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ORIGINAL ARTICLE

Quantitative Analysis of Artifacts Created by Metallic Orthopaedic Implants

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ABSTRACT

Objective: *To evaluate the magnitude of artifacts created by different materials commonly used in orthopaedic implants and their variation with the distance from the implants.*

Patients and Methods: *Metallic orthopaedic implants made of 3 different types of materials (stainless steel, brass, and titanium) were placed in a body computed tomography phantom, and variation of computed tomography numbers at different distances and angles from the implants were recorded. The variability of the computed tomography numbers was then compared between different materials.*

Results: *Implants made of stainless steel created a significantly higher magnitude of artifacts, while artifacts created by titanium and brass implants were comparable. The magnitude of artifacts reached a plateau beyond 5 cm from the implant regardless of either the implant material or density of the surrounding medium.*

Conclusion: *Using orthopaedic implants made of titanium or brass instead of stainless steel can reduce metallic artifacts. However, the beneficial effect becomes insignificant beyond a point 5 cm from the implant.*

Key Words: *Artifact, Computed tomography, Prosthesis*

INTRODUCTION

Computed tomography (CT) has been proven to be effective for evaluating musculoskeletal pathology. Unfortunately, standard transaxial CT images in the vicinity of metallic orthopaedic implants are badly degraded by artifacts. These artifacts interfere with the visual interpretation of both bone and soft tissues, thereby limiting the effectiveness of postoperative CT evaluation of local tumour recurrence following an ablative process or residual deformity following skeletal reconstruction. These artifacts, typically seen as starburst streaking, primarily result from image reconstruction involving missing projection data and also from partial volume effects, scatter, and aliasing.[1-3]

Reduction of these metal-associated artifacts can be achieved in 3 ways. The simplest method, increasing the effective X-ray energy, is to improve the beam penetration and reduce the missing projection data. However, this approach is limited by patient dose and by the requirement of a low effective energy for optimal image contrast. Another method involves reformatting of the axial CT image data into interpolated new axial, orthogonal, or oblique images.[4] Image reformatting into planes other than the scan plane will weight the true image signal over the pseudo-randomly distributed artificial signal when integrating between adjacent axial images. In this way the artifacts in the original axial images are averaged out of planar reformatting. Although this method provides satisfactory results, the subsequent degradation of spatial resolution may jeopardise the diagnostic accuracy.

In practice, it is possible to reduce the X-ray beam attenuation that produces the missing projection data by using materials with lower X-ray attenuation coefficients and/or implants with smaller cross-sectional areas. Figure 1 shows an example of artifacts arising from a metallic hemiarthroplasty prosthesis. Measuring the CT numbers at the corresponding regions of the left and right gluteus maximus muscles demonstrated a great discrepancy, resulting from the difference in distance from the metallic prosthesis. It is interesting to note how the magnitude of the artifacts varies with increasing

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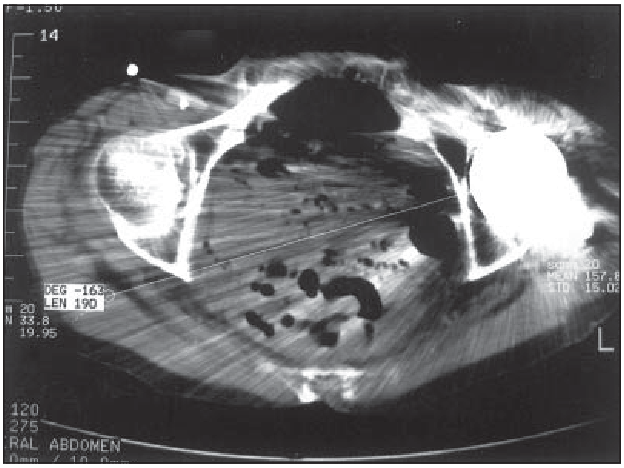

Figure 1. Computed tomography of the pelvis of an 80-year-old woman with a left hip hemiarthroplasty. The region of interest placed at the left gluteus maximus muscle and 4.5 cm from the centre of the left hip metallic prosthesis gave a computed tomography number of 157.8, while another region of interest placed at the corresponding site of the right gluteus maximus muscle and 19 cm from the centre of the prosthesis gave a computed tomography number of 33.8. This illustrates the uncertainty of accuracy of computed tomography number measurement around metallic implants.

distance from the metallic prosthesis, thus estimating the approximate accuracy of our measurements of CT number at different sites around the prosthesis. The purpose of the study was to evaluate the effect of using commercially available metallic orthopaedic implants made of different materials in terms of the magnitude of CT artifacts, and how these artifacts vary with distance from the metallic implants.

PATIENTS AND METHODS

Implants made of 3 different materials (stainless steel, brass, and titanium) were used in this study. The rod-shaped portions of the orthopaedic implants were inserted into an insertion zone of a CT body phantom (RMI, Middleton, USA). The diameters of the inserted portions were standardised to be 5 mm. To secure the implant to the CT body phantom, the implant was placed erect into the insert area filled with melted gelatin. The gelatin was prepared by mixing with different concentrations of contrast agent so that a different density of surrounding medium could be simulated. Each implant was scanned separately, after the gelatin had dried, using the standard scanning protocol for medium abdomen (120 kVp; 300 mA x 1 second; 10 mm slice, full-field). Following CT scanning, regions of interest (ROIs) were identified at different combinations of angular position (0^o to 180^o at 20^o increments) and distance (18, 25, 35, 45, 55, 65, 75, 85, and 100 mm) from the implant as illustrated in Figure 2. The CT number

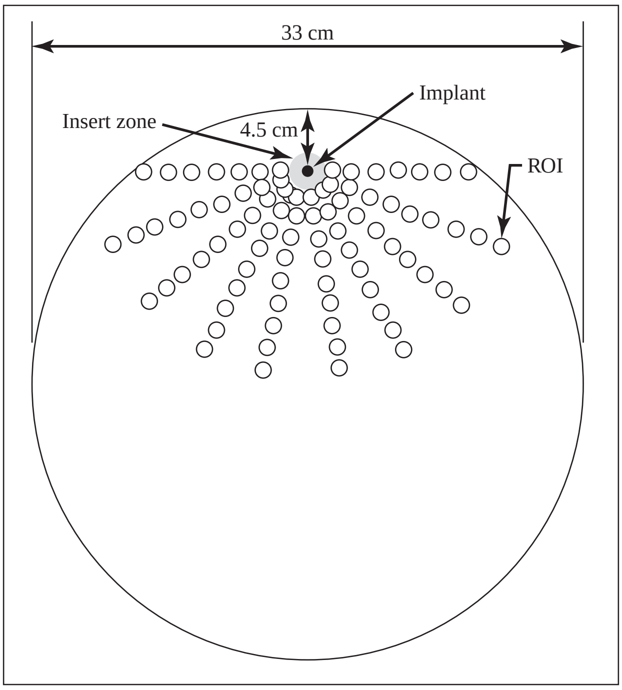

Figure 2. Computed tomography phantom: regions of interest (ROI) were identified in each computed tomography scan for different implants.

was measured for each ROI. To account for the CT number fluctuation, the maximum angular variation of CT number for each distance from the implant was calculated. This calculated quantity permitted comparison of the magnitude of artifacts created by each implant.

RESULTS

As illustrated in Figure 3, implants made of stainless steel created a significantly higher magnitude of

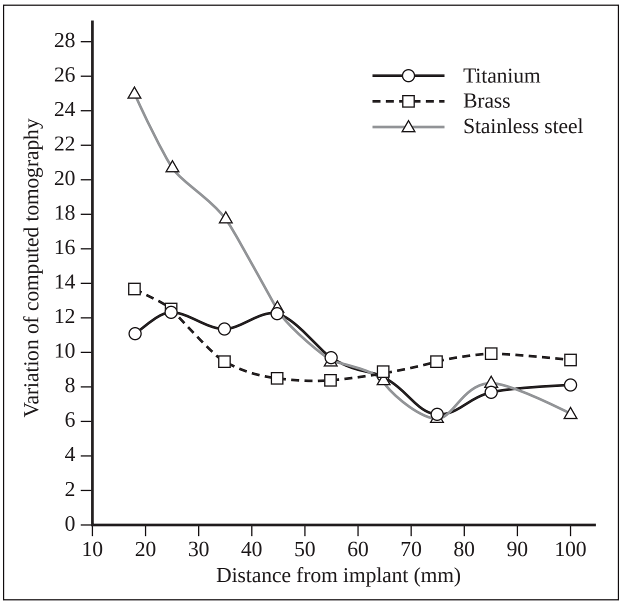

Figure 3. Artifacts caused by 3 different implants.

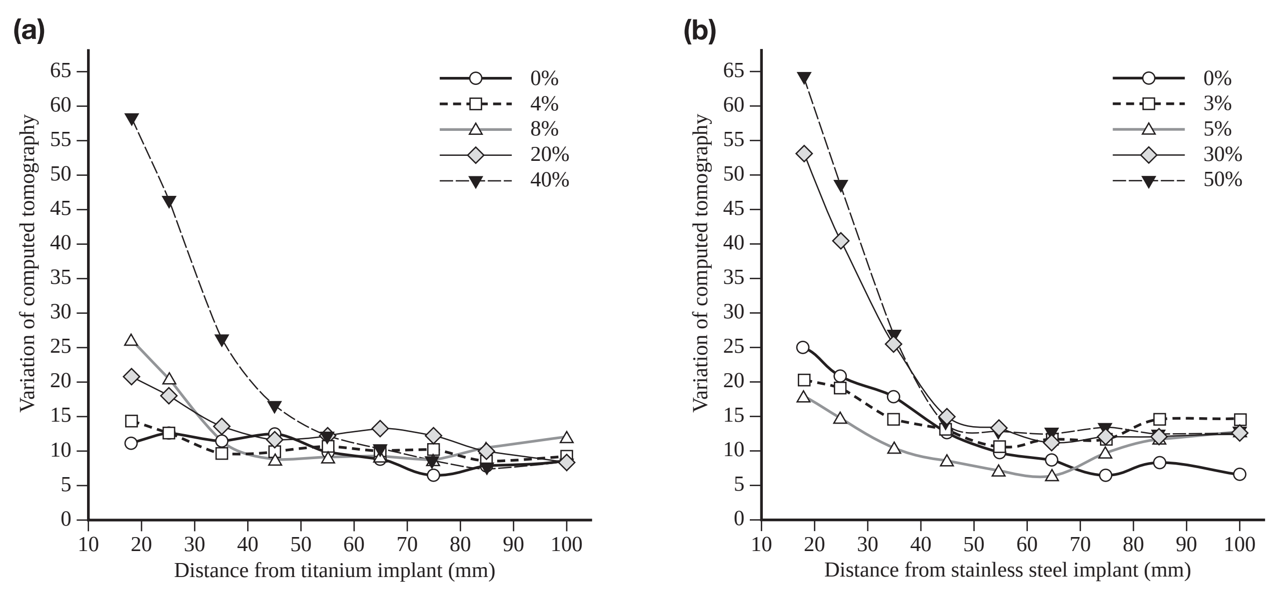

Figure 4. (a) Variation of computed tomography numbers caused by titanium implants increases with the density of the surrounding material, but reaches a plateau beyond approximately 5 cm from the implant. (b) Variation of computed tomography numbers caused by stainless steel implants increases with the density of the surrounding material, but reaches a plateau beyond approximately 5 cm from the implant.

artifacts, and artifacts created by titanium and brass implants were comparable. Similar to the findings by Robertson et al, the magnitude of artifacts was not only affected by the implant material but also increased with the density of the surrounding medium (Figures 4a and 4b).[5] One interesting finding from this study is that the magnitude seems to reach a plateau beyond approximately 5 cm from the implant, regardless of either the implant material or density of the surrounding medium (Figures 3, 4a, and 4b).

DISCUSSION

Clinically, metal-associated artifacts may degrade image quality in the vicinity of surgical clips, dental fillings, heart valves, and orthopaedic implants.[4,6-10] Artifacts from surgical clips and heart valves are primarily caused by motion, sharp edge effects, and aliasing. Artifacts around orthopaedic implants and dental fillings are primarily caused by the almost complete attenuation, in certain views, of the X-ray beam as it passes through the metal. These artifacts will not only markedly hinder the postoperative abnormality imaging, but will also affect the imaging assessment of other non-operative related pathology in the vicinity of the prosthesis.

Just as the causes of artifacts around metal objects are different, so are their reductions. Surgical clip artifacts can be reduced by use of algorithms that remove projection data inconsistencies caused by the clip and replaces these inconsistencies with data from that area.[8] The imaging of implants made from less attenuating materials will also reduce artifacts.[6,10,11] Imaging less attenuating objects and image reformatting are 2 methods of reducing orthopaedic implant-associated artifacts. Image reformatting works because metal artifacts in a given axial slice do not always align with artifacts in adjacent slices. This is due to changes in the positioning of the body and implant within the scanner. Thus, some artifacts can be averaged out by integrating between adjacent slices to create new axial, orthogonal, or oblique reformatting. Commercially available multiplanar reconstruction (MPR) features can easily be used to serve this purpose. Unfortunately, this averaging effect may also degrade the spatial resolution and jeopardise the diagnostic accuracy.

In this study, the results demonstrate that using implants made of titanium or brass instead of stainless steel can reduce artifacts. As expected, the magnitude of the artifacts increased as the density of the surrounding medium increased. Interestingly, but unexpectedly, the magnitude of the artifacts seems to reach a constant beyond 5 cm from the implant, regardless of either the material of the implant or the density of the surrounding material. This is possibly due to the masking effect from the noisy background. In other words, image degradation cannot be improved for regions far away from the implant by using different implant materials and the distance depends upon the signal-to-noise ratio of the imaging protocol. Nevertheless, this artifact problem is only one of the considerations in the decision-making of the choice of implant material. Other factors such as durability, hardness, and price should play a more important role.

REFERENCES

1. Hinderling R, Ruegsegger P, Anliker M, Dietschi C. Computed tomography reconstruction from hollow projections: an application to in vivo evaluation of artificial hip joints. J Comput Assist Tomogr 1979;3:52-57.
2. Joseph PM, Spital RD. The exponential edge-gradient effect in x-ray computed tomography. Phys Med Biol 1981;26:473-487.
3. Joseph PM, Spital RD. The effects of scatter in X-ray computed tomography. Med Phys 1982;9:464-472.
4. Fishman EK, Magid D, Robertson DD, Brooker AF, Weiss P, Siegelman SS. Metallic hip implants: CT with multiplanar reconstruction. Radiology 1986;160:675-681.
5. Robertson DD, Weiss PJ, Fishman EK, Magid D, Walker PS. Evaluation of CT techniques for reducing artifacts in the presence of metallic orthopedic implants. J Comput Assist Tomogr 1988;12:236-241.
6. Marks WM, Callen PW. Computed tomography in the evaluation of patients with surgical clips. Surg Gynecol Obstet 1980; 151:557-558.
7. Svendsen P, Quiding L, Landahl I. Blackout and other artifacts in CT reconstructions. Med Phys 1980;19:229-234.
8. Glover GH and Pelc NJ. An algorithm for the reduction of metal clip artifacts in CT reconstructions. Med Phys 1981;8:799-807.
9. Barmeir E, Dubowitz B, Roffman M. Computed tomography in the assessment and planning of complicated total hip replacement. Acta Orthop Scand 1982;53:597-604.
10. Weese JL, Rosenthal MS, Gould H. Avoidance of artifacts on computerized tomograms by selection of appropriate surgical clips. Am J Surg 1984;147:684-687.
11. Saxe AW, Doppman JL, Brennan MF. Use of titanium surgical clips to avoid artifacts seen on computed tomography. Arch Surg 1982;117:978-979.