Importance of Non-Echo-Planar Diffusion Weighted Imaging (Non-EP-DWI) on Reducing Air-Bone Interface Artefact to Improve the Image Quality in Comparison with Echo-Planar Diffusion Weighted Imaging (EP-DWI) on MRI Brain

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Abstract: ***Echo Planar Diffusion Weighted Imaging techniques were quick and commonly used to acquire the Brownian motion of water molecules in the body tissues. It is also extremely susceptible to artefacts as it causes air-bone interface in the diffusion-weighted MRI Brain images which affect the image quality. (Yoshizako et al., 2021) So, an alternative technique non-echo planar based Echo Planar called TSE-DWI sequence produces better image quality without air bone interface artefacts in the diffusion-weighted brain images. (Sheng et al., 2020) Aim and objective: The study aims to reduce the air-bone interface artefacts in the diffusion-weighted imaging to improve image quality in magnetic resonance imaging (Krupa & Bekiesińska-Figatowska, 2015). Methods and Materials: This is a cross-sectional study concentrated on certain factors that influence the image quality such as spatial resolution, signal-to-noise ratio, contrast-to-noise ratio and scan time. A total of 34 patients undergoing MRI Brain scans were included in the study. A set of two sequences, echo planar DWI and non-echo planar DWI were employed in the study for each patient using Phillips Ingenia 3 tesla MRI Scanner equipment and head coil. (Más-Estellés et al., 2012) The radiologists did diagnostic analyses to evaluate the image quality. This study included the statistical analysis of Wilcoxon Man Whitney's Mean Rank test. Results: This study showed that the non-echo planar based diffusion-weighted imaging which is turbo spin echo sequence reduces the air-bone interface artefacts drastically when compared with echo planar diffusion weighted imaging sequence in the expense of longer scan times.***

Keywords: Air-bone interface artefact, Diffusion-weighted imaging, Echo planar imaging, Turbo spin echo.

1. Introduction

Air-bone interface artefact is one of the susceptibility artefacts, it occurs when structures are with different susceptibilities present adjacent to each other that produces dark or bright signals. Which leads to difficulty in interpretation. This is the most common artefacts seen in diffusion weighted images of brain Magnetic susceptibility artefact is an artefact occurs because of the protons inside the body is getting magnetized at various degree that causes difference in the phase and the precessional frequency. This is one due to the metal within the imaging plane, and also the content of iron in the haemorrhage causes magnetization to the degree of greater extent. It is commonly seen in the gradient echo sequences. It is due to the reversal of the gradients that can't be able to compensate for the phase difference at their interface. Air-bone interface artefact is an artefact occurs in the Diffusion Weighted Imaging in the MRI brain. The interfaces like air-bone, soft tissue-bone distorts the local magnetic field and leads to an artefact in the image. It appears very dark or bright signal areas on the image. It is due to the boundaries of the air contained paranasal sinuses interfaces overlapped by the bony regions. Air and vacuum will not have any significant magnetic susceptibility. These bone and air-filled cavities like sinuses can create frequency shift and generate gradients. The artefacts are mostly seen in the temporal region, cerebellum, frontal lobe, and the pons. (*fig.1*) As they are in their order of their pixel bandwidth. (*(PDF) Susceptibility Weighted Imaging – Pearls and Pitfalls*, n. d.) The sequence causes this artefact is AXIAL-DWI. It is a Single-Shot Echo Planar based sequence which fills the lines of k-space in spiral or radial method. The reduction in the presence of large difference in susceptibilities and due to the rapid dephasing of intravoxel and short T2*. The spins that are encoded from the frequency that are dislocated. (Kim et al., 2018) When using the spin echo-based DWI sequence, it fills the k-space in the cartesian trajectory and there is no rapid dephasing as it a spin echo sequence results in a better-quality image and it is also less susceptible to artefacts. But it takes quite longer scanning time when compared to echo planar trajectories (*Comparison of TGSE-BLADE DWI, RESOLVE DWI, and SS-EPI DWI in Healthy Volunteers and Patients after Cerebral Aneurysm Clipping | Scientific Reports*, n. d.) .

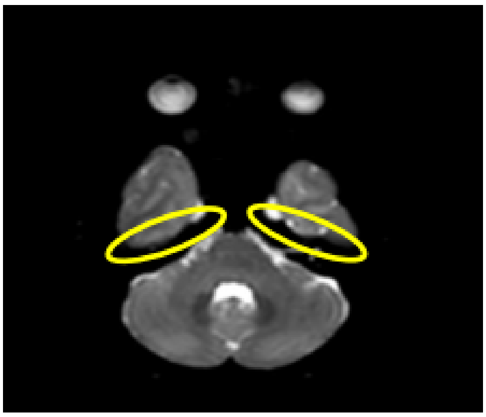

Figure 1: Depicts the air-bone interface artefact commonly seen in the diffusion-weighted images which obscures temporal and middle ear anatomy and pathologies.

2. Materials and Methods

Patient selection criteria

The study Protocol was submitted to the Institutional Human Ethics Committee (CARE IHEC-I), The committee approved the protocol IHEC-I/1674/23 with the proposal number. The study was designed and conducted as a Cross-sectional study. The study was conducted at the Department of Radiology and Imaging Sciences in the Chettinad Hospital and Research Institute located in Kelambakkam, Tamil Nadu for the period of one year from 2022 to 2023. A total of 34 patients were selected based on the inclusion and exclusion criteria. Two MRI sequences were employed namely, Echo planar Diffusion-weighted imaging and Turbo spin echo diffusion-weighted imaging to the patients for the study with the informed consent. The inclusion criteria consist of patients undergoing MRI brain study irrespective of all age groups. The exclusion criteria consist of patients with metallic implants, pacemakers, defibrillators, aneurysm clips and first-trimester pregnancy patients.

MR Imaging Protocol

MR imaging was performed on a 3T MR imaging scanner (Phillips Ingenia) using a head coil. The planning for Axial-DWI, plan the box in the sagittal plane by angling the box parallel to the genu of corpus callosum. The whole brain should be covered and check the planning box in the other two planes. In coronal plane it should be perpendicular to the third ventricle and brain stem (Migirov et al., 2014) . The parameters of EP-DWI (TR/TE= 2510/63ms), NSA= 4, Slice thickness= 4mm, time=4 minutes 12 seconds (9) and TSE-DWI (TR/TE= 7000/68ms), NSA= 4, Slice thickness= 4mm, time=6 minutes 3 seconds) was performed in all cases as per the criteria.

Imaging Analysis

A diagnostic assessment was done by three certified radiologists to evaluate the quality of the images using scores from 1 to 5 (1-poor, 2-below average, 3-average, 4-above average, 5-excellent) based on the parameters spatial distortion, signal-to-noise ratio, contrast-to-noise ratio and scan time and compared the quality of images and their probability of occurrence to artefacts.).

Statistical analysis

All statistical analyses were carried out using SPSS version 29. Quantitative variables were expressed as mean ± standard deviation and qualitative variables were expressed as frequency (percentage). Interobserver scoring was calculated using the Wilcoxon man Whitney ranking test. The threshold for two-tailed significance was set as *$p < 0.05$*.

3. Results

Patient characteristics

Thirty-four patients met the inclusion criteria, In that 17/34 (50%) are women, and 17/34 (50%) were; men [mean age- 46.5625 years ± 16.114] and Range – 15 to 75; Women [mean age – 45.9697 years ± 16.2855] was added with same image planning of two different sequences namely Echo planar diffusion-weighted and non-echo planar diffusion-weighted sequences in the MRI brain study and acquired two sets of images.

Imaging analysis

Images were acquired and three certified readers reviewed the images of the two sequences. Each sequence was evaluated under the four parameters that influence the MR image quality; spatial distortion, CNR, SNR and scan time and scoring (1 to 5) was given by the radiologist while reviewing the imaging the reader noticed that in echo-planar DWI sequence the temporal area is overlapped by sinus, whereas in the non-echoplanar DWI sequence it is significantly reduced.

The average mean and standard deviation of EP-DWI sequence for Reader 1 scoring (spatial resolution =1.9117± 0.66822, SNR=2.4412± 0.504, CNR=, 2.3823±0.4932, scan time=4.3529± 0.4850), Reader 2 (spatial resolution= 1.9117±0.3788, SNR= 2.5294± 0.5066, CNR= 2.4411± 0.5039, scan time= 4.0588 ± 0.3429) and Reader 3 (spatial resolution = 2.1176 ±0.6402, SNR= 2.5± 0.5075, CNR= 2.5294± 0.5066, scan time= 4.0588± 0.2388). The average mean and standard deviation of TSE-DWI sequence for Reader 1 scoring (spatial resolution =4.1176± 0.4776, SNR=3.7941± 0.5382, CNR= 3.5588 ±0.5039, scan time=1.6470± 0.4850), Reader 2 (spatial resolution = 4.3235±0.4748, SNR= 3.5882± 0.4995, CNR= 3.8823± 0.3270, scan time= 2.2647 ± 0.4478) and Reader 3 (spatial resolution = 3.7941 ±0.5918, SNR= 3.1764± 0.5205, CNR= 3.5± 0.5075, scan time= 2.1176± 0.7288).

Table1: Descriptive analysis with Wilcoxon Man Whitney test (scoring basis)

Parameters	Reader 1				Reader 2				Reader 3			
	SR	SNR	CNR	TIME	SR	SNR	CNR	TIME	SR	SNR	CNR	TIME
Mann-Whitney U	6	67.5	0	0	0	126	30	45	45	255	153	0
Wilcoxon W	601	662.5	692.5	595	595	721	625	599.5	640	850	748	595
Z	- 7.32	- 6.61	- 6.28	- 7.38	- 7.56	- 5.98	- 7.20	- 7.5	- 6.80	- 4.55	- 5.70	- 7.56
Asymp. Sig. (2-tailed)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Foot Note: **SR-**spatial resolution**, SNR-**signal-to-noise ratio**, CNR-**contrast-to-noise ratio**.**

When comparing the scoring between echo-planar DWI and non-echo planar DWI, the resolution of the image is significantly increased in Turbo spin echo Diffusion-weighted images and scan time is increased in echo-planar diffusion weighted sequence. (*fig 2)*

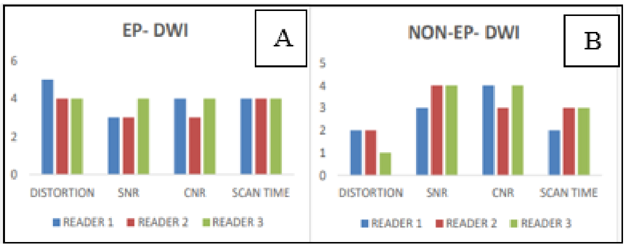

Figure 2: Demonstrates the scoring chart of the (A) EP DWI and B) Non-EP-DWI sequences by the three independent radiologists of influencing parameters in the MR image quality

Table 2: Descriptive analysis with Wilcoxon Man Whitney's Mean Rank test (n=34)

Parameters	Sequence	N	Mean Rank	Sum of Ranks
R- I Spatial Disortion	EP- DWI	34	17.68	601
	Non- EP- DWI	34	51.32	1745
R- I SNR	EP- DWI	34	19.49	662.5
	Non- EP- DWI	34	49.51	1683.5
R- I CNR	EP- DWI	34	20.37	692.5
	Non- EP- DWI	34	48.63	1653.5
R- I Scan Time	EP- DWI	34	51.5	1751
	Non- EP- DWI	34	17.5	595
R- 2 Spatial Disortion	EP- DWI	34	17.5	595
	Non- EP- DWI	34	51.5	1751
R- 2 SNR	EP- DWI	34	21.21	721
	Non- EP- DWI	34	47.79	1625
R- 2 CNR	EP- DWI	34	18.38	625
	Non- EP- DWI	34	50.62	1721
R- 2 Scan Time	EP- DWI	34	51.37	1746
	Non- EP- DWI	34	17.63	599
R- 3 Spatial Disortion	EP- DWI	34	18.82	640
	Non- EP- DWI	34	50.18	1706
R-3 SNR	EP- DWI	34	25	850
	Non- EP- DWI	34	44	1496
R- 3 CNR	EP- DWI	34	22	748
	Non- EP- DWI	34	47	1598
R- 3 Scan Time	EP- DWI	34	51	1751
	Non- EP- DWI	34	17	595

4. Discussion

In this study, the main concept is to reduce the artefacts with magnetic susceptibilities. The DWI sequence we plan in the routine brain is entirely an Echo Planar based sequence. Echo Planar sequence is rapid acquisition where all the echoes are collected in single shot which is said to be as Single Shot-Echo planar imaging. (B et al., 2006a) As the diffusion sequence are always prone to more susceptibility artefacts. Generally, the diffusion sequence is planned on the basis of the sequence SS-EPI. (De Foer et al., 2006) In this EP-DWI, the quality of the image suffers from blurring, spatial resolution that caused by bulk susceptibility artefacts generated adjacent to the tissue interfaces. When using this sequence on the brain parenchyma, an artefact arises called air-bone interface artefact. An dark or bright signal appears on the brain due to the paranasal sinus overlaps the temporal bone. (F et al., 2009) It is because of the inherent extended readout period results their acquisition of the entire k-space for given single shot slice using RF excitation pulse which always perceives the lower image quality. The reduction in the presence of large difference in susceptibilities and due to the rapid dephasing of intravoxel and short T2*. The spins that are encoded from the frequency that are dislocated. Thus, the readout time in SS-EP-DWI must be reduced to overcome this issue (*Pitfalls of Diffusion-Weighted Imaging: Clinical Utility of T2 Shine-through and T2 Black-out for Musculoskeletal Diseases*, n. d.) . (Dubrulle et al., 2006) By insisting this in our study the air-bone interface artefact produced should be either reduced or eliminated. To rectify all the above problems, the remedy is to use the sequence named TSE-DWI, it is a Spin-Echo based sequence (Dubrulle et al., 2006) . In EPI sequence, the acquisition will be very quick in a single TR period. But in TSE-DWI, it takes time for the echo train length and changes the direction of phase encoding gradients. It provides good image quality when compared to EP-DWI, with the penalty of scan time. (*fig 3*) Here the effects of static field inhomogeneity is rephrased which increases the time of echo and allows larger sampling windows and greater voxel bandwidth which produce the image with less spatial distortion. (*Comparison of Readout-Segmented Echo-Planar Imaging (EPI) and Single-Shot EPI in Clinical Application of Diffusion-Weighted Imaging of the Pediatric Brain | AJR*, n. d.) (B et al., 2006b) Thus, the spatial distortion, image blurring, geometric inaccuracy and misdiagnosis rates are completely reduced in the TSE-DWI sequence, when compared to EP-DWI.

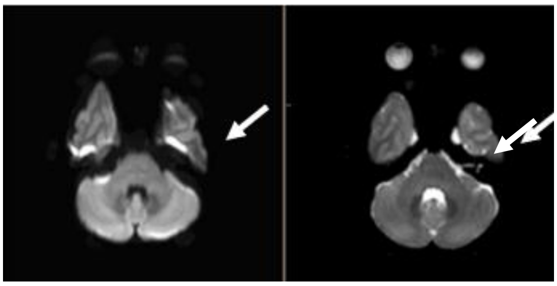

Figure 3: Example of Diffusion-weighted images on both EP-DWI and Non-EP-DWI sequences in a 23-year-old man. EP-DWI Both (A) and TSE DWI (B) demonstrate the temporal lobe image. Note the EP-DWI image shows air-bone are overlapping and causes air-bone interface artefact (*arrow*). In non-EP DWI, the air-bone artefact is significantly reduced.

5. Conclusion

The Air-Bone interface artefacts are drastically reduced when using the sequence TSE based Diffusion Weighted Imaging which is a Non-Echo Planar Imaging, when compared to the Echo Planar based the Diffusion Weighting Imaging, whose SNR and CNR ratios are higher when compared to EPI based the Diffusion Weighting Imaging which results in producing good quality of images with the expense of longer scan times. This paves the way for reducing the misdiagnosis rates for the radiologist.

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