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Comparative Analysis of CT and MRI in Diagnosis of Enlarged Vestibular Aqueduct Syndrome in Paediatric Candidates of Cochlear Implant

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Funding Source: None
Conflict of Interest: None
Received: Aug 16, 2024
Accepted: Dec 24, 2024

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ABSTRACT

Objective: To determine the frequency of LVAS in children with cochlear implant and compared the findings of CT and MRI in terms of measurement of midpoint and external aperture diameters in paediatric candidates of cochlear implant.

Methodology: This was a cross-sectional comparative study that was conducted at a Armed Forces Institute of Radiology and Imaging, Rawalpindifrom 16th August, 2023 till 15th February, 2024. After the parents provided written informed consent, 110 children with cochlear implants were enrolled and examined using a temporal CT scan and an MRI. The results on both modalities were compared and statistical analysis was performed using Statistical Package for social Sciences version 25.0

Results: The mean age of the children was 3.9±2.09 years. Mean midpoint aperture diameter in patients with EVA on CT scan was 1.64±0.09 mm and on MRI was 1.71±0.13 mm (p=0.020). Mean external aperture diameter in children with EVA on CT scan was 2.52±0.40 mm and on MRI was 2.64±0.53 mm (p=0.000). EVA was present in 7 (6.4%) children on CT scan and 8 (7.3%) children on MRI.

Conclusion: In children with cochlear implant, there were significant differences in the midpoint and external aperture diameters as assessed by CT scan and MRI and MRI was able to diagnose more cases of LVAS compared to CT scan and thus should be preferred imaging modality.

Keywords: Pediatric age, Vestibular aqueduct, Imaging.

Cite this article as: Saleem R, Khan S, Ahmed N, Halim A, Nayyar B, Khan Y. Comparative Analysis of CT and MRI in Diagnosis of Enlarged Vestibular Aqueduct Syndrome in Paediatric Candidates of Cochlear Implant. Ann Pak Inst Med Sci. 2024; 21(1):82-86. doi. 10.48036/apims.v21i1.1254.

Introduction

Enlargement of vestibular aqueduct (EVA) is defined as a vestibular aqueduct diameter greater than or equal to 1.5 mm at the median point or greater than or equal to 2 mm for the operculum.[1] Vertigo, tinnitus, and/or fluctuating, progressive hearing loss are symptoms of large vestibular aqueduct syndrome (LVAS), a kind of deafness. LVAS is a congenital inner ear deformity with a high clinical incidence that is one of the main causes of deafness in children.[2] Progressive or varying hearing loss that occurs after birth or at a young age is the main clinical manifestation of LVAS in children. The condition primarily affects one side of the body, might strike suddenly or subtly, and can strike at any time from infancy to puberty, usually between the ages of three and four.[3] Children with LVAS have a complicated pathophysiology and are resistive to treatment because there are no reliable early detection and treatment methods[4]. In order to diagnose LVAS in children, some researchers only examine the axial picture.[5] While high resolution CT scans show bilateral LVAS, it has been found that MRI scans may provide clarity on the lymphatics and lymph sac and that both CT and MRI results of LVAS showed variation in the size of the major vestibular aqueduct.[6] A diagnosis of LVAS is necessary in order to interpret audiological results, permit genetic testing and counseling, counsel the patient to avoid contact supports, guide the detection of additional labyrinthine anomalies on imaging, and possibly plan and evaluate the risks (such as perilymphatic gusher) associated with cochlear implantation.[7]

The diagnostic utility of CT versus MRI for this inner ear abnormality is still up for debate.[8] A recent meta-analysis noted that there was a lack of data from other smaller series, despite the fact that prior research suggests a higher diagnostic yield for CT.[9] Yang and Liu in a study revealed that the mean midpoint aperture diameter on CT scan was 1.96±0.40 mm and on MRI was 1.85±0.32 ($p<0.001$) and the midpoint external aperture diameter on CT was 2.91±0.21 mm and on MRI was 3.14±0.23 mm ($p<0.001$).[10] In contrast, Conner et al. revealed that there was no significant differences between the midpoint ($p = 0.76$) and operculum measurements ($p=0.82$) obtained with CT versus MRI.

Keeping these discrepancies in view and for determining if an additional CT scan is required to increase diagnostic sensitivity for LVAS because MRI is currently the main imaging modality used to assess asymmetric cochlear thresholds and congenital or progressive sensorineural hearing loss (SNHL), the current study aimed to determine the frequency of LVAS in children with cochlear implant and compared the findings of CT and MRI in terms of measurement of midpoint and external aperture diameters for establishment of diagnosis of LVAS in pediatric candidates of cochlear implant. The current study would guide whether there is any difference in the frequency of LVAS as assessed by CT or MRI and whether there is an additional need of conducting MRI when diagnosis can be established with CT scan alone.

Methodology

It was a cross-sectional comparative study. The study was carried out at the Armed Forces Institute of Radiology and Imaging, Rawalpindi in a duration of 6 months i.e. from 16th August, 2023 till 15th February, 2024. after taking approval from the Ethical Review Committee. Sample size was calculated using World Health Organization sample size calculator[20] and was estimated as 110 cases using 95% confidence level with 6% margin of error taking an expected frequency of LVAS in the pediatric population as 11.3%.[19] Non-probability consecutive sampling technique was used. Children with unilateral or bilateral hearing loss, who were between 2–12 years old of both genders and had cochlear implant were included in the study. Children with other serious diseases in organs, poor compliance, genetic disorders, children with substantial motion artefacts on radiological images and children presenting with an inner ear invasion caused by a temporal bone tumour were not included.

Children were enrolled who fulfilled the selection criteria after taking written informed consent from their parents. Detailed demographic and clinical history of all patients were taken and findings were noted down on a predesigned proforma. A pure tone audiometer was used to evaluate the children’s hearing. A 3.0-Tesla MRI scanner and a multi-detector CT scanner were used to acquire temporal bone MRI and CT images, respectively, on the same day in all patients i.e. all participants underwent CT as well as MRI examination. Sedation was administered intravenously or orally as needed. If children did not cooperate, they were administered oral 10% chloral hydrate at a dose of 40 mg/Kg per weight. The children were put to sleep, and then an imaging examination was done. The vestibular aqueduct's midpoint and exterior aperture diameter were measured using the best transversal imaging plane. Two radiologists independently read the CT and MRI images of 110 temporal bones. The operculum and midpoint measurements were carried out for the enlarged and suspiciously enlarged kinds, while no additional measurements were needed for the non-enlarged types. The EVA diagnosis for that ear was validated when the measurement satisfied the Valvassori criteria i.e. midpoint ≥1.5 mm. Three weeks following the CT assessment, the radiologists interpreted the MRI pictures. EVA was regarded as missing if the vestibular aqueduct was not evident. MRI was used to determine the vestibular aqueduct width for ears that had visible vestibular aqueducts, whether they were enlarged or not. Then, the measurements were consulted by an otorhinolaryngologist and findings were subjected to statistical analysis.

All data was entered using Statistical Package for social science (SPSS) version 25.00. Quantitative data such as age, midpoint and exterior aperture diameter was presented as mean and standard deviation. Qualitative data such as gender, findings on CT and findings on MRI was presented as frequency and percentage. Paired sample t-test was used if the data was normally distributed and Wilcoxon signed ranked test was used if the data was non-normally distributed to compare the measurements obtained by CT and MRI i.e. midpoint aperture of the aqueduct and external aperture diameter of the vestibular aqueduct and a p value of ≤0.05 was considered as significant.

Results

The mean age of the children was 3.9±2.09 years. There were 63 (57.3%) males and 47 (42.7%) were females. Hearing loss was present unilaterally in 100 (90.9%) children and bilateral in 10 (9.1%) children. Hearing loss of progressive type in 72 (65.5%) children, fluctuant type in 31 (28.2%) children and of sudden onset in 7 (6.4%) children. History of head injury was present in 24 (21.8%) children. Family history of EVA was present in 13 (11.8%) children. On CT scan, enlarged aqueducts were categorized in 7 (6.4%) children and were non-enlarged in 103 (93.6%) children. On MRI scan, LVAS was seen in 8 (7.3%) children, out of which visible aqueduct without an increased appearance was seen in 6 (5.5%) children, visible aqueduct with an enlarged appearance was seen in 2 (1.8%) children and no enlarge aqueduct was seen in 102 (92.7%) children (Table I).

Table I: Frequency distribution of patients according to the demographics and baseline clinical characteristics. (n=110)

Variables	N(%)
Age (in years) (Mean±SD)	3.9±2.09
Gender:	
Male	63 (57.3)
Female	47 (42.7)
Hearing loss:	
Unilateral	100 (90.9)
Bilateral	10 (9.1)
Type of hearing loss:	
Progressive	72 (65.5)
Fluctuant	31 (28.2)
Sudden onset	7 (6.4)
History of head injury:	
Yes	24 (21.8)
No	86 (78.2)
Family history of EVA:	
Yes	13 (11.8)
No	97 (88.2)
LVAS on CT scan:	
Yes	7 (6.4)
No	103 (93.6)
Categorization of aqueduct on CT scan:	
Enlarged	7 (6.4)
Suspiciously enlarged	0 (0)
Not enlarged	103 (93.6)
LVAS on MRI:	
Yes	8 (7.3)
No	102 (92.7)
Categorization of aqueduct on MRI:	
Visible aqueduct without enlarged aqueduct	6 (5.5)
Visible aqueduct with enlarged aqueduct	2 (1.8)
Not enlarged aqueduct	102 (92.7)

The mean midpoint aperture diameter and the mean external aperture diameter on CT scan and MRI is shown in Table II.

Table II: Mean midpoint aperture diameter and mean external aperture diameter on CT scan and MRI (n=110)

Variable	Mean±SD
Overall mean midpoint aperture diameter on CT scan (in mm)	1.09±0.199
Mean midpoint aperture in patients with EVA on CT scan (in mm)	1.64±0.09
Overall Mean midpoint aperture diameter on MRI (in mm)	1.1±0.21
Mean midpoint aperture in children with EVA on MRI (in mm)	1.68±0.14
Overall Mean external aperture diameter on CT scan (in mm)	1.56±0.33
Mean external aperture diameter in children with EVA on CT scan (in mm)	2.52±0.40
Overall mean external aperture diameter on MRI (in mm)	1.57±0.36
Mean external aperture diameter in children with EVA on MRI (in mm)	2.64±0.53

In children with cochlear implant, comparison of difference between the measurements obtained by CT scan versus those obtained by MRI in terms of mean midpoint aperture diameter was statistically significant as indicated by a p value of 0.021 and the difference was also statistically significant in terms of mean external aperture diameter as indicated by a p value of 0.001 (Table III).

Table III: Comparison of mean midpoint and external aperture diameter as measured by CT scan and MRI (n=110) using Wilcoxon signed ranked test

Diagnostic method	Mean midpoint aperture diameter (in mm)	P value	Mean external aperture diameter (in mm)	P value
On CT scan	1.64±0.09	0.021	2.52±0.40	0.001
On MRI	1.68±0.14		2.64±0.53	

Discussion

The current study findings revealed that in children with cochlear implant, LVAS was detected by CT scan in 6.4% patients and in 7.3% children by MRI. The midpoint aperture and external aperture diameters were significantly higher as assessed by MRI in comparison to CT scan.

As of right now, there is no agreement on which imaging modality should be used as a first line of treatment for children who exhibit clinical suspicions of having EVA.[11] CT can identify the enlarged vestibular aqueduct in certain patients with congenital sensorineural hearing loss, whether or not there are any concomitant inner ear abnormalities.[12] The labyrinthine fluid spaces can be seen with MR imaging, but the anatomic features of the membranous labyrinth are not visible with CT.[13] It has been observed that temporal CT scans are inferior to high resolution thin section fast spin-echo MR imaging when assessing the enlarged vestibular aqueduct.[14,15] An expanded bone vestibular aqueduct can be easily detected by CT, but the membrane labyrinth is not visible with this scan. These structures can be seen on T2-weighted images due to the strong contrast of the fluid in the membranous labyrinth.[16,17] To have a clarity about which imaging modality to be preferred over another, the current study was carried out to assess the frequency of LVAS in children with cochlear implant and compared the findings of CT and MRI in terms of measurement of midpoint and external aperture diameters in paediatric candidates of cochlear implant.

In our study, we found that on CT scan, LVAS was seen in 6.4% children and on MRI it was seen in 7.3% children with cochlear implant. In a study, Elmoursy *et al.* revealed that the frequency of EVA in children with hearing loss was 11.95%.[18] Sarioglu *et al.* revealed that EVA was present in 11.3% children.[19] These findings support our study findings that EVA is frequently found in children. However, the differences in the incidence of EVA might be because of different genetic makeup of our population compared to others i.e. the study by Sarioglu *et al.* was done on Turkish children and that by Elmoursy *et al.* was done on Egyptian children.

In our study, it was revealed that in terms of mean diameter of midpoint aperture and external aperture diameter there was significant difference between measurement obtained by CT scan and that by MRI and the diameters were higher on MRI. Yang and Liu revealed in their study that the mean midpoint diameter was higher on CT scan compared to MRI, whereas, the mean diameter of external aperture was higher on MRI compared to CT.[10] Sarioglu *et al.* in a study revealed that the measurements of midpoint and external aperture diameter were not significantly different between the CT scan and MRI.[18] Different studies have revealed different results in terms of diameter measurements by CT and MRI, however, the study by Yang and Liu is consistent with our results in that they similarly showed that the difference between measurement of external aperture on CT and MRI was significant. The difference between our results and that of Sarioglu *et al.* might be because of the differences in the genetic makeup, ethnicity and geographical location, as these measurements can vary among people of different ethnicity and different genetics. Furthermore, the differences might also be because of the expertise of a radiologist in measuring these diameters which could also vary among different areas.

The findings of our study suggested that MRI is a better imaging modality for detecting LVAS in children with cochlear implant in comparison to CT scan and must be preferred keeping in view the low ionizing radiation potential as well as better diagnostic approach.

Limitations: The current study had certain limitations. Firstly, the study was carried out at a single centre and the sample size was small so the results cannot be generalized. Secondly, the vestibular symptoms were not assessed among the children enrolled.

Conclusion

The current study concluded that in children with cochlear implant, EVA was present in 6.4% children on CT scan and in 7.3% children on MRI and there were significant differences between measurements obtained by CT scan and those by MRI of the midpoint and external aperture diameters and were higher in the MRI reports. The current study results proposed that children with EVA should have an MRI to further determine the extent of endolymphatic sac and endolymphatic duct enlargement and to reduce the risk of ionizing radiation associated with the CT scan. This will increase the rate of clinical diagnosis and provide imaging support for the diagnosis and management of LVAS in children.

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