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Reduction of CT Artifacts Caused by Metallic Implants[1]

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A technique to reduce metallic implant artifacts on computed tomography scans is presented. The implant boundaries are determined semiautomatically; the missing projection data are replaced by linear interpolation. The complete procedure requires 1-2 minutes per scan. Images with greatly improved quality were obtained in the presence of surgical clips and pelvic implants; success is limited in highly structured regions, such as the facial skull.

Index terms: Computed tomography (CT), artifact • Computed tomography (CT), image processing • Computed tomography (CT), technique

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METALLIC implants often cause severe artifacts on computed tomography (CT) scans and may render images nondiagnostic. This problem arises because satisfactory images cannot be calculated from projections with missing or distorted data (hollow projections). Most solutions presented in the literature are based on iterative or arithmetic reconstruction techniques (1, 2) and simple but inconsistent completion of the missing projection data (3-7). Efforts have been aimed at the consistent completion of projection data (4, 6, 7).

The possible merits of arithmetic reconstruction techniques and consistent completion methods are contrasted by their high demands on computer time and storage; thus they have rarely been used. Simpler methods have not become available, partly because the possibility that they would be successful was estimated to be very low (6). Despite this, we decided to take such an approach to solving the problem of artifacts on CT scans, making use of a method of linear interpolation of the missing data.

Materials and Methods

The algorithm consists of the following steps: (*a*) reconstruction of the CT image from the original distorted data, (*b*) approximate delineation of the metallic implant(s) by the operator with a light pen, (*c*) automated determination of the exact implant boundaries within the projection data, (*d*) linear interpolation of the missing data, (*e*) addition of noise to the interpolated data (optional), and (*f*) reconstruction of an artifact-reduced image from the new projection set.

The CT image that is reconstructed from the original distorted data is used to identify the number and the approximate locations of the metallic implants. Fully automated detection of metallic implants in the image is possible but appears to be too error prone. This is partly due to the fact that artifacts may have very high CT values. We therefore ask the operator to outline approximately the metallic implant(s) with a light pen. For implants in bony surroundings, wide window settings with a window center at around 1,000 HU are recommended. Up to three objects can be identified with the use of separate regions of interest.

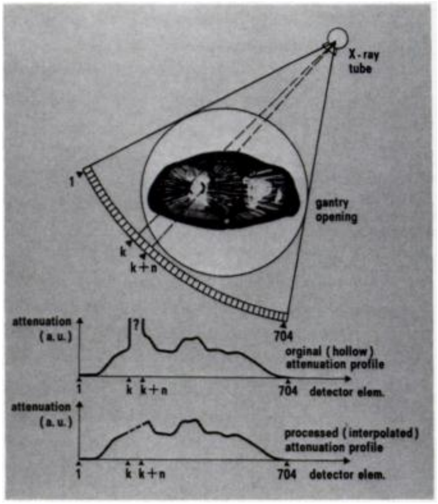

Figure 1. Schematic drawing of an object with typical geometry. A metallic implant surrounded by cortical bone is crudely encircled with an irregular region of interest. For any x-ray tube and detector position, a range of detector elements k to k + n is covered by the region of interest. Search for the implant boundaries is limited to this range.

For each projection, that is, for each angular position of the x-ray-tube-detector system, the data range covered by each region of interest is automatically determined, taking into account the system's and object's geometry (Fig. 1). The search for the boundaries of the implant in each projection is limited to the range defined by the region of interest. The search algorithm starts from the outer channels, k and k + n respectively, with use of a threshold criterion for the detection of the implant. The threshold value can be changed by the operator, and an average over several channels can be chosen to adapt more effectively to the particular problem. A simple linear interpolation is performed between the channels nearest to the left and right of the implant, which are identified as outside of the implant (Fig. 1).

It has been suggested that noise should be added artificially to the noise-free interpolated data (7, 8). We have implemented this as an option. After the linear interpolation, with or without noise addition, the new data set is submitted to the standard convolution-back-projection image-reconstruction process.

The described algorithm was implemented on a Somatom DR-H (Siemens Medical Systems, Erlangen, Federal Republic of Germany) and its host computer, a PDP11/44 (Digital Equipment, Marlboro, Mass.). The complete artifact-reduction routine takes less than 2 minutes per image.

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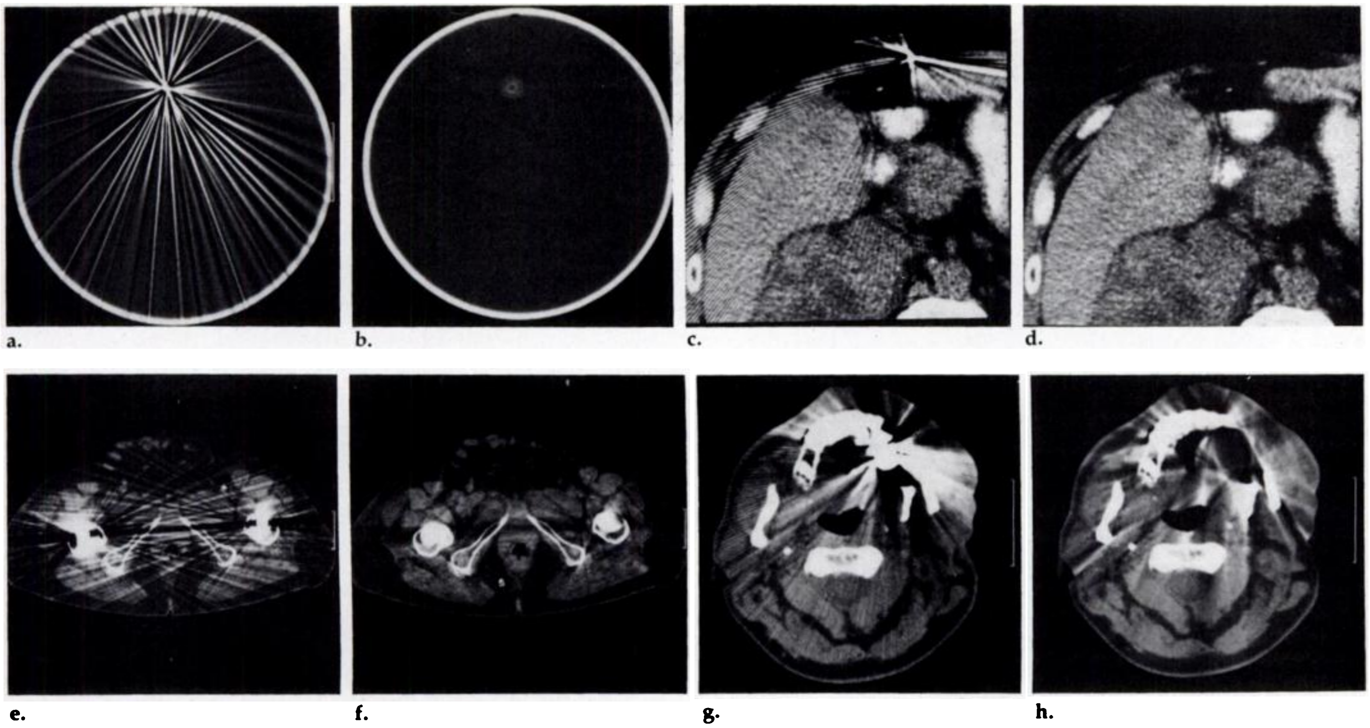

Figure 2. CT scans of objects with increasingly complex geometries. Moving surgical clips in a water phantom **(a, b)** and in a human **(c, d)**. **(e, f)** Pelvic section contains two metallic implants. **(g, h)** CT scans of a jaw with dental fillings. **a, c, e,** and **g** are original images; **b, d, f,** and **h** have undergone artifact reduction.

Results

The routine has been applied to objects with geometries that are widely varied in complexity. The routine was most successful with objects having simple geometries, such as a circular water phantom (Fig. 2a, 2b) or the lumbar portion of a patient (Fig. 2c, 2d) in which only the spine is present as a high-contrast structure. The routine was adequately successful when applied to the pelvic region (Fig. 2e, 2f); however, it was unsatisfactory in highly structured regions such as the facial skull, which has many sharp transitions between high and low attenuation (Fig. 2g, 2h).

In our subjective judgment, the addition of noise to the interpolated data did not improve image quality. The effect of noise addition was not noticeable when normal noise levels were added. As the amplitude of noise added to the interpolated data was increased, image noise and streak artifacts also increased.

Discussion

The described artifact-reduction procedure demands very little operator interaction; only an approximate identification of the metallic implants and, if desired, a change of parameters for the threshold detection are required. It appears to be practical for routine work, since it demands relatively little time to perform. Automated implant boundary detection minimizes the data range to be replaced by linear interpolation; it facilitates the work of the operator, who cannot easily determine the implant boundaries in the artifact-affected image.

In many applications, this simple procedure has decisively reduced artifacts caused by metallic implants. The degree of success depends on the structural complexity of the object. This is because inconsistencies are generated in projections in which the implant and other high-contrast structures are superimposed (6). In such cases, artifacts will remain and new artifacts are likely to be created.

This result is admittedly less than perfect. However, since to our knowledge no other practical solution to the metal artifact problem is currently available, we decided to implement this approach. A user-friendly software version has been generated and is being evaluated in a clinical setting (9). An additional benefit of this approach is that images obtained with it may be used for applying further algorithms, such as arithmetic reconstruction techniques. ■

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