Skull Vault Morphology in Subdural Hematomas: A Geometrical Analysis

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Abstract

Background The issue of cranial symmetry on the lateralization of chronic subdural hematomas has been raised in the past but not fully settled.

Aim The aim of the study was to evaluate the effect of skull morphology on the lateralization of chronic subdural hematomas.

Methods We conducted a prospective study in chronic and subacute subdural hematomas over a period of 1 year. All the patients had a CT scan of the head and the relationship of the cranial symmetry with the side of the hematomas was evaluated. We had a total of 138 patients.

Results The frontal symmetry was found in 23.18% (32/138) patients and asymmetry in 76.81% (106/138) patients. The occipital symmetry and asymmetry were found in 10.14% (14/138) and 89.85% (124/138) patients, respectively. Bilateral chronic subdural hematomas were more common in craniums that had frontal and occipital symmetry, and unilateral subdural hematomas were more common in craniums that had frontal asymmetry.

Conclusion Skull vault morphology has a significant bearing on the bilaterality and the side of the chronic and subacute subdural hematomas. This relationship may have a bearing on the future understanding of the etiopathogenesis of subdural hematomas.

Keywords
- subdural hematoma
- head injury
- skull vault morphology
- skull asymmetry

Virchow in 1857 described chronic subdural hematoma as pachymeningitis hemorrhagica interna.[1] The source of blood was attributed to the bridging subdural veins and was named as subdural hemorrhagic cyst.[2] The source of bleeding is usually from the subdural bridging veins. Bleeding from the neomembrane also adds to the collection.[3,4] About less than half of the chronic subdural hematomas are associated with past history of head injury.[2,5] Besides this, disorders in the local coagulation/fibrinolytic cascade, role of osmotic pressures, intracranial hypotension, atrophy and dehydration of brain, and evolution of subdural hygromas into subdural hematomas have also been incriminated in the progression of the hematomas.[6–10] About 86% of subdural collections are unilateral and 14% are bilateral.[5] We endeavored to study the relation of skull morphology to the lateralization of subdural hematomas.

Patients and Methods

The study was conducted on 138 patients from July 2012 to June 2013; a period of 1 year, in the Department of

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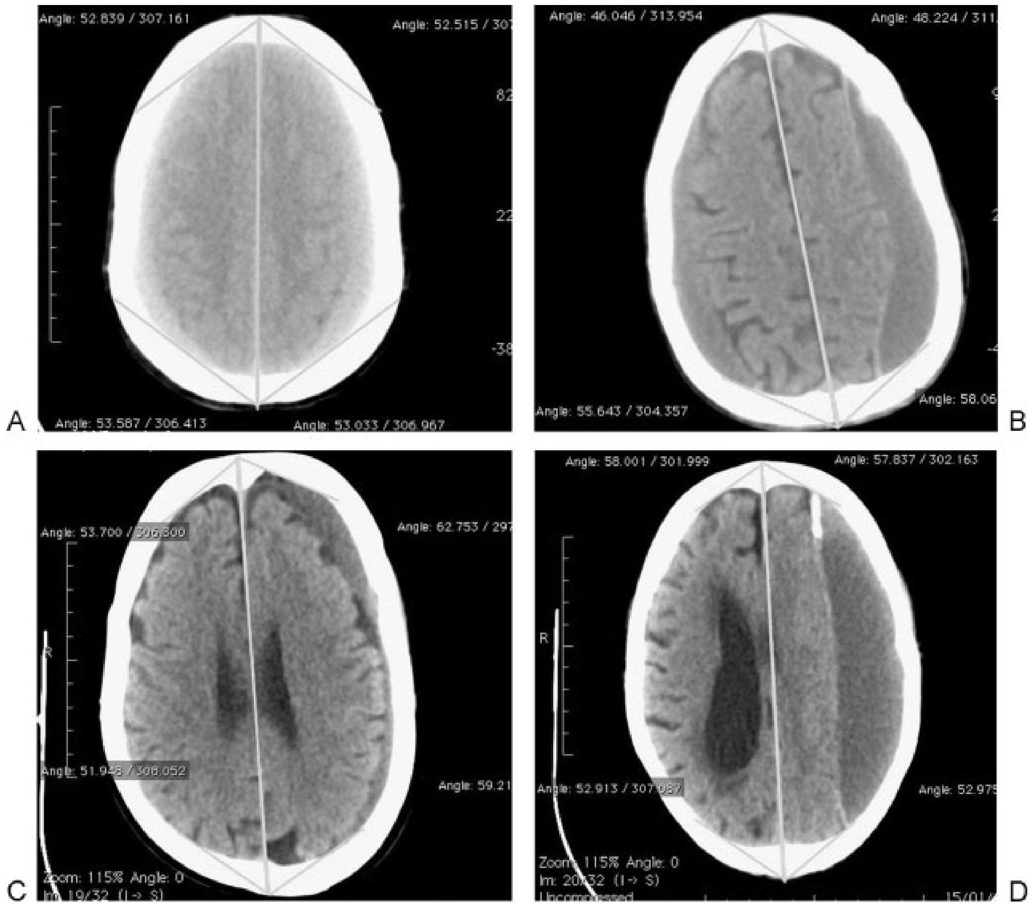

Fig. 1 Axial sections of plain CT scan of the head show bilateral SDH with symmetric frontal and occipital angles (**A**), bilateral SDH with symmetric frontal but asymmetric occipital angles (**B**), unilateral SDH with asymmetric frontal and occipital angles (**C**), unilateral SDH with symmetric frontal and occipital angles (**D**).

Neurosurgery, Sheri-Kashmir Institute of Medical sciences, Srinagar, Jammu and Kashmir (India). Patients with a computed tomographic (CT) scan diagnosis of subacute (isodense collections) and chronic subdural hematomas (hypodense collections) in all age groups were included in the study. Patients with acute subdural hematoma, that is, who presented within 72 hours of ictus, and all hyperdense subdural hematomas were excluded. All the patients had a CT scan as the mode of investigation. All the CT images of the patients were recorded on a compact disc and the images were opened by a free imaging software for Macintosh available at www.osirix.com. CT scan section taken at 7 cm above the orbitomeatal line was selected for the measurements of the angles. The midline was drawn by a line connecting the anterior and posterior attachments of the falx cerebri. From the midpoint of the outer table on the frontal side, two tangential lines were drawn through the inner table of the frontal bone on either side and the same procedure was repeated on the occipital side. The inner table was selected to avoid the effect of the thickness of the skull bone. The angles were measured between the midline and the tangential lines. A difference of more than 2 degrees between the corresponding sides was defined as unequal angles (►**Fig. 1A–D**). The angles were measured by a radiologist (F.S.) who was blind to the aim of the study. Statistical analysis was done by using the statistical package for the social sciences (SPSS, version 19). Contingency tables were evaluated by Fisher's exact test. A value of $p \leq 0.05$ was considered as statistically significant.

Results

The mean age of 138 patients was 56.6 years (range 31–72 years). There were 117 unilateral collections and 21 patients had bilateral collections. The mean right frontal angle was 53.16 degrees (range 31–84 degrees) and the mean left frontal angle was 52.96 degrees (range 29–80 degrees). The mean right occipital angle was 50.50 degrees (range 30–83 degrees) and the mean left occipital angle was 51.03 degrees (range 26–80 degrees). Frontal symmetry was noted in 22.2% (32/138) patients and asymmetry in 76.8% (106/138). Subdural collections were more often bilateral in patients with frontal symmetry than those with an asymmetry 37.50 versus 8.49% ([12/32] vs. [9/106]). The difference was statistically significant, $p = 0.003$. Similarly subdural collections were also noted more often bilaterally in patients with occipital symmetry than those with an asymmetry 35.71 versus 12.90% ([5/14] vs. [16/124]). The

Table 1A Demographic and geometric profile of patients ($n = 138$)

Age (y)	Range	31–72
	Mean	56.6
Sex	Male	92
	Female	38
Right frontal angle (deg.)	Range	31–84
	Mean	53.16
Left frontal angle (deg.)	Range	29–80
	Mean	52.96
Right occipital angle (deg.)	Range	30–83
	Mean	50.50
Left occipital angle (deg.)	Range	26–80
	Mean	51.03

difference was statistically significant, $p = 0.040$ (►**Table 1A, B**). The unilateral collections were more often located on the side of more frontal convexity (bigger angle) than on the side of less frontal convexity (smaller angle) (►**Table 2**). There was no correlation between occipital angle and the side of the subdural collection, a finding contrawise to the frontal angles (►**Table 3**).

Discussion

Although previous history of head injury is not present in all the patients of chronic or subacute subdural hematomas, head injury is still considered to be a main factor.[2,3,11] In the present study of 138 patients of subdural hematomas, only 64% of patients had a previous history of head injury. It has been debated in the past that normally subdural space does not exist and that the split in the inner dural border cell layer is the initiating factor in the development of a potential subdural space.[12] We also believe that subdural hematomas evolve when the dural border cell layer cleaves into outer and inner layers. The split may occur because of trauma. This split possibly induces tissue proliferation of the dural border cell layer resulting in neo-membrane formation. Also, the dural cell border layer of the two sides may behave differently in an asymmetric head, depending on the degree of the force generated on either side across two unequal angles. The more convex side (greater angle) is delivered more force than the less convex side, thereby increasing the chance of split of the dural border cell layer and subsequent formation of the subdural hematoma.[13] This can be explained by the following mathematical model. Consider angle $\theta > \alpha$ in ►**Fig. 2**, so $\text{Sin } \theta > \text{Sin } \alpha$.[8] The force F acting on the skull will be having components T and R normal to the tangents where $T = F \times \text{Sin } \theta$ and $R = F \times \text{Sin } \alpha$. Therefore, $T > R$ as $\text{Sin } \theta > \text{Sin } \alpha$ as stated previously. It can be concluded that the force acting on the side where the angle is larger is greater than the side where the angle is smaller.[5] Hence force (T) has more chances of tearing apart the veins on that side compared with the side where the force (R) is small. This may lead to increased incidence of hematomas on that side. Second, the larger the angle θ, the flatter the skull is on the inner side. In ►**Fig. 2**, arc PN (——) is larger as compared with PM (—). This also results in larger number of veins coming under area PN as compared with area PM. Thus larger number of veins come under the influence of the force in the area PM, which leads to the larger number of veins getting damaged in the area PN and subsequently more incidence of hematomas on that side.

This concept explains the mechanical contribution involved in the etiopathogenesis of subdural hematomas in the patients who have sustained impact on the frontal vault and also the high incidence of bilateral subdurals in patients with symmetric frontal vaults as the force produced in either direction must be equal and thus creates equal chances of developing subdural hematomas. However, the same hypothesis does not explain the very absence of such findings when the relation of laterality of subdural hematomas with occipital angles is evaluated nor does it explain the side of subdural hematomas when the impact is sustained by the nonpolar sides of the head viz; temporal regions. This could be explained by the fact that chronic subdural hematoma is a disease of elderly and brain atrophy

Table 1B Radiological profile of the patients

Laterality	Total patients	No. of patients	Subdural collections	Significance
Patients with unilateral SDH	117	Frontal symmetry (32)	20	
		Frontal asymmetry (106)	97	
		Occipital symmetry (14)	9	
		Occipital asymmetry (124)	108	
Patients with bilateral SDH	21	Frontal symmetry (32)	2	
		Frontal asymmetry (106)	9	$p = 0.003$
		Occipital symmetry (14)	5	
		Occipital asymmetry (124)	16	$p = 0.040$[a]

Abbreviation: SDH, subdural hematoma.
[a]Significant.

Table 2 Frontal asymmetric angles in unilateral subdurals ($n = 97$)

Patients with angles more on right side	Right-sided subdurals	Left-sided subdurals
45	28	17
Patients with angles more on left side		
52	18	34

Patients with symmetric frontal angles ($n = 32$) and patients with asymmetric frontal angles with bilateral collections ($n = 9$) were excluded.
$p = 0.0083$ (significant).

Table 3 Occipital asymmetric angles in unilateral subdurals ($n = 108$)

Patients with angles more on right side	Right-sided subdurals	Left-sided subdurals
49	28	21
Patients with angles more on left side		
59	27	32

Patients with symmetric occipital angles ($n = 14$) and patients with asymmetric occipital angles with bilateral collections ($n = 16$) were excluded.
$p = 0.2532$ (not significant).

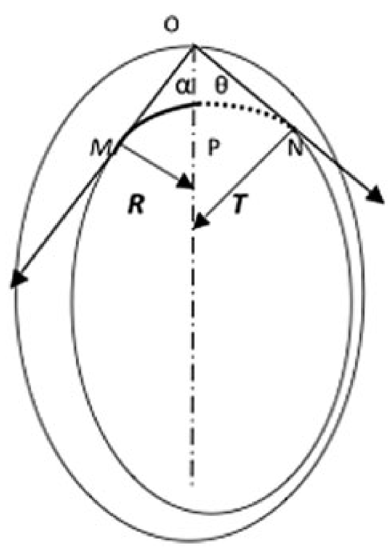

Fig. 2 Schematic diagram depicting the vector distribution of the forces applied to the skull.

is a frequent accompanying feature in this patient population.[3] Interestingly brain atrophy occurs predominantly in the frontal lobes than in the occipital lobes, and this loss of brain volume is compensated by approximately 11% increase in the extracerebral cerebrospinal fluid (CSF) volume predominantly near the frontal lobes.[4] It might hence be postulated that the principle of mechanism of development of subdurals along the lines of skull morphology model may conform better when the dural border cell layer (DBC) layer is sandwiched between the skull bone and more of CSF as occurs near the frontal vault, rather than when the DBC layer is sandwiched between the skull bone and less CSF as occurs near the occipital vault. Based on our observations, we may label frontal vault morphology as the trendsetter of subdural hematomas. To elucidate further, it requires studying the DBC layer at the frontal vault and occipital vault and to identify any differences in the ultrastructure of this layer at diametrically opposite reference points of the dura.

Conclusion

Frontal skull symmetry is more common than occipital. Frontal skull vault symmetry has a bearing on the side of the formation of subdural hematomas. Populations with symmetric frontal vaults have higher chance of developing bilateral hematomas. Occipital skull vault morphology has no role in determining the side of the subdural hematomas.

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