Chronic subdural hematoma (CSDH) develops over an extended period, but its origin remains unclear despite knowledge of the presenting neurological symptoms, hospital visits, and history of head CT. Consequently, explanations of its origin depend on fragmentary evidence and speculation. The most common proposal for the initiating event has been tearing of a bridging vein, usually caused by prior head trauma and resulting in acute subdural hematoma (ASDH). Other studies, especially those in Asia, have suggested traumatic subdural hygroma as a predisposing factor. Neuroimaging examinations are not often performed early after head injury in patients with CSDH because the preceding head injury is often minor. For this reason, imaging findings before the onset of neurological symptoms are rare in clinical cases. In Japan, head imaging is widespread, and head CT is frequently performed after trauma.

In the present study, we reviewed cases of CSDH surgery in which head CT had been performed after the initial trauma and examined imaging findings for any special indicator of future CSDH.

**Methods**

This study was approved by the institutional review board of Gunma University Graduate School of Medicine.
We reviewed 172 consecutive cases of CSDH that had been treated with surgery at Gunma University Hospital between April 2010 and December 2017. The 133 male and 39 female patients had a median age of 76 years and had 141 unilateral and 31 bilateral hematomas. All patients underwent surgery as previously described, and the postoperative course was good in all cases. One hundred ten cases of CSDH (64%) were preceded by trauma. Among these cases were 23 patients who had visited our hospital or a nearby hospital because of the initial head trauma and had undergone standard head CT within 7 days after the trauma. The head CT findings for these 23 patients were examined for the present study.

CT was performed at our hospital at the time of the initial injury in 11 cases (48%). Thin-section (5 mm) axial scans were obtained through the orbits and globes, with no administration of contrast material. Standard axial CT scans (slice thickness 4–5 mm) were taken at another hospital in the other 12 cases (52%). Head CT scans were obtained again within 7 days after injury in 8 of the 23 cases. Subdural effusion (SDE) was defined according to previously published criteria: it was identified at the thickest part of the CSDH on preoperative axial CT slices showing the frontal lobe and anterior horn as a band of low density with continuity in a direction parallel to the skull between the skull and the brain and with a clear left-right difference. A high-density line was found in the lateral direction (onion skin–like) between the skull and the brain, and in some cases, the inside was judged as the subarachnoid space and the outside as subdural space. The maximum thickness of the SDE was classified as thin at ≤ 6 mm and thick at > 6 mm, as previously reported (Fig. 1). Standard diagnostic criteria were used for CSDH. In addition, ASDH, traumatic subarachnoid hemorrhage, brain contusion, skull fracture, and facial bone fracture were identified. Two independent observers (K.K. and H.S.O.) examined a total of 76 head CT scans, and the final classifications were determined by consensus.

Results

Seventeen male and 6 female patients had a median age of 80 years (IQR 63.5–83 years; Table 1). Nineteen patients suffered a fall or tumble, 3 suffered traffic accidents, and 1 had syncope. Seven patients presented with neurological symptoms such as consciousness disorder at the time of initial injury. Eleven patients were hospitalized, and 12 received follow-up home care. The median Glasgow Coma Scale score was 15 (IQR 14–15). Initial CT detected traumatic subarachnoid hemorrhage (3 cases), brain contusion (4 cases), and ASDH (3 cases, 1 case falx) as intracranial findings. In addition, skull fractures (2 cases) and facial bone fractures (2 cases) were observed.

Of the 23 CSDH cases, 14 (61%) were unilateral and 9 (39%) were bilateral (total of 32 sides). The CT appearance of the hematoma was high density on 6 sides, isodensity on 14 sides, and mixed density on 12 sides. Head CT scans were taken on the day of injury (day 0) in 19 cases (25 sides), on the next day to 7 days after injury (days 1–7) in 12 cases (19 sides), and during both periods in 8 cases (12 sides; Table 1).

The initial CT scans of the 32 sides with CSDH were examined. ASDH was observed on 1 side (3%), thin SDE of 6 mm or less on 18 sides (56%), and thick SDE of more than 6 mm on 8 sides (25%). No enlargement of the subdural space was found in 5 sides (16%; Fig. 1).

The time course of changes ending in CSDH after injury could be observed in 12 sides of 8 cases (Fig. 2). Three sides (cases 2, 9 [right], and 20) showed normal findings on CT immediately after injury, 6 sides (cases 5, 9 [left], 12 [bilateral], and 14 [bilateral]) indicated thin SDE, 2 sides (case 10 [bilateral]) had thick SDE, and 1 side (case 8) had ASDH. Head CT 1 day after injury showed thin
TABLE 1. Summary of characteristics of 23 patients with CSDH

| Case No. | Age (yrs) | Sex | Injury Mechanism | Associated Injury | CT Performed/Period From Injury to CT (days) | Period From Injury to Op (mos) |
|----------|-----------|-----|------------------|-------------------|---------------------------------------------|------------------------------|
| 1        | 60        | M   | Syncope          | Maxillary sinus fracture | Yes                                      | —                            | 2               |
| 2        | 62        | F   | Fall             | SAH, skull fracture, cerebral contusion | Yes/Yes/1                                 | 1.5                          |
| 3        | 82        | M   | Fall             | None               | Yes/Yes/2                                 | 3                            |
| 4        | 91        | M   | Fall             | None               | Yes/Yes/7                                 | 2.5                          |
| 5        | 54        | M   | Fall             | SAH, ASDH, cerebral contusion | Yes/Yes/1                                 | 1.5                          |
| 6        | 90        | F   | Fall             | None               | —/Yes/7                                   | 2.5                          |
| 7        | 97        | F   | Fall             | None               | Yes/ —                                    | 1                            |
| 8        | 83        | M   | Fall             | ASDH               | Yes/Yes/1                                 | 2                            |
| 9        | 84        | M   | Fall             | Cerebral contusion, skull fracture | Yes/Yes/1                                 | 3                            |
| 10       | 56        | M   | Tumble           | ASDH, zygomatic fracture | Yes/Yes/4                                 | 1.5                          |
| 11       | 82        | M   | Fall             | None               | —/Yes/1                                   | 10                           |
| 12       | 33        | M   | Traffic accident | SAH, ASDH, cerebral contusion | Yes/Yes/1                                 | 4                            |
| 13       | 80        | M   | Fall             | None               | Yes/ —                                    | 1                            |
| 14       | 61        | M   | Fall             | None               | Yes/Yes/1                                 | 1                            |
| 15       | 87        | F   | Fall             | None               | Yes/ —                                    | 1.5                          |
| 16       | 83        | M   | Fall             | None               | Yes/ —                                    | 2                            |
| 17       | 77        | M   | Fall             | None               | Yes/ —                                    | 2                            |
| 18       | 82        | M   | Traffic accident | None               | Yes/ —                                    | 3                            |
| 19       | 83        | M   | Fall             | None               | Yes/Yes/5                                 | 0.5                          |
| 20       | 68        | F   | Traffic accident | None               | Yes/Yes/5                                 | 1                            |
| 21       | 74        | M   | Fall             | None               | Yes/ —                                    | 1                            |
| 22       | 65        | M   | Tumble           | None               | Yes/ —                                    | 2                            |
| 23       | 65        | F   | Fall             | None               | Yes/ —                                    | 1.5                          |

— = not applicable; SAH = subarachnoid hemorrhage.

FIG. 2. Time course of CT findings in 8 patients. These patients underwent head CT both on the day of injury (day 0) and on the next day to 7 days after injury (days 1–7). Each column shows CT scans from the same patient. Arrowheads in cases 9, 5, and 10 indicate the high-density line of the arachnoid membrane.
SDE of 6 mm or less in 2 sides (cases 2 and 9 [right]), although normal findings had been demonstrated on the day of injury. CT scanning 5 days after injury showed ASDH in 1 side (case 20).

Sides were divided into two groups based on the day on which CT scans had been obtained: group A, CT scans were obtained on the day of injury (day 0); and group B, CT scans were taken 1–7 days after injury (Table 2). Eight cases underwent CT both within 24 hours of injury and within 7 days of injury, so were included in both groups. Analysis of the subdural space was performed in 19 cases with 25 sides in group A and in 12 cases with 19 sides in group B. In group A, 5 (20%) of 25 sides showed normal findings, 16 (64%) of 25 sides had thin SDE of 6 mm or less, 3 (12%) of 25 sides had thick SDE of more than 6 mm, and 1 (4%) of 25 sides had ASDH. In group B, no side showed normal findings, 8 (42%) of 19 sides had thin SDE, 9 (47%) of 19 sides had thick SDE, and 2 (11%) of 19 sides had ASDH. These results indicated that normal findings and thin SDE were most common in group A, whereas thick SDE was most common in group B with no normal findings (Fig. 3).

CT scans at the time of injury found a high-density line in the lateral direction (onion skin–like) between the brain and the skull in 9 (35%) of the 26 sides with SDE, which was thought to be a thickened arachnoid membrane (Fig. 2). Some sides were considered to have linear and small-scale bleeding. Local minor bleeding was suspected in 2 sides (8%; cases 5 and 10), which were not ASDH but rather SDE with suspected microbleeding.

**Discussion**

We examined CT scans that had been obtained imme-
diately after the initial injury in 23 patients (32 sides) with CSDH. Initial CT (0–7 days) after injury showed 5 sides (16%) with normal findings, 26 sides (81%) with SDE, and 1 side (3%) with SDH. CT performed on the same day as injury mainly showed normal findings or thin SDE, whereas CT performed 1–7 days after injury mainly revealed thick SDE and no normal findings (Table 2 and Fig. 3).

Historically, CSDH was primarily believed to develop from ASDH based on anatomical considerations. However, head CT has since allowed reliable identification of an interesting pathological condition called “subdural effusion (SDE).” In one study, CT demonstrated 24 cases of traumatic SDE, which developed into CSDH in 6 cases. In a subsequent study, CT identification of 43 cases of SDE after trauma revealed a change to CSDH in 13 patients who were older than 65 years. CT diagnosis of 58 cases of SDE showed that 19 cases (32.8%) changed to CSDH. Three of 169 cases of SDE at the postoperative craniotomy site developed into CSDH. Recently, 22.7% of 44 cases of traumatic SDE changed to CSDH. These reports, mainly from Asia, showed that SDE caused by trauma can develop into CSDH, indicating some consensus. However, these studies are based on SDE, which is one of the candidates for the origin of CSDH; unfortunately, these studies did not investigate the origin of true CSDH.

CSDH is often treated surgically, so retrospective examination of neuroimages obtained after previous trauma may be helpful in understanding the origin of CSDH. However, many types of minor injuries may precede CSDH, and many patients do not go to the hospital. In the present study, we retrospectively examined 172 cases of CSDH treated over 7 years, but we found posttraumatic CT images in only 23 cases. Similar studies thus far have included one case report and a series of only 7 cases. In the latter study, which involved a review of 37 cases of CSDH, authors found 7 cases with CT (partial MRI) after previous trauma. Three of the 7 cases showed enlargement of the unilateral thin subdural space, which was called an “asymmetrically enlarged cerebrospinal fluid intensity extraaxial collection.” This name seems to be the radiologically correct nomenclature, but we considered this observation to represent thin SDE for the following reasons. Very thin SDE causes thickening of the dura mater to be difficult to distinguish on FLAIR imaging. Enlargement of the subdural space is probably thought to be continuously thin until the thickening of the dura. Only the presence of the cortical vein sign on preoperative MRI can currently prove that this is the subdural space. However, the cortical vein sign is only found on MRI, is difficult to identify unless the SDH is thick, and is difficult to see using head CT. But if a thin, asymmetrical, linear cerebrospinal fluid density line is found, it may be considered to be thin SDE if it is linked to future SDE and CSDH over time. This thin SDE can probably be considered as the origin of CSDH (Fig. 4).

The thin SDE as proposed is very thin and is at the boundary between detectable and undetectable on head CT, so may not be pointed out by general neuroradiologists (Fig. 4). In our study, CT immediately after the trauma most often showed only normal findings, and often SDE, except for the SDH case (Fig. 4). Therefore, we propose that SDE that subsequently develops into CSDH is often very thin immediately after the injury. Note, however, that CT on the next day and later often detected SDE, so the thickness probably increases over time. In 3 cases (cases 2, 9, and 20), CT on days 1–7 after injury showed enlargement of the subdural space, which had not been seen on the day of injury (Table 2). A previous case had a similar presentation. Exfoliation of the dura-arachnoid interface layer, which was too thin to be confirmed by CT in the early stages of injury, may be more clearly visualized with time because of the penetration of spinal fluid after trauma. CT performed 6–46 days after head injury

![FIG. 3. Comparison of CT findings of normal, thin SDE, thick SDE, and ASDH between day 0 and days 1–7. Head CT scans taken on the day of injury showed normal findings (20%), thin SDE of 6 mm or less (64%), thick SDE of more than 6 mm (12%), and ASDH (4%). CT scans taken 1–7 days after trauma showed thin SDE (42%), thick SDE (47%), and ASDH (11%).](image-url)
detected SDE in 6.6% of patients. Such SDE is expected to develop into CSDH.

The present study of CT after CSDH revealed that the arachnoid membrane at the boundary between the subdural space and subarachnoid space of the brain surface can be identified as a high-density line in some cases. This high-density line was also seen in the lateral direction (onion skin–like) between the brain and the skull on the initial CT scans in 35% of cases. The outside of this line may be considered as the subdural space. Minor bleeding was observed in this subdural space in some cases. The subdural space is not a normal anatomical cavity but results from trauma causing exfoliation of the dura-arachnoid interface layer, which may also cause minor bleeding in the subdural space. Thickening of the arachnoid membrane at the boundary between the dura and arachnoid membrane may be associated with trauma sequelae such as linear bleeding.

CT is less likely to be performed after minor head injury, which is considered to be the causative mechanism of CSDH; therefore, few cases are available for study and further investigation is needed. This study was conducted at the university hospital in our territory, which treats a high percentage of cases of severe trauma with extracranial and intracranial injuries and a low percentage of cases of minor head injury, so the characteristics of the general CSDH population and the population of this study may differ slightly.

Conclusions

We examined CT scans taken immediately after trauma in 23 patients who were subsequently treated for CSDH. Head CT performed on the day of injury most often showed normal findings or thin SDEs of 6 mm or less or, occasionally, ASDH, but no thick SDE of more than 6 mm. CT performed 1–7 days after trauma mainly showed thick SDE but no normal findings. SDE that precedes CSDH may be near the limit of detection by CT immediately after injury but becomes more apparent from the day after injury.

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Disclosures
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Conception and design: Tosaka. Acquisition of data: Komiyama, Shimauchi-Ohtaki, Aihara, Shimizu. Analysis and interpretation of data: Tosaka, Komiyama, Shimauchi-Ohtaki. Drafting the article: Tosaka, Komiyama, Shimauchi-Ohtaki. Revised the article: Tosaka, Shimauchi-Ohtaki, Aihara, Shimizu, Yoshimoto. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Tosaka. Administrative/technical/material support: Aihara, Shimizu. Study supervision: Yoshimoto.

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