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Fifteen Cases of Endoscopic Treatment of Acute Subdural Hematoma with Small Craniotomy under Local Anesthesia: Endoscopic Hematoma Removal Reduces the Intraoperative Bleeding Amount and the Operative Time Compared with Craniotomy in Patients Aged 70 or Older

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Abstract

We report cases of acute subdural hematoma (ASDH) treated by endoscopic hematoma removal with a small craniotomy under local anesthesia. From 2015 to 2019, we retrospectively analyzed 15 ASDH patients who were 70 years or older and met our criteria for endoscopic treatment: (1) comorbidities indicated risks associated with a large craniotomy under general anesthesia; (2) decompressive craniectomy was unlikely; and (3) an enlarging hematoma was absent. We also performed a case–control study using the inverse probability weighting method to compare the 15 patients to 20 ASDH patients who were 70 years or older, met criteria (2) and (3), and were treated by craniotomy between 2012 and 2019. Among the 15 ASDH patients, the median age was 86 (range, 70–101) years, and fall was the common cause. The median Glasgow Coma Scale score on admission, operative time, stay time in the operation room, and bleeding amount were 8 (6–15), 91 (48–156) min, 120 (80–205) min, and 20 (5–400) mL, respectively. The extraction rates of all the hematomas exceeded 90%. No patients required conversion to craniotomy under general anesthesia. Three patients had favorable outcomes, and five died. The comparison with craniotomy revealed that the endoscopic procedure reduced the intraoperative bleeding amount, operative time, and stay time in the operation room (p <0.001, p = 0.02, and p <0.001, respectively). In summary, endoscopic hematoma removal for selected ASDH patients aged 70 years or older did not improve functional outcomes but reduced the bleeding amount and the operative time compared with craniotomy.

Keywords: acute subdural hematoma, minimally invasive surgery, neuroendoscope, bleeding amount, craniotomy

Introduction

Traumatic acute subdural hematoma (ASDH) is a major clinical entity in traumatic brain injury. Its operative management usually includes cranioplastic craniotomy, large decompressive craniectomy, trephination/craniostomy, or a combination of these procedures under general anesthesia.[1–3] However, craniotomy or decompressive craniectomy has risks of blood loss, side effects of general anesthesia, and infection, making these procedures inappropriate in some cases, especially for the elderly or patients with comorbidities.

Recently, reports on endoscopic hematoma removal with small craniotomy for ASDH have been increasing.[4–13] This minimally invasive surgery could possibly compensate for the disadvantages of craniotomy and craniectomy under general anesthesia. However, its efficacy remains unclear because the reports on endoscopic hematoma removal remain scarce. We herein report a case series of 15 ASDH patients aged 70 years or older who were treated by endoscopic hematoma removal with small craniotomy under local

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anesthesia. This report contains a relatively large number of cases compared with previous reports, and we also performed a case–control study comparing the 15 patients to the craniotomy group, which has not been reported previously.

Materials and Methods

Study design

We conducted an observational study to test the clinical effectiveness of endoscopic surgery for ASDH using the electronic health records (EHRs) from our hospital, retrospectively. First, we compared the demographics and clinical outcomes of a series of patients who underwent endoscopic surgery with those who underwent craniotomy. Second, we tested the effects of surgery-type selection on outcomes using the inverse probability weighting (IPW) method.

Study population

We extracted the data of all patients who underwent surgery for ASDH from 2012 to 2019 using our hospital's EHR. Inclusion criteria were patients aged 70 or older who were hospitalized due to ASDH. Those aged less than 70, those who had conservative treatment without surgical intervention, those with subacute SDH, and those who had craniectomies were excluded. We defined the acute phase as the time from the onset up to 3 days.[14] A total of 63 patients were surgically treated for ASDH, and 35 of the 63 patients met our inclusion criteria: 15 underwent endoscopic surgery and 20 underwent craniotomy. The 28 excluded patients included two young patients who underwent endoscopic surgery. All patients or their families gave written consent for this study. Moreover, the study was approved by the hospital's research ethics committee. The diagnosis of ASDH was based on clinical history and the presence of ASDH on computed tomography (CT). The surgical indication was made when the patients had impaired consciousness or focal neurological deficits.

A large craniotomy or craniectomy was usually the first-choice treatment for ASDH. Endoscopic hematoma removal was proposed when (1) a patient's comorbid burden, including diabetes mellitus, cardiopulmonary complications, coagulopathy due to liver cirrhosis, and hemophilia, indicated increased risk during a large craniotomy under general anesthesia; (2) patients were less likely to require decompressive craniectomy, after comprehensive evaluation of brain edema and contusions on a head CT scan and clinical symptoms; and (3) an enlarging hematoma was absent. In patients receiving anticoagulation therapy, prothrombin time was normalized by the administration of vitamin K and/or fresh frozen plasma. Postoperatively, antithrombotic agents were discontinued for several days, depending on the patient's condition and comorbidities.

Endoscopic procedure

We performed endoscopic ASDH removal under local anesthesia for the patients meeting the criteria described earlier. We do not usually perform this procedure under general anesthesia, considering the time to start the surgery and the risks of general anesthesia. However, we also prepared for conversion to craniotomy under general anesthesia, in case the brain expanded rapidly or hemostasis was difficult endoscopically. The patients' head was rotated contralateral to the hematoma side and placed on a horseshoe headrest. An approximately 7-cm linear skin incision was made parallel to the coronal suture, and a small craniotomy of 2–3 cm in diameter was made on the point under which the hematoma thickness was largest. After a cruciate dural incision, a neurosurgeon introduced a rigid endoscope (Hopkins II, 4.0 mm, 0° or 30° angle; Karl Storz, Tuttlingen, Germany) into the subdural space to observe the hematoma. To evacuate the hematoma, another neurosurgeon used the endoscopic monitor and a combined irrigation–coagulation suction cannula (Fujita Medical Instrument, Tokyo, Japan), which can be used for irrigation and monopolar coagulation at its tip simultaneously.[15] Two neurosurgeons performed the endoscopic hematoma removal to ensure the safety of endoscopic manipulation and prepare for conversion to craniotomy under general anesthesia if required. We navigated the endoscope to the frontal and temporal base and then to the parietal region. This was done because the bridging vein is a source of bleeding,[16] and we observed it at the last of the whole procedure. Venous bleeding was stopped by compression with oxidized cellulose and fibrin glue if necessary. When the decompression seemed sufficient, we did not remove the hematoma in the parietal region more than necessary. We then covered the hematoma with oxidized cellulose and fibrin glue. Arterial bleeding was coagulated by the combined irrigation–coagulation suction cannula[15] or electrocautery. After sufficient decompression and confirmation of hemostasis, the removal cavity was filled with artificial cerebrospinal fluid. The dura mater was sutured and covered with oxidized cellulose. The piece of the cranium was fixed with metal plates, and the skin was sutured. When the brain expanded very rapidly or hemostasis by endoscopic procedure was too difficult, we switched to large craniotomy or craniectomy under general anesthesia.

Clinical variables

We collected the following data regarding physiological symptoms and medical history on admission:

age, sex, cause of trauma, systolic blood pressure, comorbidities, use of antithrombotic drugs, chief complaint, absence of light reflex, Glasgow Coma Scale (GCS), laterality, and the time from trauma to surgery. We measured the ASDH volume and thickness, midline shift, and the extraction rate of the hematoma based on head CT performed on admission and immediately after the operation. The volume of ASDH was calculated by the ABC/2 method.[17] Preoperative and postoperative prothrombin time international normalized ratio (PT-INR), activated partial thromboplastin time (APTT), values of fibrinogen, d-dimer, and platelet count were investigated. The outcome was assessed by the GCS at postoperative day 7 and the modified Rankin Scale (mRS) 6 months after the operation. We defined mRS 0–2 as a favorable outcome and mRS 3–6 poor. Intraoperative bleeding amount, operative time, and the stay time in the operation room were also collected as outcomes.

Statistical analysis

We investigated the 35 ASDH patients and compared the 15 patients in the endoscopy group with the 20 patients in the craniotomy group. The Fisher's exact test or Mann–Whitney *U* test was used for testing the differences between the two groups. To address confounding by observed covariates, we performed the IPW method, which is a type of propensity score analysis. The propensity score was calculated by a logistic regression model predicting treatment (endoscopy or craniotomy) and adjusting the baseline characteristics of age, sex, history of cardiovascular disease, use of antithrombotic drugs, GCS score on admission, hematoma volume, midline shift, preoperative APTT, PT-INR, and platelet count as independent variables. The calculated probability of receiving the treatment was evaluated by the Hosmer–Lemeshow test and *c*-statistic. The weights for each patient were calculated as the inverse of the probability of receiving the treatment. After balancing with the IPW method, we made generalized estimating equations to assess the association between the surgical procedure and each outcome. We conducted these analyses using version 21.0.0 of SPSS software (IBM, Armonk, NY, USA). The results were shown as median (range). A two-tailed $p < 0.05$ was considered as statistically significant.

Results

Characteristics of 15 patients with ASDH treated with an endoscopic procedure

Table 1 shows the characteristics of the 15 patients (nine females and six males) with ASDH treated by endoscopic procedures. The median age was 86 (70–101) years. Three of the patients had right ASDH, and the others had left ASDH. Most ASDHs were due to falls. The median GCS score on admission was 8 (6–15). The median hematoma volume was 140 (87–252) mL, and the midline shift was 12 (5–25) mm. Venous or arterial bleeding was confirmed intraoperatively in a few cases. No patients required conversion to craniotomy under general anesthesia. The intraoperative bleeding amount, median operative time, and the stay time in the operation room were 20 (5–400) mL, 91 (48–156) min, and 120 (80–205) min, respectively. The extraction rates of hematoma all exceeded 90%. Two patients had rebleeding. The median GCS score 7 days after the operation was 14 (3–15). Three (20%) patients had favorable outcomes, and five died. Other parameters are described in Table 1.

Comparison of the ASDH patients over 70 years between the endoscopy group and the craniotomy group

Age, sex, comorbidities, chief complaint, GCS score on admission, hematoma volume, midline shift, and time from trauma to the operation were not significantly different between the endoscopy and the craniotomy groups. Moreover, the use of antithrombotic drugs, preoperative PT-INR, APTT, fibrinogen, d-dimer values, and platelet count were not significantly different in the two groups (Table 2). Regarding the probability of receiving the treatment, the *p* value was 0.646 according to the Hosmer–Lemeshow test, and the *c*-statistic was 0.923. The weighted generalized estimating equations revealed that the GCS score at postoperative day 7 and the mRS score at 6 months were not significantly different between the two groups ($p = 0.83$ and $p = 0.92$, respectively). However, the bleeding amount, operative time, and the stay time in the operation room were significantly smaller or shorter in the endoscopy group than those in the craniotomy group ($p < 0.001$, $p = 0.02$, and $p < 0.001$, respectively) (Table 3).

Discussion

Experience in endoscopic surgery is still limited, and our study is the first to demonstrate the efficacy and safety of this procedure compared with those of existing surgical treatments. Endoscopic hematoma removal for selected ASDH patients aged 70 years or older did not improve functional outcomes, but it did reduce the bleeding amount, operative time, and stay time in the operation room compared with craniotomy.

Elderly patients with ASDH

Japan has a rapidly aging society. Concomitantly, the incidence of ASDH in elderly patients has also

Table 1 Clinical characteristics of endoscopic surgery in 15 patients with ASDH

No.	Age	Sex	Premorbid mRS	Comorbidities	Cause	Light reflex	GCS on admission	Antithrombotic drug	Chief complaint
1	70	F	0	HT	Idiopathic	+	15	–	Headache
2	71	F	2	SAH	Fall	+	10	–	Focal deficit
3	78	F	3	AD, AF	Idiopathic	–	6	+	Impaired consciousness
4	78	M	0	Colon cancer	Fall	+	8	–	Impaired consciousness
5	81	M	2	AF	Fall	–	13	+	Impaired consciousness
6	82	M	2	AMI, AD	Fall	+	12	+	Focal deficit
7	84	M	2	Gastric cancer, HT	Fall	+	7	–	Impaired consciousness
8	86	F	2	HT	Fall	+	8	–	Impaired consciousness
9	86	F	2	Angina pectoris	Fall	+	6	+	Impaired consciousness
10	86	F	2	SAH, AF	Fall	+	13	+	Impaired consciousness
11	88	M	4	CI, diabetes mellitus	Fall	+	6	+	Impaired consciousness
12	89	M	2	CI	Fall	+	13	–	Impaired consciousness
13	91	F	2	Angina pectoris	Fall	–	6	+	Impaired consciousness
14	100	F	4	CI	Idiopathic	–	6	+	Impaired consciousness
15	101	F	3	Dementia	Fall	+	11	–	Focal deficit
Median (range)	86 (70–101)	9 F/6 M	2 (0–4)		12 fall/3 idiopathic	11 present, 4 absent	8 (6–15)	8 present	11 impared consciousness, 3 focul deficits, 1 headache

A: arterial bleeding, AD: aortic dissection, AF: atrial fibrillation, AMI: acute myocardial infarction, ASDH: acute subdural hematoma, CI: cerebral infarction, F: female, GCS: Glasgow Coma Scale, HT: hypertension, M: male, mRS: modified Rankin Scale, OP: operation, postop: post operation, SAH: subarachnoid hemorrhage, V: venous bleeding

Time from trauma to operation	Hematoma volume (mL)	Midline shift (mm)	Bleeding source	Operative time (min)	Bleeding amount (mL)	Extraction rate (%)	Rebleeding	GCS score 7 days postop	mRS 6 months after the OP
?	102	11	–	120	10	100	–	15	0
48 hr	131	14	–	55	5	90	–	14	2
?	195	5	–	64	5	95	–	14	4
2 hr	171	15	V	100	50	97	–	Dead	6
8 hr	98	15	–	79	10	100	–	14	6
48 hr	133	13	–	53	10	100	–	14	2
6 hr	125	11	–	153	100	100	–	Dead	6
4 hr	140	10	A	48	50	100	–	14	3
2 hr	87	12	V	156	400	90	–	14	4
24 hr	99	12	–	95	10	98	–	14	4
3 hr	252	14	–	68	100	98	+	Dead	6
1 hr	150	10	–	140	30	100	–	11	5
4 hr	240	25	–	100	400	98	–	6	5
?	159	13	–	82	20	100	+	3	6
2 hr	157	7	–	91	10	100	–	7	5
6 (1–48) hr	140 (87–252)	12 (5–25)	1 A, 2 V	91 (48–156)	20 (5–400)	100 (90–100)	2 present	14 (3–15)	5 (0–6)

Table 2 Comparison of the ASDH patients over 70 years between the endoscopy group and craniotomy group

Variables	Endoscopy (n = 15)	Craniotomy (n = 20)	*p* value
Age (years)	86 (70–101)	80.5 (70–88)	0.06
70–75, n (%)	2 (13%)	4 (20%)	
76–80, n (%)	2 (13%)	6 (30%)	
81–85, n (%)	3 (20%)	4 (20%)	
86–90, n (%)	5 (34%)	6 (30%)	
90+, n (%)	3 (20%)	0 (0%)	
Women:men (% women)	9:6 (60%)	5:15	0.02*
Cause			
Fall, n (%)	12 (80%)	16 (80%)	
Traffic accident, n (%)	0 (0%)	2 (10%)	
Idiopathic, n (%)	3 (20%)	2 (10%)	
Systolic blood pressure (mmHg)	167 (112–230)	166 (112–230)	0.44
Comorbidities			
Cerebrovascular diseases, n (%)	6 (40%)	6 (30%)	0.72
Cardiovascular diseases, n (%)	6 (40%)	9 (45%)	0.99
Hypertension, n (%)	3 (20%)	6 (30%)	0.70
Diabetes mellitus, n (%)	1 (7%)	3 (15%)	0.62
Use of antithrombotic drugs, n (%)	8 (53%)	14 (70%)	0.48
Premorbid mRS score	2 (0–4)	2.5 (0–4)	0.99
Chief complaint			
Impaired consciousness, n (%)	11 (73%)	16 (80%)	0.70
Focal deficits, n (%)	3 (20%)	2 (10%)	0.63
Headache, n (%)	1 (7%)	2 (10%)	0.99
Presence of light reflex, n (%)	11 (58%)	11 (55%)	0.31
GCS score on admission	8 (6–15)	7.5 (3–14)	0.46
14–15, n (%)	1 (8%)	3 (15%)	
9–13, n (%)	6 (40%)	7 (35%)	
3–8, n (%)	8 (52%)	10 (50%)	
Left:right (% left)	12:3 (80%)	7:13 (35%)	0.04*
Hematoma volume (mL)	140 (87–252)	121 (42–280)	0.15
Midline shift (mm)	12 (5–25)	11.4 (7–32)	0.91
Preop PT-INR	1.03 (0.80–3.86)	1.11 (0.91–2.87)	0.14
Postop PT-INR	1.21 (1.18–1.38, n = 4)	1.34 (1.08–1.71, n = 4)	0.88
Preop APTT (sec)	27.0 (21.6–49.1)	30.9 (23.3–49.4)	0.24
Postop APTT (sec)	35.0 (31.4–43.1, n = 3)	38.9 (37.3–42.5, n = 4)	0.63
Preop fibrinogen (mg/dL)	335 (162–566)	298 (139–513)	0.68
Postop fibrinogen (mg/dL)	Not measured	Not measured	–
Preop d-dimer (μg/mL)	5.5 (1.0–282.0)	10.7 (1.8–223.1)	0.27
Postop d-dimer (μg/mL)	3.5 (1.39–5.0, n = 8)	9.2 (2.5–15.8, n = 2)	0.53
Preop platelet count (10^4/μL)	17.4 (5.1–33.9)	14.3 (8.9–30.6)	0.33
Postop platelet count (10^4/μL)	16.7 (10.7–27.5)	11.5 (4.7–39.4, n = 18)	0.15
Transfusion of PC or FFP, n (%)	2 (13%)	3 (15%)	0.99

Variables	Endoscopy (n = 15)	Craniotomy (n = 20)	*p* value
Time from trauma to operation (hr)	6 (1–48, n = 12)	14 (3–48, n = 19)	0.07
Bleeding amount (mL)	20 (5–400)	200 (10–2300)	0.002*
Operative time (min)	91 (48–156)	98 (61–267)	0.38
Stay time in the operation room (min)	120 (80–205)	180 (105–375)	0.005*
Hematoma removal rate	100% (90%–100%)	100% (96%–100%)	0.36
GCS score 7 days post-op	14 (3–15, n = 12)	12 (4–14, n =18)	0.36
mRS score at 6 months	5 (0–6)	5 (2–6)	0.91
Death during hospitalization, n (%)	3 (20%)	2 (10%)	0.63
Rebleeding, n (%)	2 (13%)	2 (10%)	0.99
Complication (bone infection), n (%)	0 (0%)	0 (0%)	0.99

The results are shown with the number (%) or the median (range). *p* value was calculated by the Fisher's exact test or Mann–Whitney *U* test. *p *<0.05*. APTT: activated partial thromboplastin time, ASDH: acute subdural hematoma, CT: computed tomography, FFP: fresh frozen plasma, GCS: Glasgow Coma Scale, mRS: modified Rankin Scale, PC: platelet concentrates, postop: post operation, preop: pre operation, PT-INR: prothrombin time international normalized ratio

Table 3 Effect of endoscopic procedure for each outcome tested by inverse probability of treatment weighting methods

Outcome	*B*	Standard error	*p* value	Beta	95% confidence interval for beta
Bleeding amount	–241.2	68.5	<0.001*	1.00×10^{-13}	1.00×10^{-13}–1.01×10^{-13}
Operative time	–28.8	12.5	0.02*	4.10×10^{-13}	1.00×10^{-13}–0.013
Stay time in the operation room	–62.8	15.1	<0.001*	1.00×10^{-13}	1.00×10^{-13}–1.04×10^{-13}
GCS score 7 days postop	–0.383	1.80	0.83	0.68	0.02–23.10
mRS at 6 months	–0.076	0.72	0.92	0.93	0.23–3.82

Weights are based on results from a treatment selection model, estimated using logistic regression with endoscopy or craniotomy as the dependent variable and the baseline characteristics of age, sex, history of cardiovascular disease, use of antithrombotic drugs, GCS score on admission, hematoma volume, midline shift, preoperative APTT, PT-INR, and platelet count as independent variables. The weights for each patient were calculated as the inverse of the probability of receiving the treatment. After weighting, we made generalized estimating equations to assess the association between the surgical procedure and each outcome. As to the probability of receiving the treatment, the p value was 0.646 by the Hosmer–Lemeshow test, and the *c*-statistic was 0.923. *$p < 0.05$ by weighted generalized estimating equations. APTT: activated partial thromboplastin time, GCS: Glasgow Coma Scale, mRS: modified Rankin Scale, PT-INR: prothrombin time international normalized ratio

been increasing in Japan.[18] The Cabinet Office of Japan has estimated that life expectancy will be more than 90 years in 50 years' time; therefore, advanced age should not be the only reason that elderly patients with ASDH do not undergo surgical treatment. However, older age is generally accepted to be an important predictor of poor prognosis and mortality of SDH, which has a mortality rate ranging from 35% to 80%.[19–22] Furthermore, craniotomy under general anesthesia is often inappropriate in elderly patients due to their systemic comorbid burdens, such as cardiopulmonary failure, diabetes mellitus, and the use of antithrombotic drugs. Therefore, an endoscopic procedure under local anesthesia would be useful for patients with ASDH who cannot undergo craniotomy under general anesthesia. Similar to previous reports[4–8,10–13] on the efficacy of endoscopic hematoma removal for ASDH, we considered that our case series might add to the body of knowledge regarding the endoscopic surgical procedure and help to establish this as a semi-standard treatment for ASDH in future.

Previous reports on patients with ASDH treated by endoscopic procedures

Table 4 summarizes previous reports of patients with true ASDH (but not subacute SDH) treated by means of endoscopic procedures.[4–8,10–13] Our case

Table 4 Previous reports on patients with acute subdural hematoma treated by endoscopic procedures[4–8,10–13]

Author	Year	No. of cases	Age (years)	Sex	Premorbid ADL	Preoperative GCS	Outcome
Kon et al.	2013	1	87	F	Unknown	8	Favorable
Yokosuka et al.	2015	8	84.5 (75–91)	4 F/4 M	Unknown	12.6 (6–15)	6 favorable (75%)
Miki et al.	2016	9	79.5 (65–91)	3 F/6 M	Unknown	7.7 (4–13)	All poor
Tamura et al.	2016	1	73	F	Unknown	Unknown	Poor
Kuge et al.	2017	1	31	F	Independent	6	Favorable
Kawasaki et al.	2018	15	79 (67–93)	5 F/10 M	Unknown	10.2 (3–15)	7 favorable (46%)
Maruya et al.	2018	2	60.5 (51–70)	1 F/1 M	Independent	5.5 (5–6)	1 favorable (50%)
Ichimura et al.	2019	5	87.4 (82–94)	1 F/4 M	1 independent	7.4 (3–13)	All poor
Hwang and Shin	2020	12	78.8 (65–89)	7 F/4 M	Unknown	Unknown	4 favorable (33%)
Our cases	2020	15	84.7 (70–101)	9 F/6 M	11 independent	9.3 (6–15)	3 favorable (20%)

ADL: activities of daily living, F: female, GCS, Glasgow Coma Scale, M: male

series reports a large number of cases to date. Fifty-four cases were previously reported, and the mean age of the patients in these cases was 79.1 (31–94) years. The mean preoperative GCS was 9.2 (3–15), and 20 (37%) patients had favorable outcomes. Older age and low preoperative GCS were related to poor outcomes; these findings were mostly consistent with our results.

Yokosuka et al.[4] and Kawasaki et al.[11] reported relatively high ratios (75% and 46%) of favorable outcomes after endoscopic treatment despite the older age of the patients. Our patients tended to have worse outcomes due to their higher ages than those in previous reports, and only three (20%) of the 15 ASDH patients aged more than 70 years had favorable outcomes. In contrast, 18%–36% of elderly patients more than 80 years of age who were candidates for craniotomy under general anesthesia had favorable outcomes.[22] Considering that endoscopically treated patients tended to be unsuited for craniotomy under general anesthesia due to comorbid burden, the results of endoscopic treatment were not inferior to those of traditional craniotomy under general anesthesia.

Endoscopic procedure and intraoperative bleeding amount

On average, 22.7% of patients with traumatic brain injury experience coagulopathy upon emergency room arrival, and this acute traumatic coagulopathy (ATC) may influence hemostasis or the occurrence of intracranial hematoma, which can lead to unfavorable outcomes.[1,10,23] ATC reaches a peak level in 3 to 6 hours,[24] and invasive large craniotomy or craniectomy would increase risk for difficulty in hemostasis under the ATC condition. Hagihara and Takayama et al. suggested monitoring hemostatic markers including d-dimer for coagulopathy status.[23,24] Many elderly patients are treated with antithrombotic drugs, and antithrombotic drugs naturally increase the intraoperative bleeding amount. They also lead to a higher risk of mortality and morbidity in cases with intracranial hematoma including ASDH.[25] Furthermore, massive bleeding results in disseminated intravascular coagulation, which is one of the main determining factors of poor prognosis.[26,27] Therefore, a decrease in the intraoperative bleeding amount is important in ASDH treatment.

Our results showed that endoscopic hematoma removal reduced the intraoperative bleeding amount compared to craniotomy. Craniotomy for ASDH often needs a large skin incision and a large craniotomy. In the ATC condition or during the use of antithrombotic drugs, bleeding from not only subdural space but also skin, bone, and dura can be substantial. In contrast, the endoscopic procedure does not need a large skin incision or craniotomy, so epidural bleeding can be decreased. However, if hemostasis that cannot be observed by endoscopy occurs at the site, we would need craniotomy to know what would be going under direct vision.

As another strategy for ASDH under ATC condition, hematoma irrigation with trephination therapy with fresh frozen plasma transfusion in an acute emergency situation followed by systemic management and craniotomy or craniectomy after correction of coagulopathy, namely, the "HITT and run strategy," has been performed.[23] Coagulopathy changes over time, so the best moment to perform the endoscopic procedure for ASDH after trauma is unknown. However, like the HITT and run strategy, selective endoscopic surgery following HITT for ASDH patients with severe ATC, or the "HITT and endoscopic surgery strategy," could be a new potential treatment. This combination is not as invasive and may have an important advantage in the rapid completion of hematoma removal.[10)]

Anesthesia method for the endoscopic procedure

Although general anesthesia increases the risk of excess blood pressure reduction leading to the secondary brain injury,[28)] it has neuroprotective effects by reducing cerebral edema and intracranial pressure (ICP)[29,30)] using transient hyperventilation,[29,30)] hypothermia,[31,32)] opioids, isoflurane,[31)] high-dose barbiturate administration,[29,30)] and propofol.[29,30)] Moreover, general anesthesia enables us to perform the surgery without patient movement. Our procedure under local anesthesia can be performed soon after admission, but it lacks the aforementioned benefits of general anesthesia. Furthermore, conversion from local anesthesia to general anesthesia takes time and has a risk of the surgical site infection. The anesthesia method for the endoscopic ASDH removal should be further discussed using the data of ICP monitoring.[29,30)]

Surgical indication for the endoscopic procedure

In this study, all surgeries were completed without conversion to craniotomy. The most important factors that predict a successful endoscopic procedure are that the hematoma is just compressing the brain surface without massive contusion or cerebral edema and that craniectomy against the elevated ICP is not needed. However, preoperative judgment concerning craniectomy is difficult depending on the patient's age, contusion volume, cerebral edema, and neurological severity. Kiyohira et al. reported that high APTT and low fibrinogen levels are associated with ICP elevation.[33)] In our cases, the preoperative APTT and fibrinogen levels were not as anomalous (Table 2), so these would be associated with the completion of endoscopic surgery. Furthermore, C-reactive protein,[34)] serum amyloid A,[34)] serum interleukin-6,[35)] and cerebrospinal fluid C-tau level[36)] are also biomarkers for ICP elevation. These biomarkers would be useful for the preoperative determination of the surgical strategy, namely, endoscopy, craniotomy, or craniectomy.

Advantages and disadvantages of endoscopic procedure

In summary, we found the following advantages in the endoscopic procedure: shortening of the operative time and the total time from entry to return from the operation room due to local anesthesia, reduction of intraoperative bleeding and surgical site infection by small skin incision, and surgical opportunity for patients who would not undergo general anesthesia due to comorbidities. In contrast, the endoscopic procedure has the following disadvantages: First, hemostasis cannot be achieved at sites affected by intraparenchymal hemorrhage or contralateral intracranial hematoma, as these sites cannot be observed by endoscopy. Bleeding from massive contusions or from the bleeding point after removal of the rigid hematoma could be difficult to stop using only the endoscopic procedure. Second, the endoscopic procedure with small craniotomy sometimes cannot cope with delayed cerebral edema or hemorrhage, which requires craniectomy. Third, the risk of patient movement under local anesthesia exists, and local anesthesia does not have the neuroprotective effects that general anesthesia provides. Therefore, we suggest that a large craniotomy or craniectomy be considered the first-choice treatment for ASDH. However, patients aged 70 years or older meeting our criteria may undergo the endoscopic procedure with preparation for conversion to craniotomy.

Limitation

Our study has several limitations. First, the number of patients was small because endoscopic surgery is a novel treatment for ASDH. Second, the year of surgery was potentially confounding; the endoscopic surgery began in 2015, and the surgical indication for endoscopy or craniotomy was unstable during introduction of a novel treatment. Third, there is a potential violation of the exchangeability assumption in patient selection. Some of the patients with severe comorbidities in the endoscopy group could never have undergone craniotomy under general anesthesia, and a comparator might have been conservative treatment. However, we found a preferable outcome by endoscopic surgery from our study even though we include this severe population. Fourth, we did not investigate the efficacy of endoscopic surgery for the young patients. The brain of a young patient is generally not atrophic and can be easily injured by acute increased ICP by ASDH, even if the hematoma is not massive. Therefore, the endoscopic procedure does not necessarily cope with young ASDH patients, and craniotomy or craniectomy will be needed. Further investigations into young patient outcomes are needed.

In conclusion, our results suggest that endoscopic hematoma removal with a small craniotomy in selected patients is safe and effective for the treatment of ASDH. This procedure does not improve functional outcomes, but it reduces the bleeding amount and the operative time compared to craniotomy.

Author Contributions

This manuscript was approved by all co-authors and the president of Suwa Red Cross Hospital. YK and YY contributed to conception and design. All authors were responsible for drafting the article. KK was involved in statistical analysis. YK was associated with supervision.

Conflicts of Interest Disclosure

This manuscript has not been published and is not under consideration for publication elsewhere. All the authors have read the manuscript and have approved this submission. Also, all authors report no conflict of interest related to the manuscript.

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