Clarity CT Technology

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Using state of the art algorithms Sapheneia Clarity CT allows physicians to lower radiation dose when acquiring CT data while maintaining image quality. The proprietary Clarity algorithm reconstructs an optimized CT volume from any (low dose) input volume.

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INTRODUCTION

The benefits of using computed tomography (CT) in the diagnostic process of finding diseases, trauma and, in the guidance of interventional or therapeutic procedures, are well known. Since it is a technique which is based on ionized radiation, a careful use of the equipment is always important; this is particularly true for imaging pediatric patients who are at greater risk than adults[2]. This is due to longer life expectancy and a more rapid dividing of cells which significantly increase the odds of developing cancers from radiation exposure[3]. Unnecessary radiation may also occur when CT scanner parameters are not appropriately adjusted for patient size[4].

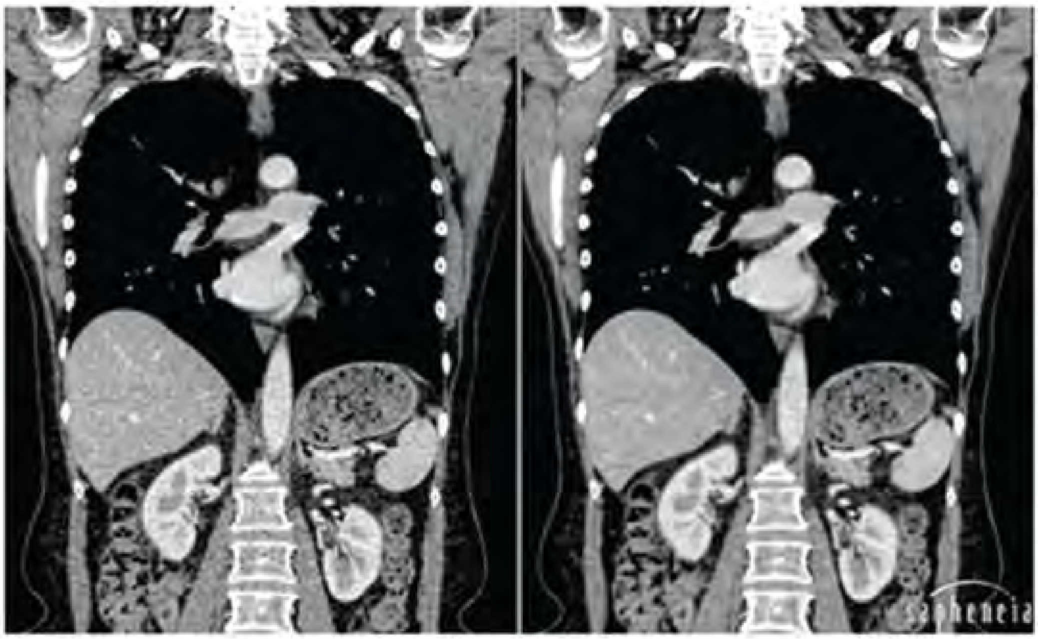


Figure 1 - *Original and processed MPR reconstruction.*

Several important measures have to be considered to manage the overexposure of patients, particularly children or small adults. It is important to use the lowest possible radiation dose, the ALARA principle (as low as reasonably achievable), without compromising clinical diagnostic value[5,6]. These measures include, but are not limited to, the use of optimized settings on the CT, minimal usage of multiple or repeated scans and usage of alternate modalities, such as ultrasound and MRI.

CT imaging has evolved significantly recently and has in many cases replaced x-ray procedures and is likely to continue to grow in popularity. Even when careful usage of CT is followed, including optimized procedures, there are still high demands for alternative protocols that can improve the image quality, without increasing the radiation dose.

One of the primary difficulties in interpreting CT images is the presence of noise. When decreasing the radiation dose during the acquisition of images of the subject, patient, the images produced will show a decreased signal to noise ratio; i.e. a “noisier” image. This causes a more difficult assessment of the diagnostic relevance for the observer.

Sapheneia has developed software tools to address the challenge of decreasing the radiation dose, while providing uncompromised image quality. The employed image-processing techniques, increase both the signal-to-noise-ratio (S/N) and lead to a clarification of edges, lines and other structures in the diagnostic images.

Sapheneia Clarity™ ***CT Solution*** provides post-processing methods giving the diagnostic and surgical observer the ability to lower the dose needed when acquiring image data. This yields reduced harmful radiation exposure to the patient, while maintaining diagnostic relevance and increasing diagnostic confidence by improving relevant structural information.

PROCESSING PRINCIPLES

The local characteristics of CT data vary greatly for different types of acquisitions, body part and types of tissues. This is illustrated in *Figure 2* where the histogram of Hounsfield values for two tissue types at different dose levels are shown. From the shape and height of the histogram peaks important information such as tissue type and noise level can be deduced. This in turn can be used to adapt the processing to the current data.

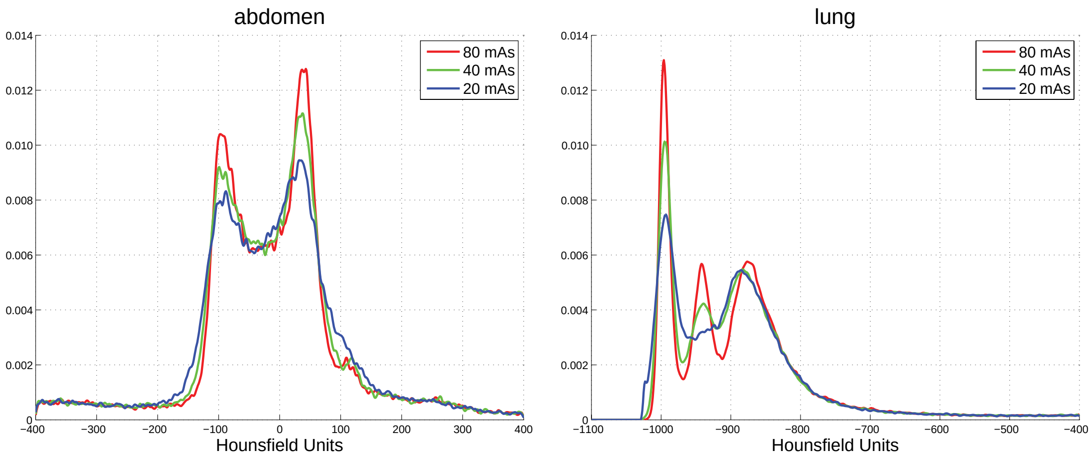


Figure 2 - *Lung and abdomen histogram at different dose, normalized histogram counts are shown on the y-axis*

The proprietary algorithm of **Sapheneia Clarity™** ***CT Solution*** is controlled by a number of parameters set in order to obtain the optimal image quality for the situation at hand; these parameters are adjustable to the observer’s preferences. This allows adjusting to different acquisition settings such as slice thickness, reconstruction kernel and so on. It further allows the observer to focus on the specific needs of different examinations, for example kidney stones versus liver lesions.

This flexibility is made possible by the way Clarity decomposes the data into a rich feature space representation based on scale, tissue and frequency. After analysis of the various parts and selective enhancement an optimized data volume is reconstructed.

WORKFLOW

Sapheneia Clarity ***CT Solution*** acts as a DICOM node that receives CT studies from the CT console, processes the data, and then forwards the optimized study to the selected destination as described in *Figure 3*. This destination can be any one or more DICOM nodes, typically either the PACS system or a specific workstation.

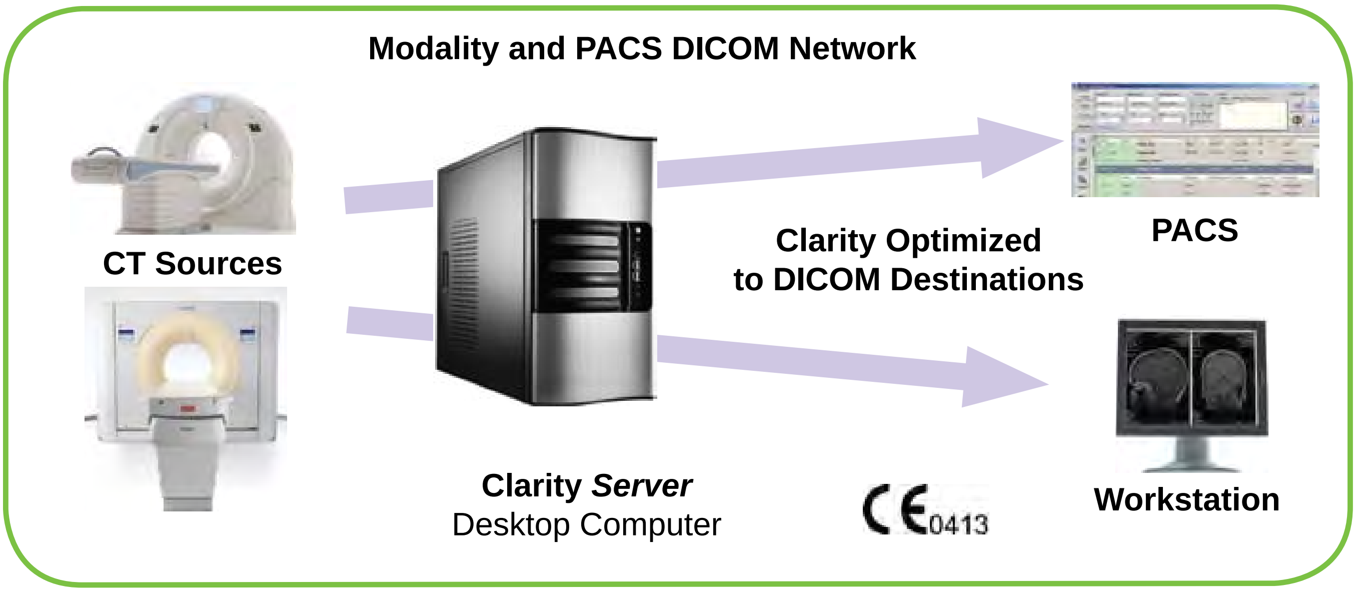


Figure 3 - *Workflow overview*

ALGORITHM

The main features of the **Clarity** proprietary algorithm and its unique processing scheme include:

- Structure Adaptation, separate relevant local structures from noise.
- Tissue Adaptation, provide processing specific to tissue types.
- Scale Adaptation, varying processing with spatial scale of observed organs.
- Noise Adaptation, adjust to different noise levels.
- Reformatting, result data sets can be produced as different MPR sets.

The following sections further illustrate these components.

STRUCTURE ADAPTION

Sapheneia Clarity ***CT Solution*** employs a sophisticated statistical analysis of the image structure in the three-dimensional neighborhood of each pixel. Using iterative robust estimation methods, the dominant structures are separated from the embedding noise. This is in contrast to other commercially viable filtering methods which do not allow for such explicit differentiation. Once the structure has been determined, it is possible to strengthen the diagnostically relevant parts while simultaneously reducing the noise.

TISSUE ADAPTATION

Different tissues have different local properties that are used to differentiate between them. Thus, the above mentioned structure adaptation process, can be tuned to match different tissues. Furthermore, the tissue adaptation method allows for individual characteristics for various tissue types; i.e., more contrast enhancement for lung tissue as opposed to more noise reduction for soft tissue areas. This is illustrated in *Figure 4* where the same image is shown both as original and as processed image, each using two display windows. In this example the lung structure has been processed to increase the contrast of small structures while the soft tissue, such as the heart, has been predominantly filtered in order to remove noise.

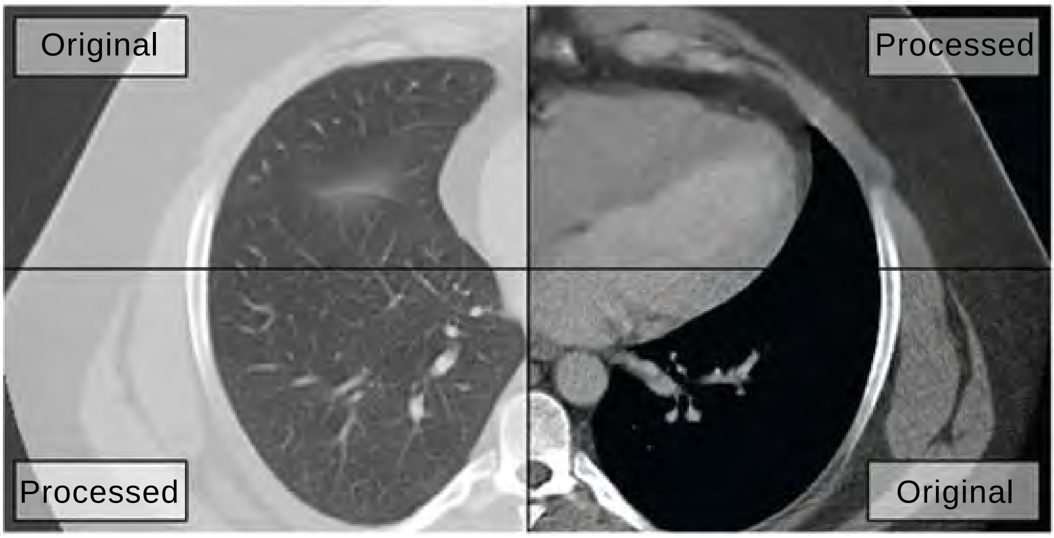


Figure 4 - *Tissue Adaption Example*

SCALE ADAPTATION

The size of important structures varies with the type of examination, and between organs. Therefore, **Sapheneia Clarity** ***CT Solution*** includes a 'scale selection' procedure that adapts the processing to the relevant scale. Also note, the type of processing that is most applicable, does change with increasing spatial scale. Large scales include, for example, organs or larger lesions where the processing becomes more 'segmentation-like.' Intermediate scales often include blood vessels, lung nodules and other oriented structures; on such scales the processing is directed more towards edge and contrast enhancement. Finally, smaller scales include considerable noise and thus noise-reduction is of primary concern. *Figure 5* illustrates three different scales that highlight the above mentioned ranges. Please note, these are only exemplary scales, **Sapheneia Clarity** ***CT Solution*** is by no means limited to these three scales.

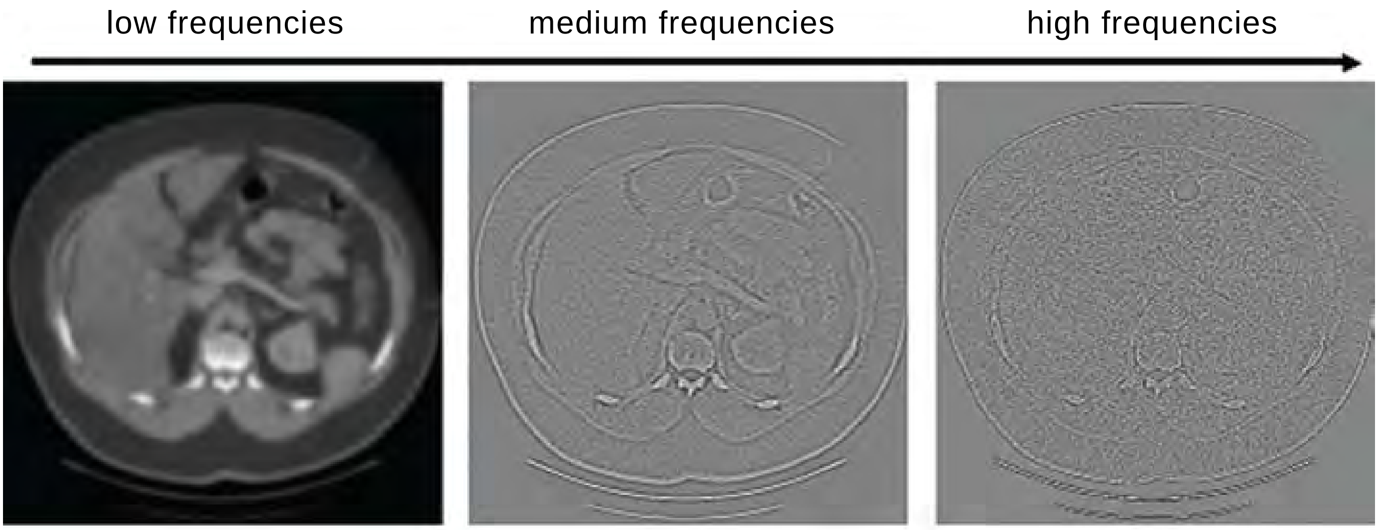


Figure 5 - *Illustration of different spatial scales*

NOISE ADAPTATION

Apart from addressing radiation dose, there are many acquisition parameters influencing the characteristics and strength of the noise present in CT data. For example, the selected slice thickness, the reconstruction kernel, as well as the exposure, greatly influence the noise in the pixel data. The inherent statistical analysis makes it possible to adapt the processing parameters to the observed noise structure. This ability to automatically adjust to various 'input characteristics' makes **Sapheneia Clarity** ***CT Solution*** an extremely versatile tool that can be used for all types of CT examinations.

REFORMATTING

From the original input volume Sapheneia Clarity can reformat the data as desired by the physician, for example into coronal or thicker axial slices. By including reformatting the coherence between slices can be exploited providing a superior processing scheme; in particular for thin slices. Without the need for an additional step in the workflow the radiologists is provided with the reformatted data as needed for the particular examination. *Figure 6* gives an example where the thin slices have been used as input and thick slices are reconstructed as output.

This Section provides a few examples of the notable processing capabilities provided by **Sapheneia Clarity** ***CT Solution***. This includes varying dose studies [per patient] to show the image quality yielded by comparing today's 'standard' acquisition protocol and the utilization of low dose acquisition protocols with Clarity processing. Please note the outcome image studies used on an obese patient further emphasize its capability. For a more objective analysis the Contrast to Noise Ratio has been measured in a phantom with and without Clarity processing.

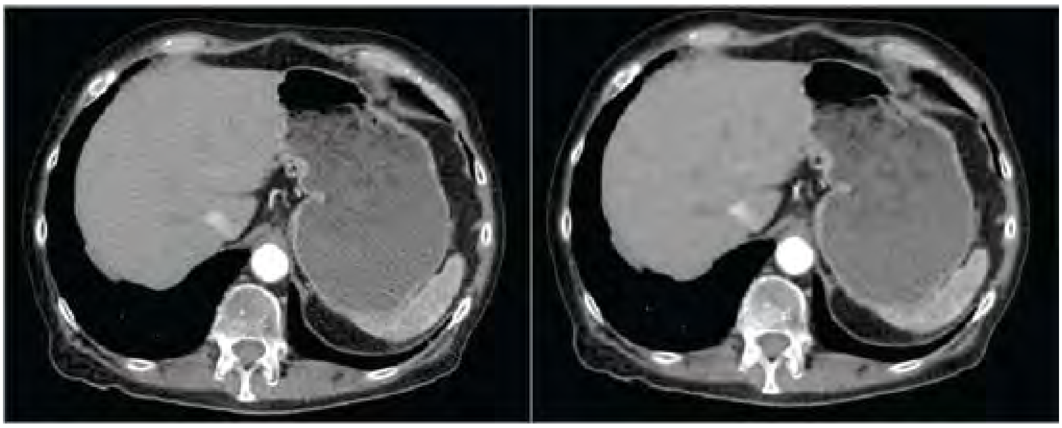

Original Processed

Figure 6 - *Thin slice input (0.625mm) is processed and reconstructed to 5mm, on the left the result of reconstructing the unprocessed data to 5mm is shown*

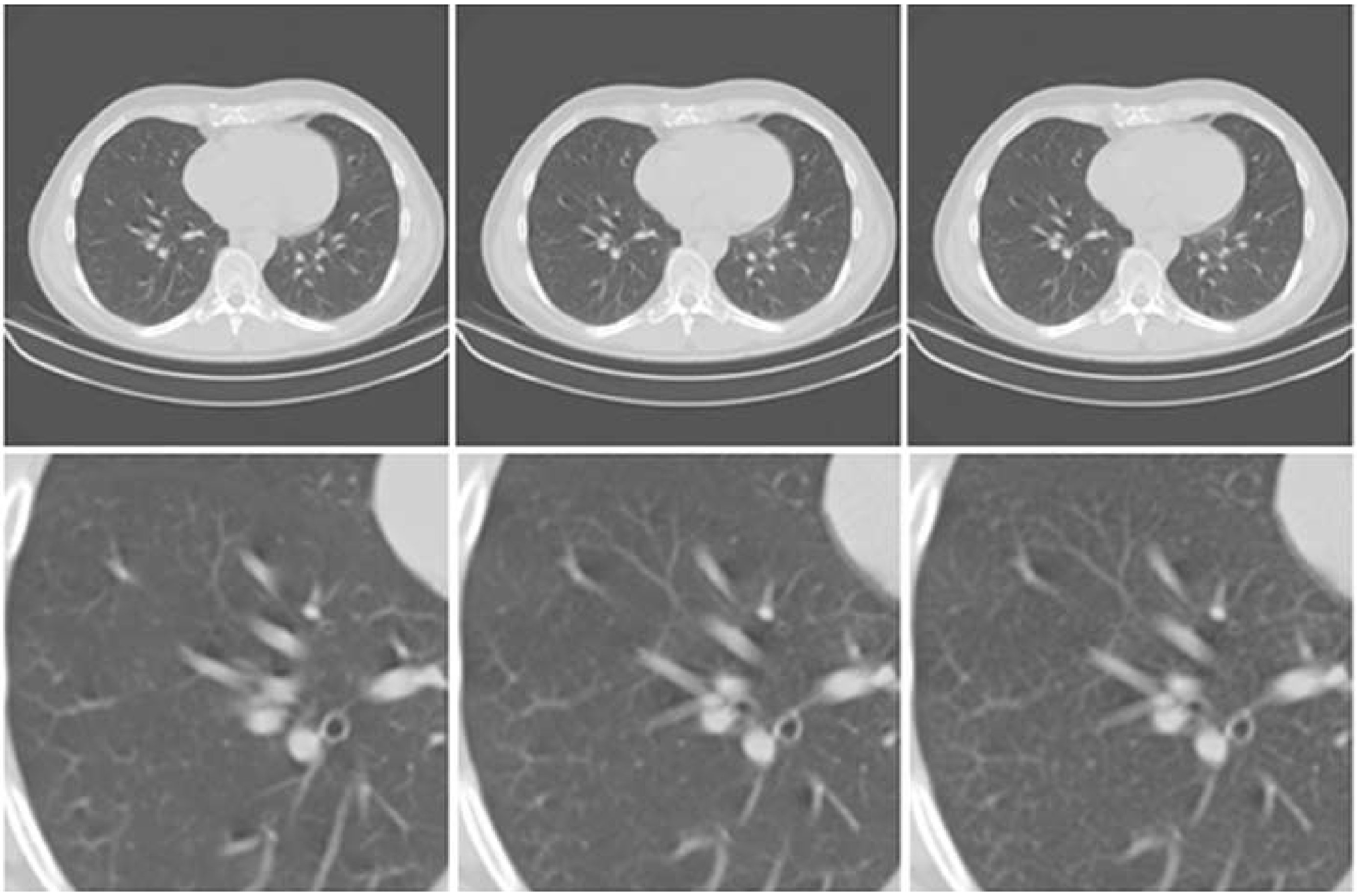
EXAMPLES

LUNG DOSE STUDY

This first diagnostic example is a low dose study of a healthy volunteer. The diagnostic data was collected using 120kVP and 5mm slice thicknesses. A slice through the lung has been scanned both with the normal dose and with a fourth of the dose. As one can observe by reviewing the diagnostic images, there is greater conspicuity of smaller detail visible in the processed low dose example than in the original at a normal dose level (80 mAs).

LIVER DOSE STUDY

The following example shows a liver study imaged at standard and 30% reduced radiation dose. The standard and low dose studies have been performed with approximately one month in between them, hence the slices do not match perfectly.



Normal dose (80 mAs) Low dose (20 mAs) Processed low dose (20 mAs)

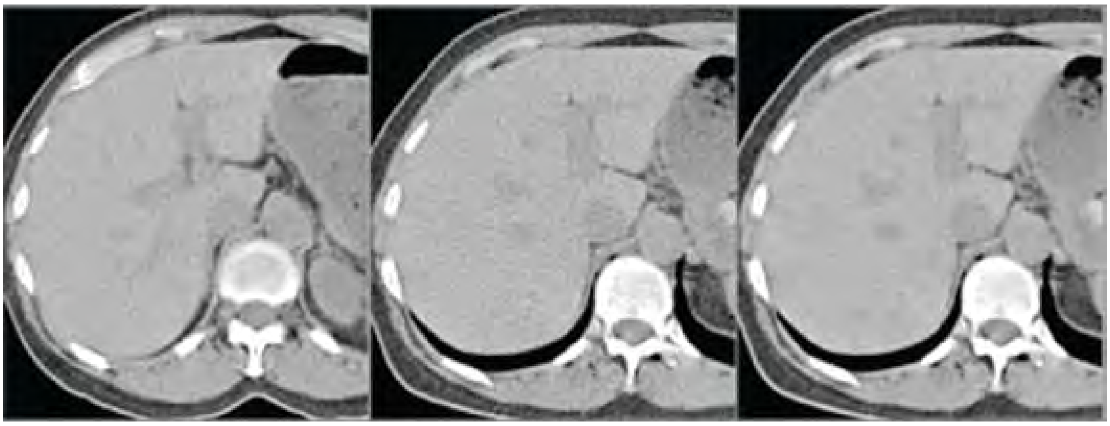
Figure 7 - *Example lung dose study*

As this example demonstrates the processed low dose image can be of comparable quality to the original standard dose image.

PEDIATRIC LIVER

A pediatric low dose liver study is presented next. The initial study had been done prior to the installation of Clarity. Shortly after Clarity has been installed a follow up with 30% lower dose was performed. Due to the different acquisition dates the slices are not exactly the same.

Again the processed low dose example is of comparable image quality as the original standard dose example.



Normal dose 30% dose reduction Processed low dose

Figure 8 - *Example liver dose study*

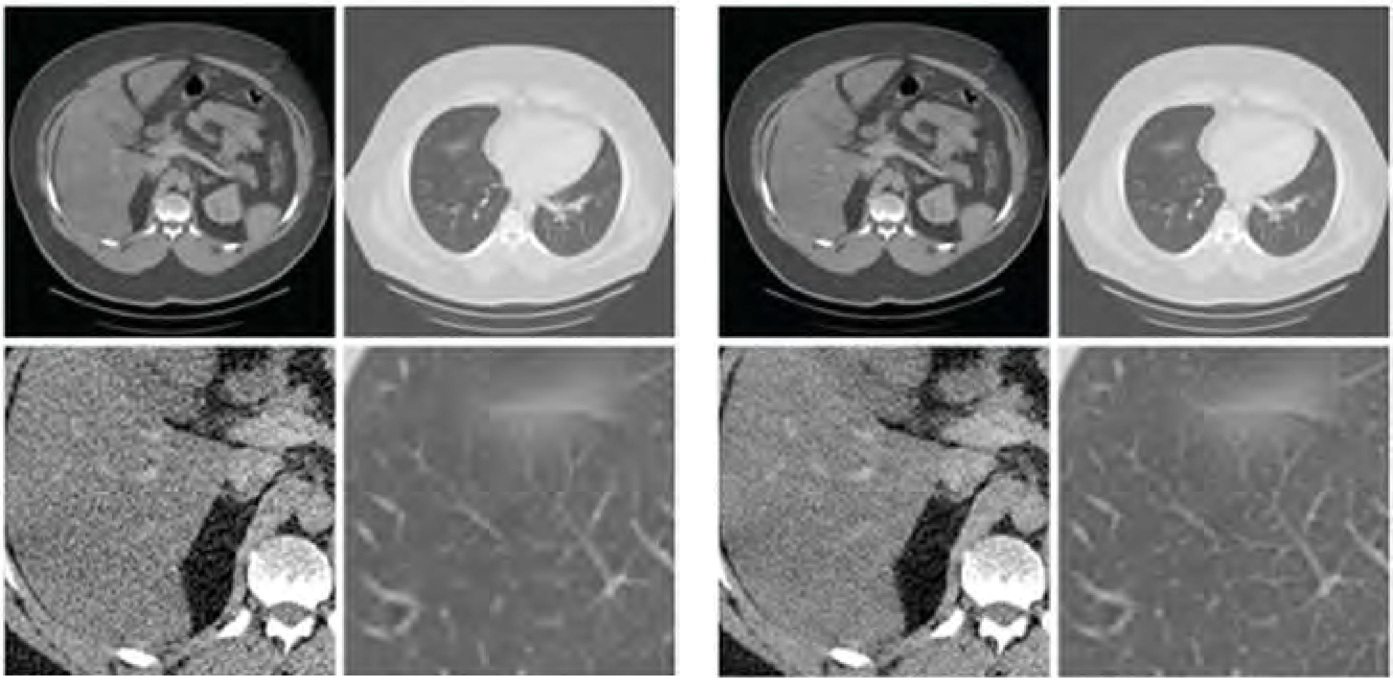
Normal dose 30% dose reduction Processed low dose

Figure 9 - *Example pediatric dose study*

OBESE PATIENT

For obese patients the x-ray generators in current CT scanners often do not produce enough radiation to ensure good image quality. As will be shown in the following example, the use of **Sapheneia Clarity** ***CT Solution*** restores image quality for obese patients.

Both the noise reduction in the liver and the enriched detail resolution in the lung are clearly visible.



Original Processed

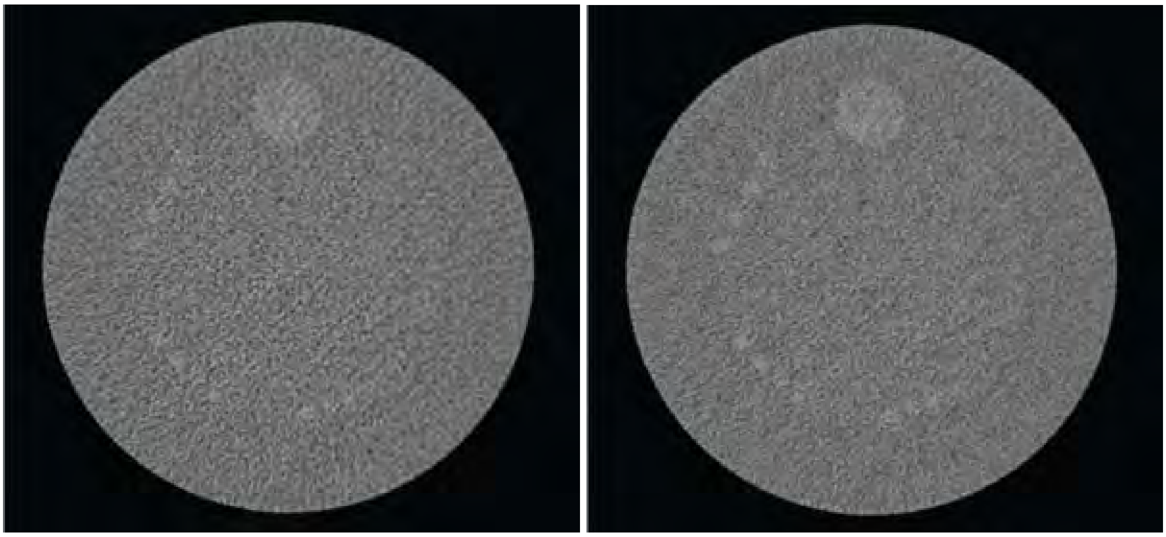
Figure 10 - *Example obese patient study*

PHANTOM CNR

The use of phantoms allows for a more quantitative assessment of the achievable results. The following example illustrates the increase of the Contrast to Noise Ratio for a standard 5mm abdomen pelvis protocol.

Similar results are obtained for all types of acquisition protocols, not shown here.

The principles behind **Sapheneia Clarity** ***CT Solution*** have been described and the resulting processing capabilities have been demonstrated on a



Original, CNR=1.04 Processed, CNR=1.31

Figure 11 - *Contrast to Noise Ratio with and without Clarity*

SUMMARY

few example cases. As we have illustrated and discussed from the above examples, it is possible to achieve excellent image quality at greatly reduced radiation dose levels.

Remember that it is not always the noise that determines the image quality, in some cases higher noise is appreciated when it comes with higher contrast. The Clarity filters will be adapted to work best with the particular acquisition protocol.

We conclude that by using **Sapheneia Clarity *CT Solution***, diagnostic and surgical imaging facilities can substantially lower the dose for many examinations on current CT modality models. As well as capitalizing the use of its second and third generation modality technologies without fork lifting, or the need of expensive manufacture upgrades to those technologies.

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LITERATURE

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