Iterative Image Reconstruction Method (ASIR): Lowering CT Radiation Dose and Improving Image Quality

- Filtered back projection (FBP), the standard method for reconstructing CT images and reducing noise, is limited in its ability to produce high quality images at low radiation doses.
- A new reconstruction algorithm, adaptive statistical iterative reconstruction (ASIR), has been introduced that effectively increases image quality by reducing noise.
- By using ASIR, it is possible to lower radiation doses by up to 80% depending on the imaging protocol and patient-specific factors.

The ability of modern CT systems to provide high-resolution images that show precise anatomic detail has led to dramatic increases in its utilization over the past two decades. Patients have benefited from quicker and more accurate diagnoses and from the anatomical information in CT images for surgical planning. However, the increasing use of CT has led to concern about the possible damaging effects of ionizing radiation, particularly for young people and those who receive multiple CT examinations. Recent estimates of radiation exposure from imaging procedures in a large population of non-elderly adults (aged 18-64 years) over a three-year period indicated that 19.4% were exposed to an annual effective dose between 3-20 mSv, 1.9% were exposed to 20-50 mSv, and 0.2% were exposed to over 50 mSv.

A recent epidemiological study has suggested that there may be a heightened risk of developing cancer from a radiation exposure of 50-100 mSv, based on studies of atomic bomb survivors. Although it is not clear how the effects of cumulative radiation exposure from medical examinations compares with the experience of atomic bomb survivors, such studies have raised concern.
In recent years, a number of strategies have been implemented for lowering radiation exposure from CT, including automated exposure control, optimizing scanner settings according to patient size and clinical indications, and cardiac gating (see Radiology Rounds on Minimizing CT Radiation Dose). While these methods have resulted in substantial reductions in CT dose, particularly for pediatric patients, there is an inherent practical limit for these methods in that the diagnostic quality of the images deteriorates when the radiation dose is too low. To address this problem, a new analytical method to reduce noise has been introduced, adaptive statistical iterative reconstruction (ASIR).

The standard method for reconstructing CT images and reducing noise is filtered back projection (FBP). This method has the advantage of being less mathematically demanding than iterative methods and image reconstruction using FBP is rapid, which is essential for clinical efficiency. However, it is not well suited to low-dose protocols where data are limited. Alternatively, model-based iterative reconstruction (MBIR) methods can incorporate a physical model of the CT system into the reconstruction process to characterize the data acquisition process, including noise, beam hardening, and scatter. While this method leads to dramatic improvements in image quality, especially in low-dose scans, MBIR is computationally very demanding and, using current computer technology, takes hours to reconstruct an image.

### Adaptive Statistical Iterative Reconstruction

The most recent strategy to be adopted, ASIR, is a compromise that relies on the accurate modeling of the noise distribution of the acquired data, rather than modeling the system optics. The result is an algorithm that is computationally fast and is effective at reducing noise, enabling radiation dose reductions that would not be possible otherwise.

The ASIR program on the scanner console allows the technologists to select the amount of ASIR, from 10% to 100%. The reconstructed image is a blend of FBP and ASIR and the image characteristics depend on the contribution of these two methods in generating the final image. ASIR application improves image quality by lowering the image noise. The extent of noise reduction is based on ASIR setting used in the image reconstruction. ASIR does not significantly alter the mean attenuation (measured in Hounsfield units, HU) but has a substantial effect the standard deviation. For example, when varying degrees of ASIR was applied to the same CT data set, the attenuation of a region of interest in the liver was 106.9 ± 15.1 HU when no ASIR was applied, compared to 106.5 ± 5.3 HU with 80% ASIR. In our collective experience with ASIR in several thousand patient studies, selection of high levels of ASIR (> 60%) gives the images a very artificial look. Radiologists are used to having some amount of image noise in the scans and its absence may lower a reader’s confidence to detect subtle abnormalities in a scan. Therefore, settings in the range of 20-60% are generally used for most diagnostic exams in the body, with the higher settings typically used for young patients, who may be at higher risk from radiation exposure, for patients who require frequent imaging, and for low-dose protocols such as that used for detecting renal stones. In addition, an ASIR setting in the upper range may be considered for non-contrast CT prior to CT angiography and also for CT angiography in organ donors. By selecting these high ASIR settings, it is possible to lower the dose by 50-80% depending on the indication (Table 1).

ASIR is also helpful in improving CT image quality for obese patients. On most conventional scanners, large body habitus introduces excessive image noise, rendering examinations of poorer quality than those for normal sized patients when standard scanner settings are used (Figure 1A). Although radiation dose concerns are not a priority in obese patients, automated tube current modulation that is routinely employed in all MDCT scanners is designed to maintain an operator-determined image quality standard, it results in increased radiation dose for obese patients rather than the decrease seen in smaller patients. By using ASIR, the image quality is substantially improved without excessive exposure to radiation (Figure 1B).

<table>
<thead>
<tr>
<th>CT Protocol</th>
<th>Dose Reduction (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Routine abdomen</td>
<td>24-58%</td>
</tr>
<tr>
<td>Stone disease</td>
<td>23-81%</td>
</tr>
<tr>
<td>CT enterography</td>
<td>6-58%</td>
</tr>
<tr>
<td>Aortic aneurysm angiography (3 phase)</td>
<td>21-58%</td>
</tr>
<tr>
<td>CT angiography, organ donors (3 phase)</td>
<td>35-54%</td>
</tr>
<tr>
<td>CT Pulmonary embolism/deep vein thrombosis</td>
<td>7-64%</td>
</tr>
</tbody>
</table>
Scheduling
At this time, the ASIR package is available on one scanner on the main campus at Mass General, the GE CT750 HD. However, we plan to add this option on other MDCT scanners. Currently, all the patients scanned on this machine undergo CTs with ASIR as defined for each protocol. There is an ongoing effort to preferentially scan younger patients and those needing frequent CT exams, all in-house patients, and those with large body habitus on this scanner. CT can be ordered through ROE (http://mghroe/) or by telephone 617-724-XRAY (9729) for all locations. CT and MR are performed at the main campus as well as Mass General West Imaging, Waltham, and Mass General Imaging, Chelsea. MR examinations are also performed at Mass General Imaging, Charlestown Navy Yard.

Further Information
For further information about ASIR, please contact Dushyant Sahani, MD, at 617-726-3937.

We would like to thank Dushyant Sahani, MD, Director of CT Imaging, Abdominal Imaging and Intervention, for his advice and assistance in the preparation of this article.

References

