Neurosurg Rev (2018) 41:447–455
DOI 10.1007/s10143-017-0861-9

ORIGINAL ARTICLE

Clinical investigation of chronic subdural hematoma with impending brain herniation on arrival

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Received: 22 March 2017 / Revised: 8 May 2017 / Accepted: 9 May 2017 / Published online: 20 May 2017

Abstract Chronic subdural hematoma (CSDH) with brain herniation signs is rarely seen in the emergent department. As such, there are few cumulative data to analyze such cases. In this study, we evaluated the clinical features, risk factors, and rates of completion with impending brain herniation on arrival in a cohort study. We analyzed 492 consecutive patients with CSDH between January 2010 and October 2015. First, we analyzed the clinical factors and compared them between patients with or without brain herniation signs on admission. Second, we compared clinical factors between patients with or without completion of brain herniation after operation among patients who had brain herniation signs on arrival. Eleven (2.2%) patients showed brain herniation signs on arrival, and six patients (1.2%) progressed to complete brain herniation. Patients with brain herniation signs on arrival were significantly older ($P = 0.03$) and more frequently hospitalized with a concomitant illness ($P < 0.0001$). Niveau formation ($P = 0.0005$) and acute-on CSDH ($P = 0.0001$) on computed tomography were also more frequently seen in patients with brain herniation signs. Multivariate logistic regression analysis showed that age older than 75 years (OR 2.16, $P < 0.0001$), niveau formation (OR 3.09, $P < 0.0001$), acute-on CSDH (OR 14, $P < 0.0001$), and admitted to another hospital (OR 52.6, $P < 0.0001$) were independent risk factors for having had brain herniation signs on arrival. On the other hand, having a history of head injury ($P = 0.02$) and disappearance of the ambient cistern ($P = 0.0009$) were significantly associated with completion of brain herniation. The prognosis was generally poor if the patient had presented with brain herniation signs on admission. Our results demonstrate that the diagnosis is often made late, despite hospitalization for a concomitant illness. When the elderly show mild disturbance of consciousness, physicians except neurosurgeons need to consider the possibility of CSDH regardless of a recent history of head injury.

Keywords Chronic subdural hematoma · Brain herniation · Trauma · Computed tomography

Introduction

Chronic subdural hematoma (CSDH) is one of the most common diseases seen by neurosurgeons and is usually associated with good recovery after treatment with burr hole irrigation and drainage under local anesthesia [1, 3, 4, 18–21]. In spite of this, 2–4% of patients have poor outcomes [1, 24]. Previous reports indicate that deterioration of a past illness, new systemic complication, surgical complication, and brain herniation are contributory causes of poor outcomes [1, 4, 21, 24].

The major clinical presentations of CSDH are usually gait disturbance, hemiparesis, headache, and dementia without severe disturbance of consciousness [1, 7, 21]. However, CSDH with brain herniation signs, such as decline of consciousness with pupillary abnormality, is rarely seen in patients presenting to the emergency department [1, 8]. In such cases, emergent surgery is needed to prevent impending complete brain herniation. In typical cases with complete brain herniation, bilateral CSDH causes central transtentorial herniation and the development of cerebral infarction in the bilateral occipital lobes and the brainstem [1, 12, 14]. Severe disability or death often results. We have recently experienced a fetal case of

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brain herniation due to CSDH. To avoid such negative outcomes in the future, we investigated the circumstance of the case. Although delayed diagnosis may be a major factor, questions surrounding the cause of delayed diagnosis of the risk factors of CSDH that lead to brain herniation remained unanswered. Several case reports have called attention to complete brain herniation due to CSDH. However, because of its rarity, there are few cumulative data to analyze cases of brain herniation due to CSDH.

In this study, to resolve the above questions, we retrospectively analyzed patients with CSDH and brain herniation signs on admission and clarified the clinical characteristics, risk factors, and rates of completion of brain herniation in a cohort study.

Methods

The study was approved by the institutional review board of our hospital. The prospectively maintained database of our hospital was searched for patients treated for CSDH between January 2010 and October 2015. Medical records, radiographic studies, operative reports, and clinical follow-up evaluations were reviewed retrospectively.

Definition of patients with brain herniation signs and completion of brain herniation

We defined patients with brain herniation signs as patients who presented with an impairment of consciousness level declining to a Glasgow Coma Scale (GCS) score less than 8 due to the mass effect of CSDH on arrival at our hospital, i.e., the time when the neurosurgeon of our hospital first examined. Completion of brain herniation was defined as cerebral infarction after surgery.

Definition of niveau formation and acute-on CSDH

We performed computed tomography (CT) on arrival at our hospital in all patients. We defined "niveau formation" as CSDH with separating layers like Fig. 1a [6, 21, 22]. Acute-on CSDH was defined as previously reported [13, 17], like Fig. 1b.

Surgical procedure

We generally performed standard burr hole irrigation and drainage. After irrigation with saline or artificial cerebrospinal fluid as irrigation solution, closed system drainage was placed in the hematoma cavity. The drain was removed within 2 days.

Patients

We surgically treated 492 patients (321 men, 171 women) with initial CSDH at our institution between January 2010 and October 2015. These 492 patients were analyzed. Recurrent cases were excluded.

Outcome measures

We assessed modified Rankin scale (mRS) score at discharge. All 492 patients were able to be accessed.

Study design

Clinical factors, including age, sex, hospitalization for concomitant illness, laterality of hematoma, history of head injury, use of anticoagulants or antiplatelet drugs, history of malignancy, mRS score at discharge, CT findings, duration between appearance of initial symptoms such as a mild disturbance of consciousness or dulled responsiveness and diagnosis, and time from arrival to surgery, were obtained. First, we analyzed these factors and compared patients with or without brain herniation signs on admission. Second, we compared patients with or without completion of brain herniation after operation among the patients with brain herniation signs on admission.

Statistical analysis

Statistical analysis was performed using the Mann-Whitney *U* test, Welch's *t* test, the Chi-square test, and Student's *t* test. All values are expressed as the mean ± SD. Differences were considered significant if the probability value was less than 0.05. Multivariate logistic regression analysis was also performed to clarify independent risk factors related to having brain herniation signs on admission. Variables with $P < 0.05$ in univariate analysis, including age, niveau formation on CT, acute-on CSDH, and hospitalization for concomitant illness, were selected for multivariate analysis. All of these statistical analyses were performed using Statcel 4 (OMS Publishing Inc. Saitama, Japan) and EZR (Easy R) [11].

Results

Eleven (2.2%) of 492 patients had brain herniation signs on arrival at our hospital. The clinical findings are summarized in Table 1. Patients ranged in age from 73 to 90 years (mean, 81.7 years) and were predominantly men (7 men and 4 women). GCS sore on arrival was 3 in two patients, 4 in three patients, and 6 in six patients. Six patients were in the hospital for another disease. Eight patients had a history of head injury, two were on anticoagulant therapy, and two had a history of malignancy. On CT, bilateral hematoma was observed in five

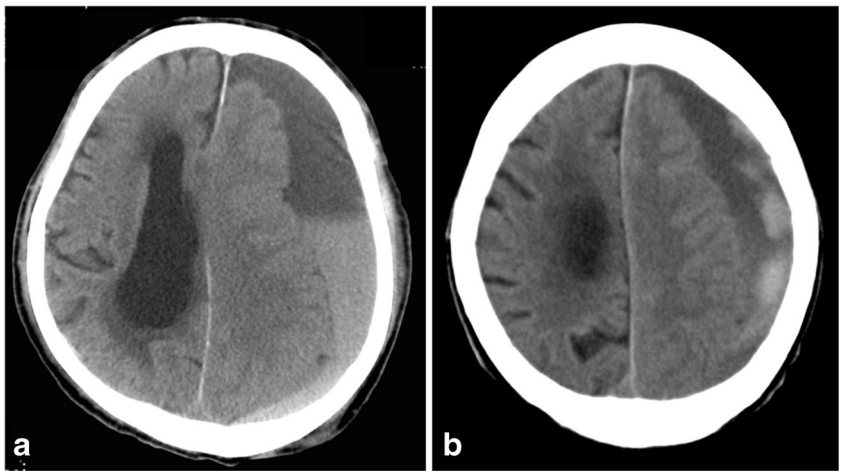

Fig. 1 **a** Computed tomography (CT) shows chronic subdural hematoma (CSDH) with niveau formation on computed tomography. **b** CT shows acute-on CSDH

patients, disappearance of the ambient cistern due to compression by hematoma was seen in six, and a high-density area in the basal cistern was seen in three. Neveau formation was seen in six patients, and acute-on CSDH was seen in four patients. Six patients showed completion of brain herniation in spite of emergent surgery; six patients had cerebral infarction in the occipital lobes and brainstem. Five patients had poor outcomes with an mRS score of 5–6.

Table 1 Summary of cases of chronic subdural hematoma with brain herniation signs on admission

Case	Age/ Sex	GCS score on arrival	Reason for admission to first hospital	Laterality of CSDH	Head trauma	CT findings Disappearance of the ambient cistern	High-density area in the basal cistern	Niveau formation
1	90/F	4	femoral fracture	bilateral	+	+	−	−
2	93/F	6	n/a	bilateral	+	+	+	+
3	79/M	3	pneumonia	unilateral	+	+	−	−
4	76/M	4	vomiting	bilateral	+	+	+	+
5	76/M	3	unidentified fever	unilateral	+	+	+	+
6	73/M	6	n/a	bilateral	+	+	−	+
7	74/F	6	pneumonia	unilateral	−	−	−	+
8	85/F	6	n/a	unilateral	+	−	−	−
9	88/M	6	n/a	unilateral	+	−	−	−
10	85/M	4	n/a	bilateral	−	−	−	−
11	80/M	6	cellulitis	unilateral	−	−	−	+

Case	Acute-on CSDH	Duration between appearance of initial clinical symptoms and diagnosis	Time from arrival to surgery	Antiplatelet or anticoagulant therapy	History of malignancy	Complete brain herniation	mRS at discharge
1	−	1 day	62 min	−	−	+	4
2	+	0 days	137 min	+	−	+	3
3	−	1 day	25 min	−	−	+	5
4	−	4 days	145 min	−	−	+	5
5	−	4 days	68 min	−	−	+	6
6	−	1 day	53 min	−	−	+	4
7	−	0 days	90 min	+	+	−	4
8	+	1 day	100 min	−	−	−	4
9	−	0 days	66 min	−	+	−	4
10	−	0 days	100 min	−	−	−	5
11	+	1 day	106 min	−	−	−	5

arrival arrival at our hospital, i.e., the time when the neurosurgeon of our hospital first examined, *CT* computed tomography, *GCS* Glasgow Coma Scale, *CSDH* chronic subdural hematoma, *mRS* modified Rankin Scale, *n/a* not applicable

In comparing clinical characteristics between patients with or without brain herniation signs on arrival (Table 2), patients with brain herniation signs were significantly older and had more frequently been hospitalized for a concomitant illness than patients without brain herniation signs. Niveau formation and acute-on CSDH on CT were also more frequently seen in patients with brain herniation signs than in patients without brain herniation signs. Bilateral hematoma was more frequently observed in patients with brain herniation signs, though this result was without statistical significance. There was no difference in sex, history of head injury, use of anticoagulants or antiplatelet drugs, or history of malignancy. The outcomes were significantly poorer in patients with brain herniation signs. Multivariate logistic regression analysis showed that over the age of 75, niveau formation, acute-on CSDH, and hospitalization for concomitant illness were independent risk factors related to brain herniation signs on admission (Table 3). Among them, hospitalization for concomitant illness was the major independent risk factor.

In comparing clinical characteristics between patients with or without completion of brain herniation after surgery among the patients with brain herniation signs on arrival (Table 4), having a history of head injury and disappearance of the ambient cistern on CT were significantly associated with completion of brain herniation. Bilateral hematoma, niveau formation on CT, and hospitalization for concomitant illness were more frequently observed in patients with completion of brain herniation, though without statistical significance. There were tendencies toward worse GCS scores and a longer duration from appearance of the initial symptom to diagnosis in patients with completion of brain herniation, though without statistical significance. A high-density area in the basal cistern on CT was seen only in patients with completion of brain herniation, but this was not statistically significant. On the other hand, acute-on CSDH was seen more frequently in patients without completion of brain herniation, though without statistical significance. There were no differences in age, sex, use of anticoagulants or antiplatelet drugs, history of malignancy, time to arrival to surgery, or rate of poor outcomes.

Table 3 Logistic regression analysis of factors related to brain herniation signs on admission

Factor	Odds ratio	95% CI	*p* value
Age (≥75 years)	2.16	0.35–13.2	<0.0001
Niveau formation on CT	3.09	0.65–14.6	<0.0001
Acute-on-CSDH	14.0	2.01–98.2	<0.0001
Admitted to another hospital	52.6	9.95–278	<0.0001

CI confidence interval, *CT* computed tomography, *CSDH* chronic subdural hematoma

Representative case

Case No. 4: A 76-year-old man with diabetes mellitus presented with repetitive vomiting to a local hospital and was admitted. He had experienced a head injury 1 month prior. He was alert without neurological deficits but had general fatigue. The patient showed a sudden decline in consciousness and was diagnosed with CSDH and was transferred to our hospital. His GCS score on admission was 4 (E1, V1, M2), and he had bilateral dilated pupils. CT of the brain showed bilateral CSDH with niveau formation, disappearance of the ambient cistern, and a high-density area in the basal cistern thought likely to be subarachnoid hemorrhage (SAH) (Fig. 2a–d). Magnetic resonance imaging and angiography (MRI and MRA) showed neither SAH nor aneurysm (Fig. 2e, f), with downward compression of the superior portion of the basilar artery (Fig. 3d). He underwent emergent surgery. However, he did not show improvement in consciousness. MRI and MRA performed 1 day after the operation showed acute cerebral

Table 2 Comparison of two groups with or without brain herniation signs on admission

	Brain herniation signs (+)*n* = 11	Brain herniation signs (−)*n* = 481	*p* value
Age (year)	81.7 ± 6.8	76.5 ± 11.7	0.03
Sex (M/F)	7:4	314:167	0.9
Admitted to another hospital	6 (54.5%)	19 (4%)	<0.0001
CT findings	5 (45.4%)	110 (22.8%)	0.08
Bilateral hematoma Niveau formation	6 (54.5%)	64 (13.3%)	0.0005
Acute-on CSDH	4 (36.3%)	24 (4.9%)	0.0001
History of head trauma	8 (72.75)	335 (69.6%)	0.8
Anticoagulant or antiplatelet medications	2 (18.1%)	114 (23.7%)	0.67
History of malignancy	2 (18.1%)	54 (11.2%)	0.47
Poor outcome	5 (45.4%)	15 (3.1%)	0.016

CSDH chronic subdural hematoma, *CT* computed tomography

Table 4 Comparison of two groups with or without completion of brain herniation

	Complete brain herniation (+) $n = 6$	Complete brain herniation (−) $n = 5$	p value
Age (years)	81.16 ± 8.28	82.4 ± 5.5	0.78
Sex (M/F)	4:2	3:2	0.81
GCS score on arrival	4.16 ± 1.47	5.6 ± 0.89	0.09
Admitted to another hospital	4 (66%)	2 (40%)	0.37
History of head trauma	6 (100%)	2 (40%)	0.02
Anticoagulant or antiplatelet medications	1 (16%)	1 (20%)	0.88
History of malignancy	0 (0%)	1 (20%)	0.35
CT findings	4 (66%)	1 (20%)	0.12
Bilateral hematoma			
Disappearance of the ambient cistern	6 (100%)	0 (0%)	0.0009
High-density area in the basal cistern	3 (50%)	0 (0%)	0.06
Niveau formation	4 (66%)	2 (40%)	0.39
Acute-on CSDH	1 (16%)	3 (60%)	0.13
Duration between appearance of clinical symptoms and diagnosis (days)	1.83 ± 1.72	0.4 ± 0.54	0.1
Time from arrival to surgery (min)	81.6 ± 48.3	92.4 ± 15.8	0.67
Rate of poor outcomes	3 (50%)	2 (40%)	0.74

GCS Glasgow Coma Scale, *CSDH* chronic subdural hematoma, *CT* computed tomography

infarction in the bilateral occipital lobes, bilateral thalami, and right brainstem (Fig. 3a–c) with recovery of the compression of the superior portion of the basilar artery (Fig. 3e), suggesting complete brain herniation. His mRS at discharge was 5.

Case No. 5: A 76-year-old man with hypertension and diabetes mellitus presented with unidentified fever and was admitted. He had experienced a head injury 2 months prior. Initially, the patient was alert without neurological deficits.

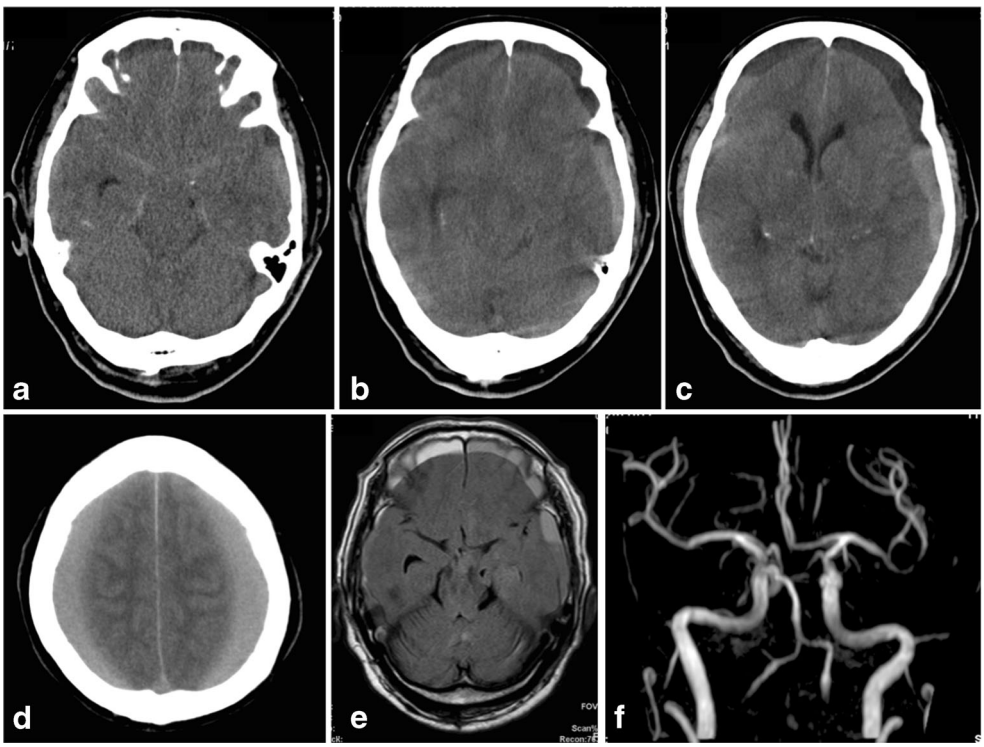

Fig. 2 **a**–**d** Preoperative computed tomography in case 4 shows bilateral chronic subdural hematoma with niveau formation, a high-density area in the basal cistern, similar to that seen in cases of subarachnoid hemorrhage (SAH), and disappearance of the ambient cistern. **e**, **f** Fluid-attenuated inversion recovery imaging and magnetic resonance angiography show neither SAH nor aneurysms

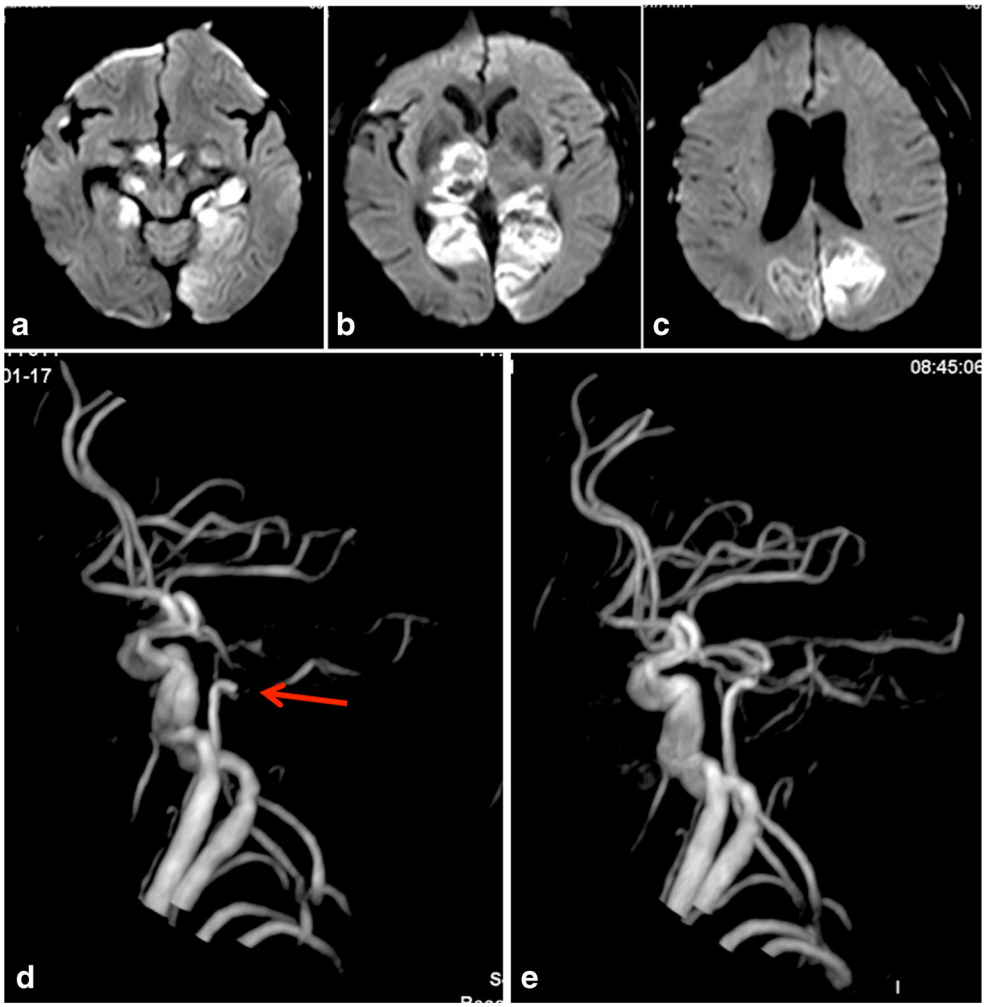

Fig. 3 **a**–**c** Postoperative diffusion-weighted imaging in case 4 shows acute cerebral infarction in the bilateral occipital lobes, bilateral thalami, and brainstem. **d** Magnetic resonance angiography (MRA) on admission shows downward compression of the superior portion of the basilar artery. **e** Postoperative MRA shows recovery of the superior portion of the basilar artery

He then had a gradual decline in consciousness and fell into a coma 4 days after admission. He was then diagnosed with CSDH and transferred to our hospital. GCS score on admission was 3, and his left pupil was dilated. CT showed left CSDH with niveau formation, disappearance of the ambient cistern, and a high-density area in the basal cistern similar to that seen in SAH (Fig. 4a–c). He underwent emergent surgery. However, he had no improvement in consciousness, and CT performed 1 day after the operation showed acute cerebral infarction in both cerebral hemispheres and the brainstem suggesting completion of brain herniation (Fig. 4d–f). He died 4 days after the operation.

Discussion

CSDH with brain herniation signs, such as decline in consciousness and pupillary abnormality, is rare and necessitates emergent surgery [1, 8]. Recent reports indicate that 1.6–3% of patients with CSDH present with brain herniation signs on admission, and 0.4–1.1% progress to complete brain herniation despite emergent surgery, with a mortality rate of approximately 0.8% [1, 7, 21]. Our data show that 2.2% of our patients had brain herniation signs on arrival, 1.2% progressed to complete brain herniation, and 0.2% died. These results are similar to other reports, demonstrating that brain herniation due to CSDH is rare.

We found that older age and hospitalization for a concomitant illness were significantly associated with CSDH with brain herniation signs on arrival. In particular, hospitalization for concomitant illness was the major independent risk factor associated with brain herniation signs on admission. It is very problematic that the diagnosis of CSDH is typically made late, when the patient falls into a coma, despite being in the hospital. In fact, all of the patients had shown a mild disturbance of consciousness or dulled responsiveness. However, physicians may consider a mild disturbance of consciousness to be symptom of a concomitant disease rather than an initial sign of CSDH because many primary diseases are accompanied by high fever or vomiting. High fever and repetitive vomiting can cause mild disturbance of consciousness, especially in elderly patients [9].

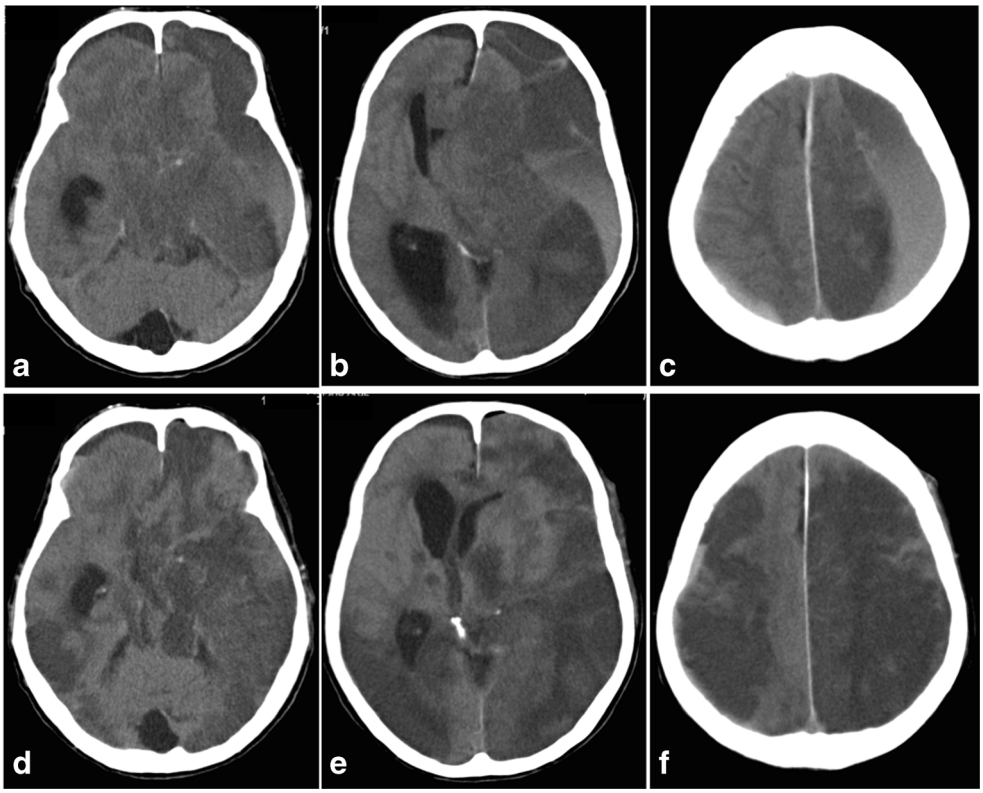

Fig. 4 **a**–**c** Preoperative computed tomography (CT) in case 5 shows a massive left chronic subdural hematoma with niveau formation, a high-density area in the basal cistern, and disappearance of the ambient cistern. **d**–**f** Postoperative CT shows a huge cerebral infarction in the bilateral cerebral hemispheres and the brainstem

We also found that niveau formation and acute-on CSDH on CT were significantly associated with CSDH with brain herniation signs on arrival. Niveau formation and acute-on CSDH are considered specific type of CSDH with disturbance of consciousness [6, 8, 22]. In such types of CSDH, abrupt expansion of hematoma tends to occur and causes rapid progression of disturbance of consciousness [6, 8, 22]. Our results indicate that risk factors for CSDH with brain herniation signs on arrival include not only late diagnosis, but also hematoma type. However, these risk factors were not associated with completion of brain herniation.

Investigations into general risk factors for poor outcomes have been made, and recent reports suggest that age, poor preoperative neurological state, bilateral hematoma, history of malignancy, liver and renal dysfunction, coagulopathy, history of neurosurgery, and anticoagulant use are factors that contribute to poor outcomes [1, 4, 5, 8, 15, 21]. Among these, bilateral hematoma is a higher risk factor for brain herniation, and most reports of brain herniation are caused by bilateral CSDH [1, 12, 14, 15]. Because of a lack of specific symptoms, such as hemiparesis, a diagnosis of bilateral CSDH tends to be delayed and results in subsequent brain herniation [1, 10, 15]. However, our results show that unilateral hematoma is more frequent in patients with brain herniation signs on arrival. These data indicate that unilateral CSDH can cause brain herniation if diagnosis is delayed. In fact, 6 of 11 (54%) patients with brain herniation signs on arrival had unilateral hematoma, and the sole death due to complete brain herniation was not bilateral, but unilateral, in our series. History of malignancy and anticoagulant use are considered to be factors associated with rapid deterioration resulting in brain herniation [1]. In patients with malignancy, hemorrhagic diathesis associated with disseminated intravascular coagulation may play a role in rapid deterioration [2, 23]. Our results show that there is no specific medical history associated with having brain herniation signs on arrival and completion of brain herniation.

When a neurosurgeon encounters a patient with CSDH and brain herniation signs, emergent surgery is necessary to prevent impending brain herniation from progressing to complete brain herniation. In our series, 6 of 11 (54%) cases progressed to complete brain herniation despite emergent surgery. However, there was no difference in time to arrival to surgery between patients with or without completion of brain herniation after surgery among the patients with brain herniation signs on arrival. Because there was a tendency toward a longer duration between appearance of the initial symptom and diagnosis in patients with completion of brain herniation, it is very important to make a diagnosis as early as possible.

In cases with complete brain herniation, a stronger mass effect due to hematoma may have been responsible. On CT, the ambient cistern was compressed and invisible in all cases with completion of brain herniation. Interestingly, a high-density area in the basal cistern similar to that seen with SAH could be seen in cases with completion of brain herniation. This specific phenomenon may be an artifact of arterial blood flow due to strong compression. Our results showed

that all cases with completion of brain herniation had a definite history of head injury, which was more frequent in patients with completion of brain herniation than in those without. However, there was no relationship between patients with or without herniation signs on arrival. Head injury is known to be a major cause of CSDH [16], but there is no evidence that the prognosis of traumatic CSDH is poorer than that of nontraumatic CSDH [7, 21]. Regarding the prognosis, our results indicate that it was generally poor once a patient has brain herniation signs on arrival, whether or not progression to complete brain herniation occurred. Hence, it is very important to diagnose CSDH before the appearance of brain herniation signs.

Limitations

This study has some limitations. Because CSDH with brain herniation signs is rare, we studied only a small number of subjects. Although our investigation identified only known risk factors for CSDH with brain herniation and was not novel, a meta-analysis or a large number of patients may bring new insights.

Conclusions

CSDH with brain herniation signs is very rare and the prognosis is generally poor. Our results demonstrate that the diagnosis is often made late, despite hospitalization for a concomitant illness. In those cases, all of the patients showed mild disturbance of consciousness before the diagnosis was made. Moreover, because specific types of CSDH, in which abrupt expansion of hematoma tends to occur, often cause brain herniation signs on arrival, it is very important to obtain an early diagnosis to avoid brain herniation. Hence, when the elderly show mild disturbance of consciousness, physicians except neurosurgeon need to consider the possibility of CSDH regardless of a recent history of head injury. Neurosurgeons have to enlighten such conditions with an aging society.

Compliance with ethical standards

Funding The authors declare that they have no funding.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This is a retrospective analysis. For this type of study, formal consent is not required.

Informed consent Informed consent was obtained from all individual participants included in the study.

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