A computed tomographic (CT) image is a display of the anatomy of a thin slice of the body developed from multiple X-ray absorption measurements made around the body’s periphery. Unlike conventional tomography, in which the image of a thin slice is created by blurring out the information from unwanted regions, the CT image is constructed mathematically, using data arising only from the section of interest. Generating such an image is confined to cross sections of the anatomy that are oriented essentially perpendicular to the axial dimension of the body.1

An artifact is any distortion or error in an image that is unrelated to the subject being studied. Artifacts are relatively common in CT imaging and may be considered as a source, or type, of noise. Their cause may not always be obvious. However, there are a number of different effects that may be responsible for artifacts in CT.

Because artifacts in CT arise as a result of the interaction between the subject and the machine, it is useful to classify the artifacts by the nature of the error made in the scanning process. In CT, artifacts may be produced by:

- Errors in X-ray attenuation measurements;
- Alterations in the energy spectrum of the X-ray beam (beam hardening) as it passes through the patient;
- The presence of high-density foreign materials in the body;
- Partial-volume averaging effect;
- Motion of the patient;
- Quantum mottle (noise);
- Malfunction of the detector arising from errors in detector calibrations and balance, geometric effects, or a machine peculiarity; or
- Inadequate temperature, humidity, or the presence of small dust particles within the computer that causes an inadequacy in the reconstruction algorithm.

This article will present common artifacts such as streaks, rings, and black and white bands that appear in CT studies. This review addresses causes of artifacts, their effects on the quality of the radiographic image, and procedures that can be used to reduce the presence of such artifacts. The reduction of artifacts enhances CT interpretive accuracy and helps to establish a correct diagnosis.

Method

During a 1-year period, 7197 CT studies were performed in a large (600-bed) teaching hospital. Within this total number of studies, 432 repeat studies were performed due to image artifacts. These repeat studies were collected and classified according to the cause of the artifacts viewed. The study included both inpatients and outpatients, but not all CT studies of uncooperative patients from intensive and coronary care units were repeated. The CT systems employed in this study included a Siemens Somatom Plus 4 spiral CT (Siemens Medical Solutions, Erlangen, Germany) and a Philips Tomoscan AV spiral CT (Philips Medical Systems, Best, Netherlands).

Results

Repeat CT studies were performed due to artifacts in 432 patients, and repeat CT studies were obtained in 6% of all CT studies performed during the review period. Major artifacts were found in the form of streaks, rings, and black and white bands. Figures 1 through 8 provide examples of artifacts on CT scans in different regions and organs in which artifacts can clearly be seen. Figure 9 presents the causes of artifacts as well as the incidence of each artifact found in the images studied. Regardless of cause, most CT artifacts found in the study were manifest as streaks in the CT image.

Discussion

Joseph2 has reported two reasons for streak artifacts. First, each individual measurement involves the evaluation of a single ray or straight-line path through the slice. A second, more subtle cause for streak artifacts arises when there is an abrupt discrepancy or inconsistency between views, as might be seen with patient motion.
The following discussion will address our results and their causes, according to each artifact etiology.

**Motion**

Patient motion has a devastating effect on image quality. This was the primary reason for the development of a body unit (spiral CT) that could complete a scan during a patient’s breath-hold.

The artifacts found in our study caused by motion were manifested as black or white bands, dark spots, loss of resolution, or distortion of anatomy (Figure 1). These artifacts account for 15% of repeated studies. Clinically, such artifacts are important not only because they degrade image quality, but also because they can sometimes be mistaken for pathologic changes, such as bronchiectasis.

Theoretically, motion artifacts can be reduced by fast scanning, gating, tube alignment, corrective reconstruction, or postprocessing of the scan.

Knowing the pattern, magnitude, and frequency of motion in advance would allow the use of an algorithm to remove the motion from the projection data and then reconstruct a motion-free or, at least, a motion-reduced image.

A technical problem is image mis-registration due to variation in breath-holding from one scan to the next. Misregistration leads to failure to image part of the lung, such that a lesion might be partially or entirely excluded on the final scan. This problem is eliminated by using spiral CT during breath-holding.

**X-ray geometry, geometric oversights**

Precise control of fan-beam position is important for the production of high-quality CT images; failure to maintain fan-beam orientation can produce image artifacts. Performance of CT systems relies mainly on geometric precision and measurement quality. Inaccurate geometry, inaccurate alignment of the X-ray tube with the detectors, or incorrect data can produce artifacts and blurring that limit spatial resolution (Figure 2). In our
study, artifacts due to geometric causes accounted for 5% of repeat studies. A precise geometric calibration procedure is required, and some corrections must be applied to the raw attenuation data in order to obtain accurate measurements. An X-ray cone-beam CT system has been developed by Rizo and Martin.\textsuperscript{15} The machine was designed to control small parts limited to a few centimeters, with a high spatial resolution close to 30 microns. They introduced the machine setup and described the calibration computing resources involved in the system. They also discussed the performance on experimental data.\textsuperscript{15}

**Detector artifacts**

Artifacts from errors in detector calibrations and balance are common. A malfunction of any one detector would incorrectly backproject along the data ring to produce the artifacts. If detectors are not matched or intercalibrated accurately, the backprojection for each data ring would be slightly different, causing multiple rings (Figure 3). These artifacts caused by equipment malfunction can be eliminated by repair or good preventive maintenance.

**Beam hardening**

Beam-hardening artifacts result from the preferential absorption of low-energy photons from the beam. The effect is more pronounced in areas of large attenuation, such as bone. The artifact is seen as a shadow beneath ribs, for example, or increased shadows in the mediastinum or skull (Figure 4). This type of artifact accounted for 21% of the repeat scans in our study. This effect occurs throughout the image but usually is not perceived except where there is a great deal of hardening, such as in the vicinity of bone. This effect can be compensated for by the use of special filters or a special correction algorithm.\textsuperscript{1}

Recent experiments using CT and transmission radiography show that gadolinium (Gd) agents can increase image contrast by up to a factor of 2 when compared with more commonly used iodinated agents on an equi-molar basis. It has also been suggested that beam-hardening artifacts may be reduced with the use of Gd. This hypothesis was tested by Ruth and Joseph\textsuperscript{16} on three different CT scanners using a circular water equivalent phantom with a contrast-filled tube inserted. It was found that the artifacts were 1.3 to 1.8 times more pronounced with the iodinated contrast when compared with gadopentetate dimeglumine (Gd-DTPA).

**High-density foreign material**

The presence of objects that have an exceptionally high or low attenuation can create streaking artifacts by forcing the detectors to operate in a nonlinear response region.\textsuperscript{1} Figure 5 demonstrates the star pattern caused by high-density foreign materials. In our study, this type of artifact caused 25% of repeat studies, one of the most common reasons for image degradation. A small metal fragment produces a star pattern, and the star effect is accentuated by any motion. The only way to avoid this problem with current mathematical reconstructions is to change the angle of the slice to exclude the foreign body, but this approach might also exclude pathology. A similar pattern can be produced by gas, for example, in the gastric fundus, but the effect is less marked.\textsuperscript{4}

**Partial-volume averaging**

When tissues of widely different absorption occupy the same voxel, the beam attenuation is proportional to the average value of the attenuation...
COMMON CT ARTIFACTS

**FIGURE 5.** CT heavy streaks or star artifacts. Metallic fillings in teeth, (A) axial view and (B) coronal view. (C) Metallic filling in a tooth appears on a CT of the sinuses (coronal view). (D) Metallic stent in the heart appears on a chest CT. (E) Surgical clips (prosthesis) in the common intrahepatic bile duct appear on abdominal CT. (F) Surgical clips around the intracavernous part of the left internal carotid artery appear on brain CT.

**FIGURE 6.** (A through C) The skull appears thicker on successively more cephalad scans, because the orientation of the bone becomes more oblique and less perpendicular to the scan section (partial-volume averaging effect).

Coefﬁcient of the voxel. A volume average is computed for such voxels, leading to the partial-volume error. The scan of the skull-brain shown in Figure 6 demonstrates this effect. Images generated with helical scanning are degraded by partial-volume artifacts caused by an increased slice thickness when compared with conventional CT scanning.\(^1\)

Partial-volume effects on measurements of CT numbers may be minimized by the use of thin sections and by the selection of a section that lies in the center of the object of interest for measurement.\(^2\)

**Quantum mottle (noise) artifacts**

In a study of 20 examinations, soft-tissue imaging degraded by scattering artifacts was reported in 14 examinations.\(^3\) Quantum mottle is dose-related image noise that has the appearance of granular steaks arising from high-
attenuation structures, such as the shoulder region. A generalized adaptive median filter (GAMF) was introduced by Hsieh for more robust noise suppression and edge preservation in CT to combat severe streaking artifacts resulting from excessive X-ray quantum noise (Figure 7).

**Temperature and humidity**

Some computer components are more sensitive to extremes of temperature and humidity than is conventional X-ray equipment. For this reason, manufacturer’s recommendations regarding air conditioner installation should be closely followed. Whenever possible, a backup air-conditioning system should be available. The low-temperature limits below which solid-state devices cannot operate appropriately will probably never be encountered in a hospital installation. Failure from moderately increased temperature, as well as humidity, will frequently take the form of unexplained malfunctions of the computer, including increasing numbers of artifacts and inappropriate responses to instructions (Figure 8).

One aspect of the computer environment that must be considered is dust particle size. The particle size of cigarette smoke is only slightly larger than the size of the air gap between the playback head and disk drive of the computer system. In addition, its relatively small size makes it particularly difficult to filter from the atmosphere. For this reason, smoking in the computer room should be strictly forbidden.
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Conclusion
In our study, CT artifacts were found to be produced by: the presence of high-density foreign materials in the body (25%); an error in X-ray attenuation measurements, as a result of alterations in the energy spectrum of the X-ray beam (beam hardening) as it passes through the patient (21%); partial-volume--averaging effects (16%); motion of the patient (15%); quantum mottle (noise) (7%); malfunction of the detector arising from errors in detector calibrations and balance (6%); geometric effects or a machine peculiarity (5%); and by inadequate temperature, humidity, or the presence of small dust particles within the computer causing an inaccuracy in the reconstruction algorithm (5%). Regardless of the causes of the artifacts found in this study, most CT artifacts manifested as streaks. Films that were repeated due to artifacts accounted for 6% of the total 7197 films taken during the 1-year period. Patient cooperation, use of thin sections, repair and/or good preventive maintenance, a clean computer environment, and suitable temperature and humidity can reduce artifacts to a minimum. AR

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REFERENCES

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