ORIGINAL ARTICLE

The Impact of View-Angle Tilting and Slice Encoding for Metal Artifact Correction Methods on the Metal Artifact Reduction in Magnetic Resonance Imaging of the Knee Prosthesis

Parisa Shahbazi [1], Behzad Yasrebi [*1], Cyrus Afshar [2], Siamak Haghipour [1], Razzagh Abedi-Firouzjah [3]

[1] *Department of Biomedical Engineering, Tabriz Branch, Islamic Azad University, Tabriz, Iran*

[2] *Orthopedic Surgeon, Valiasr Hospital, Tehran, Iran*

[3] *Department of Medical Physics Radiobiology and Radiation Protection, School of Medicine, Babol University of Medical Sciences, Babol, Iran*

*Corresponding Author: Behzad Yasrebi
Email: b_yasrebi@iaut.ac.ir

Received: 11 August 2021/ Accepted: 04 December 2021

Abstract

Purpose: At Magnetic Resonance Imaging (MRI), artifacts arising from metal implants are an obstacle to obtaining optimal images. This study aimed to evaluate the impact of View-Angle Tilting (VAT) and Slice Encoding for Metal Artifact Correction (SEMAC) techniques for the artifact reduction of patients during knee MRI with metal implants.

Materials and Methods: The MR images without any intervention of the knee from 20 patients with knee prostheses were used. The VAT and SEMAC metal artifact reduction techniques were applied to all the MR images. Volume and mass of the metal prosthesis were quantified using the MATLAB program and compared with the real measurements using nonparametric Wilcoxon tests in SPSS software. The qualitative analysis was performed by two blinded observers regarding the score of artifact size, distortions, image quality, and visualization of bone marrow and soft tissues adjacent to metal implants. In addition, Cohen's kappa values were used for inter-observer agreement.

Results: The average volume of the platinum based on the conventional, VAT, and SEMAC methods was estimated at 14.22 ± 0.43, 14.05 ± 0.4, and 13.3 ± 0.45 cm^3, respectively. The statistical analysis showed no significant difference ($P > 0.05$) between the mean value of the platinum volume for the SEMAC method and the real measurement (13.6 ± 0.33 cm^3). Furthermore, regarding the conventional, VAT, and SEMAC sequences, the mean mass of the platinum was obtained at 305.02 ± 9.22, 301.37 ± 8.58, and 285.28 ± 9.65 g, respectively, with the P-Value of 0.005, 0.009, and 0.268, compared to the real measurements (286.81 ± 8.75 g). Notably, the blinded readers demonstrated that the SEMAC method was remarkably superior quality compared with VAT and conventional acquisitions (P-Value< 0.05).

Conclusion: The knee prosthesis metal artifact was reduced using the VAT and SEMAC techniques, in a way that, the reduction was significant by the SEMAC method. In addition, concerning the qualitative observer analysis, the application of the SEMAC technique provides improved visualization of tissue structures adjacent to metal implants.

Keywords: Magnetic Resonance Imaging; View-Angle Tilting; Slice Encoding for Metal Artifact Correction; Knee Implants.

DOI: https://doi.org/10.18502/fbt.v9i4.10419

1. Introduction

The use of metal implants in orthopedic surgeries has been increased for patients having arthroplasty (joint replacement), improving severe joint conditions and arthritis, or patients with scoliosis [1]. Using knee prostheses can lead to complications such as infections, fractures, metallosis, and an increase of prosthetic debris in the peripheral soft tissues, which eventually leads to necrosis [2,3].

Although Computed Tomography (CT) can detect patterns of osteoporosis and osteolytic lesions, patients are exposed to a significant amount of ionizing radiation during this method. The other related problems for this imaging modality are poor soft-tissue contrast [4], low image quality in the presence of metal artifacts, and beam hardening effects [5]. Therefore, introducing a method for resolving the above-mentioned issues could be helpful. Magnetic Resonance Imaging (MRI), which provides excellent soft-tissue contrast, is one of the best diagnostic modalities for such complications [6]. However, it should be noted that metal implants cause inhomogeneity in the magnetic field [7,8] and disrupt the static (B_0) and dynamic (B_1) magnetic fields, causing areas of the signal void, image contrast changes, geometric distortions, and signal pile-ups [9]. There are several methods used to decrease the metal artifacts in MR imaging, such as Single-Point Imaging (SPI) [10], selecting Spin- Echo (SE) sequences instead of Gradient-Echo sequences (GRE), Short T1 Inversion Recovery (STIR) for fat suppression instead of spectral fat saturation [9], applying a large image matrix, and short-term echo projection reconstruction [11]. In addition, particular sequence strategies based on other crucial approaches have been effectively created, including View-Angle Tilting (VAT) [12] and Slice Encoding for Metal Artifact Correction (SEMAC) [9,13]. VAT applies a compensated slice select gradient during the signal readout to correct in-plane geometric distortions; however, it does not correct through-plane distortions. Since distortions related to metal artifacts during MRI are remarkable issues, a technique for reducing this problem could be necessary [9,14]. SEMAC technique is used to correct metal-induced artifacts through-plane distortions by applying additional z-phase encoding steps in the slice direction [13,14].

The purpose of the current study was to evaluate the efficacy of the VAT and SEMAC techniques to reduce knee metal artifacts compared to the conventional imaging protocols. The results of the present study can clarify the value of MR images of platinum-containing implants with different imaging techniques for clinical practice.

2. Materials and Methods

2.1. Patients

In the present analytical-observational study, the methods have been approved by the National Ethics Committee (approved ID: 10240111972031). Twenty patients (age range 55-75 years) with knee prostheses (Freeman-Swanson) were selected randomly, and the MR images were examined. Notably, the knees imaging process was performed for clinical purposes, rather than for research investigation. The images were qualitatively investigated by two experienced reviewers.

2.2. MR Imaging

The MR imaging procedures were performed by a Siemens Avanto MRI system (Siemens Healthineers, Germany) with the magnetic field power of 1.5 Tesla along with Syngo computer software (Siemens Healthineers, Germany) to process the data and image reconstruction. In MRI, three imaging techniques were carried out for the

Table 1. The parameters related to conventional Magnetic Resonance (MR) imaging, View- Angle Tilting (VAT) and Slice Encoding for Metal Artifact Correction (SEMAC) techniques

Parameter	Conventional			VAT	SEMAC
	T1 weighted	T2 weighted	STIR weighted		
# of slices	16	16	16	19	19
Slice thickness [mm]	3	3	3	3	3
Echo Time (TE) [ms]	10	70	25	83	93
Repetition Time (TR) [ms]	900	3500	4000	2570	4500
Readout bandwidth [Hz/Px]	120	120	120	625	630
FOV [mm- in x,y directions]	181.6 ± 12.2	179.6 ± 8.1	175.5 ± 9.9	186.6 ± 7.3	183.4 ± 11.7
Matrix size (resolution)	256 × 256	256 × 256	256 × 256	256 × 256	256 × 256

patients; conventional MR imaging, VAT, and SEMAC techniques. In Table 1, the parameters related to these techniques have been depicted for the studied patients.

2.3. Knee Implant Volume and Mass Calculation Using MATLAB Software

The implant volumes in the MRI images were determined using the isoline (contour line) method. A detailed description of this method could be found in Arsat *et al.*'s study [15]. This procedure was accomplished on the MRI images of the knee, which included a higher contrast of metal prostheses. Using the afore-mentioned method, the contours of the implant were separated from the original image and the number of enclosed pixels in each slice was counted and multiplied by the pixel dimensions, and finally, the volume of the contoured implant was calculated. The platinum mass of the implant was estimated by multiplying the volume of the platinum part with the density of the platinum (21.45 g/cm^3).

2.4. Qualitative Analysis

Two experienced reviewers, one radiologist and one orthopaedist, have assessed the quality of the images. The MRI images obtained from the three techniques (conventional, VAT, and SEMAC) were shown side by side on the screen in a random order. To quantify a subjective impression of image quality, the images for each method were retrospectively reviewed by the observers who were unaware of the protocol settings. For each structure (Table 2), the reviewers have then scored the quality of the images from 1 to 4.

2.5. Statistical Analysis

The volume and mass of the artifacts related to the knee prosthesis were quantified and compared using nonparametric Wilcoxon tests using SPSS software (v.22, SPSS Inc., Chicago, IL). Cohen's kappa statistic (K-value) was used to determine the inter-observer agreement in the qualitative analysis. The K-value was read by the following standard criteria: $K \leq 0.4$ low agreement, $0.4 < K \leq 0.7$ moderate, and $0.7 < K \leq 1$ strong agreement. The 95% confidence level was considered as the level of statistical significance of the results.

3. Results

The prosthesis volume on MRI images with a MATLAB program determined that the average calculated volume based on the conventional, VAT, and SEMAC techniques were 14.22 ± 0.43, 14.05 ± 0.4, and 13.3 ± 0.45 cm^3, respectively. These volumes were significantly higher than the real prosthesis volume (13.6 ± 0.33 cm^3), except for the values obtained from the SEMAC technique (Table 3). Notably, the calculated prosthesis volume with the SEMAC method had a significant difference compared to the other two methods (P-Value < 0.05).

Table 2. Average mass and volume in conventional, VAT, and SEMAC methods. The P-Values have been calculated between the real measurements compared to the conventional, VAT, and SEMAC imaging techniques

Techniques	Conventional	VAT	SEMAC
Average volume (cm^3)	14.22 ± 0.43 (13.57-14.72)	14.05 ± 0.4 (13.43-14.45)	13.3 ± 0.45 (12.68-13.89)
P-Value	0.05	0.05	0.32
Average mass (g)	305.02 ± 9.22 (289.31-315.1)	301.37 ± 8.58 (288.21-310.01)	285.28 ± 9.65 (272.11-298.02)
P-Value	0.005	0.009	0.268

Table 3. Questions and answers for scoring the image quality regarding the artifact size, image quality, distortion and the ability to visualize tissue structures

Question	Answer
Score with respect to the size of the metal artifact	1= least, 4 = most 1, 2, 3, 4
Score with respect to overall image quality	1= best, 4 = worst 1, 2, 3, 4
Score with respect to distortion of normal structures adjacent to the metal artifact	1= least, 4 = most 1, 2, 3, 4
Score with respect to the ability to visualize the bone marrow, bone cortex and soft tissues surrounding it, in particular, adjacent to the metal implant	1= best, 4 = worst 1, 2, 3, 4

In addition, the average calculated mass of the platinum regarding the conventional MR imaging was obtained 305.02 ± 9.22 g, which was significantly higher than the real measurements, 286.81 ± 8.75 g (P-Value < 0.05). The mass value based on the VAT imaging was obtained at 301.37 ± 8.58 g, which also has a significant variation in comparison with the real measurement (Table 3). The average calculated mass of the platinum using the SEMAC method was 285.28 ± 9.65 g, which was a not significant variation with the real measurement (P-Value > 0.05). The difference in the mean mass between the SEMAC imaging compared to conventional and VAT methods was equal to 19.74 and 16.09 g, respectively. The detail of the average calculated mass and volume in the three investigated methods, and also the P-Value between the real measurements with the above-mentioned imaging techniques have been depicted in Table 3.

Figures 1 and 2 show the samples of conventional MRI, VAT, and SEMAC images (3 consecutive slices) of the knee prosthesis in sagittal and coronal views, respectively. It is obvious that the clutter in VAT imaging is lower than the conventional image reconstruction technique. Furthermore, the metal artifact was approximately eliminated for the SEMAC technique, and also the image distortion decreased remarkably in this method.

The results of the recorded scores regarding the answers to the questions in Table 2 based on the artifact size, image quality, distortion, and the ability to visualize tissue structures are presented in Figure 3. Notably, according to Table 2, a score equal to 1 is considered as the best performance. The lowest size of metal artifacts was allocated to the SEMAC technique with a mean score (and Standard Deviation) of 1.1 (SD = 0.2). In the second level, the VAT technique with the score of 1.8 (SD = 0.3) had a higher size of metal artifacts compared to the SEMAC, but a lower size compared to the conventional technique with the score of 2.8 (SD = 0.4). The amount of distortion of adjacent normal structures was 1.4 (SD = 0.1), 2.1 (SD = 0.5), and 3.2 (SD = 0.5), for the SEMAC, VAT, and conventional MR techniques, respectively, showing better performance of the SEMAC. The SEMAC technique also showed a better ability to visualize the different types of tissues with the mean score of 1 (SD = 0), and the VAT and conventional MR techniques were scored to 1.7 (SD = 0.4), and 3.0 (SD = 0.7), respectively. A similar trend was observed for overall image quality in which SEMAC had the best performance (1.5, SD = 0.2), and conventional MR technique (2.9, SD = 0.6) showed the worst result. Furthermore, in reference to the questions of overall image quality, and visualization of bone marrow and soft tissue adjacent to metal implants, the two reviewers ranked all the techniques from the best to worst as follow: SEMAC, VAT, and conventional MR images (K = 1; P-Value < 0.001). The inter-observer agreement K-values showed that the reviewers had a strong agreement with each other (K = 0.85; P-Value < 0.001).

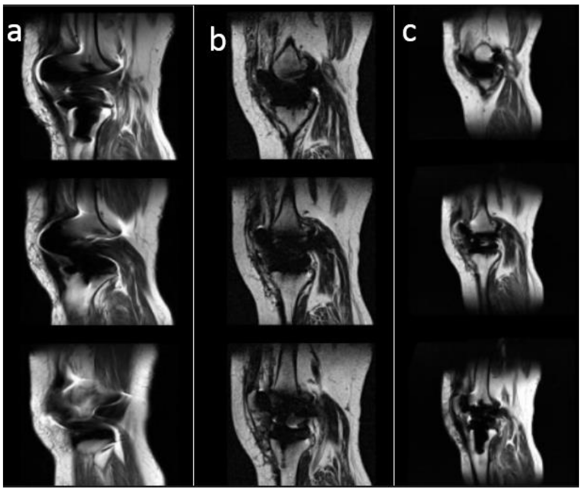

Figure 1. Sample of Magnetic Resonance Imaging (MRI) images in sagittal view in (a) conventional MRI, (b) View- Angle Tilting (VAT), (c) and Slice Encoding for Metal Artifact Correction (SEMAC) methods

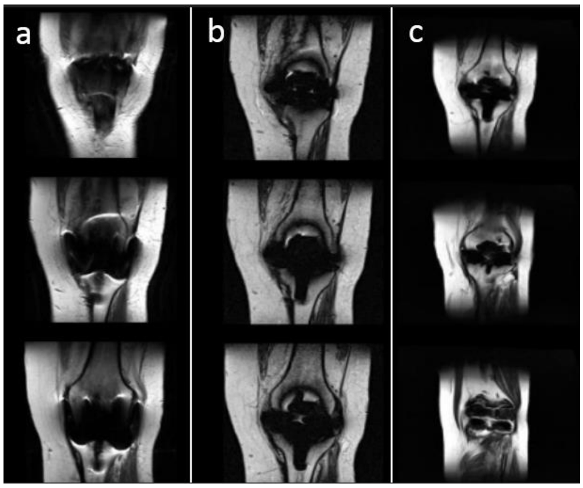

Figure 2. Sample of MRI images in coronal view in (a) conventional MRI, (b) VAT, (c) and SEMAC methods

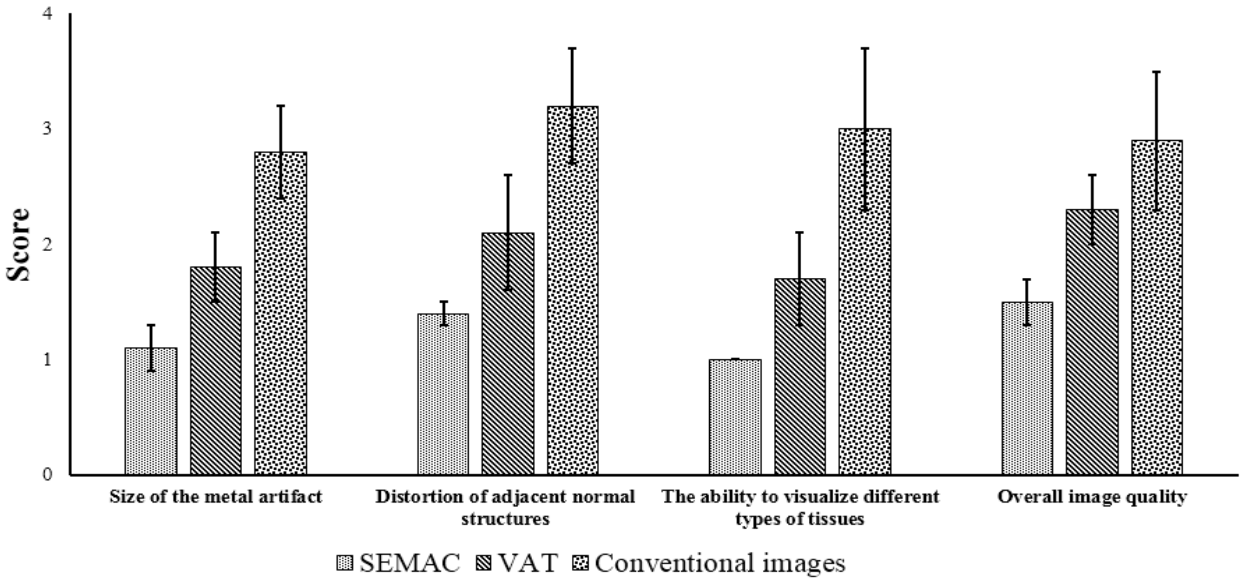

Figure 3. The results of the recorded scores regarding the answers to the questions of Table 2 for the artifact size, image quality, distortion, and the ability to visualize tissue structures

4. Discussion

In general, CT and MRI imaging are more sensitive in depicting periprosthetic osteolysis compared to routine radiography, in a way that, MRI is the most accurate modality for the detection of these lesions [16–18]. Displacement artifacts can cause signal loss which is also occurred by spin dephasing due to the large resonance frequency variations of the magnetic field [19,20]. Since in 3D imaging a slice selection gradient is absent, metal artifacts would increase compared to 2D imaging, for this reason, 2D imaging techniques are used for evaluating patients with metal implants generally [9].

Knee implant is the most commonly replaced joint [21], which increases the distribution of the main magnetic field around postoperative joints. MRI is one of the main modalities in which its images are used for treatment planning in the radiotherapy of cancer patients [22, 23]. Therefore, any artifacts from the metal implant can cause a problem for the planning of tumors during radiotherapy [24]. In other words, metal prostheses with high density and atomic numbers cause major changes in scattering and attenuation of radiation which affect the radiotherapy dose distribution. Hence, any methods to decrease the metal artifact can be a crucial subject. Thus, in the current study, we assessed the impact of susceptibility artifact reduction using VAT and SEMAC MRI sequences of the knee implants. It should be noted that the novelty of the current study is to evaluate both image quality and metal artifact reduction using the SEMAC and VAT techniques based on the reviewer evaluations. In addition, following our search, this is the first study evaluating the artifacts of Freeman-Swanson knee prostheses in MRI technique.

The findings demonstrated that the increasing the platinum volume and mass in the SEMAC images was not significant compared to the real values which mean the SEMAC technique had not any image distortion. In addition, the average calculated mass and volume in the SEMAC technique were significantly lower than those of conventional and VAT techniques (P-Value < 0.05), showing the higher ability of SEMAC in the metal artifact reduction. In accordance with the results of the current study, several studies are reporting the superiority of the SEMAC compared to conventional and VAT techniques in MR imaging of metal implants like the orthopedic or simple steel rod implants [10, 17, 22]. For instance, Ai *et al.* [9] evaluated the ability of four MRI metal artifact reduction techniques to correct the stainless steel implants artifacts in phantom and patients. Three 2D techniques (VAT, SEMAC, and SEMAC-VAT) were assessed in their study. The methods involving SEMAC, especially SEMAC encoding with VAT (SEMAC-VAT), had a remarkably higher reduction of metal artifacts with higher image quality. In another study by Chen *et al.* [14], two MRI techniques, including SEMAC and Multi-acquisition Variable-Resonance Image Combination (MAVRIC) were evaluated to correct knee implant artifacts in comparison with conventional imaging. They have declared that SEMAC and MAVRIC reduced artifact significantly in comparison to conventional imaging; however, these two techniques did not show significant differences from each other. Reichert *et al.* [25] investigated metal artifact reduction in MRI (1.5 and 3 T) using VAT, SEMAC-VAT, and conventional sequences.

They have found that SEMAC-VAT significantly reduced metal artifacts (83 ± 9%) for the screw and also for the plate (89 ± 3%) at 1.5 T compared to the conventional sequence. This decrease was 72 ± 7% and 38 ± 13% for the screw and plate at 3.0 T, respectively.

Furthermore, several studies evaluated the various sequences at the other organs like the spine and auditory implants. For instance, Park *et al.* [6] compared the SEMAC-VAT sequence and conventional MR sequence regarding image quality, visibility of periprosthetic structures, and diagnostic confidence in patients who underwent pedicle screw fixation (between the thoracic vertebrae and the sacrum). They have expressed that although the SEMAC-VAT significantly reduced metal artifact, conventional images are better for spinal canal evaluation. In line with this study, our findings also showed good results corresponding to the SEMAC method, however, it is important to understand the advantages and disadvantages of SEMAC and to use it properly. Also, in a study by Wimmer *et al.* [26], they have assessed the clinical usefulness of SEMAC-VAT WARP as an MRI sequence for metal artifact suppression for patients with transcutaneous bone conduction implants. Their results demonstrated that the SEMAC-VAT WARP sequence significantly improved the diagnostic usefulness of the post-implantation MRIs. In addition, imaging of intracranial and supra- and infra-tentorial brain pathologies is clinically more valuable than standard diagnostic MRI sequences.

The artifacts in the MR images may produce at the image plane (In-Plane artifacts or IP artifacts) or in adjacent planes (Through-Plane artifacts or TP artifacts). VAT technique can decrease the IP artifacts, but it has no effect on the TP distortions, however, the SEMAC technique reduces both IP and TP artifacts. In addition, SEMAC is based on a 2D VAT- SE sequence and it can resolve distorted excitation profiles of each slice by selecting additional z-phase encoding steps in the slice-selection direction. On the other hand, the blurring in the VAT method particularly resulted from additional slice profile modulation (low-pass filtering effect) [27]. These differences between the SEMAC and VAT methods may be the reason for the superiority of the SEMAC technique regarding metal artifact reduction.

There are several limitations in the current study. In this study, all the conventional image sequences did not involve and we just used the SE T1, T2, and STIR weighted images, due to their higher image quality and applications in clinical practice. Furthermore, blurring was not quantitated in this study as a parameter of image quality. Therefore, for future study, it is suggested to compare different implant types and MRI sequences with the higher number of patients. Furthermore, assessment of blur and optimization of sequence parameters relative to this measure represent possible future research.

5. Conclusion

The present study demonstrated that the use of the SEMAC imaging techniques and to some extent VAT technique can greatly help to reduce the MR imaging artifact due to the knee metal implant. Additionally, the qualitative observer-based analysis indicated that the application of the SEMAC technique provides improved visualization of tissue structures adjacent to metal implants.

Acknowledgments

This study has been supported by the research dissertation of master in Medical Engineering of Islamic Azad University, Tabriz Branch with the ethical code number of [10240111972031]. We would like to thank the staff of Valiasr Hospital (Tehran, Iran) for their sincere cooperation.

References

1- L Rony, R Lancigu, and L Hubert, "Intraosseous metal implants in orthopedics: a review." *Morphologie,* Vol. 102 (No. 339), pp. 231-42, (2018).

2- Shakti Condil Sharma, "Assessment of Cases of Total Knee Arthroplasty and Their Outcome-A Clinical Study." (2019). https://pesquisa.bvsalud.org/portal/resource/pt/sea-189153".

3- Ismail Sahan and Konstantinos Anagnostakos, "Metallosis after knee replacement: a review." *Archives of orthopaedic and trauma surgery,* Vol. 140 (No. 11), pp. 1791-808, (2020).

4- Fatemeh Bakhtiari-Asl, Baharak Divband, Asghar Mesbahi, and Nahideh Gharehaghaji, "Bimodal magnetic resonance imaging-computed tomography nanoprobes: A Review." *Nanomedicine Journal,* Vol. 7 (No. 1), pp. 1-12, (2020).

5- Jin Hur, Dongjoon Kim, Yeong-Gil Shin, and Ho Lee, "Metal artifact reduction method based on a constrained beam-hardening estimator for polychromatic x-ray CT." *Physics in Medicine & Biology,* Vol. 66 (No. 6), p. 065025, (2021).

6- Chankue Park *et al.*, "Spine MR images in patients with pedicle screw fixation: comparison of conventional and SEMAC-VAT sequences at 1.5 T." *Magnetic Resonance Imaging,* Vol. 54pp. 63-70, (2018).

7- Kevin M Koch, John E Lorbiecki, R Scott Hinks, and Kevin F King, "A multispectral three-dimensional acquisition technique for imaging near metal implants." *Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine,* Vol. 61 (No. 2), pp. 381-90, (2009).

8- KM Koch, BA Hargreaves, K Butts Pauly, W Chen, GE Gold, and KF King, "Magnetic resonance imaging near metal implants." *Journal of Magnetic Resonance Imaging,* Vol. 32 (No. 4), pp. 773-87, (2010).

9- Tao Ai *et al.*, "SEMAC-VAT and MSVAT-SPACE sequence strategies for metal artifact reduction in 1.5 T magnetic resonance imaging." *Investigative radiology,* Vol. 47 (No. 5), pp. 267-76, (2012).

10- Rodolfo Reda, Alessio Zanza, Alessandro Mazzoni, Andrea Cicconetti, Luca Testarelli, and Dario Di Nardo, "An update of the possible applications of magnetic resonance imaging (MRI) in dentistry: a literature review." *Journal of imaging,* Vol. 7 (No. 5), p. 75, (2021).

11- Djaudat Idiyatullin, Curt Corum, Jang-Yeon Park, and Michael Garwood, "Fast and quiet MRI using a swept radiofrequency." *Journal of magnetic resonance,* Vol. 181 (No. 2), pp. 342-49, (2006).

12- Kim Butts, John M Pauly, and Garry E Gold, "Reduction of blurring in view angle tilting MRI." *Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine,* Vol. 53 (No. 2), pp. 418-24, (2005).

13- Wenmiao Lu, Kim Butts Pauly, Garry E Gold, John M Pauly, and Brian A Hargreaves, "SEMAC: slice encoding for metal artifact correction in MRI." *Magnetic Resonance in Medicine: An Official Journal of the International Society for Magnetic Resonance in Medicine,* Vol. 62 (No. 1), pp. 66-76, (2009).

14- Christina A Chen *et al.*, "New MR imaging methods for metallic implants in the knee: artifact correction and clinical impact." *Journal of Magnetic Resonance Imaging,* Vol. 33 (No. 5), pp. 1121-27, (2011).

15- Zainal Abidin Arsat, A Halim Kadarman, Amran Ahmed Shokri, Mohd Ezane Aziz, and Solehuddin Shuib, "Magnetic resonance imaging sequence analysis of tibiofemoral contact area assisted by Matlab software." *Jurnal Teknologi,* Vol. 76 (No. 7), (2015).

16- Tim A Walde *et al.*, "Comparison of CT, MRI, and radiographs in assessing pelvic osteolysis: a cadaveric study." *Clinical Orthopaedics and Related Research (1976-2007),* Vol. 437pp. 138-44, (2005).

17- Femke F Schröder, Corine E Post, Frank-Christiaan BM Wagenaar, Nico Verdonschot, and Rianne MHA Huis in't Veld, "MRI as diagnostic modality for analyzing the problematic knee Arthroplasty: a systematic review." *Journal of Magnetic Resonance Imaging,* Vol. 51 (No. 2), pp. 446-58, (2020).

18- Julien Galley, Reto Sutter, Christoph Stern, Lukas Filli, Stefan Rahm, and Christian WA Pfirrmann, "Diagnosis of periprosthetic hip joint infection using MRI with metal artifact reduction at 1.5 T." *Radiology,* Vol. 296 (No. 1), pp. 98-108, (2020).

19- Brian Hargreaves, Pauline W Worters, Kim Butts Pauly, John M Pauly, Kevin M Koch, and Garry E Gold, "Metal induced artifacts in MRI." *AJR. American journal of roentgenology,* Vol. 197 (No. 3), p. 547, (2011).

20- Tim Hilgenfeld *et al.*, "Protocol for the evaluation of MRI artifacts caused by metal implants to assess the suitability of implants and the vulnerability of pulse sequences." *JoVE (Journal of Visualized Experiments),* (No. 135), p. e57394, (2018).

21- Reto Sutter, Erika J Ulbrich, Vladimir Jellus, Mathias Nittka, and Christian WA Pfirrmann, "Reduction of metal artifacts in patients with total hip arthroplasty with slice-encoding metal artifact correction and view-angle tilting MR imaging." *Radiology,* Vol. 265 (No. 1), pp. 204-14, (2012).

22- Doenja MJ Lambregts, Thierry N Boellaard, and Regina GH Beets-Tan, "Response evaluation after neoadjuvant treatment for rectal cancer using modern MR imaging: a pictorial review." *Insights into imaging,* Vol. 10 (No. 1), pp. 1-14, (2019).

23- Yanzi Wan *et al.*, "The value of detailed MR imaging report of primary tumor and lymph nodes on prognostic nomograms for nasopharyngeal carcinoma after intensity-modulated radiotherapy." *Radiotherapy and Oncology,* Vol. 131pp. 35-44, (2019).

24- F Seif, S Hamidi, and S Bagheri, "Investigating the Impact of Knee Prosthesis in Patients' Body on Radiation Dose Distribution: A Monte Carlo Approach." *Journal of Biomedical Physics & Engineering,* Vol. 9 (No. 3), p. 345, (2019).

25- M Reichert, T Ai, JN Morelli, M Nittka, U Attenberger, and VM Runge, "Metal artefact reduction in MRI at both 1.5 and 3.0 T using slice encoding for metal artefact correction and view angle tilting." *The British journal of radiology,* Vol. 88 (No. 1048), p. 20140601, (2015).

26- Wilhelm Wimmer *et al.*, "MRI metal artifact reduction sequence for auditory implants: first results with a transcutaneous bone conduction implant." *Audiology and Neurotology*, Vol. 24 (No. 2), pp. 56-64, (2019).

27- Kwan-Jin Jung and Chan-Hong Moon, "Effect of slice angle on inhomogeneity artifact and its correction in slice-selective MR imaging." *Concepts in Magnetic Resonance Part A: An Educational Journal*, Vol. 34 (No. 4), pp. 238-48, (2009).