

# Intraventricular cerebrospinal fluid pulsation artifacts on low-field magnetic resonance imaging: Potential pitfall in diagnosis?

Godwin I. Ogbole, Mayowa A. Soneye<sup>1</sup>, Chinonye N. Okorie<sup>1</sup>, Steffen Sammet<sup>2</sup>

Department of Radiology, University of Ibadan, <sup>1</sup>Department of Radiology, University College Hospital, Ibadan, Nigeria, <sup>2</sup>Department of Radiology, University of Chicago Medical Center, Chicago, IL 60637, USA

## ABSTRACT

**Background:** Intraventricular cerebrospinal fluid (CSF) pulsation artifact can pose a diagnostic problem in fluid-attenuated inversion recovery (FLAIR) brain magnetic resonance images (MRI) appearing as intraventricular hyperintensity. The extent of this challenge among radiologists in Africa using low-field MRI systems is relatively sparsely documented in the literature. The purpose of this study was to identify the presence and frequency of ventricular CSF pulsation artifact (VCSFA) on FLAIR axial brain images with a low-field MR system. **Materials and Methods:** FLAIR axial images were obtained on a low-field 0.3T unit (6000 ms/108 ms/2 [repetition time/echo time/excitations], inversion time = 1700 ms, field of view = 28 cm, matrix = 195 × 256, and 6 mm contiguous sections). Two experienced radiologists independently rated VCSFA in the lateral, third, and fourth ventricles in 202 consecutive patients (age range 1–100 years) referred for brain MR for various indications. We reviewed the pattern of artifacts, to determine its relationship to age, gender, and third ventricular size. **Results:** The low-field FLAIR MR brain images of 33 patients (16.3%) showed VCSFA in at least one ventricular cavity. The fourth ventricle was the most common site of VCSFA ( $n = 10$ ), followed by the third ventricle ( $n = 8$ ) and the lateral ventricles ( $n = 7$ ). Eight patients had VCSFA in multiple locations, one of them in all ventricles. A smaller third ventricular size and, to a lesser extent, younger age was significantly associated with VCSFA. CSF Pulsation of VCSFA did not occur across the brain parenchyma in the phase encoding direction. **Conclusion:** VCSFA may mimic pathology on low-field axial FLAIR brain images and are more common in young patients with smaller ventricular size. Although these artifacts are less frequently observed at lower magnetic field strengths, their recognition on low-field MRI systems is important in avoiding a misdiagnosis.

**Key words:** Africa, fluid-attenuated inversion-recovery, low-field magnetic resonance imaging, pitfalls, pulsation artifacts

### Address for correspondence:

Dr. Godwin I. Ogbole,  
Department of Radiology, University  
of Ibadan, Ibadan, Nigeria.  
E-mail: gogbole@gmail.com

## INTRODUCTION

Fluid-attenuated inversion-recovery (FLAIR) is a magnetic resonance imaging (MRI) technique that uses an inversion pulse to null the signal from intraventricular cerebrospinal fluid (CSF) on heavily T2-weighted images with long echo times (TE).<sup>1</sup> FLAIR images provide increased sensitivity in depicting lesions against a suppressed CSF background.

The contrast in FLAIR is dependent on the inversion time (TI) (the time between the 180° inversion pulse and the following excitation pulse). TI increases with the strength of the static magnetic field. FLAIR images, compared to standard T1- and T2-weighted images, provide additional information in the evaluation of a variety

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of disorders, ranging from degenerative and vascular to infective and autoimmune conditions of the brain.<sup>2-4</sup> FLAIR images are susceptible to CSF artifacts that may degrade the diagnostic value of the scans even though this sequence is established for excellent lesion conspicuity in central nervous system (CNS) diseases.<sup>5,6</sup> It possesses a high sensitivity especially for the assessment of subarachnoid space lesions which in many studies have been found to be strongly associated with CSF flow artifacts which have high signal intensities.<sup>7</sup> The inflow of CSF into the field of view (FOV) is the cause of CSF flow artifacts most commonly observed in the posterior fossa.<sup>8,9</sup>

FLAIR subarachnoid space hyperintensities can be encountered with both normal and pathological conditions. Their presence and importance have been extensively described with high-field MR systems.<sup>10-14</sup> However, in low-field systems which are used mostly in developing countries due to their cost-effectiveness amidst poor power infrastructure,<sup>2</sup> these characteristics have been sparsely reported in the literature. Ventricular CSF pulsation artifact (VCSFA) often compromise FLAIR images and lead to false-negative as well as false-positive interpretations of ventricular abnormalities.<sup>9</sup> Knowledge of VCSFA, their characteristics, and associated findings, may help in avoiding misinterpretation and misdiagnosis among low-field MR system users.<sup>2,8</sup>

The goal of our study was to provide a detailed retrospective review of low-field (0.3T) brain MR FLAIR images acquired in 202 patients to determine the presence and frequency of VCSFA.

## MATERIALS AND METHODS

This retrospective study was carried out at a Nigerian tertiary health institution observing all Ethical considerations and comprehensive approval of the institutional review board. The image database in our hospital was searched for FLAIR images in all patients that had MRI examinations from January to December 2014. The study group included 202 eligible patients (age range 1–100 years). Ninety-three (46%) of the patients were males, and 109 were females (54%). The mean age of patients was 44 years (standard deviation  $\pm$  12) with an age range of 100 years. Indications for the MRI examinations included recurrent headaches, visual disturbances, and stroke. All FLAIR images of these patients were reviewed independently by two radiologists, one with subspecialty training in neuroradiology. Axial FLAIR images in the canthomeatal plane were obtained on a 0.3T MRI system (MagSense 360, Shenzhen Mindray Bio-medical Electronics Co., Ltd. China) scanner with the following sequence parameters: Repetition time (TR) = 6000 ms, TE = 108 ms, 2 excitations, TI = 1700 ms, FOV = 28 cm, matrix = 195  $\times$  256, and 6 mm contiguous sections.

The radiologists rated independently VCSFA (hyperintensities on FLAIR images) in the lateral, third, and fourth ventricles of the patients. Positivity threshold for VCSFA was defined as hyperintense signal in the ventricles that did not correspond to any normal anatomic structure. The largest left to right mid-third ventricular diameter was also measured. Any disagreement about the location and identification of CSF flow artifact was resolved by consensus agreement following a second review of images. FLAIR images with poor image quality were excluded from the study. The correlation of CSF flow artifacts to the size of third ventricular space was done on the MRI scanner console with magnification technique by placing calipers and measuring distances from left to right at mid-point along the anterior-posterior diameter of the ventricle.

## RESULTS

Low-field (0.3T) FLAIR image datasets of 202 patients were reviewed in this study. The agreement between reviewers was almost 97% (196/202). Abnormal MRI findings were seen in 64.9% ( $n = 131$ ), whereas 35.1% ( $n = 71$ ) had normal findings. Abnormalities ranged from trauma to degenerative conditions with stroke/vascular lesions and neoplasms topping the list with a frequency of 20.3 and 23.3%, respectively [Table 1]. Among the patients with abnormal MRIs, 62 were males and 69 were females. Of the 71 normal patients, 31 were males and 40 were females.

Typical examples of VCSFA on FLAIR images are shown in Figures 1-4. The data correlating location and frequency of VCSFA to ventricular size, age, and sex are presented in Table 2.

Mean third ventricular size diameter was  $3.1 \pm 2.1$  mm in those with VCSFA and  $4.5 \pm 4.7$  mm in those without artifacts ( $P = 0.11$ ). In total, 33 patients (16.3%) had VCSFA in at least one ventricular cavity. These artifacts were found in 11 abnormal MRI cases and in 22 normal MRI studies. There was an almost equal gender distribution among this group, 16 were male and 17 were female. VCSFA was commonly found throughout the ventricular system at all ages. The highest number of VCSFA was found in the fourth

**Table 1: Distribution of magnetic resonance imaging findings among the 202 patients evaluated**

MRI findings	Frequency (n)	Percentage
Normal	71	35.1
Congenital	10	5.0
Degenerative	26	12.9
Inflammatory	6	3.0
Tumor	42	20.8
Vascular and stroke	47	23.3
Total	202	100.0

MRI – Magnetic resonance imaging

ventricle in 10 patients (27% of all cases with VCSFA) [Table 2 and Figure 2]. The second most common VCSFA was found in the third ventricle [Figure 3]. Eight patients had VCSFA in more than one ventricle. Lateral ventricular VCSFA was usually adjacent to the foramen of Monro [Figure 4]. Pulsation ghost artifacts of the VCSFA in the fourth, third, or lateral ventricles were not seen in any of the patients. No significant correlation existed between the lateral, third, and fourth ventricular artifacts ( $P > 0.05$ ). Patient sex also showed no significant statistical correlation to the presence of VCSFA ( $P = 0.10$ ). The relationship between third ventricular size and VCSFA is shown in Table 2. Among all patients evaluated, the group with VCSFA ( $n = 33$ ) did not have significantly larger third ventricles ( $P = 0.011$ ). There was no significant difference in age between those

patients with VCSFA (mean =  $37.9 \pm 21.1$ ) as compared with those without VCSFA (mean =  $43.3 \pm 24.2$ ) ( $P = 0.22$ ) 95% CI -14.37 to 3.43.

**Table 2: Ventricular cerebrospinal fluid pulsation artifacts on fluid-attenuated inversion recovery magnetic resonance images correlated to sex, age, and third ventricular diameter**

Artifact location	Total	Male	Female	Mean age (years±SD)	Third ventricle diameter (mean mm±SD)
Lateral ventricles	7	4	3	27.7±11.0	3.1±1.4
Third ventricles	8	4	4	41.8±19.6	3.6±2.0
Fourth ventricles	10	5	5	38.8±26.8	2.9±1.9
Multiple	8	3	5	41.6±21.9	3.1±3.2
Total	33	16	17		

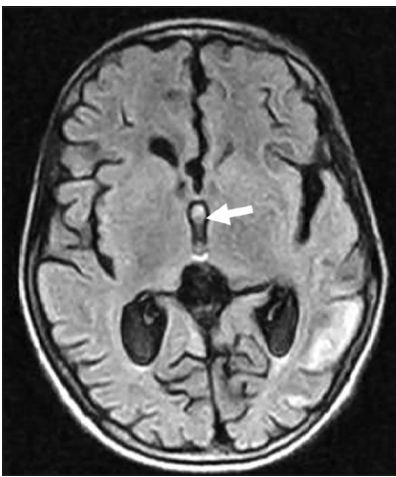
SD – Standard deviation



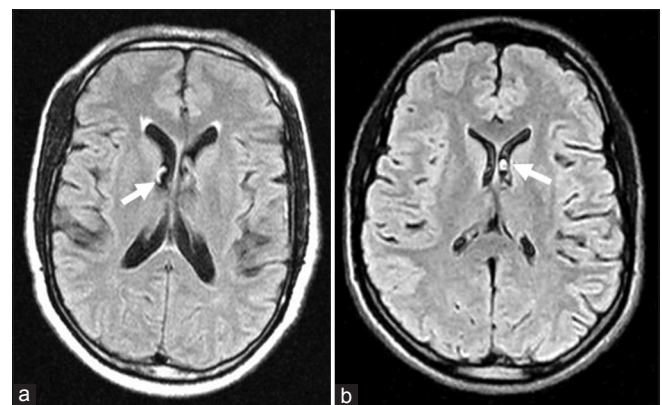
**Figure 1:** Axial 0.3T fluid-attenuated inversion-recovery magnetic resonance image of a 76-year-old man with a history of worsening visual disturbances. Ventricular cerebrospinal fluid pulsation artifact seen in both lateral ventricles (arrows). Moderate periventricular white matter changes are also noted



**Figure 2:** Fourth ventricular intraventricular cerebrospinal fluid pulsation artifact in a 40-year-old woman who presented with headache. The artifact almost completely fills the fourth ventricle on this 0.3T fluid-attenuated inversion-recovery image



**Figure 3:** A third ventricular intraventricular cerebrospinal fluid pulsation artifact (arrow) present on an axial 0.3T fluid-attenuated inversion recovery image of a 14-year-old boy with recurrent seizures. The image also shows hyperintense signal along the cortical areas of the left parietal lobe, central atrophy, and corpus callosal agenesis



**Figure 4:** (a) Lateral ventricular intraventricular cerebrospinal fluid pulsation artifact in a 35-year-old man who presented with a head injury showing focal right lateral ventricular intraventricular cerebrospinal fluid pulsation artifact. (b) Focal left lateral ventricular intraventricular cerebrospinal fluid pulsation artifact in the region of the foramen of Monro in a 15-year-old female patient who presented with seizures



## DISCUSSION

This study is an assessment of the topography of VCSFA on axial FLAIR MR Images acquired with a low-field (0.3T) MRI system in a developing African country. Our findings indicate that the frequency of VCSFA on axial FLAIR images obtained with low-field MRI in patients of all ages is <20%.

VCSFA is especially more obvious and more common in the fourth [Figure 2] and third ventricles [Figure 3]. VCSFA on low-field FLAIR MRI did not correlate with third ventricular size or age as reported by a previous study using a 1.5T system.<sup>9</sup> Our patient population with third ventricular VCSFA did not have significantly larger third ventricles.

VCSFA is caused by inflow of uninverted or partially inverted CSF into the selected slice during the long TI required for CSF signal nulling.<sup>9,15</sup>

The null-point of CSF is usually reduced at low-field strength as determined by its T1 relaxation time.<sup>16</sup> This consequently shortens TI. The shorter TI associated with low static magnetic field strength appears to be responsible for the low incidence of VCSFA observed on low-field MRI systems. Bakshi *et al.* had used in a previous study, a three-point ordinal scale to assess severity of VCSFA.<sup>9</sup> The severity of VCSFA, defined as the intensity of the abnormal signal, increased with the age of the patients. The visual evaluation in our study did not reveal any substantial differential signal intensity changes of the CSF signal in the ventricles when VCSFA was present.

CSF constantly pulsates within the ventricles; therefore, any residual nonnulled CSF signal also causes pulsation artifacts that may result in ghosting effects in the phase encoding direction. This usually may mimic parenchymal lesions.<sup>9</sup> Our series did not witness any motion in the phase encoding direction suggestive of ghost pulsation artifacts which had concomitantly contributed to VCSFA in higher field MR systems. This may be because the most important factor theorized to be responsible for the change in intraventricular signal is the inflow of CSF into the selected slice which triggers the entry slice effect. However, instead of the saturation effects, the mechanism directly responsible for VCSFA is attributed to lack of nulling of the uninverted or partially inverted CSF signal which entered the selected slice within the time from inversion.<sup>9,11</sup> Thus, the decreased incidence of VCSFA observed in our study could also have contributed to the nonexistence of ghost pulsation artifacts. Second, for moderate CSF pulsation, the use of shorter TI at 0.3T compared to 1.5T could reduce the severity of the appearance of ghost artifacts by decreasing the ghost signal.<sup>17</sup> The TI that we used in this study had been optimized by the clinical applications specialist at installation of the MRI system to produce the highest quality FLAIR images, we did not explore the effects of

changing or altering the TI on the severity of artifacts as this was a retrospective analysis.

Several factors have been theorized to be responsible for the increase in VCSFA incidence in the third and fourth ventricle in high-field MR systems. The most important being the reflux of spinal CSF into the inferior ventricles through the posterior fossa. Another is the increased velocity of CSF flow through the third and fourth ventricles, which increases the rate of superior entry of CSF from the lateral ventricles during inversion delay.<sup>9,14</sup>

The presence and frequency of VCSFA among our cohort were relatively low, nevertheless, the need for vigilance among junior and inexperienced radiologists cannot be overemphasized. The motivation for this effort was borne from the recognized failure among radiology and neurosurgical residents of identifying and misrepresenting the intraventricular pulsation artifacts which is a real pitfall.

These low-field artifacts may indeed mimic intraventricular lesions, which may prompt further unnecessary tests and raise anxiety, if not properly recognized and diagnosed. Attempts to avoid these artifacts by changing parameters to accommodate the reduce scan time from protocol changes such as reducing TR usually affects the tissue contrasts on higher field MR systems and its likely to be same with low-field systems.

We did not study the effects of individual or specific pathologies in causing VCSFA. However, it appears that the variety of pathologies seen in our study did not result in a significant increase in frequency of VCSFA. Nevertheless, it is possible that some pathology such as haemorrhage<sup>10</sup> could be masked by VCSFA. The role of pathologic conditions such as infection, neoplasia, and hydrocephalus in masking or exaggerating VCSFA in low-field MR systems may require further evaluation.

In our study, we discovered that VCSFA where more common among younger patients and those with smaller third ventricular diameter. This is in contrast with previous authors that suggested a direct increase in VCSFA with increased CSF rate and volume in axial sections.<sup>10-14</sup> These divergent findings may be because previous studies on VCSFA were performed on high-field MRI systems which were used to demonstrate the flow dynamics.

Studies have shown that as ventricular size increases with age, so does CSF flow velocity.<sup>11,18-21</sup> Acquisition of thicker slices, however, could counter the velocity induced increase in hyperintensities by reducing entry slice effect. Low-field scanners are usually not able to acquire thin slices with decent image quality without increasing the scan time.<sup>16</sup> In our study, 6 mm thick slices were acquired. This may have been the reason for observing no significant changes from increased CSF flow velocity.

It is also noteworthy that other investigators have stated that the contribution of aging and ventriculomegaly to the development of VCSFA is most likely multifactorial, as these artifacts have also been recorded in younger patients with smaller ventricles.<sup>9</sup> It is, therefore, pertinent to say that VCSFA may occur at any age, any ventricular size, and using any magnetic strength in diverse intracranial conditions.

This assertion makes it imperative for radiologists reviewing cranial MRI to be particularly mindful and not be quick to report intraventricular pathologies on FLAIR images which may raise anxiety and cause further investigations. Having a good knowledge of the possibilities and occurrences of VCSFA will help inexperienced observers in avoiding this potential pitfall.

## CONCLUSION

VCSFA on axial FLAIR images occurs less frequently on low-field MRI systems compared with high-field MRI systems. In our low-field study series, these artifacts were most commonly found in the third and fourth ventricles, and less commonly in the lateral ventricles. Their frequencies are not necessarily affected by the presence of intracranial pathologies. VCSFA on low-field FLAIR MR images is potential pitfalls in intracranial diagnosis as they could obscure or mimic intraventricular disease. Astute vigilance and attentiveness are recommended for neuroradiologists working with low-field MR systems.

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## Conflicts of interest

There are no conflicts of interest.

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