ORIGINAL RESEARCH

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The Effect of MAR Technique on Image Quality of the Anorectal Region in Pelvic CT in Patients with Metallic Hip Prostheses

Metalik Kalça Protezli Hastalarda Pelvik BT'de MAR Tekniğinin Anorektal Bölgenin Görüntü Kalitesine Etkisi

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Abstract

Objective: In this study, we aimed to compare the effects of using the iterative reconstruction (IR) method alone and together with metallic artifact reduction (MAR) on the image quality in computed tomography (CT) imaging of the anorectal region in patients with a metallic hip prosthesis, and to evaluate the contribution of IR+MAR approach to radiological evaluation.

Method: In 22 patients carrying hip prosthesis, as subjective criteria, the degree of metal artifact visualization and critical anatomical structures as the anal canal (AC), inferior rectum (InR), mesorectum (MsR), perianal fat tissue (PFT), and levator ani muscle (LAM) were evaluated in the images of pelvic CT with IR and MAR reconstructions, using only IR technique and IR+MAR approach. As objective criteria, most pronounced hypodense artifacts obscuring the pelvic soft tissue and hyperdense artifacts were measured in the images with MAR and without MAR technique.

Results: It was found that the use of the MAR technique for common metal artifacts observed after CT imaging significantly increased the diagnostic value on AC, InR, MsR, PFT, and LAM radiologically. It was determined that the method provided a significant increase in the visualization of the pelvic bone and muscle tissues and the quality of diagnosis. The differences between hypodense artifact measurements and hyperdense artifact measurements were statistically significant.

Conclusion: Performing IR+MAR reconstruction on pelvic CT in patients with a metallic hip prosthesis improves image quality and the diagnostic value of CT. It can be used in the imaging of anorectal pathologies in patients who cannot undergo magnetic resonance imaging.

Keywords: Anorectal pathologies, hip prosthesis, iterative reconstruction, MAR technique

Öz

Amaç: Bu çalışmada metalik kalça protezi olan hastalarda anorektal bölgenin bilgisayarlı tomografi (BT) görüntülemesinde yinelemeli rekonstrüksiyon (IR) yönteminin tek başına ve metalik artefakt azaltma (MAR) ile kullanılmasının görüntü kalitesi üzerindeki etkilerini karşılaştırmayı ve IR+MAR yaklaşımının radyolojik değerlendirmeye katkısını değerlendirmeyi amaçladık.

Yöntem: Kalça protezi taşıyan 22 hastada, sübjektif kriterler olarak metal artefakt görselleştirme derecesi ve anal kanal (AK), alt rektum (InR), mezorektum (MsR), perianal yağ dokusu (PFT) ve levator ani kası (LAM) gibi kritik anatomik yapılar, sadece IR tekniği ve IR+MAR yaklaşımı kullanılarak IR ve MAR rekonstrüksiyonları ile pelvik BT görüntüleri değerlendirildi. Objektif kriterler olarak, MAR tekniği ve MAR tekniği uygulanmayan görüntülerde pelvik yumuşak dokuyu kapatan en belirgin hipodens artefaktlar ve hiperdens artefaktlar ölçüldü.

Bulgular: BT görüntüleme sonrası gözlenen yaygın metal artefaktları için MAR tekniğinin kullanılmasının radyolojik olarak AC, InR, MsR, PFT ve LAM'de tanısal değeri önemli ölçüde artırdığı bulundu. Yöntemin pelvik kemik ve kas dokularının görüntülenmesinde ve tanı kalitesinde belirgin bir artış sağladığı belirlendi. Hipodens artefakt ölçümleri ile hiperdens artefakt ölçümleri arasındaki farklar istatistiksel olarak anlamlıydı.

Sonuç: Metalik kalça protezi olan hastalarda pelvik BT'de IR+MAR rekonstrüksiyonu yapılması görüntü kalitesini ve BT'nin tanısal değerini iyileştirmektedir. Manyetik rezonans görüntüleme yapamayan hastalarda anorektal patolojilerin görüntülenmesinde kullanılabilir.

Anahtar kelimeler: Anorektal patolojiler, iteratif rekonstrüksiyon, kalça protezi, MAR tekniği

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Introduction

Many radiological methods are used in the evaluation of soft tissue pathologies located in the pelvic region. For this purpose, the use of pelvic magnetic resonance imaging (MRI) becomes more widespread (1-3). The superiority of pelvic MRI in the evaluation of malignant and non-malignant diseases of rectal, perirectal, and perianal regions has been demonstrated in many studies (1,2). However, some factors such as claustrophobia, pacemaker, and eye prosthesis may be present in patients, which limits MRI scanning (4). Therefore, other radiological methods are preferred. Computed tomography (CT) is recommended as the other non-invasive and most frequently used radiological method in these patients (5). The presence of hip and femoral head prostheses, the use of which is increasing day by day, especially in the elderly population, makes it almost impossible to evaluate the pelvic region. The presence of metal artifacts in standard CT scans also limits the evaluation of organs and soft tissues in the pelvic region and may cause existing pathologies to be overlooked. Different methods have been tried to improve these images and reduce possible artifacts. Metal artifact reduction techniques (MAR), which have been used in recent years, stand out as the most effective method (6). In this study, we aimed to investigate the effectiveness of the IR+MAR technique compared to the use of IR alone in eliminating the image disorders arising from the artifacts caused by a metal prosthesis in CT scans in patients with hip implants.

Materials and Methods

Formal Aspects

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was granted by the Local Ethics Committee (date: 05.04.2021/no: 2021/04-653). Informed consent was obtained from all individual participants included in the study.

Patients

We retrospectively reviewed our PACS database for medical records from May 2020 to April 2021. Patients who met the inclusion criteria were those who were scanned with a pelvic CT, having uni or bilateral hip prostheses. We evaluated the metal artifact reduction technique in patients without contrast alone. IV, oral, and rectal contrast used patients were excluded so that the study could be performed in a homogeneous group.

CT Examination Protocol

All patients underwent a pelvic CT without contrast medium, using a 160 mm, 3rd generation MDCT scanner (Revolution CT, GE Healthcare, Milwaukee, WI, USA). Pelvic CT scanning mode had the following parameters: tube voltages were 120 kV; Assist mode, 80-120; tube current, SmartmA mode 100-400 mA; detector width, 80 mm; helical pitch, 0.992:1; rotation time, 0.60s; slice thickness, 1.5 mm and slice interval, 1.5 mm. CT reconstructions were made by using 40% adaptive statistical iterative reconstruction (ASIR) alone and with both smart metal artifact reduction (SMAR) algorithm and 40% ASIR.

Image Reconstruction and Analysis

CT images were reconstructed by using ASIR and prototype SMAR algorithm (abdominal parameters). SMAR was performed by using a vendor-specified ''ABDOMEN'' setting, which entails predetermined SMAR reconstruction parameters appropriate for pelvic anatomy and hardware.

Each study was evaluated by viewing ASIR and SMAR with ASIR images side-by-side, with soft tissue settings [400 Hounsfield units (HU) window width and 40 HU window level]. Images were only evaluated in the axial plane without multiplanar reformations. After reconstructions, images were loaded onto Advantage Windows Workstation 4.7 (GE Healthcare, Milwaukee, Wisconsin/USA) for viewing.

Subjective Evaluation Criteria and Image Analysis

Qualitative image analyses and evaluations were performed in consensus by two radiologists with 16 years and 10 years of experience. In the first session, they graded the degree of metal artifacts and visualization of critical anatomical structures in images reconstructed with ASIR and SMAR and with ASIR alone. As the study was limited to the hip prosthesis in the pelvic region, critical anatomical structures were defined as the anal canal (AC), inferior rectum (InR), mesorectum (MsR), perirectal fat tissue (PFT), and elevator ani muscle (LAM) (7,8). Two radiologists concurrently evaluated the image quality of critical anatomical structures using a 5-point image quality scale for soft tissue (400/40 HU) on ASIR reconstructed and SMAR with ASIR reconstructed CT images. The scale was rated as follows (9,10): 1) Severe artifacts with the invisibility of surrounding structures, 2) Obvious artifacts with significant distortion and insufficient identification of surrounding structures, 3) Moderate artifacts that allow identification of surrounding structures, 4) Mild artifacts with the blurring of surrounding structures, 5) No artifacts. A total of 12 separate scorings was made by assessing the

soft tissue window settings for the ASIR images and SMAR with ASIR images of critical anatomical structures.

Objective Image Analysis

Quantitative analyses were performed according to previous studies (10-12). Regions of interest (ROI) were placed in the same axial slice close to the metal implant, medially in the most pronounced hypodense artifacts obscuring the pelvic soft tissue, laterally in the most pronounced hyperdense artifacts. Furthermore, ROIs were placed in the acetabulum, the gluteus maximus muscle, subcutaneous fat, not affected by the artifacts, as well as in the urine-filled bladder. ROIs were placed in the soft tissue window [width: 400 Hounsfield Units (HU), level: 40 HU]. The sizes of ROIs were only adjusted to prevent the inclusion of tissues not affected by the artifacts. The mean attenuation values [± standard deviations (SD)] of these structures were recorded. The SD of the CT number (expressed in HU) was used to measure image noise (Figure 1).

Statistical Analysis

The Wilcoxon signed-rank test was performed by comparing the categorical scores provided by the radiologists for the degree of visualization of metal artifacts and critical anatomical structures as AC, InR, MsR, PFT, and LAM, using ASIR and SMAR with ASIR in soft-tissue images, depending on the image quality and the ability to evaluate. Paired t-test was used to compare noise, hypodense, and hyperdense artifacts on ASIR and SMAR images with ASIR images, as the data were normally distributed (SPSS 13.0, SPSS Inc., Chicago, IL). For all comparisons, statistical significance was defined as $p<0.05$.

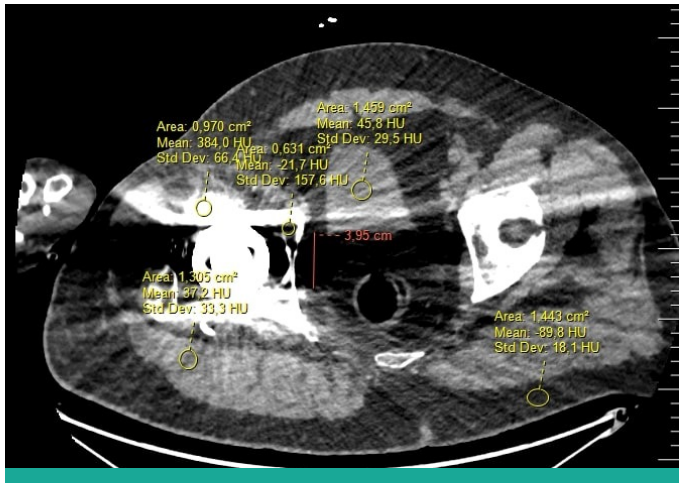

Figure 1. Quantitative assessment of image quality, regions of interest (ROI) were placed on soft tissue window (width 400, length 40). Furthermore, ROI was placed close to metal prosthesis, superiorly in the most pronounced hyperdense artifact. Additionally, ROIs were placed in the subcutaneous adipose tissue, adjacent bone (acetabulum), muscle (gluteus maximus muscle), and the urine filled bladder. The width of most pronounced hypodense artifact was measured

Results

A total of 22 patients, including 10 female and 12 male, met the inclusion criteria (mean patient age=66 years; range=26-93 years). Of these patients, 20 had unilateral hip prostheses (13 left prostheses and 7 right prostheses) and 2 had a bilateral hip prosthesis. This study was carried out completely retrospectively on the films of patients with metallic hip prostheses, who had pelvic CT for other indications (Figure 2 a, 2 b). No CT scan was performed on

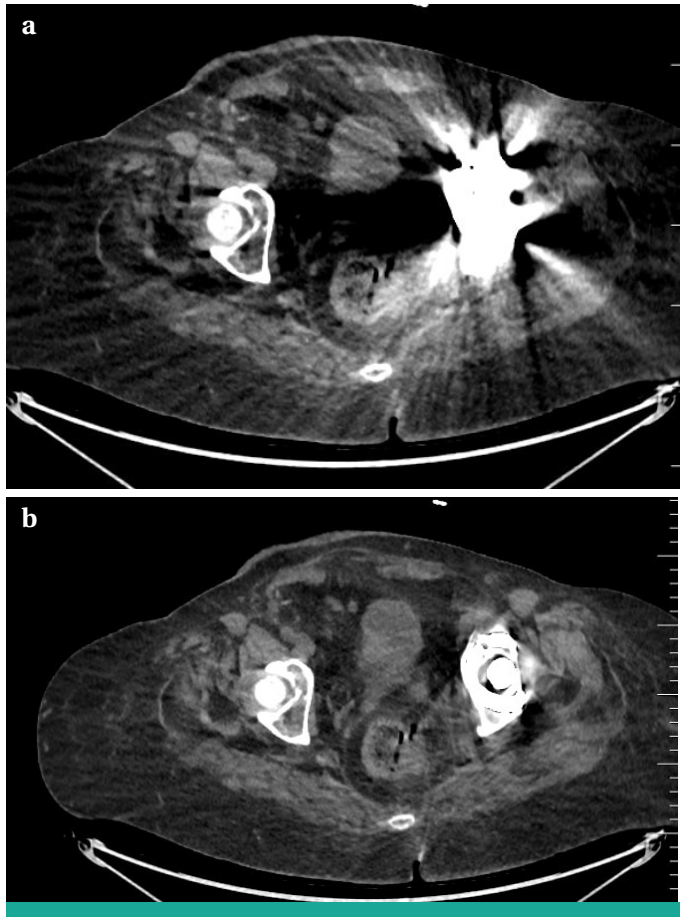

Figure 2. Forty-five-year-old man with trauma, who was checked for abdominal and pelvic hematoma. a) Axial computed tomography (CT) image reconstructed with iterative reconstruction (IR) technique (ASIR, General Electric Healthcare) without iterative metal artifact reduction shows wide beam hardening artifacts accompanied by low-attenuation and high-attenuation streak artifacts that obscure pelvic structures. b) Axial CT image reconstructed with both IR technique and smart metal artifact reduction technique (SMAR, General Electric Healthcare) are reduced. Pelvic regions were better visualized

the patients for the study. The indications for CT included the evaluation of trauma (n=10), bone metastasis (n=4), urinary system calculi (n=3), acute appendicitis (n=3), acute diverticulitis (n=1), and spontaneous rectus sheath hematoma (n=1) (Table 1).

In IR and IR+SMAR images, the scores of critical anatomical structures and metal artifact visualization degrees (as median, minimum, and maximum) for subjective evaluation are given in Table 2. Soft tissue visualization scores (median) of critical anatomical structures were 4 and 4 for AC (Z=-3.557, p<0.001), 3 and 4 for InR (Z=-3.666, p<0.001), 3 and 5 for MsR (Z=-3.482, p<0.001), 3 and 5 for PFT (Z=-3.493, p<0.001), 3 and 5 for LAM (Z=-3.461, p=0.001) in IR and IR+SMAR imaging, respectively. Metal artifact visualization degrees were found to be 2 and 4 (Z=-4.200, p<0.001), in IR and IR+SMAR imaging, respectively. All the differences were statistically significant.

Table 1. Demographic data and prosthetic sideness

Age (year)	66±19.6 (26-93)
Gender	**n**
Female	10
Male	12
Hip prothesis	
Bilateral	2
Unilateral right	7
Unilateral left	13

In addition, as objective criteria, the measurements of hypodense (in mm) and hyperdense (in HU) artifacts and noise values obtained from bone and muscle tissue adjacent to the prostheses, distant fat tissue, and bladder are presented in Table 2.

The differences between hypodense artifact (mm) measurements and hyperdense artifact (HU) measurements on ASIR and ASIR+MAR images were statistically significant (p<0.001). Although the differences about bone and muscle and bladder values in proximity were statistically significant (p<0.001) in noise measurements, the values of distant subcutaneous adipose values were not statistically significant (p=0.028).

Discussion

Although MRI is a priority in the diagnostic evaluation of pelvic and proctological pathologies, this is not possible in some patients. Different recommendations have been presented in the evaluation of pelvic pathologies, especially in patients who cannot undergo MRI due to claustrophobia, cardiac pacemakers, and metallic implants in critical regions such as the eye (13). On the other hand, MRI is also not preferred in patients with pelvic trauma because of the long scan time. As a matter of fact, in some studies, perineal ultrasound (USG) and rectal USG, which are invasive procedures, have been recommended in such cases (14). However, the diagnostic value of perineal USG is low especially in perirectal/perianal inflammatory diseases,

Table 2. ASIR only and SMAR with ASIR, subjective and objective analysis results

	ASIR (min-max)					**ASIR + SMAR (min-max)**					**p**
Subjective (median)	AC	InR	MsR	PFT	LAM	AC	InR	MsR	PFT	LAM	
Soft-tissue visualization score	4 (2-4)	3 (2-4)	3 (2-5)	3 (2-5)	3* (1-5)	4 (4-5)	4 (4-5)	5 (4-5)	5 (4-5)	5* (4-5)	p<0.001 p=0.001*
Degree of visualization metal artifact	2 (1-4)					4 (4-5)					p<0.001
Objective (mean)											
Width of hypodense artifact (mm)	33 (10-68)					4.5 (0-20)					p<0.001
Attenuation of hyperdense artifact (HU)	576 (183-995)					221 (36-664)					p<0.001
Noise (HU)											
Bone	129					59					p<0.001
Muscle	38					26					p<0.001
Subcutaneous fat	23					21					**p=0.028**
Bladder	27					24					p<0.001

AC: Anal canal, InR: Inferior rectum, MsR: Mesorectum, PFT: Perirectal fat tissue, LAM: Levator ani muscle, HU: Hounsfield units, ASIR: Adaptive statistical iterative reconstruction, SMAR: Smart metal artifact reduction. As a statistical test, the Wilcoxon signed-rank test is used for subjective evaluations and paired t-test is used for objective evaluations

and it is very difficult to perform these examinations in emergency services in patients with rectal trauma (15). CT is widely used for pelvic and anorectal imaging in patients with contraindications for MRI and trauma. However, the use of CT is limited in patients with hip prostheses due to severe metal artifacts in the pelvic and perianal region (16). Pelvic CT scans of patients with hip prostheses show a significant decrease in the quality of images of the AC, distal rectum, perirectal adipose tissue, and middle and lower segments of the rectum due to the metal artifacts (17). On the other hand, with the use of the MAR technique, a significant increase in the quality of images of the same regions and significant improvements in subjective and objective evaluation parameters are observed. In their experimental study, Morsbach et al. (16) reported that the image quality was improved using the MAR technique and it was especially useful in determining HU values in soft tissue. In our study, after a statistically significant decrease in the noise values obtained from the bone and muscle structures in proximity and the bladder using IR together with the MAR technique, it was observed that there was a significant improvement in the image quality of all pelvic organs. It was observed that there was no significant difference in the noise values obtained only from the distal subcutaneous adipose tissue. Accordingly, it was observed that the use of the IR+MAR approach did not affect the quality of the image of the distal subcutaneous adipose tissue.

The use of CT in the evaluation of infected perianal fistulas and abscesses has recently become widespread. Perineal USG and endorectal USG are frequently used in the evaluation of these patients admitted to the emergency services, but these procedures are not preferred since they are too painful. On the other hand, long MRI scan time in painful patients can be a difficult process for the patient to endure. Khati et al. (5) showed that CT could be an alternative in this patient group. However, the presence of hip prostheses is a hindering factor because of impairing the imaging of perianal tissues in these patients due to the artifacts (7). On the other hand, the use of the MAR technique makes it possible for these patients to be scanned with pelvic CT and increases the diagnostic value of CT by increasing the image quality.

The role of CT in the local staging of rectal cancers is very limited and has an accuracy of 70% (17). Therefore, pelvic MRI is more recommended among the non-invasive procedures (8,18). Maizlin et al. (19) showed the superiority of pelvic MRI over CT in local staging of rectal tumors. Tan and Iyer (20) demonstrated the superiority of MRI in showing local staging, lymph node involvement, mesorectal fascia, and surrounding tissue invasion. However, the inability to evaluate these patients, who cannot undergo MRI for various reasons and who have extensive artifact formation on conventional CT due to hip prosthesis, creates a major handicap. As a result, it is not possible to make an optimal radiological evaluation with MRI and conventional CT in this patient group. In this case, the CT scan using the MAR technique allows radiological evaluation. On the other hand, studies showing artifact reduction by using MAR technique in hip MRI have been published in the literature in recent years (21). Delli Pizzi et al. (4) reported that they could not evaluate patients with hip replacement in their MRI-supported study to evaluate the response to treatment in rectal tumors as well. Therefore, Liang et al. (8) recommended pelvic CT as a non-invasive procedure in this patient group. On the other hand, Ippolito et al. (22) reported that these patients who underwent pelvic CT could not be evaluated due to metal artifacts. CT using the MAR technique is also useful in these patients.

Especially with the aging of the population, the number of patients having rectal cancer with hip replacement is increasing (23). Non-invasive methods are required for local staging and postoperative follow-up in these patients (13,24,25). In cases where pelvic MRI cannot be performed and CT is taken, metal artifact distortions related to the prosthesis seen on CT can be eliminated by MAR methods and the diagnostic value of CT can be increased. Today, CT has been used more frequently in the postoperative follow-up of local recurrences and the radiological detection of anastomotic leaks (26,27). Widespread use of the MAR technique will further increase this frequency. Thus, a scan with CT has become possible not only in patients who cannot undergo MRI but also in other conditions demonstrated by the American College of Radiology where pelvic CT is indicated, including hip replacements (27).

In our study, we investigated whether there is a significant difference in image quality in terms of radiological evaluation by using the MAR technique in patients who underwent pelvic CT for other reasons and had hip prostheses. For this reason, none of our patients had rectal pathology. In the subjective evaluation made in our study, it was observed that the MAR technique provided powerful improvements in image quality in all AC, InR, MsR, PFT, and LAM examinations. It was observed that the average of the metal artifact visualization grade increased from 2 to 4. In the objective criteria evaluation, a significant decrease was observed in hypodense and hyperdense artifacts. It

was determined that there was a statistically significant decrease in noise values obtained from bone and soft tissue close to the prosthesis. Only the noise value measured from the subcutaneous adipose tissue, which is the furthest from the prosthesis, did not show a statistically significant difference.

Study Limitations

First, our study followed a retrospective study design with a small number of patients. Second, we did not use dual-energy CT for the examinations. Several studies have shown that metal artifact reduction with dual-energy CT is affected by the composition of the material used for prosthesis. In routine clinical practice, it is difficult to know the composition of the material. Third, the performance of various metal artifact reduction algorithms from different CT manufacturers may differ. Comparative studies analyzing these various algorithms may be needed. Finally, we evaluated the effect of MAR only in cases without pathology in the anorectal region. We believe that our study will be an inspiration and a cornerstone for prospective studies with larger series on the ability of MAR to evaluate pathological conditions and especially comparative prospective studies with MRI.

Conclusion

In pelvic CT using MAR, image quality and radiological evaluation efficiency are significantly increased compared to CT without MAR. CT together with MAR can be considered as an alternative approach in patients with hip prosthesis and anorectal pathologies, who cannot undergo pelvic MRI for various reasons. Therefore, it can be used as a non-invasive and effective method in the preoperative local staging of rectal cancers, in the diagnosis of inflammatory diseases, in the detection of localized fistulas in the pelvic region, in the follow-up of local recurrence and anastomotic leakage in patients with hip replacement surgery for rectal cancer.

Ethics

Ethics Committee Approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Approval was granted by the Local Ethics Committee (date: 05.04.2021/no: 2021/04-653).

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Peer-review: Internally and externally peer-reviewed.

Authorship Contributions

Concept: S.B., Design: S.B., Data Collection or Processing: S.B., E.Z., Analysis or Interpretation: S.B., E.Z., Literature Search: S.B., E.Z., Writing: S.B., Manuscript Review and Revisation: S.B., E.Z.

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