Transient Acute Hydrocephalus After Spontaneous Intracranial Bleeding in Adults
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BACKGROUND: Acute hydrocephalus (AH) is commonly encountered after spontaneous or traumatic intracranial bleeding in adults. In the setting of AH, external ventricular drainage is usually proposed as the urgent management. But in rare occasions, AH could be transient and resolve spontaneously without invasive management. Although its actual incidence might be higher, only a few case reports on transient AH (TAH) after spontaneous intracranial bleeding in adults have been reported.

METHODS: A retrospective review of the medical records of the patients admitted for spontaneous intracranial bleeding was performed at the neurosurgical department of our institution. We also performed a systematic PubMed search of the published studies written in English for patients developing TAH after spontaneous intracranial bleeding.

RESULTS: In all there were 10 patients (5 women) including 5 cases in our case series. The time interval from hemorrhagic ictus to AH ranged from 7 hours to 9 days; although the time interval from AH to evident resolution ranged from 50 minutes to 9 days. No patient experienced recurrence of AH or shunt-dependent hydrocephalus in the long term.

CONCLUSIONS: The osmotic and hydrostatic state in the microvessels, lymphatic pathways for the drainage of the interstitial fluid and cerebrospinal fluid, and aquaporins on the astrocytes of the patients might have important roles in the genesis and resolution of TAH. The difficulty at present is to differentiate the patients who would experience TAH from those needing surgical interventions. If surgical intervention could not be carried out temporally, vigilant monitoring and osmotic diuretics are proposed.

INTRODUCTION
Acute hydrocephalus (AH) is commonly encountered after spontaneous or traumatic intracranial bleeding in adults. According to a recent study by Hughes et al., 28.6% of their studied patients with intraventricular hemorrhage (IVH) developed AH and required external ventricular drainage (EVD). In the setting of AH, EVD is usually proposed as the urgent management. But in rare occasions, AH could be transient and resolve spontaneously without invasive management.²,³ Although its actual incidence might be higher, only a few case reports on transient AH (TAH) after spontaneous intracranial bleeding in adults have been reported.²,³ Therefore, the mechanism, characteristics, management, and prognosis of this specific entity is quite obscure to us. In this retrospective study, we want to present a case series of adult TAH after spontaneous intracranial bleeding. This case series was different from the past reports, not only for its larger sample size, but also for the composition of primary diseases. As all the reported cases were due to IVH, some of the patients in the present case series were after spontaneous subarachnoid hemorrhage (SAH). To better illustrate this rare entity, a comprehensive review of the literature was also conducted.
METHODS

Definition of TAH After Spontaneous Intracranial Bleeding in Adults
Because no clear definition of TAH was previously proposed, we used the following criteria for this issue.

- Acute hydrocephalus after recent spontaneous intracranial bleeding (IVH, cerebral or cerebellar hemorrhage with ventricular involvement, or SAH) before the blood was fully absorbed on imaging investigations.
- The hydrocephalus resolved spontaneously without any invasive treatment regardless of conservative managements.
- The affected patient was >16 years.
- No other definite cause responsible for the genesis of TAH was identified by the radiologic, laboratory, and clinical investigations.

Searching Strategy in Our Institution
A retrospective review of the medical records (from January 2013 to July 10, 2016) of the patients admitted for spontaneous intracranial bleeding was performed at the neurosurgical department of our institution, which was under the ethical approval of The First Hospital of Jilin University. Clinical information including demographic characteristics, auxiliary investigations, accompanying chronic diseases such as diabetes or/and hypertension, management, outcome, and follow-up information were collected for data interpretation.

Systematic Literature Review
A systematic PubMed search of the published studies written in English for patients developing TAH after spontaneous intracranial bleeding from January 1980 to July 9, 2016 was conducted. The following key words were used in relevant combinations: acute hydrocephalus, transient, intracranial hemorrhage, cerebral hemorrhage, cerebellar hemorrhage, and intraventricular hemorrhage. The reference lists of the identified articles were also manually searched for additional studies.

RESULTS

Current Series
From January 2013 to July 10, 2016, 2746 consecutive adult patients were admitted to our institution for spontaneous intracranial bleeding. Among them 5 patients (3 women) developed TAH according to our inclusion criteria (Table 1). The predisposing diseases were cerebral hemorrhage with IVH, SAH, and aneurysmal SAH (aSAH) in 1, 2, and 2 patients, respectively. The time interval from intracranial bleeding to AH was 7 hours.
to 9 days. All the patients experienced spontaneous resolution before invasive management was initiated in a time course from 4 hours to 9 days after the detection of AH by imaging modalities. Accompanying chronic diseases, such as diabetes or/and hypertension, were only identified in 1 patient. No recurrence of hydrocephalus was noticed in the outpatient follow-up, which ranged from 6 months to 3 years.

Illustrative Cases

Patient 1. A 57-year-old woman with 6 years of hypertension history was admitted to the local hospital for the right thalamus hemorrhage with ventricular involvement (Figure 1A). She had experienced an uneventful conservative management until 9 days later, after which her mental state progressively declined. Neurological examination revealed a Glasgow coma scale (GCS) score of 10. Computed tomography (CT) showed acute enlargement of the lateral and third ventricles (Figure 1B). Then she was transferred to our institution immediately after intravenous administration of mannitol with the anticipation of an EVD. Physical examination on admission showed that she had a GCS score of 12. Her pupils were equal, miotic but reactive sensitively to light. However, CT performed 10 hours after the ictus of consciousness disturbance showed evident relief of the hydrocephalus (Figure 1C). Therefore the EVD procedure was canceled. Cerebrospinal fluid (CSF) routine test by lumbar puncture showed elevated white blood cells (120 × 10^6/L; reference range, 0–8 × 10^6/L) and protein (888 mg/L; reference range, 200–400 mg/L). Blood biochemistry revealed mild hyponatremia (135 mmol/L; reference range, 137–147 mmol/L). Her consciousness gradually improved with intravenous mannitol administration and mild hypertonic saline. She was discharged 7 days later. Outpatient follow-up for 2 years showed that she had experienced a good psychosomatic recovery process and no recurrence of hydrocephalus.

Patient 4. A 54-year-old woman was admitted for progressive decline of consciousness for 1 hour. Eleven hours before her presentation she had experienced a sudden onset of headache, nausea, and vomiting. She had been healthy and had no history of any chronic diseases before this event. On examination, she had a GCS score of 7. Head CT performed on admission showed extensive SAH and enlargement of the lateral, third, and fourth ventricles, and the aqueduct (Figure 2A–D). Further CT angiography revealed 2 intracranial aneurysms located at the right internal carotid and anterior choroid artery. An emergent EVD placement combined with endovascular coiling of the aneurysms was proposed but was refused by her family. She was managed conservatively with the medication aiming for reducing intracranial pressure and alleviating cerebral vasospasm. Her mental state did not worsen further. Thirty-two hours after her consciousness deterioration she experienced a slow recovery of consciousness. Head CT performed 48 hours after her mental state decline showed evident resolution of the ventricular system (Figure 2E–H). Because her mental state was greatly improved, her family member agreed to further aggressive management, therefore an endovascular coiling of the intracranial aneurysms was performed. The patient experienced an unremarkable recovery process. The last follow-up, 6 months later, showed no recurrence of the hydrocephalus and her modified ranking scale was 0.

Searching Results

Five studies were identified in the literature search reporting of 5 patients (Table 1) who met the inclusion criteria. In all there were 10 patients (5 women, 50%) including 5 cases in our case series (Table 1). The inflicted patients were aged from 33–86 years (59.6 ± 9.6 years). The time interval from hemorrhagic ictus to AH ranged from 7 hours to 9 days, whereas the time interval from AH to evident resolution ranged from 50 minutes to 9 days. Accompanying chronic diseases, such as diabetes or/and hypertension, were identified in 3 patients (30%). Six patients (60%) developed TAH after IVH or intracerebral hemorrhage with IVH extension, 4 patients after aSAH or SAH. Two of the 5 (40%) previously reported patients received osmotic diuretics, whereas all of the present cases received osmotic diuretics. No patient experienced recurrence of AH or shunt-dependent hydrocephalus in the long term.
DISCUSSION

TAH is a rarely reported entity in adults after spontaneous intracranial bleeding, although the actual incidence might be higher. In our literature review, only 5 cases were identified. All of the previously reported cases were secondary to relatively mild IVH or cerebral hemorrhage with intraventricular extension. However, 4 of the 5 cases in the present series were due to SAH or aSAH. According to the previous literature, the mechanism of TAH was due to acute and transient blockage of the aqueduct by a migrating hematoma clot, which was based on the identification of hematoma at the level of aqueduct or base of the third ventricle, but there were exceptions. Just as our patient 1 showed, no hematoma was identified below the level of third ventricle 9 days after intracerebral hemorrhage. Furthermore, as our patient 4 illustrated, the lateral, third, and fourth ventricles, and the aqueduct were all enlarged and collapsed soon afterward, which indicated that the obstruction level was farther away from the fourth ventricle. Therefore, transient blockage of the aqueduct by a migrating hematoma clot could not explain the TAH.

According to the traditional hypothesis, CSF is actively secreted from the choroid plexuses in the lateral and fourth ventricles and circulates unidirectionally along the ventricular system toward the cortical subarachnoid space and is passively absorbed into the venous sinuses through arachnoid villi. With the development of

Figure 2. (A–D) Computed tomography (CT) shows extensive subarachnoid hemorrhage and enlargement of the lateral, third, and fourth ventricles, and the aqueduct. (E–H) CT performed 48 hours later shows evident resolution of the ventricular system.
CSF physiology, however, a new hypothesis of the CSF hydrodynamics has been proposed and is impacting our common sense on this issue. A new hypothesis, the interstitial fluid (ISF) and CSF constitute a functional unit and are regulated by changes in osmotic and hydrostatic pressure in microvessels of the central nervous system. Namely, water, which constitutes 99% of ISF-CSF fluid, is filtered across the arterial capillary walls under hydrostatic pressure into the ISF-CSF unit and reabsorbed into the venous capillaries and postcapillary venules by osmotic counter-pressure produced during the process of water filtration. The CSF and ISF are in continuity, and the turnover of CSF and ISF are unrelenting and are driven by to-and-fro fluid pulsations. The flow of CSF is not unidirectional but multidirectional, and the exchange of CSF among different parts of the ventricular system is not so quick as previously thought. Therefore factors affecting osmotic and hydrostatic forces in the microvessels might influence the volume of CSF accordingly. In this study, 2 of the 5 previous cases and all of the patients in our case series received osmotic diuretics. The actual effect that osmotic diuretics could exert in these patients is obscure, but might give us some implications. The osmotic and hydrostatic state in the microvessels of the patients might play a role in the genesis and resolution of TAH. Furthermore, other studies implied that lymphatic pathways for the drainage of ISF and CSF, and aquaporins on the astrocytes might have important roles in CSF circulation. Although the recent studies are insufficient to overturn the classic theories of CSF hydrodynamics, they could at least give us some implications that the formation of hydrocephalus are not restricted to the

Figure 2. (continued).
mechanical obstruction of the ventricular system and reabsorption disorder by arachnoid villi. Some other mechanisms on hydrocephalus formation need to be clarified, which might shed light on the mechanism of TAH after spontaneous intracranial bleeding.

The diagnosis of AH is not difficult based on the declined mental state and typical radiologic images. But it is difficult to differentiate the patients who would experience TAH from those needing surgical interventions. In this review the time interval from AH to evident resolution ranged from 50 minutes to 9 days. Hence, it is very hard for the medical practioner to give the recommendation of surgical intervention or conservative management. According to the literature and our experience we proposed 2 points that might support vigilant monitoring and postponed surgical intervention: a) relatively small amount of hemorrhage in the ventricular system, and b) no further rapid deterioration in mental status. Even so, 3 of the patients in our case series experienced TAH not because of doctors’ professional advice but the family members’ insistence. Therefore, when AH occurs after spontaneous intracranial bleeding, the primary management is still EVD. If surgical intervention could not be carried out temporarily, vigilant monitoring and osmotic diuretics are proposed. The prognosis of TAH is promising according to the current cases. No patient experienced recurrence of AH or shunt-dependent hydrocephalus in the long term.

CONCLUSIONS

The actual mechanism of TAH is far complicated than acute and transient blockage of the aqueduct by a migrating hematoma clot. The osmotic and hydrostatic state in the microvessels, lymphatic pathways for the drainage of ISF and CSF, and aquaporins on the astrocytes of the patients might have important roles in the genesis and resolution of TAH. At present the difficulty is to differentiate the patients who would experience TAH from those needing surgical interventions. If surgical intervention could not be carried out temporarily, vigilant monitoring and osmotic diuretics are proposed. The efficacy of osmotic diuretics in reversing acute hydrocephalus is another interesting issue that warrants further study.

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