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The Relationship Between Arachnoid Cysts and the Subarachnoid Space by Hounsfield Unit Value in Computed Tomography Scans: Identification of Isolated and Communicating Arachnoid Cysts in a Cohort Study

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Abstract

Background: Arachnoid cysts are formations containing cerebrospinal fluid (CSF). They may be associated with the subarachnoid space. This feature is a factor that can affect the change in the size of arachnoid cysts over time. Hounsfield Unit (HU) value measurements provide rational numeric representation of imaging of tissues in computed tomography (CT) examinations. In this study, we aimed to define isolated or communicated arachnoid cysts, and whether arachnoid cysts communicate with the subarachnoid distance, with the HU values obtained in CT examinations.

Methods: Patients with radiological diagnosis of arachnoid cyst were identified retrospectively by examining the CT database. HU value measurements were recorded over the Picture Archiving and Communication System (PACS) in the area where the arachnoid cyst was detected. HU value measurements are a method that rationally shows the amount of radiograph absorption of tissues in CT examinations. HU value measurements were performed in cerebrospinal fluid (CSF) and arachnoid cysts, and whether arachnoid cysts had equal HU values with CSF. They were defined as homogeneous or heterogeneous by measuring HU values in different regions of arachnoid cysts.

Results: Data on 478 cases were obtained. An average of 2.82 CT scans were detected per case. A change in arachnoid cyst size was detected in 47 (9.8%) cases. In cases of arachnoid cysts of varying size, the mean HU value of arachnoid cysts was 9.32 ± 1.93 (6.43 ± 1.67 in the lateral ventricle and 7.04 ± 1.71 in the fourth ventricle). HU value of arachnoid cysts with a change in size significantly differed from CSF.

Conclusion: Arachnoid cysts with HU values equal to CSF are not real arachnoid cysts, and significant volume changes are not expected. Arachnoid cysts, which have a different HU value than CSF, may secrete a different fluid from CSF. This type of arachnoid cyst is a real cyst that can be detected in various sizes on CT examinations at different times since they are not in communication with the subarachnoid space.

Keywords: Arachnoid cyst; Computed tomography; Cyst; Cerebrospinal fluid; Magnetic resonance imaging.

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Introduction

Arachnoid cysts are the most common intracranial cysts detected in 1% of all intracranial space-occupying lesions.[1,2] Acquired forms of arachnoid cysts are rarely encountered.[3] The most common cause is trauma in their acquired forms, which occurs due to the entrapment of cerebrospinal fluid (CSF) within the arachnoid scar tissue. It is also known that arachnoid cysts may occur due to chemical irritation, tumoral, and vascular events.[4]

Arachnoid cysts in communication with the ventricular system are not defined as true arachnoid cysts and may rarely show size differences during the follow-up period. Although the most detailed information in radiological examinations of intracranial lesions is obtained in magnetic resonance imaging (MRI) examinations, Hounsfield Unit (HU) values obtained in computed tomography (CT) provide objective data for quantitative measurements of radiograph absorption properties of tissues and lesions. Therefore, data related to the communication of arachnoid cysts with the ventricular system can be determined by HU measurements in arachnoid cyst cases. In this study, we aimed to compare the HU values of cysts and CSF in cases with arachnoid cysts, to reveal whether the arachnoid cysts are the communicating or non-communicating type.

Materials and Methods

Patients diagnosed with arachnoid cysts during 2013-

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2021 were obtained from outpatient clinic records and radiology database searches. The cases diagnosed by scanning the words "arachnoid cyst" on the outpatient clinic records and Picture Archiving and Communication System (PACS) were determined. For radiological imaging examinations, only the database of brain CT and brain MRI scans was scanned. Regardless of the number of radiological imaging, the number of people was determined and the proportion of cases diagnosed was calculated. Measurements of the dimensions of arachnoid cysts were performed using the PACS. The exact measurements were made in the control radiological examinations of the cases, and changes in arachnoid cyst dimensions were revealed.

Since arachnoid cysts have a similar appearance to CSF in radiological examinations, HU values of the lateral ventricles were also recorded to reveal their differences quantitatively. HU values in the lateral and fourth ventricle were recorded as comparison data to demonstrate the homogeneity difference between CSF and arachnoid cyst. The lowest and highest HU values were recorded, and mean HU values were calculated since the same HU values could not be obtained in every region of the same tissue. The difference between the highest and lowest HU values in the arachnoid cyst or ventricle was recorded as the "heterogeneity index".

Comparing HU values of arachnoid cysts and CSF reveals whether their internal dynamics form or communicate with the ventricular system. The clinical findings and prognoses of the cases were not evaluated in the study.

Description of the Heterogeneity Index

Continuously circulating CSF has a very homogeneous structure. In the case of arachnoid cysts containing CSF, the HU value of the cyst is equal to the CSF; and there is no significant difference in HU value between different cyst regions. However, if the arachnoid cyst has its internal dynamics and produces cyst content in a component other than the CSF, the HU value will differ from the CSF. Therefore, the liquid's heavy components, defined as xanthochromic, will be located at the bottom, and the light components will be at the top. The HU values between the inferior and superior will differ in this case. In this situation, the heterogeneity index will be higher.

The most typical example of the heterogeneity index can be described in CT examinations of chronic subdural hematoma cases with acute components. Acute hematoma is located inferiorly, and chronic hematoma is found superiorly. The difference between HU values of acute and chronic hematoma is relatively high. For this reason, the heterogeneity index is higher in the hematoma. In isolated chronic subdural hematoma (without an acute component) the difference between HU values in different regions is lower since the hematoma contains only the chronic bleeding component, both superior and inferior. Therefore, the heterogeneity index is low.

Statistical Analyses

A database was created by saving the data of the cases to an Excel 2016 file. Statistical calculations of demographic characteristics were performed with SPSS software, version 22. The *t* test was used to evaluate the difference between the group means. The Independent samples *t* test method was used to determine the differences between the means of independent groups. A $P<0.05$ was considered statistically significant.

Results

The database search determined that after examining 87320 different cases, 526 (0.6%) cases were diagnosed with arachnoid cysts. 478 patients met the study criteria including 313 men and 165 women with a mean ± SD age of 38.25 ± 22.37 years. The number of cranial CT examinations evaluated was 1348, and the average number of examinations per case was calculated as 2.82. The mean duration of the control radiological examination was calculated as 14.3 months. The most common arachnoid cyst was found in the middle fossa (48.32%).

Unitary volume change was detected in 47 (9.8%) cases of arachnoid cyst size compared to the first CT. An increase in arachnoid cyst size was seen in 27 cases and a decrease in 20 cases. The mean duration of radiological follow-up was calculated as 22.80 ± 8.82 months in cases with changes.

The mean ± SD unit volume was 875.00 ± 389.20 at the first admission; the mean ± SD unit volume was 1069 ± 442 in the CTs with an increase in volume. The mean ± SD unit volume was 974.40 ± 462.85 at the time of diagnosis; the mean ± SD unit volume was 813.95 ± 383.94 in the CTs with a decrease (Table 1). Although it was determined that the mean HU value of arachnoid cysts with volumetric increase and decrease in the control CTs changed, it was not statistically significant ($P=0.127$). Comparisons of size and HU values of arachnoid cysts and HU values of ventricles are shown in Table 2.

Mean HU values of lateral ventricle, fourth ventricle, and arachnoid cysts are shown in Table 1. HU value of the ventricles was recorded as 6.73 ± 1.69. However, the HU value of arachnoid cysts was 9.32 ± 1.93. The high HU value ranges of arachnoid cysts indicate that arachnoid cysts are more heterogeneous than CSF (Table 3).

In 17 cases with bilateral arachnoid cysts (bi-temporal), the lowest and highest HU values and heterogeneity indices of both arachnoid cysts were significantly different from each other. The lowest and highest HU values obtained in these cases and heterogeneity indices differed considerably from the ventricles ($P<0.001$). When the HU index differences between the lateral ventricle and the fourth ventricle were compared, it was found

that there was no difference in terms of heterogeneity ($P=0.165$). Comparisons of heterogeneity index in cases with bilateral arachnoid cysts show in Table 4.

Discussion

Arachnoid cysts are mostly incidentally detected, static formations that do not change size. They are formations with the same density as CSF in CT and MRI examinations.[5,6] Significant size changes are rarely encountered in radiological examinations and usually do not require surgical intervention. Surgical intervention is recommended for arachnoid cysts that grow progressively in size. The most commonly preferred diagnostic method is MRI, and it is superior to CT in showing the structural features of arachnoid cysts and their relationship with the surrounding tissues.[5,7] However, in CT examinations, HU values provide objective and quantitative data by showing the radiograph absorption of tissues. HU value is 0 for water, -1000 for air, which is the least, and 1000 for bone. Since radiographs show absorption properties, different structures are expected to show different HU values. Therefore, it is a quantitative measurement to show tissue homogenization under investigation.

Arachnoid cysts may have xanthochromic contents.[4] Moreover, arachnoid cysts associated with the ventricles are not real cysts since they actively participate in the circulation with the CSF (Figure 1).[8] It is also discussed that the cyst wall forms its content. Another theory is that arachnoid cysts are associated with the subarachnoid space and structure in which inward CSF circulation occurs with a unilateral valve mechanism.[9-11]

The HU value range of CSF is 0-10 in CT examinations. Since CSF is in continuous circulation in the subarachnoid space, HU values are expected to be equal in all regions. Therefore, CSF is considered to be a homogeneous liquid.

Arachnoid cysts in direct communication with the subarachnoid space or the ventricles should be expected to be of the same density as the CSF. Therefore, it is necessary to expect arachnoid cysts and CSF to have the same density and HU values in CT examinations. However, it was also shown that the HU values of arachnoid cysts and CSF differed (Table 2). The difference between the lowest and highest HU values detected in the arachnoid cyst is significantly different from the HU value ranges detected in the ventricles (Figure 2). Therefore, arachnoid cysts are more heterogeneous than CSF and are not always

Table 1. Comparisons of Arachnoid Cyst Unitary Volume Averages and HU Values in Cases With Volumetric Changes

	First CT Mean Unity Volume	Volumetric Change in Control CT	Average of First CT Arachnoid Cyst HU Value	Average of HU Value in Control CT	Heterogeneity Index (First CT)	Heterogeneity Index (Control CT)
Increase detection volumetric mean (n=27)	875.00±389.20	1069.70±442.23	7.92±2.10	7.75±2.01	15.85±4.20	15.51±4.01
Decrease detection volumetric mean (n=20)	974.40±462.85	813.95±383.94	7.22±2.43	6.50±2.09	14.45±4.87	13.00±4.18

Abbreviations: CT: computed tomography; HU: Hounsfield Unit.
Note. The control CT examination with the highest HU value average was taken into account. Heterogeneity index: The difference between the highest and lowest HU value. Difference index: HU value difference between both lateral ventricles.

Table 2. Comparisons of Size and HU Values of Arachnoid Cysts and HU Values of Ventricles

	Lateral Ventricle			Fourth Ventricle			Arachnoid Cyst		
	Lowest HU	Highest HU	Mean HU	Lowest HU	Highest HU	Mean HU	Lowest HU	Highest HU	Mean HU
First CT (n=431)	-5.12±2.47	7.75±2.27	6.43±1.67	-5.23±2.41	8.86±2.52	7.04±1.71	-7.29±2.56	11.34±2.88	9.32±1.93
Cysts that change in size (n=47)	-5.34±2.65	6.80±1.88	6.07±1.52	-4.68±1.99	8.65±2.62	6.67±1.70	5.38±3.89	9.87±2.49	7.62±2.25

Abbreviations: CT: computed tomography; HU: Hounsfield Unit.

Table 3. Heterogeneity Index Comparisons in Arachnoid Cysts With and Without Change in Size

	Lateral Ventricle Heterogeneity Index	Fourth Ventricle Heterogeneity Index (First CT)	Arachnoid Cyst Heterogeneity Index (First CT)
Cysts that do not change in size (n=431)	12.87±3.35	14.09±3.43	18.64±3.87
Cysts that change in size (n=47)	12.14±3.05	13.34±3.40	15.25±4.50

Abbreviation: CT: computed tomography.

Table 4. Comparisons of Heterogeneity Index in Cases With Bilateral Arachnoid Cysts

	Left Temporal	Right Temporal	Lateral Ventricle	Fourth Ventricle
Heterogeneity index (First CT)	13.76±2.75	18.00±4.18	12.05±2.68	12.41±3.08
Heterogeneity index (Control CT)	13.52±2.87	17.11±4.12	13.05±2.94	12.82±2.81

Abbreviation: CT: computed tomography.

associated with the subarachnoid space. It is also possible that arachnoid cysts detected at the same density as CSF are not in communication with CSF. Since the wall structure of the arachnoid cyst is also in the arachnoid structure, it may not cause a very different fluid secretion than CSF (Figure 3).[12]

According to the unilateral valve mechanism, arachnoid cysts should have a HU value equal to CSF but be as homogeneous as CSF. However, homogenization between arachnoid cysts and CSF is also different. According to the unilateral valve mechanism, arachnoid cysts should grow progressively. Activities such as cardiac pulsation and the Valsalva maneuver that increase intracranial pressure are also expected to cause a continuous flow of CSF into the arachnoid cyst. CSF, which cannot come out of the arachnoid cyst due to unilateral valve mechanism, is expected to progressively increase the size of the arachnoid cyst.

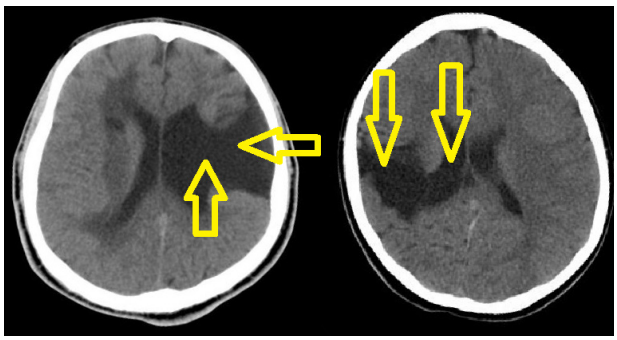

Figure 1. Cysts communicating with the ventricle should not be called true arachnoid cysts and do not have their internal dynamics. The HU and heterogeneity of this type of cyst are the same as CSF. The HU value of these arachnoid cysts is equal to the HU value of CSF (Yellow arrows)

For the same reason, arachnoid cysts should also be structures that cause significant mass effects and have a significant compression effect on adjacent tissues.[13,14] However, the rate of cases with a growing tendency among the cases evaluated in the study was 5.65%. The ratio of arachnoid cysts decreasing in size is 4.18%. The significantly higher proportion of arachnoid cysts that reduce the size and remain stable does not support the unilateral valve theory described for the etiopathogenesis of arachnoid cysts.

Arachnoid cysts that rapidly filled with contrast material were also described in contrast-enhanced cisternography.[7,8] Cystic structures associated with the subarachnoid area should not be considered structures with real cystic features. Since these structures communicate with subarachnoid structures, they should be regarded as pseudo-arachnoid cysts rather than arachnoid cysts. Since these structures directly communicate with the CSF, they should be expected to

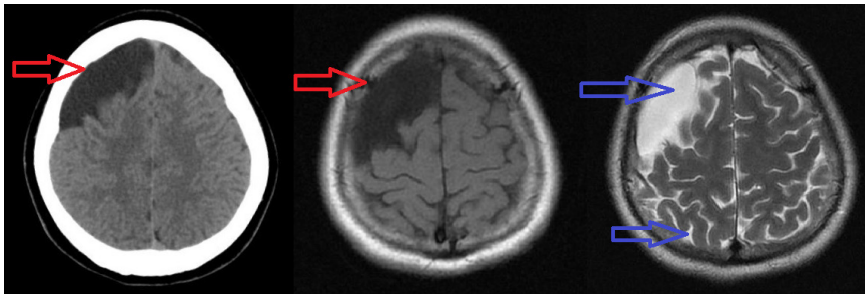

Figure 2. Partial thinning is observed in the right frontal bone (red arrows). Cysts with a HU value different from the ventricles and with a heterogeneous structure can be considered cysts with their internal dynamics (blue arrows). These dynamic properties may have an indirect effect on the surrounding tissue

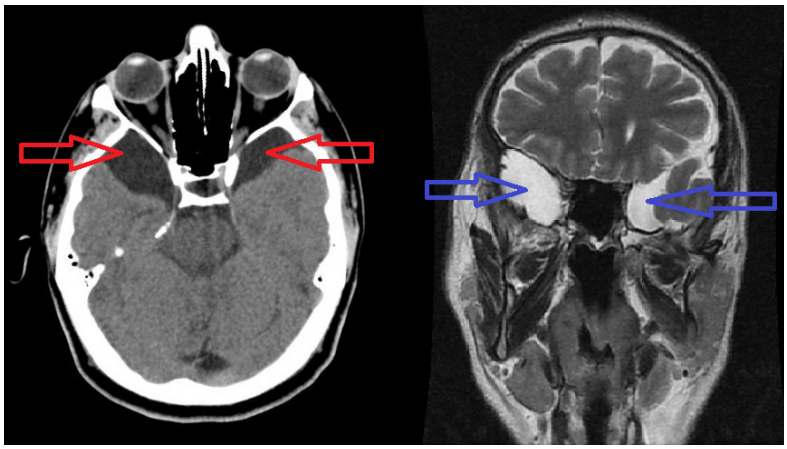

Figure 3. Congenital arachnoid cysts may cause agenesis (red arrows). Differences in their internal dynamics can change the surrounding tissues. Different cyst sizes and temporal lobe agenesis are detected in the heterogeneous bi-temporal arachnoid cyst case. Color differences and heterogeneity in cysts can also be reached qualitatively in MRI examination (blue arrows)

respond passively to intracranial pressure variables. The internal pressures of these cavitary structures cannot be different from the intracranial pressure. Therefore, they cannot play an active role in intracranial pressure and cannot increase intracranial pressure. It should be accepted that the cystic structure is not active and cannot change the dynamics of intracranial pressure in cases where rapid filling of the cyst is detected after intrathecal contrast application.

The arachnoid cysts that change in size can be explained by the active circulation of their arachnoid walls. To balance the density difference between the CSF and the arachnoid cyst, osmotic processes may come into play.[15] Osmotic activity in arachnoid cysts; can continue until the adjacent tissues' intracranial pressure and mass resistance are reached. The fact that the wall of arachnoid cysts also consists of arachnoid cannot activate the intra-cystic density difference and osmotic processes to a high degree. Since the osmotic process can develop into and out of the arachnoid cyst, arachnoid cysts should be considered dynamic formations. However, since the osmotic process can occur bilaterally, arachnoid cysts should be regarded as passive-dynamic formations upon intracranial pressure's effect.

When the HU values of CSF and arachnoid cysts are compared, the difference between the highest and lowest HU values detected in arachnoid cysts -heterogeneity index is higher than the CSF. Therefore, arachnoid cysts are more heterogeneous than CSF. For the same reason, it also indicates that arachnoid cysts have internal dynamics. The fact that the mean HU values of CSF and arachnoid cysts are equal or close to each other does not indicate that arachnoid cysts do not have their internal dynamics. Because the wall of arachnoid cysts is also made of the arachnoid, their contents may show similar properties to CSF.[16]

Significant HU grade differences between CSF and arachnoid cyst do not give enough information about how the volumetric change of the arachnoid cyst will develop. Intracranial pressure, CSF circulation, and mass resistance of structures adjacent to the arachnoid cyst are other factors determining the cyst volume.

Limitations of the Study

Measurements were made on the sections where the arachnoid cyst was seen as the widest and longest. The height value was obtained by multiplying the number of areas in which the arachnoid cyst was seen and the distance between the CT sections. The height multiplier was accepted as 1 for each cyst for volume calculation since accurate measurements could not be performed after 3-D reconstruction in CT examinations with large intervals. Since the volumetric differences are proportional, each cyst's height multiplier of arachnoid cysts was kept constant. Therefore, the volume measurement was accepted as "unit volume." Cases with only an MRI examination, single CT examination, and a history of previous cranial surgery were excluded from the study.

Each pixel has a different HU value. In measuring HU value in a computer environment. The CSF of both lateral ventricles is expected to be homogeneous and have the same HU. Differences in HU values between the lateral ventricles were accepted as the "differentiation index" in HU measurement. Differences of less than 5 mm were not considered in measuring arachnoid cysts of the same case. Clinical findings and prognoses of the cases were not discussed in the study.

Conclusion

Arachnoid cysts communicating with the subarachnoid space should have equal HU and heterogeneity with the CSF. Arachnoid cysts with different HU and heterogeneity values from CSF are true arachnoid cysts and have their internal dynamics. Arachnoid cysts in communication with the subarachnoid space have equal HU and heterogeneity with the CSF; therefore, the potential to change in size is not expected.

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Competing Interests

No.

Ethical Approval

Ethics committee approval was received for this study from the Local Clinical Research Ethics Committee of Kirsehir Ahi Evran University (No: 20-18-09/86).

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