Reducing metal artefacts and radiation dose in musculoskeletal CT imaging

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CHAPTER 3

LOW-DOSE CT-IMAGING OF A TOTAL HIP ARTHROPLASTY PHANTOM USING MODEL-BASED ITERATIVE RECONSTRUCTION AND ORTHOPAEDIC METAL ARTEFACT REDUCTION.


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ABSTRACT

Objective: To compare quantitative measures of image quality, in terms of CT number accuracy, noise, signal-to-noise-ratios (SNRs) and contrast-to-noise ratios (CNRs), at different dose levels with filtered-back-projection (FBP), iterative reconstruction (IR) and model-based iterative reconstruction (MBIR) alone and in combination with orthopaedic metal artefact reduction (O-MAR) in a total hip arthroplasty (THA) phantom.

Materials and Methods: Scans were acquired from high to low-dose (CTDI<sub>vol</sub>: 40.0, 32.0, 24.0, 16.0, 8.0 and 4.0 mGy) at 120 and 140-kVp. Images were reconstructed using FBP, IR (iDose<sup>4</sup> level 2, 4 and 6) and MBIR (IMR, level 1, 2 and 3) with and without O-MAR. CT number accuracy in Hounsfield Units (HU), noise or standard deviation, SNRs and CNRs were analysed.

Results: IMR showed lower noise levels (p<0.01), higher SNRs (p<0.001) and CNRs (p<0.001) compared to FBP and iDose<sup>4</sup> in all acquisitions from high to low-dose with constant CT numbers. O-MAR reduced noise (p<0.01) and improved SNRs (p<0.01) and CNRs (p<0.001) while improving CT number accuracy only at low-dose. At the low-dose of 4.0 mGy, IMR level 1, 2 and 3 showed respectively 83%, 89% and 95% lower noise values, respectively a factor 6.0, 9.2 and 17.9 higher SNRs and respectively 5.7, 8.8 and 18.2 higher CNRs compared to FBP.

Conclusions: Based on quantitative analysis on CT number accuracy, noise values, SNRs and CNRs, we conclude that the combined use of IMR and O-MAR enables a reduction in radiation dose of 83% compared to FBP and iDose<sup>4</sup> in the CT-imaging of a THA phantom.

Keywords: Computed Tomography; metal artefacts; radiation dose reduction; model-based iterative reconstruction; IMR; total hip arthroplasty phantom; quantitative analysis; O-MAR
INTRODUCTION

Computed tomography (CT) is a widely used imaging modality for postoperative follow-up in patients after total hip arthroplasty (THA). The CT imaging of metal hip prosthesis results in metal artefacts due to photon-starvation, beam-hardening and scatter [1] which impede the detection of prosthetic-related pathological conditions of soft tissues and bone.

The orthopaedic metal artefact reduction algorithm O-MAR is an iterative metal artefact reduction algorithm specially developed for CT-imaging of large metal orthopaedic implants [2]. O-MAR is a sinogram in-painting technique that identifies and replaces those projections that passed through metal with interpolated data from adjacent projections that did not pass through metal. With O-MAR, Hounsfield Units (HUs) are corrected towards baseline levels and contrast-to-noise-ratios (CNRs) are boosted [3–6]. Recently, we showed in a phantom study that O-MAR significantly reduces metal artefacts when combined with iDose⁴ and IMR, which are Philips’ proprietary iterative reconstruction (IR) technique and model-based iterative reconstruction technique (MBIR) respectively [7,8]. CT number accuracy, signal-to-noise-ratios (SNRs) and CNRs were significantly improved, while noise values decreased. We found that IMR strongly improves overall image quality and that O-MAR is most effective in reducing severe metal artefacts and when combined with IMR compared to iDose⁴ and filtered back-projection (FBP) using a large head metal-on-metal (MoM) THA phantom [8]. O-MAR post-processes the projection data taking into account metal only classified images, tissue classified images and original input images thereby providing more regular attenuation profiles before image reconstruction, which can improve the general performance of iDose⁴ and IMR [2].

Besides improved overall image quality using model-based iterative reconstruction techniques such as IMR at similar radiation dose levels, the use of IMR is expected to allow a radiation dose reduction [9–16]. The rationale behind this assumption is that model-based iterative reconstruction techniques are better capable in handling increased detector noise levels at reduced dose compared to the standard reconstruction technique filtered back-projection (FBP) and iterative reconstruction techniques since it incorporates data statistics, image statistics and system models. Furthermore, IMR does not involve blending with FBP like hybrid iterative reconstruction techniques, which results in significantly better image quality. Using low-dose protocols, while maintaining image quality, could increase the acceptance
of using CT in orthopaedic imaging in clinical routine due to the reduction of radiation exposure to the orthopaedic patient population. To test the hypothesis that it is possible to lower radiation dose while maintaining sufficient image quality or even improving image quality in a challenging population, we performed this phantom study.

The aim of this study was to compare quantitative measures of image quality, in terms of CT number accuracy, noise, SNR and CNR values, at different dose levels with FBP, iDose\(^4\) and IMR alone and in combination with O-MAR in a THA phantom.

**MATERIALS AND METHODS**

A THA phantom was scanned on an iCT Brilliance 256-slice CT scanner (Philips Healthcare). Static scan parameters were 64 × 0.625 mm collimation, 0.9 mm slice thickness with 0.45 mm increment, 330 mm field-of-view, 0.398 pitch, 512 × 512 image matrix and a rotation time of 1.0 s. The computed tomography dose volume indexes (CTDI\(_{vol}\)) of a CT scan of the THA phantom while using the CT protocol at 140-kVp is approximately 24.0 mGy using the iterative reconstruction technique iDose\(^4\) level 4. Scans were acquired from high to low-dose with fixed CTDI\(_{vol}\) of 40.0 (high), 32.0, 24.0, 16.0, 8.0 and 4.0 mGy (low) at 120 and 140-kVp. The higher CTDI\(_{vol}\) of 40.0 and 32.0 mGy were taken into account since we were also interested in radiation dose levels in case of non-iterative reconstruction techniques using FBP. All scans were reconstructed with FBP, iDose\(^4\) and IMR with and without O-MAR (Philips Healthcare). iDose\(^4\) can be used at 7 different levels of noise reduction where levels 2, 4 and 6 were chosen. For IMR reconstructions, an IMR prototype reconstruction system (version R11) was used. IMR can be used in three levels of noise reduction and were all investigated. Hard or sharp filter types, which are standard filters for imaging bone structures were used for all reconstruction methods in order to increase the contrast and enhance edges between bone, soft tissues and prosthesis.

The custom made water-filled total hip arthroplasty phantom was made of polymethyl methacrylate (PMMA) with dimensions of 320 mm width, 130 mm height and 290 mm depth. Additional PMMA shields were placed below and on top of the phantom to increase the sagittal diameter to 190 mm to represent more realistic patient dimensions, based on the water-equivalent diameter (WED) of 29.15 cm and coronal diameter of 320 mm derived from a BMI of 25 using a formula of Menke et al. (2005) (Fig. 1) [17]. A commonly used total hip prosthesis configuration at our
institute was used. The stem consists of a Titanium-Aluminium-Vanadium (Ti₆Al₄V) alloy where the head of the prosthesis consists of a Zirconia hardened Alumina-Ceramic. The composition includes SrO, Y₂O₃ and Cr₂O₃ [18]. The cup is made of Ultra-High-Molecular-Weight-Poly-Ethylene [19]. The prosthesis was fixated with custom-made PMMA moulds to prevent movement. The phantom contains 18 cylindrical hydroxyapatite/calcium carbonate pellets representing bone with a height and diameter of 10mm. The density of the pellets is calibrated with a documented tolerance of ± 0.5%, simulating healthy bone [7]. On each side 9 pellets were fixated at clinically relevant Gruen zones and DeLee and Charnley zones [20,21].
Chapter 3

The effects of radiation dose reduction on overall image quality, metal artefacts and metal artefact reduction was quantified by analysing CT numbers in HU, noise levels, SNRs and CNRs within fixed regions of interest (ROIs). Noise was measured by calculating the standard deviation (SD) of CT values in a ROI. Local SNRs were calculated by dividing CT numbers of the pellet ROI in HU by the standard deviation of the background ROI placed in water. Local CNRs were calculated by subtracting the average HUs of the local background from the average HUs of the pellet and dividing this by the standard deviation of the local background ROI. Coronal DICOM slices, aligned at the middle of the pellets and prosthesis were used for quantitative measurements. A standardized measurement template was manually created using ImageJ (V 1.48) consisting of 9 left pellet ROIs (L0-L8) and 9 right pellet ROIs (R0-R8) in order to enhance the reliability the measurements were executed using Matlab (2014b) (Fig. 2). ROIs placed in the pellets had a diameter of 14.7 pixels or 6.6 mm, of the actual 10 mm diameter of the pellet, thus minimizing partial volume effects. Amount of pixels were matched for the background ROIs and pellet ROIs (Fig. 2).

Figure 2: The measurement template mask including the ROIs of the 18 pellets, 9 left pellets (L0-L8) and 9 right pellets (R0-R8) is shown. A single pellet is enlarged with the inner pellet ROI 1 and outer background ROI 2.
Pellet L0, L4, R0 and R4 were unaffected by metal artefacts due to their position in the phantom and thereby served as reference (Fig. 2). The lack of metal artefacts in these four pellets was in concordance with previous work [7,8]. Reference values regarding CT number accuracy, noise values, SNRs and CNRs were determined by averaging values of these unaffected pellets L0, L4, R0 and R4 for each CTDI<sub>vol</sub> from high dose (40.0 mGy) to low-dose (4.0 mGy), for 120 and 140-kVp acquisitions and for each of the reconstructions. In case of metal artefacts, image quality, metal artefact and metal artefact reduction was quantified by analysing CT numbers, noise values, SNRs and CNRs of the most affected pellet, pellet R6, from high to low-dose in 120 and 140-kVp acquisitions and these results were compared to reference values of unaffected pellets.

Statistical analysis was performed by means of repeated measures ANOVA (full factorial, type III). For reference values of unaffected pellets one within-subject factor i.e. reconstruction technique (FBP, iDose<sup>4</sup> level 2, 4 and 6 and IMR level 1, 2 and 3) was used, generalizing to scan protocol containing the 12 different acquisitions. A separate analysis was performed for the most severe metal artefacts in pellet R6 by means of two within-subject factors notably reconstruction technique and O-MAR (‘off’, ‘on’). Greenhouse-Geisser produced p-values were interpreted and a two-sided alpha of 5% was used as significance level.

RESULTS

No artefacts - CT number accuracy and noise values
CT numbers of the unaffected pellets L0, L4, R0 and R4 were significantly lower for 140-kVp acquisitions compared to 120-kVp acquisitions (p<0.001) and CT numbers in IMR reconstructions were systematically lower compared to iDose<sup>4</sup> and FBP reconstructions (p<0.005). Noise values or standard deviations were higher for FBP reconstructions at all dose levels and both kVps compared to iDose<sup>4</sup> and IMR reconstructions. Especially in low-dose acquisitions, noise values increased with FBP compared to iDose<sup>4</sup> and IMR (Fig. 3). Noise values were lowest for 24.0 and 32.0 mGy for respectively 120-kVp and 140-kVp results in all reconstructions. With IMR noise values were lowest compared to FBP and iDose<sup>4</sup> reconstructions (p<0.01) and CT numbers remained constant from high to low-dose (Tab. 1).

SNRs
In general, SNRs decreased from high to low-dose for all reconstruction techniques
and both kVp values. SNRs were higher in all acquisitions using IMR compared to iDose\(^4\) and FBP (p<0.001). With IMR, peak SNRs were found at CTDI\(_{\text{vol}}\) of 24.0 for 120-kVp results. For 140-kVp results, peak SNRs were found at CTDI\(_{\text{vol}}\) of 32.0 mGy for all reconstruction techniques. These peak SNRs were caused by lower noise values at these dose levels since CT numbers were constant for all reconstructions using iDose\(^4\) and IMR (Tab. 1).

CNRs
CNRs decreased from high to low-dose for all reconstruction techniques and kVps except for IMR level 3 reconstructions. In IMR level 3 reconstructions CNRs increased when decreasing the tube current i.e. decreasing radiation dose (Tab. 1). CNRs in IMR reconstructions were higher compared to iDose\(^4\) and FBP and CNRs with iDose\(^4\) were higher compared to FBP (p<0.001). Focusing on levels of noise reduction regarding iDose\(^4\) level 2, 4 and 6 and IMR level 1,2 and 3, higher levels of reconstruction level resulted in higher SNRs and CNRs due to lower noise levels (Tab. 1).

When observing 120 and 140-kVp results for all dose-levels, IMR results in more than 59% noise reduction and SNRs and CNRs were more than a factor 2.3 and 2.2 higher in case of IMR level 1, and more than 83% noise reduction and SNRs and CNRs were more than a factor 5.9 and 4.5 higher in case of IMR level 3 compared to FBP reconstructions. At the low-dose of 4.0 mGy IMR level 1, 2 and 3 showed respectively 83%, 89% and 95% lower noise values, respectively a factor 6.0, 9.2 and 17.9 higher SNRs and respectively 5.7, 8.8 and 18.2 higher CNRs compared to standard FBP reconstructions while maintaining constant CT numbers.

Metal artefacts without O-MAR
Since our main focus was to investigate dose reduction capabilities in the CT imaging of a metal hip prosthesis using IMR, we only focused on the by metal artefact most affected pellet, which was pellet R6 (Fig. 2). In pellet R6 metal artefacts were most pronounced reflected by relatively large deviations of CT numbers, noise values, SNRs and CNRs from unaffected reference values obtained from pellet L0, L4, R0 and R4.

CT numbers, noise values, SNRs and CNRs
CT numbers of pellet R6 were lower compared to unaffected pellets for all reconstruction techniques and acquisitions due to the influence of metal. At reduced radiation dose, CT numbers were clearly more deviated compared to reference
values than in higher radiation dose acquisitions (Fig. 5). Largest deviations were observed in FBP reconstructions compared to iDose\(^4\) and IMR where IMR results showed the least deviations in CT numbers. Noise values or standard deviations of pellet R6 were increased and SNRs and CNRs were decreased compared to reference values due to the influence of metal.

The combined use of IMR and O-MAR

In general, O-MAR reduces metal artefacts in pellet R6 by improving SNRs (p>0.01) and CNRs (p>0.001) while decreasing noise values (p>0.001) (Fig. 4, 5). The use of O-MAR did not result in significant improvement of HU deviations in all acquisitions. Only in low-dose acquisitions, the use of O-MAR resulted in a correction of by metal artefact deviated HUs towards reference values of unaffected pellets (Fig. 5a). CT numbers in IMR and O-MAR reconstructions were constant from high to low dose.

O-MAR decreased noise values of pellet R6 when combined with FBP, iDose\(^4\) and IMR in nearly all acquisitions. Largest noise reduction was observed at low-dose using IMR level 1,2 and 3. Also deviations in SNRs and CNRs of pellet R6 compared to reference values were largest in IMR reconstructions due to clearly higher reference values (Fig. 5). SNRs were not improved by O-MAR in all acquisitions. Absolute SNR improvements by O-MAR were largest at the low-dose acquisition of 4.0 mGy for all reconstructions techniques and were more than a factor 2 higher when combined

![Figure 3: Images acquired at 140 kVp and 4.0 mGy reconstructed with FBP (a), iDose\(^4\) level 4 (b) and IMR level 2 (c) with the use of O-MAR. Lower noise values and improved overall image quality can be observed in images reconstructed with IMR level 2 compared to FBP and iDose\(^4\).](image-url)
Table 1: Reference CT numbers, signal-to-noise-ratios (SNRs) and contrast-to-noise-ratios (CNRs) for filtered back-projection (FBP), iterative reconstruction iDose\(^4\) (levels 2, 4 and 6) and iterative model-based reconstruction (IMR) (levels 1, 2 and 3) at computed tomography dose indexes (CTDI\(_{vol}\)) of 40.0, 32.0, 24.0, 16.0, 8.0 and 4.0 mGy at 120 and 140-kVp without the influence of metal artefacts. Reference values were determined by averaging values of the unaffected pellets L0, L4, R0 and R4.

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<td>7.7 ± 1.1</td>
<td>13.7 ± 2.1</td>
<td>21.0 ± 2.9</td>
<td>40.8 ± 5.8</td>
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with IMR compared to FBP and iDose\textsuperscript{4} in 4.0 mGy acquisitions. With the use of O-MAR, CNRs were strongly improved where largest improvements were observed when combined with IMR. Fig. 6a illustrates that a 4.0 mGy acquisition at 140-kVp reconstructed with IMR and O-MAR shows superior image quality compared to 24.0

Figure 4: Images acquired at 140-kVp and CDTivol of 24.0 mGy reconstructed with FBP (a), FBP + O-MAR (b), iDose\textsuperscript{4} level 4 (c), iDose\textsuperscript{4} level 4 + O-MAR (d), IMR level 2 (e) and IMR level 2 + O-MAR (f). IMR level 2 and O-MAR results (Fig. 4f) show the least noise with reduced metal artefacts compared to conventional FBP and iDose\textsuperscript{4} reconstructions.
mGy acquisitions at 140-kVp reconstructed with FBP (Fig. 6a) and iDose\(^4\) level 4 (Fig. 6b), which corresponds to a radiation dose reduction of 83% with reduced metal artefacts.

**DISCUSSION**

This phantom study shows that the iterative model-based reconstruction technique IMR improves overall image quality with higher SNRs (p<0.001) and CNRs (p<0.001) and lower noise values (p<0.01) compared to FBP and iDose\(^4\) while maintaining constant CT numbers from high to low-dose. In the case of metal artefacts, 140-kVp acquisitions are advised due to smaller deviations in CT numbers, noise values, SNRs and CNRs compared to reference values than in 120-kVp acquisitions. The lower CT numbers for IMR results compared to FBP and iDose\(^4\) results are in concordance with previous work and can be explained by the use of a different reconstruction filter. The IMR reconstruction filter uses edge-enhancement, which can influence CT numbers in small objects [8]. The orthopaedic metal artefact reduction algorithm O-MAR reduced metal artefacts by improving SNRs (p<0.01) and CNRs (p<0.01) while decreasing noise values (p<0.01) and showed the largest absolute improvements in low-dose acquisitions where metal artefacts were most pronounced. O-MAR is most effective when combined with IMR based on the largest CNR improvements. Subsequently, O-MAR is most effective with an increased reconstruction level for both iDose\(^4\) and IMR. Regarding deviated CT numbers due to the influence of metal artefacts, O-MAR only improved CT number accuracy in low-dose acquisitions with the most severe artefacts. In general, larger deviations compared to reference values due to the influence of metal artefacts will result in larger absolute corrections by O-MAR of these deviations. However, reference values of unaffected pellets were not reached.

Our results showed that 4.0 mGy (17%) 140-kVp acquisitions reconstructed with IMR and O-MAR resulted in comparable or higher SNRs and CNRs and lower noise values compared to 24.0 mGy (100%) acquisitions reconstructed with FBP or iDose\(^4\) with O-MAR with constant CT numbers. This enables a radiation dose reduction of 83% based on this quantitative phantom study. There is no data available on dose reduction capabilities in the CT imaging of a metal implants using iterative model-based reconstruction without or with the use of metal artefact reduction software. However, our results are in concordance with several recent studies, which show that model-based iterative reconstruction techniques are able to reduce image
Figure 5: CT numbers (a), noise values (b), SNRs (c) and CNRs (d) of pellet R6 with and without the use of O-MAR compared to reference values for all reconstructions and 140-kVp acquisitions from high to low-dose.
noise up to 75%-88% and radiation dose up to 75%-92% and improve SNRs and CNRs in other CT protocols also [9–16]. In a previous study, we showed that IMR improves overall image quality and that O-MAR is most effective in severe artefacts and when combined with IMR in improving CT number accuracy, SNRs and CNRs while decreasing noise [8].

This study mainly focused on improving image quality and reducing metal artefacts using IMR and O-MAR at regular dose levels instead of focusing on dose reduction capabilities. However, it needs to be stated that the Titanium-Aluminium-Vanadium prosthesis used in the current study, and most often used in our patient population, resulted in less severe artefacts compared to the metal-on-metal (MoM) prosthesis used in our previous study, which was composed of a Cobalt-Chrome-Molybdenum alloy with a greater atomic weight.

O-MAR did not reduce differences in CT numbers of pellet R6 compared to reference values in all acquisitions but mainly in low-dose acquisitions (Fig. 5). This confirms earlier findings stating that O-MAR is most effective in severe artefacts, since at low-dose acquisitions the reduced number of photons will induce more severe artefacts. A recent study of Boudabbous et al. (2015) showed that model-based iterative reconstruction reduces the size of metal artefacts on CT images and allows a better

Figure 6: A 24.0 mGy acquisition at 140-kVp reconstructed with (a) FBP and (b) iDose4 level 4. A 4.0 mGy acquisition at 140-kVp reconstructed with IMR level 2 and O-MAR (c). IMR and O-MAR results in Fig. 6c show a clearly improved image quality with reduced metal artefacts compared to Fig. 6a and 6b reconstructed with FBP and iDose4, while reducing radiation dose with 83%.
analysis of the soft tissue surrounding the metal implant compared with FBP [22]. This is the only study investigating metal artefacts using MBIR, however without the use of metal artefact reduction software and without investigating dose reduction capabilities. We observed no differences in metal artefacts in IMR and FBP results since artefacts did not seem to differ in size or severity (Fig. 4 a, c and e).

In general, noise increases when lowering CT radiation dose. In our results, 24.0 mGy and 32.0 mGy showed lowest noise values for 120-kVp and 140-kVp results respectively. Since we only made a single scan for each condition there may be some uncertainty in the estimated noise levels that might be larger than the differences found between those conditions. This is more likely for the cases where the noise levels are low and differences in noise levels are relatively small as for the IMR results. In by metal affected and unaffected regions and with and without the use of O-MAR, overall image quality is superior using IMR level 1, 2 and 3 compared to FBP and iDose\(^4\) level 2, 4 and 6. Subsequently, image quality in IMR level 3 results, with the highest level of noise reduction, is superior to IMR level 1 and 2 results. CNRs of unaffected pellets in images reconstructed with IMR level 3 stood out since a decrease in radiation dose lead to an increase in CNRs. A possible explanation for the observed IMR trends could be its (over-) effectiveness in noise reduction CNRs increased due to a decrease in noise levels in the background ROIs where CT numbers showed a slight increase from high to low-dose acquisitions. Since noise increases at decreased radiation dose, noise is highest at a CTDI\(_{vol}\) of 4.0 mGy. IMR level 3 is best capable of dealing with these increased noise levels. A side effect of this magnitude of noise reduction in low-dose images is the increasing smoothing effect. McCollough et al. (2015) found in a phantom study that for radiation dose reductions of more than 25%, the ability to resolve 6 mm rods in the ACR CT accreditation phantom can be lost [23]. When detecting soft tissue pathology in THA patients involving low-contrast lesions, relatively low noise levels and high spatial resolution is required. Our results showed that noise levels remain low using IMR also in low-dose acquisitions thereby probably enabling a dose reduction in clinical practice also. However as stated before, caution should be taken in case of such dose reduction steps since the smoothing effect could lead to a loss of small detail and low-contrast detectability. Den Harder et al. (2016) recently found that the use of iDose\(^4\) did results in an increased number of false-positive findings in the computer-aided detection of pulmonary nodules at reduced dose levels and that CT volume measurements of pulmonary nodules at low-dose using IMR were lower compared to iDose\(^4\) and FBP [24,25]. Kaasalainen et al. (2015) evaluated
image noise, soft tissue contrast and bone tissue contrast in a study using pediatric anthropomorphic phantoms while reducing radiation dose in craniosynostosis CT. They found that while reducing radiation dose up to 83% and 88% image quality remained adequate. Besides the high bone tissue contrast, like we investigated in our study, also soft tissue contrast remained more or less constant while reducing radiation dose using MBIR. Furthermore a study of Brænne et al. (2016) showed that iterative algorithms, and model-based iterative reconstruction algorithms improve lesion detectability of low-contrast lesions in a liver phantom, however it may result in poorer image quality when applying aggressive radiation dose reduction [26]. Results of these studies involving radiation dose reduction using (model-based) iterative reconstruction methods all state that caution should be taken. Additionally, especially in low-dose situations, photon-starvation artefacts will be more apparent due to the reduced number of photons. Despite the fact that we did not observe signs of increased photon-starvation artefacts, we are aware of possible side-effects in dose reduction especially in case of severe metal artefacts and relatively large patient sizes in THA patients.

Our study has several limitations. We have only performed quantitative analyses using a standardized measurement template. Additional subjective image quality scoring could give more insights in the clinical usefulness and opinions of radiologists in evaluating low-dose CT scans. Secondly, the hydroxyapatite/calcium carbonate pellets with a high density resulted in high contrast values between the pellets and its background. Adding pellets with different densities or soft tissue structures can give more insights in the possible additional clinical value in patients, especially regarding low-contrast detectability in low-dose situation. Furthermore, adding total hip arthroplasties consisting of different metal alloys can provide important information regarding the influence of different metal alloys while reducing radiation dose since heavier metals may impede radiation dose reduction. At last, known smoothing effects due to noise reduction could result in a loss of small objects or details, which needs to be investigated by subjective image quality scoring. Therefore, most important regarding future prospective, in order minimize radiation dose levels in the CT imaging of total hip arthroplasty in patients, a clinical patient study needs to be started with qualitative and quantitative image quality scoring focusing on the evaluation of the musculoskeletal anatomy and pathology.

We have used a total hip arthroplasty phantom reflecting the dimensions of a patient with an average BMI. We addressed image quality, metal artefacts and the degree of MAR by quantifying CT numbers, noise, SNRs and CNRs. We addressed noise
as the standard deviation of pixel intensities within a ROI, and are aware of the fact that both noise and artefact will influence the standard deviation. Based on previous studies, we conclude that the measured noise reduction by O-MAR is mainly caused by a reduction of metal artefacts resulting in a lower standard deviation since O-MAR has no influence on images without metal artefacts.

Based on quantitative analysis on CT number accuracy, noise values, SNRs and CNRs, we conclude that with the combined use of model-based iterative reconstruction (IMR) and orthopaedic metal artefact reduction (O-MAR) image quality parameters are maintained at a reduction in radiation dose of 83% compared to FBP and iDose\(^4\) in the CT-imaging of a total hip arthroplasty phantom. Although results of this phantom study are promising, future clinical studies are needed to determine if the results of this phantom study can lead to radiation dose reduction in THA patients.

REFERENCES


Chapter 3


