Iterative Reconstruction in Image Space (IRIS)

White Paper

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Siemens is continually looking for new, effective ways to reduce radiation dose and improve patient care. Over the past few years, Siemens has been developing a novel mathematical algorithm built on the theoretical concept of Iterative Reconstruction (IR). IR is a well developed concept, which in theory can provide optimal low noise, high contrast images by looping through "iterative" reconstruction cycles.

For instance, once an image is reconstructed from the measured projections, a "forward" projection, which follows the original reconstruction rays through the original image, is performed to calculate a new image. This new "forward projected" image simulates the CT measurement process, but now, the image serves as the measured object (in place of the patient). If the original image reconstruction was perfect, the measured and simulated (forward) projections would be identical. In reality, they are not identical and the differences between these two sets of projections are used to reconstruct a "corrected" image, which in turn, is used to update the original image.

In each update cycle, non-linear processing ("regularization") of the updated image is performed to ensure the stability of the reconstruction and to selectively reduce image noise in more homogenous areas. After the correction/regularization, the cycle is repeated; thereby improving the image with each iteration (contains less noise and, therefore, a better contrast-to-noise ratio). Carefully modeling the data acquisition system of the CT scanner, and its physical properties, during forward projection can also improve the spatial resolution of the images.

While IR is a very robust and beneficial technique, it is also impractical in computational power and time; requiring more hardware capacity than is currently available to avoid long image reconstruction times. In order to implement IR on CT scanners, some vendors have attempted to simplify theoretical IR with less complexity and faster reconstruction times. However, in order to achieve this, they have had to sacrifice the accuracy of the forward projection (CT system modeling) and the calculation of the correction image. This may result in strange, unfamiliar noise textures and a plastic-like look to the resulting images. Another common downfall of other IR algorithms is a change in CT numbers (Hounsfield Units) before and after applying the simplified IR algorithm. However, as shown in Figure 4, this issue can be avoided.

Siemens has taken a different approach. Our physicists have developed an IR algorithm, IRIS* (Iterative Reconstruction in Image Space), that optimally utilizes all raw (measured data) in a master volume reconstruction. The master volume reconstruction provides all available image detail information, but at the expense of significantly increased noise. The benefit of this master reconstruction is that it moves the iterative reconstruction loop into the image domain, thus avoiding the time-consuming, traditional forward projections. In order to deal with the increased noise in the master image, an advanced image enhancement, similar to the regularization step in IR, is applied to the volume reconstruction for 3 to 5 iterations to significantly reduce noise and enhance object contrast step-by-step. IRIS reconstruction occurs fast enough for routine clinical use and concurrently provides images with noise texture similar to standard, well-established convolution kernels.

*In clinical practice, the use of Iterative Reconstruction in Image Space (IRIS) may reduce CT patient dose depending on the clinical task, patient size, anatomical location, and clinical practice. A consultation with a radiologist and a physicist should be made to determine the appropriate dose to obtain diagnostic image quality for the particular clinical task.

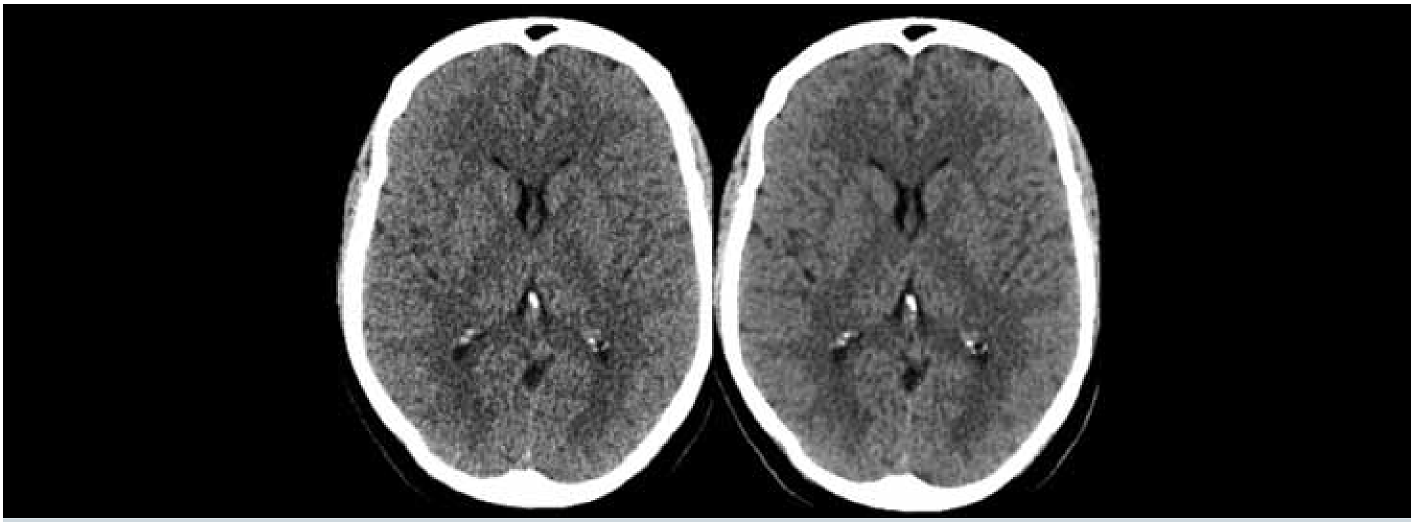

Figure 1. 70% dose H41kernel (left image), 70% dose with IRIS* (J40kernel – right image)

The following examples will illustrate how IRIS* is used to achieve low doses in neurological exams, improve diagnostic image quality in obese cardiac exams, and both lower doses and improve image quality in abdominal exams.

Figure 1 illustrates how helpful IRIS can be in neurological exams. In this case, IRIS is applied to an image where dose has been reduced by 30%. The image on the left is the original image, and the image on the right is displayed after applying IRIS and Neuro BestContrast. Notice the decreased noise levels, and improved image quality. IRIS, in combination with Neuro BestContrast, has allowed physicians to lower routine spiral head exams to 38 mGy. (E.P. Lindell, ISCT 2010)

Besides neurological exams, abdominal exams traditionally require higher dose to the patient than CT exams in other areas of the body. This is due to greater X-ray attenuation through the multiple organs within the abdomen, and to the complexity and level of detail involved in making a correct diagnosis in this region. However, by using IRIS in the reconstruction process, significant dose reduction is possible, while still preserving diagnostic image quality. Figure 2 is a fantastic example of how IRIS can improve patient care by significantly reducing dose in routine exams.

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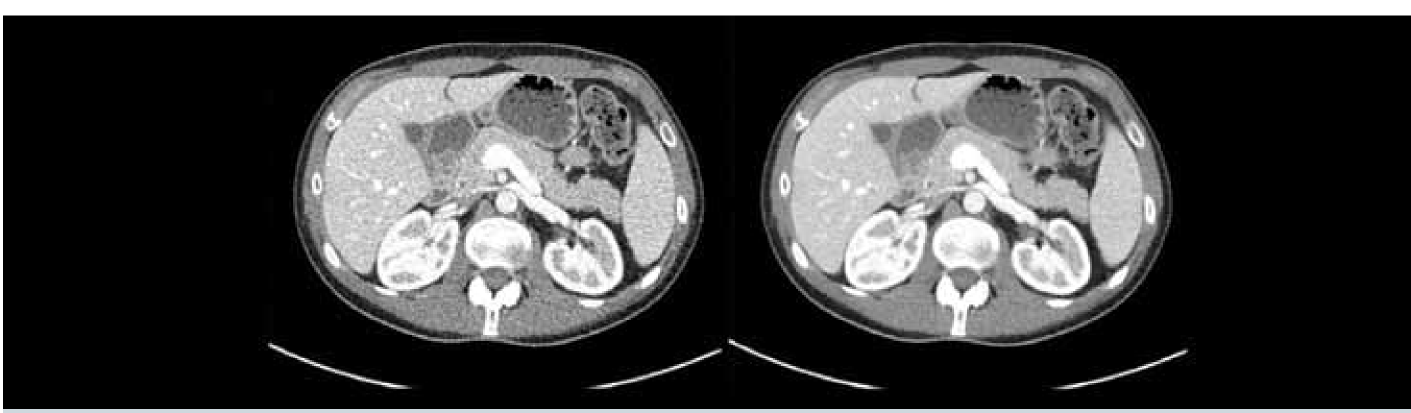
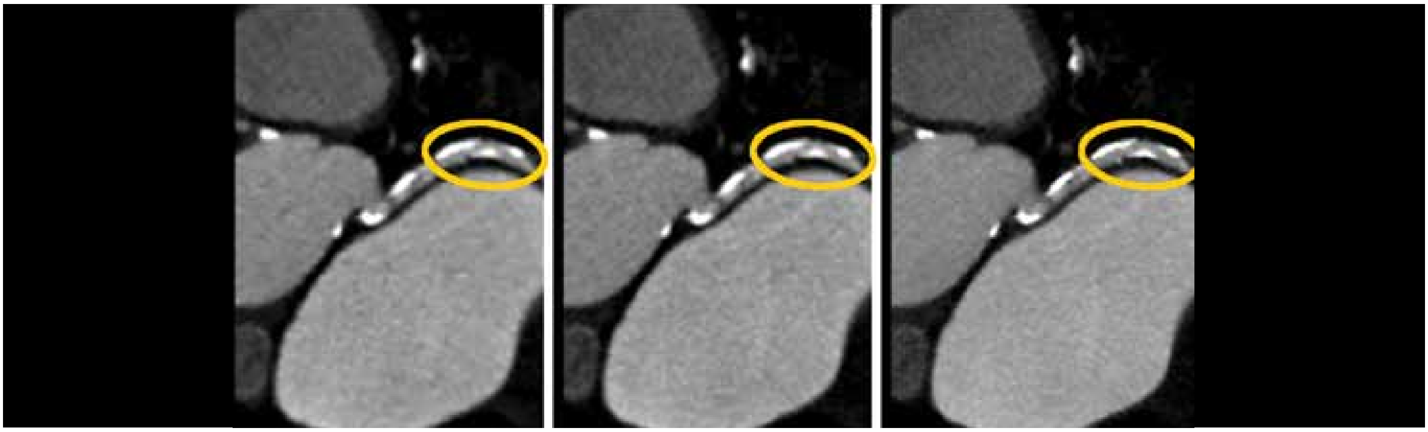


Figure 2. Example of IRIS* used in an abdominal exam. The image on the left is at 50% dose (reconstructed from only 1 tube of a dual source exam). The image on the right is after applying IRIS.



(a) 60% Dose with IRIS **(b) Full Dose Standard Kernel** **(c) Full Dose with IRIS**

Figure 3. Two different benefits of IRIS* are illustrated above. By applying IRIS (a), noise and resolution levels similar to the standard full dose image (b) can be achieved. By applying IRIS to a full dose image (c), we can reduce blooming artifacts, thus improving image quality compared to the standard full dose image.

While low dose scans are a fantastic achievement, IRIS* is NOT a dose reduction tool alone. IRIS can be extremely beneficial to patient care by providing a way to improve, or even "save" an exam, possibly preventing a re-scan. At routine doses, images of obese patients often contain higher levels of noise and artifact, making a confident diagnosis difficult. By applying IRIS to exams for obese patients, noise levels can be reduced significantly while preserving and even improving spatial resolution. This improved resolution can be seen in the cardiac exam shown in Figure 3, where the blooming artifact has been reduced, providing the physician with more diagnostic confidence. Another option is to reduce dose to the patient while maintaining resolution similar to the routine dose exam. A combination of these benefits can also be applied to images. In Figure 4, notice that IRIS does not affect CT numbers.

Several institutions around the world have already integrated IRIS into their routine practice. While these improvements to routine care through dose reduction are not yet published, we can provide some ideas for dose reduction in combination with IRIS, based on customer experience.

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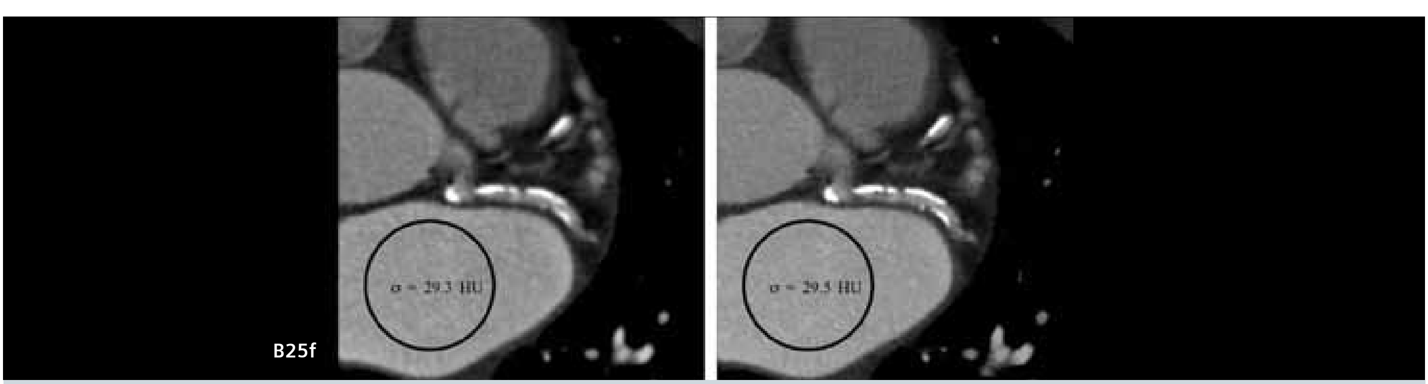

Figure 4. CT number (Hounsfield Units or HU) are unaltered when applying IRIS* to images as demonstrated by the mean HU values between regions of interest in the original B25f kernel image on the left and the IRIS image on the right.

Table 1.

Exam Type	Reduce Dose (mAs) by:	New IRIS* Protocol after Dose Reduction				Original Base Protocol			
		mAs	kV	CTDIvol (mGy)	Kernel	mAs	kV	CTDIvol (mGy)	Kernel
Abdomen	30%	150	120	10.1	I30	210	120	14.2	B30
Thorax/Chest	40%	65	120	4.4	I70	110	120	7.4	B31
HR Thorax	50-60%	50	120	3.4	I70	110	120	7.4	B80
Head (spiral)	30%	275	120	41.2	J30	390	120	59.6	H31
Sinus/Orbit	40%	75	120	10.6	J70	125	120	17.6	H60
Spine	30%	230	120	15.5	I30	330	120	22.3	B30
Peds-Body Angio	25%	70	80	1.1	I30	90	80	1.4	B30
Cardiac Flash	30%	260	100	~2.5	I26	370	100	~3.6	B26
DE Thorax	20%	71/60	100/140Sn	5.8	Q30	89/76	100/140Sn	7.3	D30
CTA Body	37%	75	120	5.1	I30	120	120	8.1	B30

The numbers in Table 1 are examples of dose reductions that have been successfully implemented into clinical practices across multiple institutions worldwide. Table 1 is based on Siemens default protocols; dose reductions (% decrease in mAs) should be applied to Siemens original base protocols in order to derive IRIS* protocols. It is important to note, however, that image quality requirements at each institution may differ significantly, and thus, will affect the percent dose reduction that may be achieved for individual protocols. Each institution should thoroughly compare its current protocol parameters to those stated below when utilizing IRIS.

While it has been demonstrated that IR techniques are extremely effective in lowering patient dose, it is important to remember the percent of dose reduction is not as important as the actual dose delivered to the patient. For example, a 50% dose reduction from a starting point of 45 mGy is 22.5 mGy; whereas a 25% dose reduction from 25 mGy is 18.75 mGy. Also, even when low doses are achieved, diagnostic image quality must be the final result.

Table 2.

Examination	ACR Reference Levels (CTDIvol)
CT head	75 mGy
CT adult abdomen	25 mGy
CT pediatric abdomen (5 years old)	20 mGy

*From The American College Of Radiology: *Practice Guideline For Diagnostic Reference Levels In Medical X-Ray Imaging*, 2008.

In summary, IRIS can be used to significantly reduce dose while preserving and even improving image quality compared to standard full dose exams. Thus, IRIS is a fantastic new addition to the already powerful arsenal of dose reduction techniques available on Siemens scanners, which allow Siemens to deliver the lowest dose and our customers to provide the best possible patient care.

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