Original Research Article

Artefacts in magnetic resonance imaging (MRI) and their remedies

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Abstract

Background: An enormous number of artefacts are encountered in magnetic resonance imaging (MRI) which jeopardize the image quality. A comprehensive knowledge of the sources and the remedial measures needed is pivotal to enhance and optimize the image quality in magnetic resonance imaging (MRI).

Objectives: The primary objectives of the study were to identify different MRI artefacts, to find the reason/cause of these artefacts and to find methods for correction of these artefacts.

Materials and methods: This was a prospective study which included all the patients that were referred to our department for various MRI examinations. The study was carried at 1.5 tesla Magnetom Avanto Siemens, Germany. All the MRI examinations were performed by trained technologist in presence of an experienced radiologist. The MR images acquired were studied for the presence of any artefacts during the performance of MRI examination, the MR parameters at which the artefacts appeared and subsequently the remedial measures undertaken.

Results: A total of 209 patients comprising 95 females and 114 males, referred to our department for MRI examinations of various body parts were studied. The commonest artefact observed was motion artefact in 43 (20.6%) patients followed by susceptibility artefact and aliasing artefact. Less common artefacts observed were chemical shift artefact, herring bone artefact, Gibb’s artefact, Moiré fringe artefact, zipper artefact and magic angle phenomenon.

Conclusion: Thorough understanding of the sources of magnetic resonance imaging (MRI) artefacts and the mechanism of their production enables institution of preventive and remedial measures thereby helping in optimization of MRI imaging.

Key words

Artefacts; MRI; Magnetic Resonance Imaging; Remedies.

Introduction

Complex interplay of myriad interactions between the various components of magnetic resonance imaging (MRI) equipment, patient factors and some external factors result in a colossal number of unwanted image distortions called as artefacts. A thorough understanding of the genesis of these artefacts is pivotal in avoiding these undesirable artefacts and thus helping in optimizing the image quality [1]. Humongous technological advancements in the computer engineering and MRI hardware have resulted in exponential growth of the clinical and experimental applications of MRI [2, 3, 4]. In a bid to adjust to the pace of growing clinical demands of MRI, radiologists and technologists have to learn to optimally apply MRI and to identify the various artefacts and take corrective measures. The different components of an MR imaging system are the main magnet, gradient coil, radiofrequency coil and workstation. The sources of artefacts in MRI could be broadly classified as equipment-related, image reconstruction–related and patient physiology-related sources [4]. The MRI hardware and room shielding-related artefacts include zipper artefact, herring-bone artefact, zebra stripes, moiré fringe artefact, radiofrequency overflow artefact, aliasing (wrap-around) artefact, inhomogeneity artefact, central point and shading artefact. MRI software-related artefacts include cross-talk artefact and cross-excitation artefact. Patient motion and physiological motion-related artefacts are ghosting and phase encoded motion artefact. Tissue heterogeneity and foreign body-related artefacts are magnetic susceptibility artefact, magic angle artefact, chemical shift artefact and dielectric effect artefact. Fourier transformation-related artefacts are Gibb's (truncation) artefact and zero-fill artifact [1-6]. The purpose of this study was to help radiologists identify common MRI artefacts, enhance their understanding of the genesis of these artefacts and to lay down the practical solutions to minimize these artefacts.

Materials and methods

This was a prospective study conducted in our department of radiodiagnosis and imaging from February 2018 to February 2019. Informed consent was taken from all patients and institutional ethical committee clearance was obtained prior to study. The primary objectives of the study were to identify different MRI artefacts, to find the reason/cause of these artefacts, to find methods for correction of these artefacts and the measures undertaken to reduce artefacts in non-modifiable causes like patients with metallic implants and other organ artefacts. The study included all the patients that were referred to our department for various MRI examinations. The study was carried at 1.5 tesla Magnetom Avanto Siemens, Germany. All the MRI examinations were performed by trained technologist in presence of an experienced radiologist. The MR images acquired were studied for the presence of any artefacts during the performance of MRI examination. In cases where artefacts were seen, we noted down the various MRI parameters employed. This included the body part which was being examined, the pulse sequence in which the artefact occurred, phase and frequency encoding direction, field of view (FOV), time of repetition (TR), time of excitation (TE), slice thickness and matrix. We also checked for technical factors like whether the RF coil was properly fastened around the part being examined and to look for any external magnetic disturbances like mobile phone devices, transistors and other electronic devices. Subsequently we employed the corrective measures to remove or lessen these artefacts. The data was analyzed using statistical softwares SPSS v 20 and STATA v 11. Categorical variables were described in terms of percentage.

Results

We studied a total number of 209 patients comprising 95 females and 114 males, referred to our department for MRI examinations of various body parts. The commonest artefact observed was motion artefact in 43 (20.6%) patients. This artefact was commonly encountered while imaging moving body parts such as heart and liver. Additionally, it was encountered in uncooperative patients and while imaging body parts located close to moving body structures. The second most common artefact observed was susceptibility artefact or metallic artefact. It was observed in 40 (19.1%) patients. The frequency with which different artefacts were observed are given in tabulated form in **Table - 1**. We noted down the pulse sequence in which the artefacts appeared and their possible cause and the remedial measures employed (**Table - 2**).

Table - 1: Different MRI artefacts observed and their frequency.

MRI Artefact	**No. of patients (n)**	**Part of body imaged in which artefact was seen**
Motion artefact. Periodic Non-periodic	 17 26	Liver Brain Heart
Gibbs (truncation) artefact	05	Cervical spine, Dorsal spine Lumbar spine.
Cross talk artefact	21	Lumbar spine
Aliasing or wrap around artefact.	29	Brain, Pelvis, Feet Abdomen , Foot, Ankle
Susceptibility artefact or metallic artefact.	40	Spine, Brain, Face.
Herring bone or crisscross artefact.	13	Brain, Liver
Zipper artefact	27	Brain, Abdomen, Cervical spine.
Moiré fringes artefact.	11	Abdomen, Shoulder.
Chemical shift artefact.	15	Brain, Pelvis
Magic angle artefact	5	Knee

Discussion

Motion artefact was the commonest artefact encountered in 20.6% (43) examinations. This artefact was commonly encountered while imaging moving body parts such as heart and liver. However, non-periodic motion due to patient movement in uncooperative or altered mental status patients was also observed in imaging of many body parts. Bowel peristalsis also contributed to motion artefacts in imaging of abdomen. Pulsation artefacts were also seen while imaging of structures close to vessels. Periodic motion artefacts were eliminated or reduced by employing respiratory gating in imaging of upper abdomen. Cardiac gating was employed to reduce artefacts while cardiac imaging. The effect of pulsation artefacts was nullified by changing phase encoding direction. Saturation bands were used when artefacts were produced by moving structures located outside the field of view. Shortening scan time by using turbo spin echo (TSE) and gradient recalled echo sequences, were also used in many instances to counter motion artefacts (**Figure - 1a, 1b**). Motion artefacts deteriorate the image quality by producing ghosting or smearing [6-9]. The second most common artefact observed was susceptibility artefact or metallic artefact. It was observed in 40 (19.1%) patients. This artefact was commonly encountered while imaging the body parts with the presence of ferromagnetic materials. Some patients referred from orthopedic department having joint replacements, containing metal implants create image distortion and susceptibility artifact [10]. Patients referred from neurosurgery having MR compatible implants like shunts (**Figure - 2**) and aneurysmal clips also create these artefacts [10].

Table - 2: Change of various MRI parameters for rectification of artefacts.

Name of artefact	Artefact seen in part and sequence	Parameters in artefact image	Parameters in artefact rectified image
Motion artefact	Brain (T1, T2, FLAIR, DWI)	Phase encoding direction A-P	Phase encoding direction H-F
Aliasing or wrap around artefact	Brain, Pelvis, Ankle, Foot, Hand(T1, T2)	Read FOV-220 FOV phase-69.6 Slice thickness-5mm phase encoding direction A-P	Phase encoding direction R-L Read FOV 250 slice thickness- 5mm FOV phase 80
Susceptibility or metallic artefact	Brain-T1 SWI & spin echo	Band width -80, TE-40 Slice thickness- 5mm matrix 256	Band width – 190 TE-49.0 Slice thickness- 3mm Matrix – 512
Magic angle artefact	Knee, PD axial	TE- 25 MS	TE- 40 MS
Chemical shift artefact	Brain (DWI)	BW- 1184 FOV-260	BW- 1628 FOV- 230

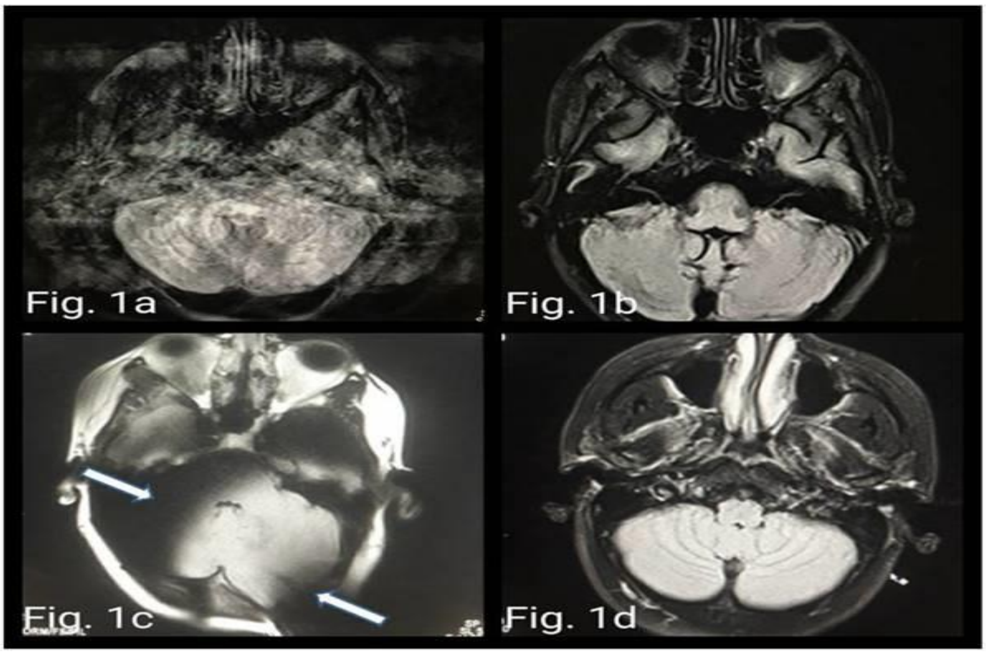

FIGURE 1. Fig. 1a showing motion artefact as the patient moved during acquisition. Fig. 1b shows disappearance of the artefact after the patient was sedated and the scan time and number of signal averages were decreased. Fig. 1c shows distortion of image due to presence of hair pins in the scalp. After proper screening the hair pins were removed and Fig. 1d shows disappearance of the artefact.

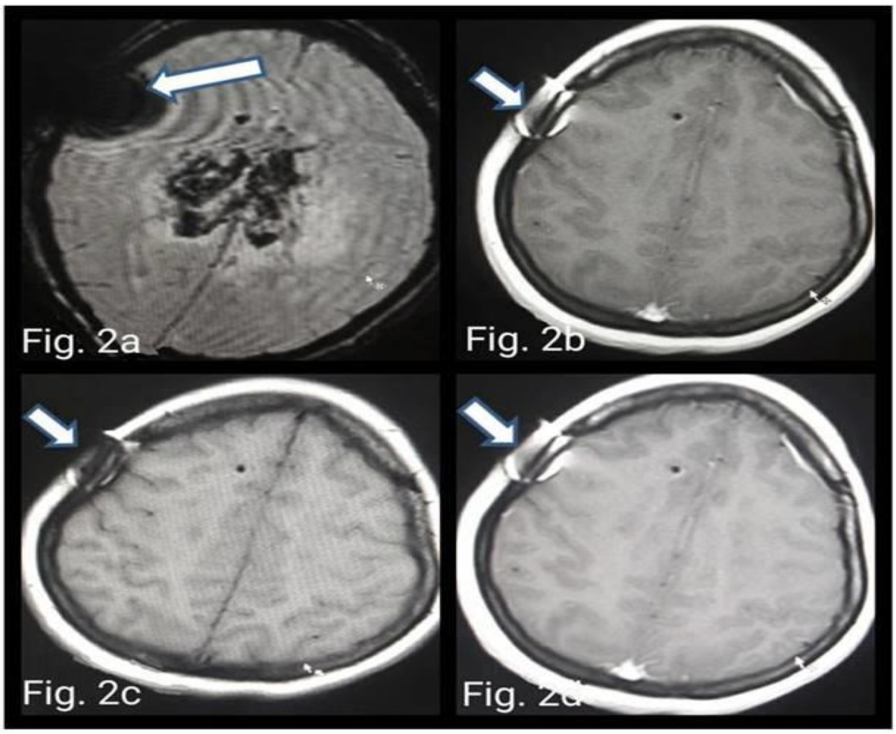

FIGURE 2. Axial Gradient (SWI) (Fig. 2a) of brain showing large susceptibility artefact (arrow) due to presence of a shunt. Parameters used were bandwidth 80, TE of 40ms and slice thickness of 2mm. Fig. 2b,2c,2d show progressive reduction in metal artefact due to use of spin echo (T1W) sequence, increase in bandwidth (190) and matrix and reduction in TE value (8.9ms)

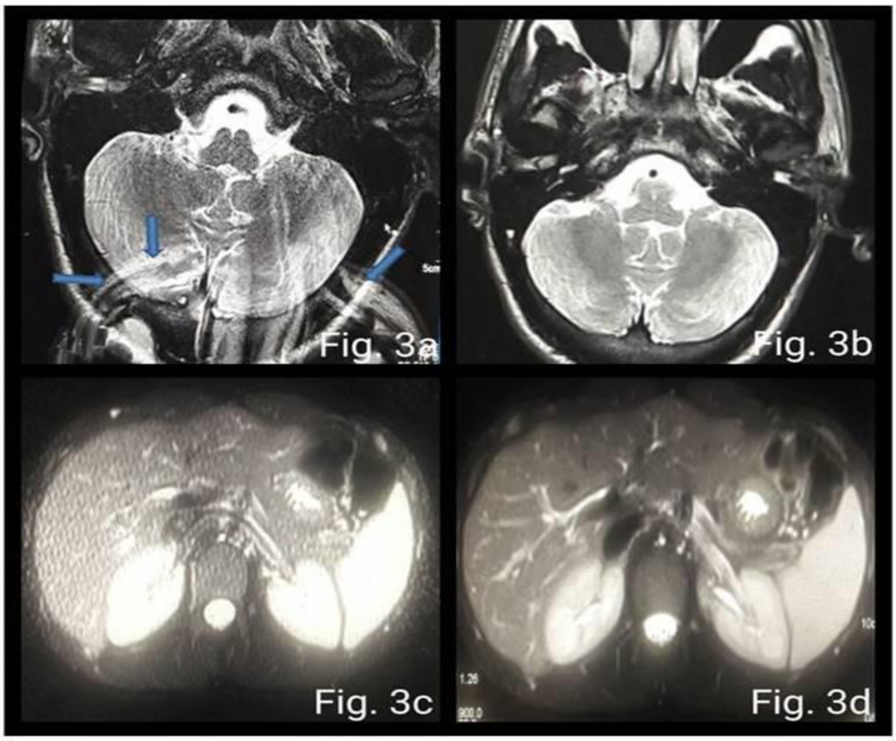

FIGURE 3. Aliasing (wrap-around) artefact in axial T2W sequence of brain (Fig. 3a). After increasing field of view (FOV) the artefact disappeared (Fig. 3b). Zipper artefact (Fig. 3c) visualized as vertical lines produced due to the open door of MRI scanner. Correction of the artefact (Fig. 3d) after closing door of the scanner.

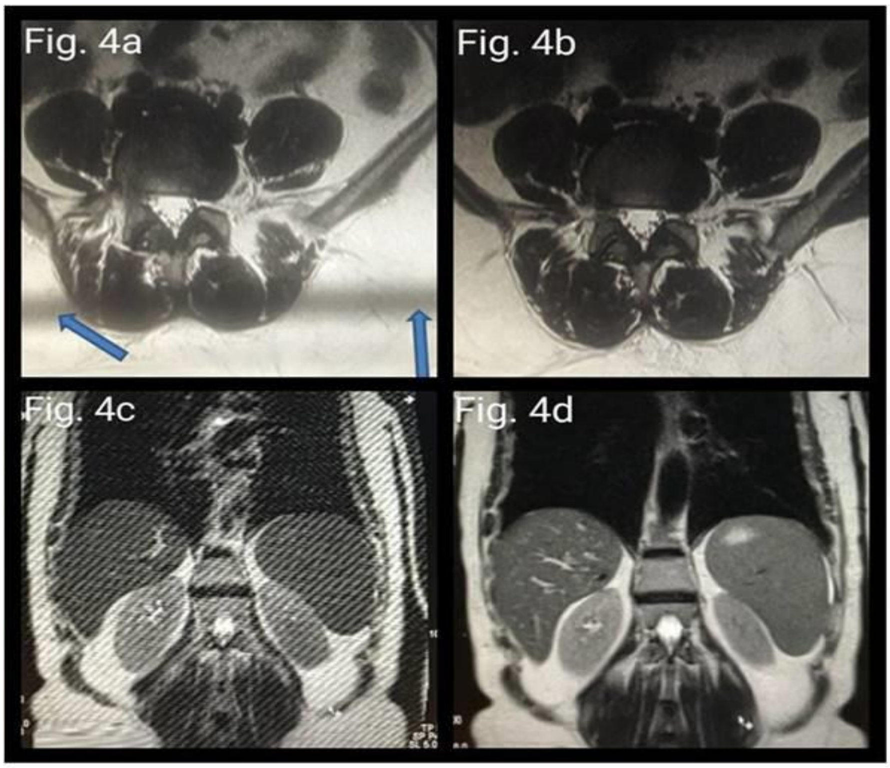

FIGURE 4. Cross talk artefact (Fig. 4a) seen as dark band (arrows) posterior to lumbar spine. The artefact was removed by using shallow angle to avoid intersection of adjacent slices (Fig. 4b). Herring bone artefact (Fig. 4c) seen as multiple transverse lines across chest and abdomen possibly due to fluctuating power supply. The artefact was corrected (Fig. 4d) by the service engineer.

Improper screening of patients before MRI examination by technologists was found to create the artefact in an image as patients retain some metallic objects within his /her garments or jewelry worn by them. Some bullet and pellet retained injuries referred for MRI investigations also create susceptibility artefacts. Some of the metallic artefacts were totally rectified after removing metallic objects from the scanned part [10] (**Figure - 1c, 1d**). In case of metallic implants where the artefact could not be removed fully, however, reduction of artefact was effected by changing some parameters such as using spin echo sequence, increasing band width, reducing TE, using thin slices and using high matrix field. The third commonest artefact observed was aliasing or wrap-around artefact seen in 13.9% (29) patients. This artefact was commonly found while imaging foot, ankle, abdomen and brain. The main reasons of occurrence of this artefact were smaller FOV than the body part imaged. Various remedies were employed to check this artefact like enlargement of FOV (**Figure - 3a, 3b)**. However, spatial resolution was compromised. Another easy method was switching off phase and frequency direction. If artefact was found in a sequence having phase direction anterior to posterior (AP), it was switched to left to right (L to R). Oversampling method was also used to eliminate this artefact with other parameters remaining constant, however, oversampling in phase encoding direction increased acquisition time proportionally. Additional method for reducing aliasing artefact includes using surface coils to diminish the amount of signal received from outside the region of interest. Use of pre-saturation bands was also employed when reducing of FOV was not possible to eliminate the artefact. Another artefact encountered in 12.9% (27) patients was zipper artefact which was observed in different types of MR studies such as MRI brain, MRCP, cardiac MR and MR spine imaging studies. This artefact was especially observed when RF entered the scanning room from the exogenously placed electronic equipment e.g. mobile phone devices or any other electronic device near the gantry room. The frequent cause of the artefact was observed when the door of the MR scan room was open during acquisition **(Figure - 3c, 3d)**. The outer RF entering the MR scanning room was being picked by imaging system. Some causes of zipper artefact were also noted due to hardware and software problems which were beyond the control of technologists and radiologists. To rectify this type of problem concerned engineer was called upon. Before any MR examination patients were advised to remove all metallic objects and were also searched by metallic detector so that no electronic gadget could enter into the scanning room with the patients or with the attendant. All the penetration panels where the cables entered the room were checked for any entry of RF from outer electronic sources. Crosstalk was another common artefact found in10.04% (21) patients and mostly occurred during lumbar spine imaging. We encountered this artefact frequently while obtaining axial slices of lumbar spine. The cause of this artefact was interference between adjacent slices of the scan. If the slice distance is too small, there is cross talk between the slices which can affect T1 contrast. Different remedies were employed to eliminate this artefact like using more shallow angles or removing overlapping region dorsally out of the anatomy of interest [11] (**Figure - 4a, 4b**). Chemical shift artefact was another MRI artefact observed in 7.2% (15) patients in different imaged parts, e.g. brain, pelvis and abdomen. This type of artefact was observed at places where there was close fat and water combination in area of interest to be imaged because protons in fat and water inherently precess at different frequencies in an applied magnetic field and the suppression between their resonance frequencies increases with increasing field strength. Since the resonance frequencies of fat and water are used to encode their spatial locations the chemical shift differences lead to spatial misregistration of the MR signal [12, 13]. This artefact was reduced or eliminated by using various methods such as by increasing receiver bandwidth sampling rates. We used fat suppression techniques to eliminate this artefact. Another alternative method to eliminate this artefact was to adjust the orientation of frequency encoding gradients. Decreasing of FOV was also good method to remove the artefact. Herring bone or crisscross artefact (**Figure - 4c, 4d**) was seen in 6.2% (13) patients while imaging various body parts like brain, liver and spine. Its appearance was observed as fabric of herring bone. The main causes of this artefact are electromagnetic spikes by gradient coils, fluctuating power supply and RF pulse discrepancies. This type of artefact was also beyond the ambit of technologist and radiologist for rectification. Only a service representative could rectify it when he was called upon. Moiré fringe artefact was observed in 5.3% (11) patients in different parts of body such as abdomen, shoulder, and pelvis. They appeared like pattern of roughly horizontal dark and light bands on the image. The various causes of this artefact include inhomogeneity of the main magnetic field caused by aliasing and interference echoes from different excitation modes (with different echo times). Some useful remedies were undertaken to eliminate this artefact such as spin-echo based techniques, use of surface coils and improving the shimming. After applying these remedial measures, the artefact was totally eliminated. Gibbs or truncation artefact was an uncommon artefact found only in 2.4% (5) patients in our study. It was mostly found in spine imaging. The cause of this artefact was found as under sampling of the data. The appearance of this artefact was observed as series of lines in the MR images parallel to abrupt intense changes in the object at that location [14]. Some measures were taken to reduce or remove this artefact like using smooth filters, increasing of acquisition matrix and use of fat saturation techniques. These methods greatly reduce this artefact, hence increasing imaging quality. Magic angle artefact was also uncommonly encountered, found only in 2.4%

(5) patients. This artefact was observed in MR knee studies. The appearance of this artefact was like bright spots in tissues with increased T2 time on short echo time (TE) images e.g. collagen fibers of tendons and ligaments, which are oriented at the magic angle of approximately 54.7° angle to the main magnetic field direction [15]. These artefacts were easily removed after lengthening of TE and altering of position of anatomy (tendons and ligaments should not be oriented at about 54.7°angle to the main magnetic field direction).

Conclusion

In conclusion, there are a plethora of MRI artefacts resulting from complex interaction of contemporary imager subsystems with the patient and the external environment. These could be broadly classified as image reconstruction–related, equipment-related and patient's physiology-related artefacts. Thorough understanding of the sources of these artefacts and mechanism of their production enables their prevention and rectification, resulting in optimization of MRI imaging. MRI technologists and radiologists should work in unison on MRI console during acquisition to minimize these artefacts. In nutshell, eyes see only what brain knows, thus eloquent understanding of these artefacts is a sine quo non for their prevention/ reduction and subsequent MR imaging optimization.

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