Original Article

Association between cranial asymmetry severity and chronic subdural hematoma laterality

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ABSTRACT

الأهداف: تحليل العلاقة بين شدة التباين في الجمجمة والورم الدموي تحت الجافية المزمن (CSDH) الجانبي.

الطريقة: أجرينا دراسة بأثر رجعي لتقييم 120 مريضا يعانون من CSDH أحادي الجانب المعالج جراحيًا خلال الفترة من يناير 2009م إلى ديسمبر 2018م. استخدمنا صور التصوير المقطعي المحوسب قبل الجراحة لتحديد زوايا قبو القذالي، مناطق الجمجمة الثنائية، ومؤشر الجمجمة من التناظر (CIS).

النتائج: كان الجنس الذكري (70%) هو العامل السائد في تعزيز التسبب في المرض CSDH. في مجتمع الدراسة الإجمالي (متوسط العمر 71.3 عام؛ CSDH على الجانب الأيسر، 58/120 [48%] من المرضى؛ CSDH على الجانب الأيمن بسبب الجمجمة المسطحة على الجانب الأيمن، 38 مريضًا؛ CSDH على الجانب الأيسر بسبب الجانب الأيمن الجمجمة المسطحة، 37 مريضا). ارتبط عدم تناسق الجمجمة المسطحة بشكل غير ملحوظ مع جانبية CSDH (p-value=.689)). ومع ذلك، قدم معظم مرضى 86.7%) CSDH من 120 مريضًا) مناطق غير متداخلة من الجانب السائد على الجانب الأيسر. ثلاثة عشر (81.3%) من المرضى الذين يظهرون مناطق غير متداخلة في الجانب الأيمن لديهم CSDH على الجانب الأيمن، و 55 (52.9%) من المرضى لديهم منطقة غير متداخلة في اليسار لديهم CSDH على الجانب الأيسر (p-value=0.01). كانت نسبة CIS أعلى بشكل ملحوظ في المرضى الذين يعانون من مناطق غير متداخلة في الجانب الأيمن من أولئك الذين لديهم مناطق غير متداخلة في الجانب الأيسر (97.2% مقابل 95.9%، القيمة الاحتمالية أقل من 0.0001).

الخلاصة: غلبة الورم الدموي على الجانب الأيسر لا تترافق مع الجمجمة المسطحة والجانب الجانبي لـCSDH من جانب واحد. علاوة على ذلك، قد يتنبأ كثرة الأقحف غير المتماثلة مع نسب CIS أقل بـ CSDHs اليسرى، في حين أن CSDHs على الجانب الأيمن قد تكون أكثر شيوعًا في القحف المتماثل مع نسب CIS أعلى. من المحتمل أن يُعزى الجانب الجانبي لـ CSDH إلى شدة التباين في الجمجمة.

Objectives: To analyze the association between cranial asymmetry severity and chronic subdural hematoma (CSDH) laterality.

Methods: We retrospectively assessed 120 patients with surgically treated unilateral CSDH from January 2009 to December 2018. Preoperative computed tomography images were used to determine occipital vault angles, bilateral cranium areas, and cranial index of symmetry (CIS) ratios.

Results: The male sex (70%) was the predominant factor promoting CSDH pathogenesis. In the overall study population (mean age, 71.3 years; left-sided CSDH, 58/120 [48%] patients; right-sided CSDH due to right-sided flat cranium, 38 patients; left-sided CSDH due to right-sided flat cranium, 37 patients). Flat cranial asymmetry was nonsignificantly associated with CSDH laterality (p-value=.689). However, most CSDH patients (86.7% of 120 patients) presented dominant-sided nonoverlapping areas on the left side. Thirteen (81.3%) patients presenting right-dominant nonoverlapping areas had right-sided CSDH, and 55 (52.9%) patients had left-dominant nonoverlapping area had left-sided CSDH (p-value=0.01). The CIS ratio was significantly higher in patients with right-dominant nonoverlapping areas than in those with left-dominant nonoverlapping areas (97.2% vs 95.9%, p-value<0.0001).

Conclusion: Left-sided hematoma predominance is not associated with a flat cranium and laterality of unilateral CSDH. Moreover, more asymmetric crania with lower CIS ratios may predict left-sided CSDHs, whereas the right-sided CSDHs may be more common in symmetric crania with higher CIS ratios. The CSDH laterality is potentially attributable to cranial asymmetry severity.

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Chronic subdural hematoma (CSDH), a common neurosurgical entity, is considered a delayed manifestation of head trauma, occurring mostly in older men.[1] Although CSDHs can occur in unilateral or bilateral intracranial spaces, left-sided predominance has been previously reported.[2,3] Few studies have reported that cranial morphology and gravity contribute to the laterality of CSDH.[4-6] Cranial asymmetry is more common among crania flattened toward the right side, influencing the left-sided predominance of CSDH.[6] The cranial index of symmetry (CIS) with a semiautomated method has been introduced to objectively determine the severity of cranial deformations including plagiocephaly.[7] A preliminary study reported that the objective nonradiographic method potentially serves as an unbiased measurement of cranial asymmetry.[7] The flat side has been simply defined by a smaller angle through a simple method considering angles among 3 lines.[4-6] However, the angles may be manually affected by the points of the intersection of the manually selected lines, thus obstructing cranial asymmetry assessment. Therefore, here, we aimed to clarify the association between the severity of cranial asymmetry and the laterality of CSDH by using an objective semiautomated method.

Methods.

Patient selection. In this retrospective study, we reviewed the medical records of patients who underwent surgical treatment for CSDH at our institute from January 2009 to December 2018. Our study was approved by the Institutional Review Board of Cathay General Hospital in Taiwan (CGH-P108069). The inclusion criteria were as follows: (1) CSDH confirmed through brain computed tomography (CT) without contrast enhancement, (2) presentation of only unilateral CSDH with neurological symptoms, and (3) age >20 years. The exclusion criteria were as follows: (1) concomitant occurrence of other types of traumatic brain injury; (2) performance of previous neurosurgical procedures including craniectomy, craniotomy, or shunting procedures; (3) development from non-traumatic etiologies such as vascular abnormalities or neoplasm; and (4) missing data or images. In total, 120 patients with unilateral CSDH were enrolled.

Radiological evaluation. Preoperative CT images of all patients were obtained to assess cranial symmetry and the location of CSDH. Cranial asymmetry in axial view of CT images was defined using 2 methods: the conventional angle method and the objective semiautomated method developed here.

In the angle method (**Figure 1**), cranial asymmetry was investigated using 3 lines passing the midline bilaterally along the cranium, as previously described.[4,6] The flat side was the side of the smaller angle. Cranial "asymmetry" was defined as a difference of >2° in both angles. In the objected semiautomated method developed here, cranial asymmetry was analyzed in accordance with the concept described by Zonenshayn et al.[7] The image analysis software was developed on the basis of the LabVIEW system (National Instruments, Texas, USA). CT images were loaded into this software system. The nasion and inion, manually denoted by black spots, were considered the midline. The subsequent analysis was automated, including subtraction of the skull bone, encoding of the number of pixels, and determination of each cranial area. Considering the midline as the axis, one side of the cranium could be horizontally flipped onto the other side to determine the overlapping and nonoverlapping areas (**Figure 2**). The dominant nonoverlapping side was defined as the side of the larger nonoverlapping area. The CIS ratio was determined as twice the overlapping area divided by the total area.

Statistical analysis. Statistical analyses were performed using SPSS (version 22.0). The data are presented as means and their standard deviations. Between-group comparisons were performed using the independent-samples Student t test, Fisher exact test, and cross-table analysis. Differences were considered statistically significant when p-value<0.05.

Results.

Of the 120 patients enrolled, male sex (70%) had unilateral CSDH. The mean age of the entire study population was 71.3±12.9 (range, 36-98) years. However, only 58 (48%) patients had left-sided CSDH.

Based on CSDH laterality, all patients were divided into 2 groups: right-sided and left-sided CSDH (**Table 1**). Of the 79 patients cranial asymmetry defined as a difference of >2° in both angles, we analyzed the association between the laterality of CSDHs and the side of flat cranium. Among 53 patients with right-sided flat cranium, there were 27 right-sided CSDH and 26 left-sided CSDH. Among 26 patients with left-sided flat cranium, 14 hematomas occurred in right side and

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12 hematomas occurred in left side. This association was not significant (p=0.689).

By using the objective semiautomated method, the areas of total hemisphere, right hemisphere, and left hemisphere in the right-sided CSDH group were similar to those in the left-sided CSDH group (**Table 2**). However, patients with right-sided CSDH had a significantly larger right-sided nonoverlapping area than did those with left-sided CSDH (p=0.002). Furthermore, the left-sided nonoverlapping area was significantly larger in patients with left-sided CSDH than in those with right-sided CSDH (p=0.003). The CIS ratio was slightly but nonsignificantly higher in patients with right-sided CSDH than in those with left-sided CSDH (p=0.05).

Based on the dominant side of the nonoverlapping area, patients were divided into right- and left-dominant nonoverlapping groups (**Table 3**). Among 120 CSDH patients, most patients (86.7%) displayed left-sided predominance in the nonoverlapping area. The mean age and sex gender between 2 groups were not significantly different. Moreover, the association among the dominant nonoverlapping area, flat cranium, and asymmetric cranial morphology was not significant. The areas of the total, right side, left side, and overlapping regions were similar in both groups. 13 (81.3%) of 16 patients with right-dominant nonoverlapping areas had right-sided CSDH, where 55 (52.9%) of 104 patients had left-sided CSDH. The dominant-sided nonoverlapping area was significantly associated the same-sided hematoma (p=0.011). Furthermore, the CIS ratio was significantly higher in patients with right-dominant nonoverlapping areas than in those with left-dominant nonoverlapping areas (p<0.0001). As the abovementioned results, high cranial asymmetry with a low CIS ratio may predict left-sided CSDH (**Figure 3A and B**), whereas right-sided CSDH is potentially more common among symmetric crania with a high CIS ratio (**Figure 3C**).

Table 1 - Summary of chronic subdural hematoma laterality and cranial asymmetry in the patients.

Variables	Hematoma side		
	Right (n=62)	Left (n=58)	*P*-value
Age	69.3 ± 12.9	73.4 ± 12.7	0.085
Gender			0.524
Female	17	19	
Male	45	39	
Cranial morphology			0.944
Symmetry	21	20	
Asymmetry	41	38	
Flat side			0.777
Right	38	37	
Left	24	21	

Table 2 - Summary of cranial areas and chronic subdural hematoma laterality.

Variables	Hematoma side		
	Right (n=62)	Left (n=58)	*P*-value
Cranial area (mm^2)			
Total	16212±2549	16080±2109	0.759
Right side	7984±1290	7767±994	0.306
Left side	8228±1290	8313±1171	0.706
overlapping	17894±3083	17830±2886	0.907
Non-overlapping			
right	389±402	187±286	0.002
left	934±746	1437±1038	0.003
CIS ratio (%)	96.5±1.8	95.7±2.5	0.05

CIS - cranial index of symmetry

Discussion.

The CSDH is a well-documented neurosurgical entity, mostly occurring among older people. The incidence of CSDH has increased worldwide because of progressive aging of the population, a lower

Table 3 - Summary of patients with chronic subdural hematoma based on dominant nonoverlapping areas.

Variables	Non-overlapping dominant side		
	Right (n=16)	Left (n=104)	*P*-value
Age	69.1±14.8	71.6±12.6	0.462
Gender			0.907
Female	5	31	
Male	11	73	
Hematoma side			0.011
Right	13	49	
Left	3	55	
Flat side			0.267
Right	8	67	
Left	8	37	
Cranial morphology			0.385
Symmetry	7	34	
Asymmetry	9	70	
Brain area (mm2)			
Total	15952±2757	16178±2281	0.72
Right	8118±1423	7842±1114	0.377
Left	7834±1341	8336±1205	0.129
overlapping	17967±3401	17845±2925	0.882
Non-overlapping			
right	822±361	210±288	<0.001
left	180±148	1331±905	<0.001
CIS Ratio (%)	97.2±0.9	95.9±2.3	<0.001

CIS - cranial index of symmetry

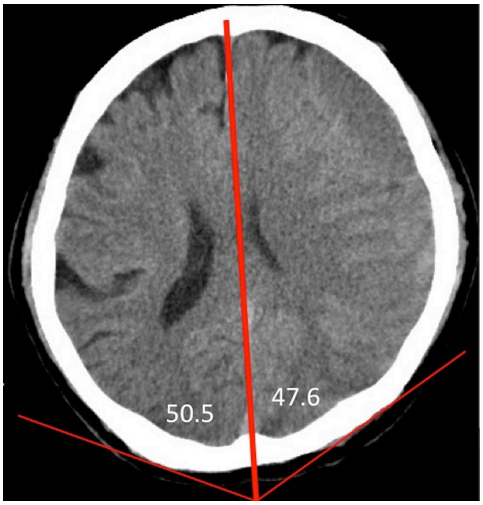

Figure 1 - Angle method, involving 3 lines traversing the midline and both sides of the cranium.

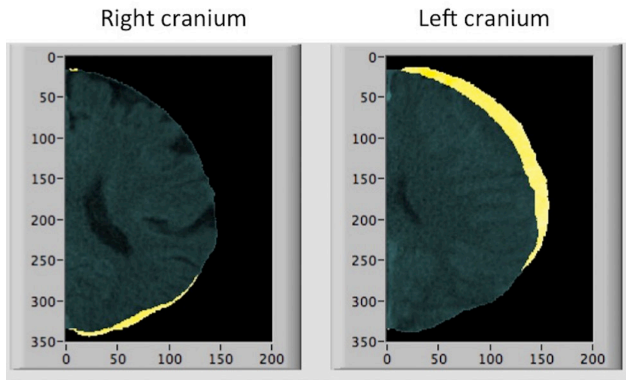

Figure 2 - Objective semiautomated method (developed here) to assess the cranial cross-sectional area, including the overlapping (grey green) and nonoverlapping (yellow) areas.

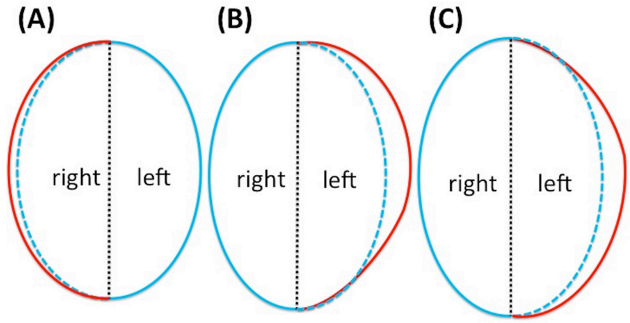

Figure 3 - Schematic illustration of the computed tomography images of asymmetric crania to predict the laterality of chronic subdural hematoma. (**A and B**) In left-sided hematoma, cranial asymmetry presents with a lower cranial index of symmetry (CIS) ratio and larger left-sided nonoverlapping areas. **C**) Right-sided hematoma more commonly occurs in symmetric crania with a high CIS ratio and slightly larger nonoverlapping areas. Red line - hematoma side, black dotted line - midline, blue line - opposite side of hematoma, blue dotted line - horizontal flip on image to the opposite side.

imaging threshold for patients with head trauma, and increased use of anti-coagulants or antiplatelet agents.[8-10] Brain atrophy, hemorrhage from a tear in the bridging vein after initial heat trauma, and local inflammation or angiogenesis owing to hematoma markedly contribute to CSDH pathogenesis in older people.[1,10-12] The CSDH with left-sided predominance has been described previously.[2,3] Nayil et al[3] retrospectively reviewed 863 patients with unilateral CSDH and reported that the hematoma was left-sided in 55.9% of cases. Of 215 patients with CSDHs, MacFarlane et al [2] reported 123 (57%) patients with left-sided CSDH. Here, most patients were male (70%) and older with a mean age of 71.3 years. However, only 58 (48%) of 120 patients had left-sided CSDH, in contrast to previous reports.[2,3]

The reason underlying this left-sided predominance in CSDH is unclear. Cranial morphology may be associated with CSDH laterality.[2,4-6] On using the conventional angle method, bilateral CSDHs were frequently observed in patients with cranial asymmetry, whereas CSDH was more commonly located at the region opposite the skull toward the flat side.[4] Kim et al[6] retrospectively assessed 182 patients with CSDH and reported that in the right flat cranium, hematoma more commonly occurred on the opposite side of the flat side. Among patients with left flat crania, CSDH was more common on the same side. However, Akhaddar et al[5] assessed the angles in the frontal and occipital vault and reported that in patients with asymmetric crania, hematoma was more commonly present on the same side of the most curved frontal or occipital convexity. These results are in contrast to those of Kim et al.[6] Here, we determined the angles in the occipital vaults, using a method similar to that of Lee et al[4] and Kim et al,[6] and only unilateral CSDH patients were enrolled here. The present results indicate that flat cranial asymmetry was not significantly associated with CSDH laterality, indicating that the laterality of CSDH does not contribute to cranial flatness, as determined through flat angle measurements.

Cranial morphology may not always be similar between the right and left hemispheres.[5,6,13] Although determination of the angle on the cranium is a simple method, these angles cannot accurately reflect cranial asymmetry. Based on computerized simulations, cranial symmetry may be assessed using an objective semiautomated method.[7] After defining the midline with 2 dots, the intracranial vaults at the right and left sides can be analyzed by encoding the number of pixels. The overlapping and nonoverlapping areas can be compared and calculated through horizontally flipping. Here, most patients (86.7%) displayed left-sided predominance in the nonoverlapping areas. The CIS ratio was higher in patients with right-dominant nonoverlapping areas than in those with left-dominant nonoverlapping areas. Patients with right-dominant nonoverlapping area more commonly displayed right-sided CSDH, whereas those with left-dominant nonoverlapping areas more frequently presented left-sided CSDH, indicating that most patients had a left-sided predominant cranial asymmetry and a higher risk of left-sided CSDH. Otherwise, left sided CSDH is commonly among higher asymmetric crania with a low CIS ratio, whereas symmetric crania with a high CIS ratio may predict right-sided CSDH. Our results support the hypothesis that CSDH laterality contributes to the severity of asymmetric crania.

This study has some limitations. First, our sample was relatively small. Second, this was a retrospective study, only including patients receiving surgical intervention for CSDH. Third, differences between bilateral and unilateral CSDH were not compared using the objective semiautomated method developed here. Further prospective studies with larger samples are required to confirm the present findings.

In conclusion, although most patients with unilateral CSDH present with right-sided hematoma, this study compared the conventional angle method and the objective semiautomated method developed here to assess CSDH laterality. This study shows that high cranial asymmetry with a low CIS ratio potentially predicts left-sided CSDHs, whereas right-sided CSDHs are potentially more common in symmetric crania with a high CIS ratio. The present results indicate that the laterality of CSDH is potentially associated with the severity of cranial asymmetry.

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