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Abstract

Background: The aim of the study is to define the morphology of calcifications belonging to a not very well-known anatomical structure [Calcification of foramen of luchka/Bochdalek's flower basket calcification (Boc FBC)].

Materials and methods: 264 computed tomography (CT)s belong to healthy patients were included in the study [50.0038 ± 24.78309 (0-92 years old) (mean age± SD; range)]. The morphology of the calcifications in the fourth ventricle (CFV) and Boc FBC was evaluated and compared with other common intracranial calcifications in each patient.

Results: Boc FBC was detected in 22.35% (59/264) of the patients. Out of 101 patients whose age is above 60 years old, 59 presented Boc FBC (the rate increased to 55,45%), thus in our sample 94,91% of the detected Boc FBCs (56/59) were seen after 60 years old. No Boc FBC was found under the age of 50. Statistically, there is a highly significant correlation between Boc FB and Pineal / habenular ($p<0.01$) as well as choroid plexus calcifications ($p<0.01$). The

correlation between CFV and Boc FBC was significant ($p<0.05$). 37.3% of Boc FBCs had a conical form. This form was not accompanied by any vascular calcifications (VC) neither basilar nor vertebral. Therefore, seeing the conical form was valuable in the differential diagnosis.

Conclusions: In our study, Boc FBCs are seen in advanced age and are not encountered under the age of fifty. The conical form is seen in one-third of the cases, but it is a very beneficial finding for distinguishing Boc FBC from other calcifications if any. In the advanced age group calcifications; especially choroidal plexus calcifications and pineal/habenular calcifications; are highly associated with Boc FBC. In the presence of CFV, the probability of encountering Boc FBC is very high.

Key words: Foramen Luschka, Bochdalek's flower basket, computed tomography, intracranial calcifications

INTRODUCTION

Outward indentation of the choroid plexus from the foramen of Luschka; also known as Boc FB; was first found by the Czech anatomist Vincent Alexander Bochdalek (1801-1883), who also described the Bochdalek hernia [1]. Although this finding is relatively common, it does not take a place in radiological reports and is often overlooked [2]. So far, studies on this subject are based on examination with magnetic resonance imaging (MRI). The morphology of Boc FB is emphasized in MRI studies. However, Boc FB can also be calcified like the choroid plexus. While MRI show anatomical structure very well, calcifications are technically the weak point for this method. Therefore, our study was based on non- contrast CT since it is the gold standard for calcification assessment. To the best of our knowledge, our study is the first CT study on this subject and there is no detailed information in English literature about Boc FB calcifications (Boc FBC). It is important to know the features of calcifications along with the part of the choroid plexus in this region. Since calcifications don’t occur in all of the parts of Boc FB, it may be confused with the surrounding non-calcified fragment, haemorrhages and with cerebellopontine angle masses because this entity is not well-known by some radiologists [2,3,5]. Although textbooks express that the distinction between haemorrhage and calcifications can be made with coarse morphology and

measurements of HUs, there are many pitfalls. Based on calcium amount and ROI cursor, the HU values change [4]. Since vascular calcifications and Boc FBCs are seen in the same age group, when the vessel is tortuous, the Boc FBCs and vascular locations overlap and can be confused. Therefore, calcifications of the vertebral and basilar arteries are part of the differential diagnosis of Boc FBC due not only to the age group but also to the location [2-6].

When we mention choroidal plexus calcifications, usually calcifications of the lateral ventricle or rarely the plexus part of the third ventricle come to mind. However, the choroid plexus extends to the fourth ventricle and can reach variationally cerebellopontine cistern via foramen of Luschka. In other words, calcifications originating from the choroid plexus can be seen not only in the lateral ventricle and the third ventricle but also on the wall of the fourth ventricle as well as out of the ventricles as Boc FBC [5,7].

Some areas such as the basal ganglia, the pineal/ habenular glands, other parts of choroidal plexus and vascular structures tend to calcify with ageing [8]. As far as we know, the relationship between these calcifications and Boc FBCs has been also compared for the first time in our study.

The study aims to help prevent erroneous reporting by identifying the morphology of a not well-known variational anatomical structure's calcification ‘Boc FBC’.

MATERIALS AND METHODS

This study was approved by Muğla Sıtkı Koçman University Human Research Ethics Committee with the document number: 200027/2020. The design and conduct of the study were in accordance with the general principles set out in the Declaration of Helsinki. The patients who underwent CT scans between January 2016 and June 2021 for various indications were retrospectively evaluated in terms of Boc FBC and accompanying intracranial calcifications. All of the images were obtained from picture archiving communication systems (PACS).

Power analysis was performed with a G-power test. An appropriate sample size was calculated at 111 for creating 0,95 (actual power: 0.9503016, critical t: 1.6589535) Power (1-β prob) based on 0,05 alfa error prob. The number of patients in our study is sufficient. 264 CTs of healthy patients [50,0 ± 24,78/0-92 years old (mean± SD / range)] as 120 females (45,5%) and 144 males (54,5%) were included in the study. We excluded twenty-four patients from the

study because of the following medical reasons: 23 patients had different major pathologies (Mass, infarct, aneurysm, infection, bleeding), 9 had history of operation, 2 had motion artifacts.

Cranial CT scans were performed with a 256-slice multi-detector CT scanner (Somatom, Siemens Healthcare, Erlangen, Germany). The protocol used for cranial CT is as follow: Voltage/ampere: 120kv/35 mA, applied radiation dose: 55-60 mGy, time interval: 1 sn, slice thickness: 0,6 mm. Evaluation windows are W(width): 80 L(length): 40 for brain, W: 2800 L: 600 for temporal bones, W: 350–400 L: 20–60 for soft tissues.

Double-blind evaluation method was used in the study. Cranial CTs were evaluated separately by two radiologists. If a discrepancy was found in the evaluation's result, the cases were re-evaluated by both observers and a common consensus was achieved. The calcifications of fourth ventricle (CFV) were evaluated and classified according to anterior, posterior and lateral localization. Both Boc FBC were classified as unilateral and bilateral and the measurements were divided into three groups according to size of the calcifications: <10 mm, between 5mm and 10 mm, <5mm. If there was more than a 10% of difference between the size of the calcifications, it was considered asymmetric, otherwise it was considered symmetrical. The morphological forms of the calcifications were also taken into account. They were classified into three different groups: linear, oval/nodular and conic. Besides, the presence of four common intracranial calcifications (calcifications of basal ganglion, habenular/pineal gland, choroid plexus, and vascular structures) was assessed. They were cross-matched with Boc FBC and associations were evaluated. The assessed calcifications are shown in Fig.1.

Statistical analysis: The data were stored on a Microsoft office excel file (Excel 2010, Microsoft). Statistical software (SPSS, version 22.0, IBM) was used for analysis. Student's t-test was used for the means of normally distributed data, and Mann-Whitney U test was used for parametric data that did not show normal distribution. Pearson chi-square ($\chi 2$) analysis was performed to evaluate the relationship between the categorical variables. $p \leq 0.05$ was considered significant.

RESULTS

3.78% (10/264) of the patients had wall calcifications of fourth ventricle (CFV). 4 of the them were located on the posterior wall, 3 on the anterior wall and 2 on the lateral wall. 5 of these 10 patients had concomitant Boc FBC, and all of them were bilateral. Out of 10 patients with CFV, 9 had also choroid plexus calcifications, 9 had pineal and/or habenular gland calcifications, 3 had basal ganglia calcifications and 2 of them had vertebral artery calcifications. The mean age of the patients with CFV was 61.6 ±19.05 years old and age range was 36-89 years old. 8 of the patients with CFV were males and 2 were females. There was statistically a significant male predominance (p:0,042).

Boc FBC was detected in 22.35% of our sample (59/264) [72.6 ± 12.9; 8-92 years old (Age± SD; age range)]. Out of 59 patients with Boc FBC, five (8,47%) had concomitant CFV. There was no statistically significant gender difference (p:0,76). 69,5% of the Boc FBCs were bilateral. 53.7% of bilateral Boc FBCs were symmetrical while 46.3% of them were asymmetric. 52.6% of unilateral Boc FBCs was located at right while 47.4% were at left. 57.7% of the calcifications were <5 mm, 25.4% of the calcifications were between 5mm and 10 mm, 16.9% of the calcifications were >10 mm.

Shapes of Boc FBC were evaluated. 37,3% of the patients had conic shaped Boc FBCs. Regarding the conical-shaped calcifications, the percentage of calcifications whose size was> 10 mm, 5 mm to 10 mm and <5 mm was 45.5%, 31.8% and 22.7%, respectively.

For the Boc FB calcifications whose size was <5mm, 41,2% were linear, 44,1% were oval or nodular and %14,7 were conic. For the Boc FB calcifications whose size >5mm, the rates of linear and conic forms were respectively at 32% and 68%. Oval/nodular calcifications were not present in this group. Boc FBCs were accompanied by calcifications of basal ganglia, pineal/habenular, choroid plexus and vascular structures. The rates of these calcifications were respectively 20.3%,94.9%,93.2% and 39%. When only the patients with Boc FBCs were taken into account (N: 59), statistically there were highly significant correlations between Boc FBC and choroid plexus calcifications as well as pineal/habenular calcifications (p<0,01) but this relationship is not mutual. Out of all patients (N:264), basal ganglia, pineal/habenular, choroid plexus and vascular calcifications were seen respectively at the rate of 8.7% (23/264), 81.1% (214/264), 78.8% (208/264),14.8% (39/264).

The rates of Boc FB in patients with basal ganglia calcifications and vascular structures calcifications were respectively 52.2% (12/23) and 59% (23/39). In the comparison

to other intracranial calcifications, the correlations between Boc FB and calcifications of the basal ganglia / vascular structures were statistically significant ($p<0,05$)

The rates of BOC FB in patients with Pineal/habenular calcifications and choroid plexus calcifications were respectively 26,2% (56/214) and 26,4% (55/208). However, according to both Pearson chi-square ($\chi 2$) test and Whitney Mann U tests, there was no statistically significant correlation for the latter ($p>0,05$)

Demographic, morphometric findings and relation with other intracranial calcifications were shown in Table 1.

As for CFV, Boc FBC and total population, age was taken into account. the distribution of age groups from largest to smallest was respectively CFV> Boc FB> Study population. The distribution is shown with a box plot graphic in Fig. 1.

DISCUSSION

Boc FB is the overextension of the choroid plexus of the fourth ventricle towards the cerebellopontine angle. Bulbous terminal parts, also known as cornucopiae, are peripheral linear parts of Luschka where the choroid plexus is located and the farthest pieces that include choroid plexus tissue. Body and cornucopiae create an appearance similar to flowers basket which gives the name of the anatomical structure [9]. Choroid plexus of the fourth ventricle originates from mesenchymal epithelium [10]. It is constituted by a central portion and lateral parts. The central portion is located on the posterior side of the fourth ventricle while the other parts cover the lateral faces [11,12].

Anatomical definition is essential because calcifications occur in the same location as the choroid plexus. Foramen Luschka is therefore a border between the lateral parts and Boc FB if there is any [13,14]. Boc FB was considered to be a blind-ending outward extension of the fourth ventricle choroidal plexus when this structure was first described by Bochdalek. Later, it was understood that it includes linear structures [2,10,14].

In our study, we evaluated Boc FBC besides CFV. There was a significant difference between the frequency of Boc FBCs and CFV. While Boc FBCs were detected in 59 patients, only 10 patients had CFV. Boc FBC accompanied CFV in 50% of patients. But this relationship was not reciprocal. Out of all patients with Boc FBC, only 8,5% of patients had CFV. The samples were demonstrated in Fig. 2.

Sharifi et al. divided the Boc FBC into two parts which is similar to the definition of CFV. According to this study, the average choroid plexus extension after the foramen of Luschka was about 5-6 mm. However, according to our study especially in elderly patients, Boc FBCs extend to 2 cm far from the center. This different result shows that tortious basilar and vertebral artery calcifications can overlap with Boc FBCs in the cerebellopontine angle [15]. Bradac et al. found symmetry between two sides of the choroid plexuses of the fourth ventricle in 96.5% of 57 brain dissections [16]. Even though the choroid plexuses are symmetric, their calcification may not be symmetrical. In our study, CFVs were located at different points and asymmetric. Out of all the patients with Boc FBC, 30,5% had unilateral calcifications and only 53,7% of the patients that had bilateral calcifications presented symmetry.

Aneurysms, haemorrhages, cerebellopontine angle masses and tumours take part of the differential diagnosis of Boc FBCs on CT and MRI [2]. In our study, Boc FBCs were conical shaped with a rate of 37.29%. This shape is not an appearance seen in the pathologies cited above for the differential diagnosis. In the case of the conical-shaped calcifications being over 5 mm, the ratio significantly increased [17/25(68%)]. Conical shaped calcifications were never detected among the vertebral artery calcifications seen in the same region. According to our study, conical form is not seen in every patient but it is evidence of Boc FBC if any. As far as we know, it is a new sign and there is no information about this sign in the literature.

It is well known that MRI is better in the demonstration of the choroid plexus. CT cannot show clearly Boc FB. However, CT is superior to MRI in the detection of calcifications. For this reason, we preferred non-contrast CT instead of MRI [2,14].

94.91% of the patients with Boc FBCs were over 60 years of age. No Boc FBC was found in the patients under 50, therefore other diagnoses should be considered in this age group. In elder patients, vascular calcifications included in the differential diagnosis of Boc FBC are vertebral, basilar, anterior inferior cerebellar artery (AICA) and posterior inferior cerebellar artery (PICA) calcifications. Venous sinus calcifications may present similar appearances in the initial period. In more young patients; haemorrhages, calcific masses should be primarily considered in the differential diagnosis [17-21].

Intracranial calcifications are caused by calcium and iron deposition with ageing in especially highly vascularised localisations. They are almost always observed during CT examinations. In some cases, these can be linked to pathologies. However, they are often considered physiological when no concomitant disease can be identified [21,22]. Since

Intracranial calcifications increase with age [23] they seem associated with the aging process [24].

Modic et al. found that the incidence of lateral ventricular choroid plexus calcifications was 0.5% in the first decade and 86% in the eighth decade [25]. In our study, Boc FBC were compared with other intracranial calcifications. There is a high rate of association with choroidal plexus calcifications and Habenular / pineal calcifications. The association rate of Boc FB with choroidal plexus calcifications, habenular / pineal calcifications, vertebral calcifications and basal ganglia calcifications was respectively 94.9%, 93.2%, 39.0% and 20,3%.

Let’s point that Heterotopic ossification is a different entity that must be differentiated from calcifications. It refers to a large amount of bone and is seen mainly in the extremities. However, heterotopic ossifications may occur because of thermal traumas and surgical procedures of the intracranial region in the head or in soft tissue [26].

The study has some limitations. First, study was retrospective and a limited number of patients had both MRI and CT therefore, Boc FBC were only assessed from CT and the volume of Boc FB omitted. Secondly, Since the article length is limited, only the most common four intracranial calcifications were chosen and compared with Boc FBC.

CONCLUSIONS

There are very limited studies about Boc FB and its calcifications, in other word Boc FBCs, are an underreported finding in the literature. This entity is important because it can be confused with very important pathologies like haemorrhage or calcific masses. Although, it is reported that Boc FBs are symmetrical, according to our results their calcifications are rarely symmetrical. This condition has increased the margin of error. According to our study's results, Boc FBCs are seen in the advanced age group and don’t encounter under the age of fifty. The conical form is seen in one-third of the cases but it is a very beneficial finding for distinguishing Boc FBC from other calcifications if any. The advanced age group calcifications especially choroidal plexus calcifications and pineal/habenular calcifications are highly associated with Boc FBC. In the case of the presence of CFV, Boc FBCs accompany at a high rate.

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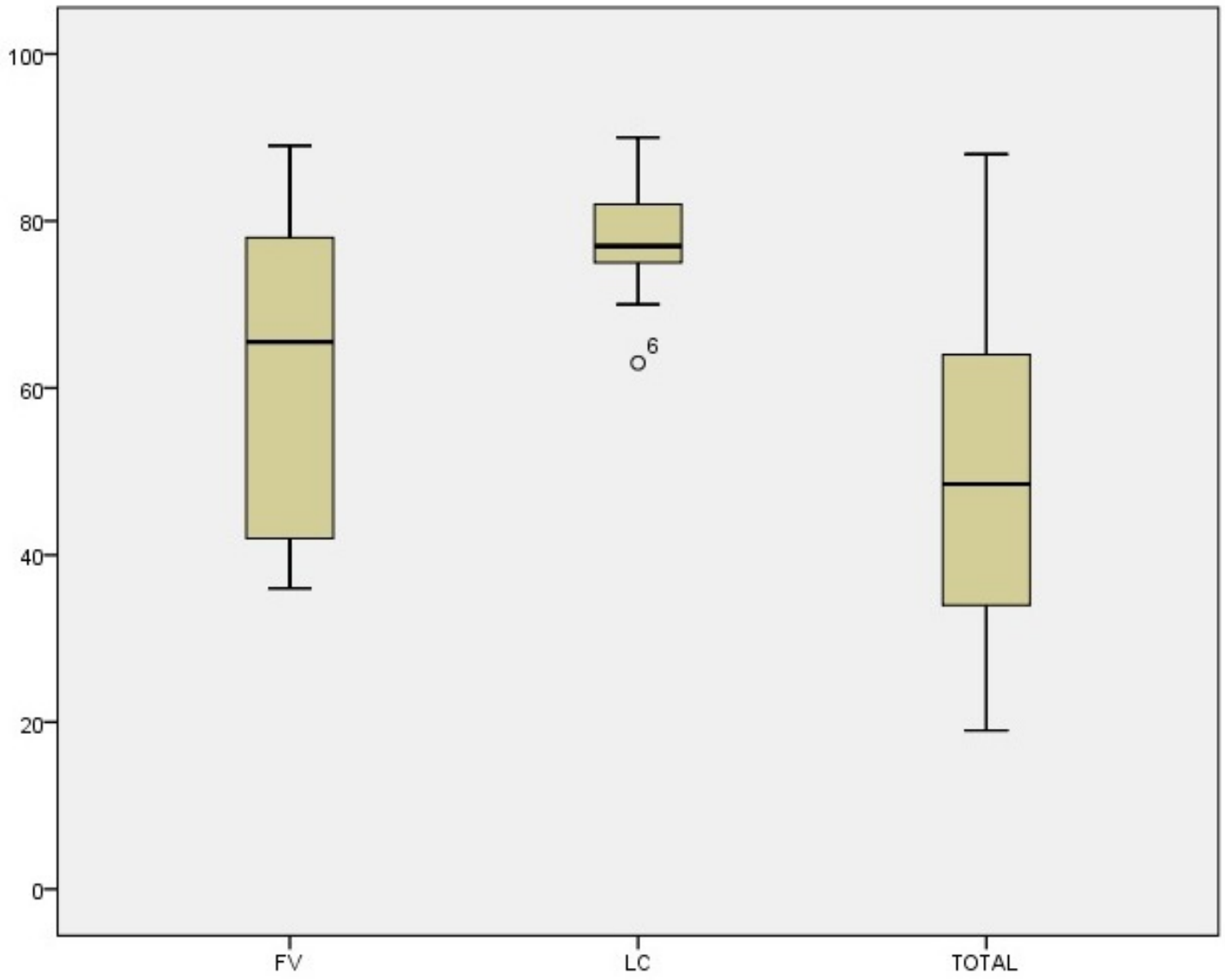
Table 1.

Parameter (N:59)	**Values**	**Percentage**
Age± SD; age range	72.6 ± 12.9; 8-92	-
Gender (M/F)	29/30	49,2%/50,8%
Unilateral/bilateral	18/41	30,5%/69,5%
Symmetrical/asymmetric	22/19	53,7%/46,3%

(Bilateral)		
Left/right (unilateral)	10/9	52,6%/47,4%
Size >10 mm 5-10mm <5 mm	 10 15 34	 16,9% 25,4% 57,7%
Conic shape Present Absent	 22 37	 37.3% 62.7%
Diameter of conic shaped Boc FB 10mm> 5-10mm 5mm>	 10 7 5	 45,5% 31,8% 22,7%
Morphology of <5mm Boc FB Linear Oval or nodular Conic	 14 15 5	 41,2% 44,1% 14,7%
Morphology of >5mm Boc FB Linear Oval or nodular Conic	 8 0 17	 32,0% - 68,0%
Basal ganglion calcifications Present Absent	12/59 12 37	 20,3% 79,7%
Pineal habenular calcification Present Absent	56/59 56 3	 94,9% 5,1%
Choroid plexus calcification Present Absent	55/59 55 4	 93,2% 6,8%
Vertebral artery calcification Present Absent	23/59 23 36	 39,0% 61,0%

Figure 1: Box pilot figure shows age distribution of studied calcifications and study population.

Figure 2: a. Point calcification (arrowhead) on the posterior wall of the 4th ventricle in 56-year-old female patient; **b.** Bilateral linear Boc BF calcifications in a 77-year-old female patient (cut arrowhead); **c.** 84-year-old male patient with obvious circular left vertebral artery calcification (small arrowhead). Conical Luschka calcification on the left in a 65-year-old female patient (arrowhead)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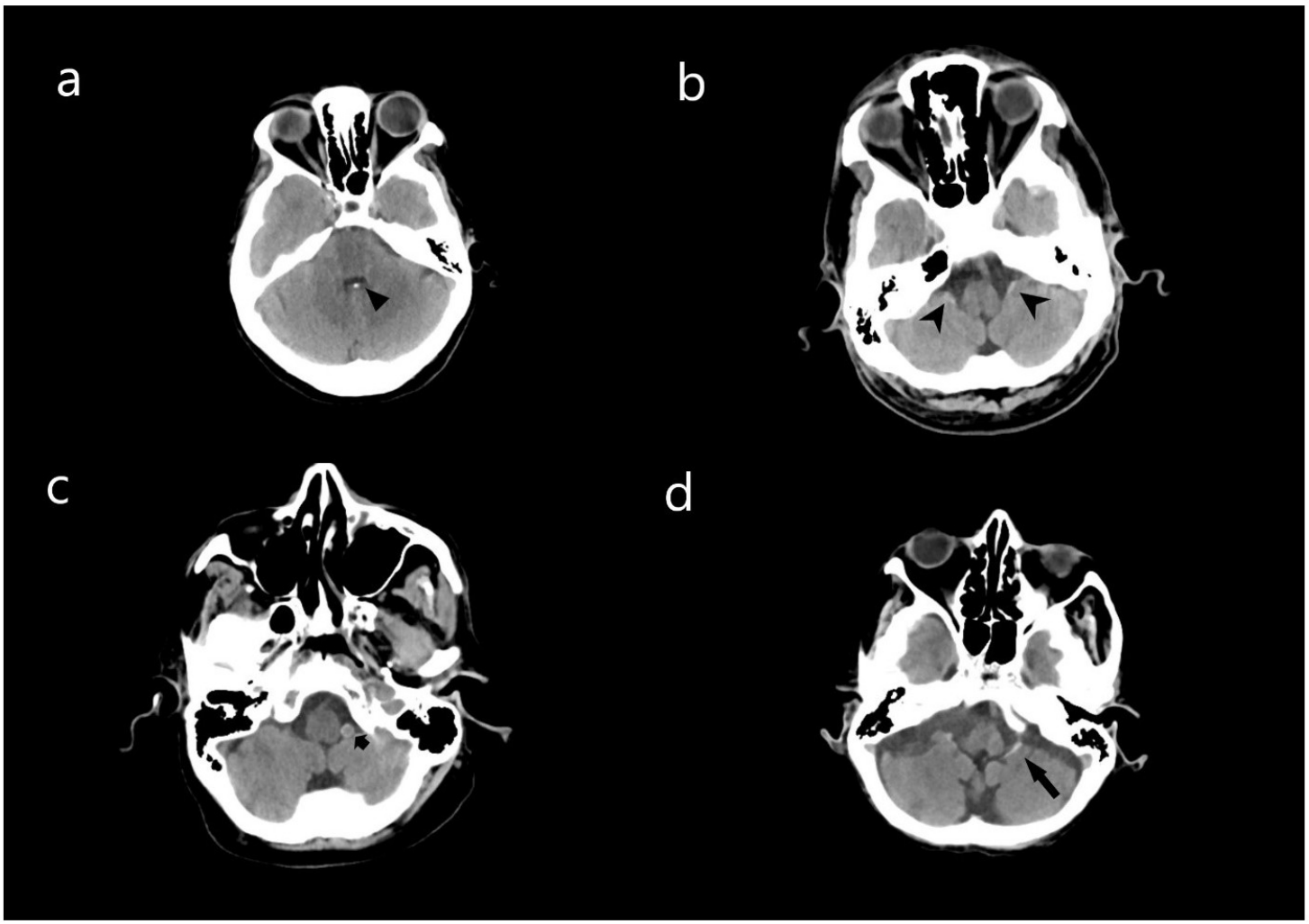
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