high-density spots (blood clots) in HU of subdural fluid volume below the bone flap on serial CT scans. The HU value of subdural fluid volume was measured using region of interest (ROI) analysis on the picture archiving and communication system (PACS) workstation.

2.3. Statistical analysis

Measurements for each group are expressed as means \pm standard deviation. Comparisons between two groups were assessed using the Mann-Whitney U test, and Fisher's exact test. Differences were deemed statistically significance if $p < 0.05$. A receiver operating characteristic (ROC) curve analysis was performed to define the diagnostic value of subdural fluid volume affecting the occurrence of CSDH for plot sensitivity versus 1-specificity for a range of results. Univariate analysis was performed, and factors with a value of $p < 0.10$ were included in the multivariate logistic regression analysis. Significance was considered for values of $p < 0.05$.

3. Results

Of the 209 patients, 110 were treated with ARP during aneurysm clipping. Baseline characteristics are summarized in Table 1. CSDH developed in 12 patients (5.7%), all patients required burr hole irrigation surgery. Ten of 12 patients (83%) were MCA aneurysm and 1 ACA aneurysm (8%) and 1 ICA aneurysm (8%). The interval to the onset of CSDH was 68 ± 33 days (Table 2). No significant differences in baseline characteristics were evident between the two groups besides mean age. Mean age was significantly higher in the 12 patients who required burr hole irrigation (70 ± 8 years) than in non-CSDH patients (64 ± 11 years, $p = 0.034$). In the CSDH group, subdural fluid volumes on POD1, POD8 and POD30 were significantly larger than those in the non-CSDH group (38.4 ± 33.5 cm³, 54.8 ± 36.3 cm³, 77.2 ± 36.1 cm³ vs 10.0 ± 7.7 cm³, 16.1 ± 12.8 cm³, 14.0 ± 17.5 cm³, $p < 0.001$, respectively) (Table 2).

For the 12 patients in the CSDH group, the collected average HU value for the subdural fluid space on POD30 was significantly higher than that for the non-CSDH group (38.6 ± 16.6 , 26.9 ± 10.4 ; $p = 0.018$), but no significant differences in collected average HU value of

Table 2
Subdural fluid volume and HU after surgery between groups.

Variable	CSDH group (n = 12)	non-CSDH group (n = 197)	p value
Subdural fluid volume of XYZ/2 (cm ³)			
Day 1	38.4 ± 33.5	10.0 ± 7.7	< 0.001*
Day 8	54.8 ± 36.3	16.1 ± 12.8	< 0.001*
Day30	77.2 ± 36.1	14.0 ± 17.5	< 0.001*
HU value			
Day 1	33.5 ± 17.1	25.9 ± 8.7	0.260
Day 8	25.4 ± 4.4	26.4 ± 7.7	0.813
Day 30	38.6 ± 16.6	26.9 ± 10.4	0.018*
Conventional ARP	8 (67%)	102 (52%)	0.481
Time to CSDH onset (days)	68 ± 33	n.a.	n.a.

* p < 0.05. HU, Hounsfield units; CSDH, chronic subdural hematoma; ARP, arachnoid-plasty.

Table 3
Postoperative subdural volume and HU values with/without conventional ARP.

Variable	with conventional ARP (n = 110)	without conventional ARP (n = 99)	p value
Subdural fluid volume XYZ/2 (cm ³)			
Day 1	12.5 ± 13.9	9.9 ± 1.07	0.098
Day 8	20.4 ± 19.6	16.8 ± 15.6	0.204
Day 30	19.0 ± 23.0	16.8 ± 25.8	0.140
HU value of subdural space			
Day 1	26.3 ± 9.8	26.4 ± 9.2	0.639
Day 8	26.3 ± 7.4	26.4 ± 7.7	0.935
Day 30	29.7 ± 13.0	25.4 ± 8.2	0.078

ARP, arachnoid-plasty; HU, Hounsfield units.

the subdural fluid space on POD1 and POD8 were seen between groups (Table 2). On the other hand, no significant differences in subdural fluid volume or HU value on POD1, POD8, or POD30 with or without intraoperative conventional ARP, and intraoperative conventional ARP did not suppress the onset of CSDH (Table 3).

ROC curve analyses demonstrated that postoperative subdural fluid volumes on POD1, POD8, and POD30 could predict onset of CSDH after surgery (area under the curve, 0.84, 0.85, 0.94; confidence interval, 0.44 – 0.76, 0.32 – 0.64, 0.55 – 0.88; p = 0.26, 0.81, 0.02, respectively) (Fig. 2). Multivariate logistic regression analysis revealed that the large subdural fluid volume on POD8 or POD30 was the only risk factor independently associated with development of CSDH (Table 4).

4. Discussion

CSDH reportedly follows unruptured cerebral aneurysm surgery in about 1.7–5.1% of cases [4–8] Since these reports extracted the number of CSDH events only by counting those that were symptomatic and required surgery, both symptomatic and asymptomatic CSDH following unruptured aneurysmal clipping surgery may not be rare pathologies at all. Background patient factors associated with the onset of postoperative CSDH include male sex, old age, postoperative anticoagulation drug intake, and extent of cerebral atrophy. [4–6,8,14] In the present study, mean age was significantly higher in the CSDH group than in the non-CSDH group, consistent with previous reports. However, multivariate logistic regression analysis revealed that the large subdural fluid volume was the only risk factor independently associated with development of CSDH. Indeed, CSDH is commonly found in many elderly individuals, and aging has been described as contributing to poor elasticity of the brain surface and poor brain swelling. In addition, due to cerebral atrophy, the decrease in the volume of brain gray matter

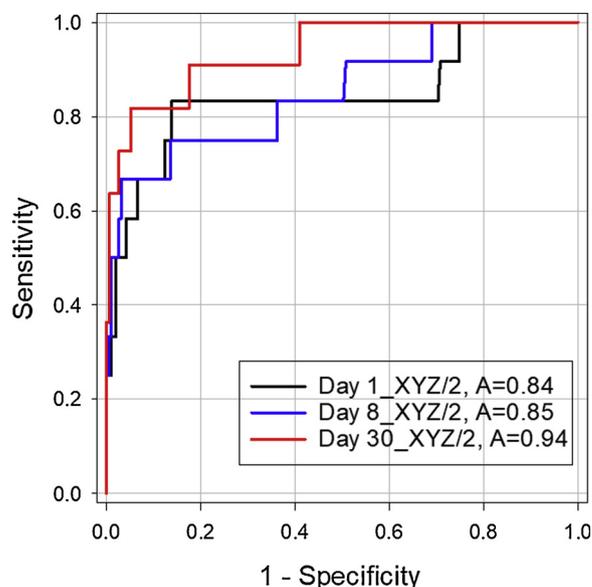


Fig. 2. Relationship between postoperative subdural fluid volume and the onset of CSDH. ROC curve of postoperative subdural fluid volume affecting the occurrence of CSDH after clipping surgery, demonstrating that postoperative subdural fluid volume on POD1, POD8, and POD30 could predict the onset of CSDH after surgery (area under the curve, 0.84, 0.85, 0.94; 95% confidence interval, 0.44 – 0.76, 0.32 – 0.64, 0.55 – 0.88; p = 0.26, 0.81, 0.02, respectively).

increases the CSF volume of the sylvian fissure. [1,2] The surgical operation causes a communication between the subdural cavity and cerebrospinal fluid cavity, resulting in a one-way valve causing an increase in subdural fluid volume [1,8]. This pathology can explain why aged patients tend to develop CSDH after clipping surgery and clinicians should pay attention to the onset of CSDH after clipping surgery as well as after traumatic brain injury in elderly patients. Regarding gender, some reports have noted that brain atrophy occurs more frequently among men than among women with advancing age. [15,16] In contrast, a certain amount of blood entering the subdural space during a surgical procedure or in traumatic brain injury can promote the development of CSDH [2,4,17]. Kwon et al. conducted a retrospective study after ruptured and unruptured cerebral aneurysm clipping surgeries, and found that the highest HU value in the subdural space immediately after surgery correlated with the onset of postoperative CSDH if the value was over 40 HU and a small amount of bleeding clot (as a well-known initiating mechanism in CSDH formation) had formed through inflammatory and fibrinolytic processes. This process is thought to be related to formation of a new membrane in the subdural space [10,19]. In the present series, however, no significant difference in HU values on POD1, POD8 was evident between groups. Conventional AP may decrease the HU value of subdural fluid postoperatively because 110 patients (53%) underwent conventional AP procedures in the present study.

Several methods have been reported for conveniently approximating the subdural fluid volume. Won Jae Lee et al. evaluated the subdural fluid volume with the maximum width of the subdural cavity and set a cutoff value of 10 mm. Univariate analysis showed a significant difference in postoperative CSDH onset, but multivariate analysis found no significant difference [20]. Ohno et al. used this method and reported that postoperative CSDH occurred predominantly in the subdural fluid collection group with head CT showing more than 5 mm width of the subdural cavity at 1 week postoperatively, with the cut-off set at 5 mm [5]. On the other hand, a simple method for estimating CSDH volume, the XYZ/2 method, has been described. Sucu et al. evaluated the volume of CSDH using three components of XYZ, and compared 5 kinds of measurement methods. They demonstrated that

Table 4
Logistic regression analysis of factors associated with onset of CSDH after surgery.

	Univariate		Multivariate	
	p value	RR (95%CI)	p value	RR (95%CI)
Age	0.055	0.262 (0.059-1.167)	–	–
Gender	0.057	2.782 (0.936-8.264)	–	–
Hypertension	0.952	0.965 (0.301-3.905)	–	–
Diabetes	0.269	0.445 (0.106-1.869)	–	–
Hyperlipidemia	0.656	1.333 (0.373-4.762)	–	–
Current smoker	0.100	4.565 (0.602-34.590)	–	–
ARBs	0.898	0.930 (0.305-2.831)	–	–
Statin	0.936	0.949 (0.267-3.372)	–	–
Antithrombotic	0.269	0.445 (0.106-1.869)	–	–
Conventional ARP	0.324	0.561 (0.174-1.804)	–	–
POD1 SDFV	< 0.001*	0.043 (0.010-0.189)	0.011*	18.41(1.92-176.10)
POD8 SDFV	< 0.001*	0.067 (0.019-0.237)	0.023*	13.94(1.45-134.2)

ARBs, angiotensin II receptor blockers; ARP, arachnoid-plasty; SDFV, subdural fluid volume.

POD1 / POD8 SDFV cut-off values were 11.47 cm³ and 29.95 cm³, respectively, defined by ROC curve analysis for the occurrence of CSDH after clipping surgery.

* $p < 0.05$.

combination of integral value X: (maximum width of CSDH among all slices from axial head CT), Y: (maximum length of CSDH among all slices from axial head CT), Z: (+ depth of CSDH) was the most accurate integral value and correlation coefficient were 0.932, which was the most accurate and more convenient [13]. The present study therefore calculated postoperative subdural fluid volume using this measurement method.

We demonstrated in the present study that the onset of CSDH after unruptured cerebral artery aneurysm clipping was associated with increased postoperative subdural fluid volume. These results are consistent with findings from previous reports [10,14]. This therefore suggested the possibility of suppressing postoperative CSDH development by not increasing postoperative subdural fluid volume. The utility of ARP surgery has been reported as a method to suppress increases in the volume of the subdural space after surgery [6,12]. Various techniques have been considered for forming a membrane: 1) sealing the arachnoid membrane opened during the operation as much as possible; 2) sealing with fibrin glue on the arachnoid membrane; 3) sealing the arachnoid membrane by coating the fibrin glue with Surgicel; 4) sealing the arachnoid membrane as much as possible. A method of replacing air with artificial cerebrospinal fluid during surgical operation of the subarachnoid space has been reported [21]. In this series, to use a simple, easy procedure that avoids inter-operator technical differences, we are conducting conventional ARP by forming an artificial arachnoid membrane using method 3), but no significant difference was found in postoperative subdural fluid volume between methods with and without conventional ARP. Indeed, conventional ARP can protect the cerebrospinal fluid communication between the opened cistern and the subdural cavity, and can avoid a one-way valve causing an increase in subdural fluid volume after clipping. However, this approach would be insufficient to obtain suitable brain surface re-expansion, especially in cases involving an aged atrophic brain. On the other hand, Yagi et al. [6] and Abe et al. [21] reported that they placed a tube in the subarachnoid space in addition to the arachnoid membrane formation, and injected artificial cerebrospinal fluid into the subarachnoid space. The incidence of postoperative CSDH subsequently reduced significantly. Taken these results together, we speculate that conventional ARP and injection of artificial cerebrospinal fluid into the arachnoid space can reduce postoperative subdural fluid volume and could suppress the onset of CSDH. Further investigation is required in the form of prospective multicenter randomized trials to confirm whether the ARP procedure with artificial cerebrospinal fluid injection into the subarachnoid space can reduce postoperative subdural fluid volume and suppress the onset of CSDH.

Various limitations to this research must be considered. First, this

was a retrospective study of a single facility with no randomization of the conventional ARP procedure, so several biases may be involved. Small number of CSDH cases may affect the efficacy of ARP procedure. Second, we included cases in which CSDH developed a relatively long time after clipping surgery. Third, cases of unrecognized brain trauma-induced CSDH development may have been included in the present series. Furthermore, brain atrophy may have affected the incidence of CSDH since the degree of preoperative brain atrophy has not been evaluated in this study. Forth, the collected average HU value for the subdural fluid space on POD30 was significantly higher in CSDH group. CSDHs might have been occurring and developing on POD 30 in CSDH group.

5. Conclusions

In this study, among 209 patients who developed postoperative CSDH and postoperative extensive subdural fluid volume, 12 cases (6%) showed onset of CSDH after unruptured aneurysmal clipping surgery. Although no significant association was seen between use of intraoperative conventional ARP and occurrence of CSDH, the ARP procedure with artificial cerebrospinal fluid injection into the subarachnoid space may reduce can reduce subdural fluid volume and may suppress the onset of CSDH after clipping surgery.

Funding

None.

Ethical approval

This study was approved by the institutional review board at Nara Medical University (Approval no. 2046).

Informed consent

Obtained from all patients.

Declaration of Competing Interest

No conflict of interest in all authors.

Acknowledgements

None

References

- [1] H. Koizumi, A. Fukamachi, H. Nukui, Postoperative subdural fluid collections in neurosurgery, *Surg. Neurol.* 27 (February 2) (1987) 147–153.
- [2] K. Mori, M. Maeda, Risk factors for the occurrence of chronic subdural hematoma after neurosurgical procedures, *Acta Neurochir (Wien)*. 145 (July7) (2003) 533–540.
- [3] Y. Tanaka, M. Mizuno, S. Kobayashi, K. Sugita, Subdural fluid collection following craniotomy, *Surg. Neurol.* 27 (April 4) (1987) 353–356.
- [4] J. Inamasu, T. Watabe, T. Ganaha, Y. Yamada, S. Nakae, T. Ohmi, S. Imizu, T. Kaito, K. Ito, Y. Nishiyama, T. Hayashi, H. Sano, Y. Hirose, Clinical characteristics and risk factors of chronic subdural haematoma associated with clipping of unruptured cerebral aneurysms, *J. Clin. Neurosci.* 20 (August 8) (2013) 1095–1098.
- [5] T. Ohno, K. Iihara, J.C. Takahashi, N. Nakajima, T. Satow, T. Hishikawa, I. Nagata, K. Yamada, S. Miyamoto, Incidence and risk factors of chronic subdural hematoma after aneurysmal clipping, *World Neurosurg.* 80 (November 5) (2013) 534–537.
- [6] K. Yagi, S. Irie, T. Inagaki, Y. Ishii, O. Saito, T. Lee, H. Nakagawa, K. Saito, S. Nagahiro, Intraoperative arachnoid plasty has possibility to prevent chronic subdural hematoma after surgery for unruptured cerebral aneurysms, *Neurol Med Chir (Tokyo)*. 55 (6) (2015) 493–497.
- [7] W.J. Lee, K.I. Jo, J.Y. Yeon, S.C. Hong, J.S. Kim, Incidence and risk factors of chronic subdural hematoma after surgical clipping for unruptured anterior circulation aneurysms, *J. Korean Neurosurg. Soc.* 57 (April 4) (2015) 271–275.
- [8] J. Park, J.H. Cho, D.H. Goh, D.H. Kang, I.H. Shin, I.S. Hamm, Postoperative subdural hygroma and chronic subdural hematoma after unruptured aneurysm surgery: age, sex, and aneurysm location as independent risk factors, *J. Neurosurg.* 124 (February 2) (2016) 310–317.
- [9] T. Ohno, Y. Nishikawa, K. Aoyama, K. Yamada, K. Iihara, Postoperative chronic subdural hematoma following clipping surgery, *Nagoya Med. J.* 42 (2014) 1–8.
- [10] M.Y. Kwon, C.H. Kim, C.Y. Lee, Predicting factors of chronic subdural hematoma following surgical clipping in unruptured and ruptured intracranial aneurysm, *J. Korean Neurosurg. Soc.* 59 (September 5) (2016) 458–465.
- [11] Y.J. Jun, J.S. Ahn, E.S. Park, D.H. Kwon, B.D. Kwun, C.J. Kim, Surgical results of unruptured intracranial aneurysms in the elderly: single center experience in the past ten years, *J. Korean Neurosurg. Soc.* 49 (6) (2011) 329–333.
- [12] S. Kawabata, S. Tani, H. Imamura, H. Adachi, N. Skai, Postoperative subdural air collection is a risk factor for chronic subdural hematoma after surgical clipping of cerebral aneurysms, *Neurol Med Chir (Tokyo)*. 58 (June 6) (2018) 247–253.
- [13] J.H. Kim, C.H. Kim, C.Y. Lee, Efficacy of arachnoid-plasty on chronic subdural hematoma following surgical clipping of unruptured intracranial aneurysms, *World Neurosurg.* 104 (2017) 303–310.
- [14] H.K. Sucu, M. Gokmen, F. Gelal, The value of XYZ/2 technique compared with computer-assisted volumetric analysis to estimate the volume of chronic subdural hematoma, *Stroke* 36 (May 5) (2005) 998–1000.
- [15] J.H. Kang, S.K. Huh, J. Kim, K.Y. Park, J. Chung, Subdural fluid collection after the clipping of unruptured intracranial aneurysms: Its clinical course and significance, *World Neurosurg.* 116 (2018) e266–e272.
- [16] C.E. Coffey, J.F. Lucke, J.A. Saxton, G. Ratcliff, L.J. Unitas, B. Billig, R.N. Bryan, Sex differences in brain aging: a quantitative magnetic resonance imaging study, *Arch. Neurol.* 55 (February 2) (1998) 169–179.
- [17] J.A. Kaye, C. DeCali, J.S. Luxenberg, S.I. Rapoport, The significance of age-related enlargement of the cerebral ventricles in healthy men and women measured by quantitative computed X-ray tomography, *J. Am. Geriatr. Soc.* 40 (March 3) (1992) 225–231.
- [19] Y. Takahashi, J. Mikami, M. Ueda, K. Ito, H. Sato, H. Matsuoka, S. Takeda, S. Ohkawara, Analysis of chronic subdural hematoma based on CT (Part III). Clinical stage classification based on CT findings, *Neurol Med Chir (Tokyo)*. 24 (8) (1984) 607–614.
- [20] W.J. Lee, T.M. Nam, K.I. Jo, J.Y. Yeon, S.C. Hong, J.S. Kim, Modified arachnoid plasty reduces chronic subdural hematoma after unruptured aneurysm clipping: technical note, *J. Korean Neurosurg. Soc.* 61 (November 6) (2018) 761–766.
- [21] J. Abe, T. Ichinose, Y. Terakawa, N. Tsuyuguchi, T. Tsuruno, K. Ohata, Efficacy of arachnoid plasty with collagen sheets and fibrin glue: an in vitro experiment and a case review, *Surg. Neurol. Int.* 6 (2015) 90.