

Efficacy of Three Dimensional Fast Imaging Employing Steady State Acquisition Combined with Conventional MRI in Evaluation of Patients with Cerebellopontine Angle Lesions

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ABSTRACT

Introduction: The Three Dimensional Fast Imaging Employing Steady state Acquisition (3D FIESTA) has higher spatial resolution between the Cerebrospinal Fluid (CSF) and cranial nerves with accurate identification of Cerebellopontine Angle (CPA) and internal auditory canal tumours and takes shorter acquisition imaging time than conventional Magnetic Resonance Imaging (MRI) scan.

Aim: To evaluate the efficacy of 3D FIESTA imaging as a screening tool for CPA lesions, hence to depict the fine anatomy of the cisternal and canicular segments of the facial nerve and vestibulocochlear nerves in order to elucidate the aetiopathogenesis of unexplained inner ear symptoms.

Materials and Methods: The present study was a hospital based cross-sectional study which was done in Department of Radiodiagnosis, Chettinad Hospital and Research Institute, Chennai, Tamil Nadu, India. The study was conducted on 30 patients, who were referred for MRI Brain to the department and diagnosed with cerebellopontine angle lesion from August 2018 to October 2019. A 1.5 Tesla, MRI scanner was used to scan all patients with a 8 channel Neurovascular (NV) radiofrequency coil. Along with routine conventional MRI sequences, 3D FIESTA sequence was also performed. All the data was collected and

analysed by Statistical Package for Social Sciences (SPSS) software version 23.0. Data for descriptive statistics i.e. frequency and percentage analysis, mean±Standard Deviation (SD), sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) were calculated.

Results: On Histopathological Examination (HPE), 63.3% were schwannoma, 16.7% meningioma, 10% epidermoid cyst and 3.3% intracanalicular lipoma. In 6.7% of patients, imaging features were in favour of CPA arachnoid cyst. The size of the intracanalicular part of tumour was underestimated in T2 weighted images (T2WI). 3D FIESTA gave a better estimated tumour area, even though slightly less but almost equivalent to that in post-contrast imaging. In this study, post-contrast imaging was considered as the gold standard. It was proven that conventional sequences like T2WI showed a sensitivity of 85.71% and specificity of 100% whereas 3D FIESTA sequence showed 100% sensitivity and specificity in assessing the CPA tumour extent and cranial nerve involvement.

Conclusion: 3D FIESTA imaging is a sensitive technique for the diagnosis of retrocochlear and CPA lesions without contrast administration. 3D FIESTA imaging can be considered as a useful screening tool for patients presenting with inner ear symptoms.

Keywords: Diagnostic importance, Inner ear, Post-contrast imaging, Retrocochlear lesions, VII cranial nerves, VIII cranial nerves

INTRODUCTION

The pons, cerebellum and petrous part of the temporal bone bound the CPA cistern which is filled with CSF. Lesions in this area can be identified in cross-sectional imaging. In adults, approximately 5-10% of all intracranial mass occur in the posterior fossa as CPA tumours [1]. The most common of such tumours are vestibular schwannomas and meningiomas, which make up 70-80% and 10-15% of CPA tumors respectively. Most of these patients suffer from tinnitus and hearing loss. For retrocochlear lesions, Auditory Brainstem Response (ABR) is a diagnostic rule [2]. Screening ABR is the most commonly used test for patients presenting with inner ear symptoms. ABR test and MRI are the two tests employed to investigate the patients. However, ABR has proven to be less sensitive as the size of the tumour decreases.

For assessment of retrocochlear lesions, MRI has high sensitivity and specificity. In a study conducted by Rigby PJ it was stated that only 7% of the patients with an acoustic schwannoma smaller than

1 cm was diagnosed by abnormal ABR [3]. In the 1980s, after the introduction of MRI in the field of diagnosis of retrocochlear lesions increased the specificity and sensitivity upto 100% and which later was considered to be the most accurate diagnostic tool [4]. Contrast enhanced thin section T1 weighted MRI is currently the accepted standard imaging approach. Disadvantage of conventional MRI is that it will provides soft tissue resolution, but spatial resolution which is necessary for defining cranial nerves may not be sufficient with this imaging. Recently, the T2 weighted 3D FIESTA sequence has been introduced. It doesn't need any contrast media and has shorter imaging acquisition compared to conventional MRI.

For accurate detection of internal auditory canal and CPA small tumours, high spatial resolution with excellent image contrast between the cranial nerves and CSF is required. 3D FIESTA is used for identifying cisternal and canicular segments of cranial nerves VII and VIII and adjacent vascular variations. It is also used for determining the relationship of Anterior Inferior Cerebellar Artery

(AICA) variations between cranial nerves. 3D FIESTA is highly useful to assess these tiny details by using CSF window efficiently. It is also useful in displaying small arteries, veins with slow flow apart from distinguishing the mass and inflammation in T1W MRI after the use of paramagnetic intravenous agents.

Anatomy of CPA: The CPA is a region in the posterior fossa that consists of CSF, cranial nerves VII and VIII, AICA, and arachnoid tissue. The CPA is situated in between margins of cerebellum and pons [5]. When viewed in the axial plane, the CPA cistern is a triangular space filled with CSF. The CPA cistern is contiguous with the cisterna ambiens (peri-mesencephalic) through the tentorial hiatus. The roof of CPA is formed by the tentorium and attached to petrous bone. Cerebellum is closely applied to the tentorium above and the occipital duramater below. The pia mater and arachnoid fuse and seal off the CPA cistern [6].

The FIESTA technique had been a true Fast Imaging with Steady-state Precession (FISP) sequence. Yano J and Yachandra VK [7] in 1987 said that pulse sequences where the Repeattion Time (TR), equal to or less than the Time (T^2) of the sample was technically impossible. With advances in gradient and power amplifier design, by the late 1990s, true-FISP imaging was revisited. FIESTA uses very short and TEs (Echo Times), which produces images with high Signal to Noise Ratios (SNR). The FIESTA sequence is a fluid-bright sequence. While imaging the CPA and basal cisterns, CSF appears uniformly hyperintense in these sequences. This sequence clearly demonstrates the dural reflections of posterior fossa cranial nerves [4].

Hence, the present study was done to evaluate the efficacy of 3D FIESTA imaging as a screening tool for CPA lesions, which can be used to depict the fine anatomy of the cisternal and canalicular segments of the facial nerve and vestibulocochlear nerves in order to elucidate the aetiopathogenesis of unexplained inner ear symptoms.

MATERIALS AND METHODS

A hospital based cross-sectional study was conducted in the Department of Radiodiagnosis, Chettinad Hospital and Research Institute, Kelambakkam, Chennai on 30 patients subjected to MRI Brain scan and diagnosed with CPA lesions during the study period from August 2018 to October 2019 after obtaining the informed consent from all participants. The study was approved by the Institutions Ethical Committee (Approval letter no. 115./IHEC/06-18).

Inclusion criteria: Patients of age group 18-55 years, who were subjected to MRI brain and diagnosed with CPA lesion, or those who were referred by Ear Nose Throat (ENT) Department with headache, inner ear symptoms, facial and trigeminal nerve related symptoms were included in the study.

Exclusion criteria: Patients who were claustrophobic, or with metallic implants, cochlear implants and cardiac pacemaker and female patients with early pregnancy were excluded from the study.

All the patients who visited the Department of Radiodiagnosis of the selected study research institute during the study period and fulfilling the inclusion criteria were included in the study.

MRI Acquisition

A 1.5 Tesla SIGNA GE HDxt MRI scanner was used to scan all patients with an 8 channel NV (NAVIGATOR) radiofrequency coil. The bore size of the machine was 60 cm. Along with routine conventional MRI sequences 3D FIESTA sequence was added. The images thus obtained were evaluated and a diagnosis was made. The results were then analysed using appropriate statistical methods.

FIESTA Capital

This sequence uses gradients to produce a constant or steady amount of transverse magnetisation. This spin coherence is maintained by using short TRs. This sequence requires shimming to decrease inhomogeneity below 1 ppm (parts per million) as it is very sensitive to

field inhomogeneities. The TR of this sequence is much smaller than the T2 of the tissue under investigation. The difference in the ratio of T2/T1 in the tissue provides image contrast in FIESTA. Tissues with long TR values would have increased signal as short TRs are used in this sequence. The ratio of T2 to T1 values of the tissue along with high SNR values improves the image contrast which makes true FISP imaging unique. This technique contains submillimetre sections which help in imaging of small tumours. The perilymph and endolymph fluid present within the inner ear appear hyperintense on this sequence which helps in better visualising the cochlear and semicircular canals, which was not possible on T1 weighted sequences.

On the basis of obtained images, tumours are classified as stated in study by Mohammed Jawad MS [8] into small (1-10 mm), medium (10-25 mm), large (26-40 mm) and giant (>40 mm) tumours based on their size.

STATISTICAL ANALYSIS

The collected data were analysed with International Business Management (IBM). SPSS software version 23.0. To describe the data descriptive statistics frequency and percentage analysis was used for categorical variables and the mean±Standard Deviation (SD) was used for continuous variables. The Receiver Operator Characteristic (ROC) curve analysis was used to find the sensitivity, specificity, PPV and NPV to assess the efficacy of the tools. The probability value of 0.05 is considered a significant level in the above statistical tool. Post-contrast sequences were analysed using Image J Software.

RESULTS

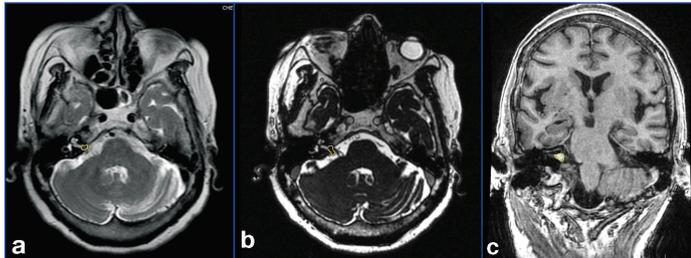
Out of total sample of the study i.e. 30 patients, 18 (60%) were females and 12 (40%) were males. A 17 (56.7%) of total patients who presented with symptoms belonged to the age group of 41 to 60 years, 8 (26.7%) between 21 to 40 years and 5 (16.6%) between 61 to 80 years. Total 53.3% patients had lesions on the left side and 46.7% had lesions on the right side. Patients presented with symptoms of hearing loss 20 (30.3%), vertigo 17 (25.8%), tinnitus 9 (13.6%), facial palsy 6 (9.1%), trigeminal nerve dysfunction 2 (3.0%) and headache 12 (18.2%). [Table/Fig-1] shows distribution based on size of lesions.

Size of lesions	Frequency (n)	Percentage (%)
Small	5	16.7
Medium	6	20.0
Large	14	46.7
Giant	5	16.6
Total	30	100.0

[Table/Fig-1]: Distribution of patients based on size of lesions.

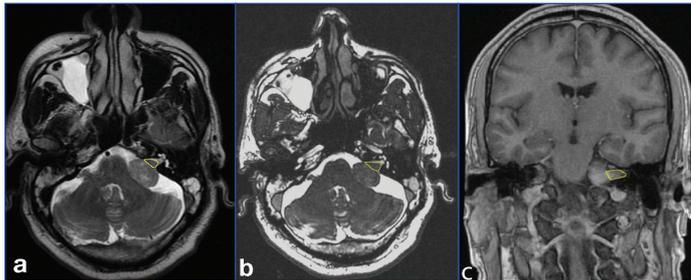
A 36.7% of tumours showed homogeneous enhancement. Heterogeneous enhancement was noted in 53.3% of tumours especially in large and giant tumours and three cases didn't show any enhancement. Total 40% of tumours had cystic changes. Post-contrast T1 weighted images demonstrated an area of hypointensity within the brightly enhanced lesion. This finding was suggestive of necrosed tissue within the lesion. This was a very significant finding as cystic acoustic schwannoma may expand at the rate of 10 times faster growth as compared to non-cystic lesions. The FIESTA sequence did demonstrate these lesions but in some cases, the changes were not to its full extent. Out of 30 lesions, two lesions showed restriction on diffusion weighted imaging which later proved to be epidermoid cysts on HPE. Out of 30 lesions, 25 (83.3%) cases had intracanalicular components and 10 cases (33.3%) of tumours showed widening of Internal Acoustic Canal (IAC). Out of 25 cases of intracanalicular tumours, the canal extension in two lesions was found only on FIESTA and post-contrast study and was missed on routine conventional sequences.

Also two lesions which were purely intracanalicular without a CPA component were exclusively diagnosed in the FIESTA sequence and post-contrast study. In lesions, which had IAC extension, the intracanalicular tumour size was measured in T2 weighted image, 3D FIESTA. Multiple comparison charts were put up in order to compare the difference in mean areas of the intracanalicular tumour in three different sequences. When these areas were compared, it was found that size of the intracanalicular part of tumour was underestimated in T2 weighted images. 3D FIESTA gave a better estimated tumour area, even though slightly less but almost equivalent to that in post-contrast imaging [Table/Fig-2].



[Table/Fig-2]: A 59-year-old female presented with complaints of headache and dizziness for the past two months. a) Axial T2 weighted image shows an iso-hypointense lesion in the right CPA; b) 3D FIESTA sequence shows the intracanalicular tumour extension with involvement of VII and VIII nerve complexes; c) Post-contrast study shows homogeneous enhancement of the tumour.
CPA: Cerebellopontine angle; 3D FIESTA: 3-Dimensional fast imaging employing steady state acquisition

The exact extent and lateral depth of the IAC tumour is of much importance for the surgeon. Far lateral tumour impacting the fundus with extension above and below the transverse crest of the IAC, complicates tumour removal and decreases the chances of hearing preservation [Table/Fig-3].



[Table/Fig-3]: A 50-year-old male presented with complaints of headache and vertigo since two weeks. a) Axial T2 weighted image showing a hyperintense lesion in the left CPA. The lesion is seen extending into the IAC causing widening of the IAC. There is involvement of VII and VIII nerve complexes. Mass effect is noted on the left middle cerebellar peduncle; b) 3D FIESTA image shows a better extent of the intra-canalicular tumour in the left CPA; c) The intracanalicular component of the tumour is better assessed by post-contrast study.

Depth of tumour extension is essential especially with a sub-occipital approach for surgical resection. Tumours occupying more than two-thirds of the length of the IAC complicate resection because the tumour cannot be directly visualised and cochlear nerve dissection is more difficult and the risk for residual tumour also increases. With the exact size of the extra-canalicular and intracanalicular tumours, the type of approach for tumour resection can also be chosen.

In two cases, the vascular loop of Anterior Inferior Cerebellar Artery (AICA) was diagnosed. One patient had Type I and another had Type II vascular loop. Vascular loop was missed on routine conventional sequence and post-contrast study which was diagnosed only on 3D FIESTA sequence. In this study, use of contrast agents was not required to distinguish the AICA and its variations in the CPA. Especially due to variations, sequence selection before the surgery is highly important so as to obtain an accurate image of the anatomic course of cranial nerves in the CPA and their complex adjacency with vascular structures and to decide on decompression surgery. The 3D FIESTA images showed that 81 temporal bones had type I vascular loops (65.9%), 33 had type II (26.8%), and 9 had type III vascular loops (7.3%).

In the imaging of these tiny details, 3D FIESTA sequence stands out as a highly successful sequence using CSF window efficiently. The intracanalicular VII and VIII nerve complex involvement was well assessed in 3D FIESTA and post-contrast imaging in four cases which were not assessed in T2 weighted image [Table/Fig-4].

VII and VIII cranial nerve complex involvement	T2		FIESTA		CONTRAST	
	Frequency (n)	%	Frequency (n)	%	Frequency (n)	%
Not assessed	6	20	2	6.7	2	6.7
Assessed	24	80	28	93.3	28	93.3

[Table/Fig-4]: Intracanalicular VII and VIII nerve complex involvement.

The V Cranial Nerve (CN) involvement was seen in four cases of giant tumours which was well-assessed with 3D FIESTA and contrast study. The T2 weighted image did not provide details on 5th nerve involvement [Table/Fig-5].

Comparative imaging analysis	T2		FIESTA		Post-contrast	
	Freq.	%	Freq.	%	Freq.	%
Not assessed	30	100	26	86.7	26	86.7
Assessed	-	-	4	13.3	4	13.3

[Table/Fig-5]: Comparison table based on 5th nerve involvement.

On Histopathological examination (HPE), majority of tumours (63.3%) were confirmed to be schwannoma, 16.7% meningioma, 10% epidermoid cyst and 3.3% intracanalicular lipoma. Two cases (6.7%) were diagnosed to be arachnoid cyst based on the imaging features and these patients were put on follow-up. In 24 cases, there were no postoperative complications. Among the remaining six, two patients had CSF leak, two cases had meningitis and one patient had cranial nerve palsy and one had worsening of hearing loss.

In this study, complications were noted in patients with large or giant tumours. Therefore the risk to develop postoperative complications can increase with larger tumours. In this study, post-contrast imaging was considered as the gold standard. It was proved that conventional sequences like T2WI showed a sensitivity of 85.71% and specificity of 100% whereas 3D FIESTA sequence along with post-contrast images and confirmations, showed 100% sensitivity and specificity in assessing the CPA tumour extent and cranial nerve involvement.

DISCUSSION

The technique of 3D FIESTA could be potentially used for assessment of exact tumour size in CPA and intracanalicular tumour extension. Small tumours arising within the IAC were diagnosed with FIESTA sequence which was missed in other conventional routine sequences. The intracanalicular VII and VIII nerve complex involvement by the tumour was better assessed with 3D FIESTA as compared to conventional sequences. Trigeminal nerve involvement in case of giant tumours was diagnosed with FIESTA.

Thin section contrast-enhanced T1-weighted imaging is currently considered as the standard imaging technique. FIESTA sequence was found to have a diagnostic capability almost equivalent to that of post-contrast study. 3D FIESTA is useful in imaging of tumours especially like acoustic schwannomas [4,5]. Whereas the imaging features of epidermoid cysts were better assessed with other conventional sequences because of its cyst-like signal intensity and the diagnosis was sought with DWI sequence. In cases of CPA arachnoid cysts and lipoma, there had been no added imaging benefits with 3D FIESTA sequence compared to other sequences [6].

It is believed that 3D FIESTA sequence with its ability of high resolution imaging helped to diagnose vascular variations like vascular loops and predict their involvement in symptom origin. The diagnosis was considered complete after the FIESTA sequence in patients who were not found to have any pathology in the conventional sequences

and was confirmed with HPE. Those patients in whom FIESTA sequence demonstrates pathology or lesion in the CPA should be further investigated by post-contrast T1-weighted sequences [6]. In addition, in cases where contrast cannot be administered, such as in pregnant patients or patients who are sensitive to gadolinium, the FIESTA sequence can be used in isolation to exclude acoustic schwannomas [9].

Sequence selection before the decompression surgery is highly important especially due to anatomical variation. Therefore, an accurate image of anatomic course of cranial nerves in CPA and adjacent vascular structures is necessary before decompression surgery to prevent complications during surgical intervention [9]. The 3D-FIESTA sequence gains the accuracy of T1-weighted sequences acquired with gadolinium, without the need for exogenous contrast agents [3].

With the use of FIESTA sequence as a protocol for diagnosing acoustic schwannoma, the time taken for examination can be reduced by eliminating the need for contrast administration and detailed anatomy of the inner ear can be assessed [5]. FIESTA only protocol without post-contrast imaging can have few disadvantages. With post contrast T1W images further characterisation of the tumour can be done, other inner ear pathologies can be diagnosed and postoperative changes can be better demonstrated [9].

With these findings, authors suggest that 3D-FIESTA imaging could be a reliable screening test for patients who complain of otologic symptoms [9]. These studies suggest that contrast enhanced T1-weighted images can be avoided in patients who have contraindications for contrast agents. Therefore, the diagnosis of CPA pathology can be considered to be complete with the addition of 3D FIESTA sequence in routine sequences.

Limitation(s)

Because of slow switching rates of the gradients, in FIESTA technique, low rise times, and small slow rates, steady state free precession imaging were not clinically feasible. Problems which can be encountered in employing FIESTA sequence are increased acoustic noise, peripheral nerve stimulation and the patients with contraindications for contrast agents.

CONCLUSION(S)

The 3D FIESTA sequence is a high resolution T2W sequence that provides excellent image contrast with high SNR. The 3D FIESTA sequence allows better visualisation of small vascular structures with higher anatomical details, which are clearly depicted in other sequences. A screening sequence for diagnosis should be specific, sensitive, invasive and inexpensive when compared to the contrast-enhanced T1-weighted sequence. By these criteria, the FIESTA sequence is an ideal tool for investigation of possible acoustic schwannoma and other CPA tumours with or without neural involvement.

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