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Initial Clinical Experience of Dual Energy Blended Images and Iodine Mapping Visualization

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Introduction

The concept of dual energy scanning was developed back in the 1970s [1,2], however it has only recently become clinically viable due to technical improvements in CT scanner technology. Dual energy has shown the potential to improve characterization of the composition of materials as well as to increase specificity in diagnostic imaging. Multi-spectral data acquisition allows for the decomposition of materials through the use of attenuation differences produced by two distinct energy spectra.

The theory behind dual energy is that the attenuation measured by the detector is based on the energy of the incident beam as well as on the properties of the object such as atomic composition, density or thickness. The use of more than one energy beam allows for material decomposition due to these attenuation differences at different energies. One of the challenges that arise from dual energy acquisitions is the interpretation of the increased amount of data available. Improved visualization methods may be beneficial in reviewing and interpreting dual energy data.

Dual energy CT allows for decomposition of materials and thus the differentiation of materials with high atomic numbers such as iodine. An iodine map image data set using dual energy methodology can display the distribution of iodine and thus differentiate regions of vascularity within the organ post scanned. The iodine enhancement map is usually a color overlay over an anatomical image to emphasize the differences in vascularity and to allow anatomical localization.

Beyond decomposition analysis there are methods that provide additional valuable information on the characteristics of the materials being imaged, for example blended images. Essentially, a blended image is a fusion of the 135 kVp scan and the 80 kVp scan to produce one combined image. This type of visualization improves SNR (signal to noise ratio) by using the noise characteristics of the 135 kVp scan as well as CNR (contrast to noise ratio) by using information from the 80 kVp scan.

The two different techniques can be applied in parallel for more effective patient evaluation. In this paper we present our initial clinical experience assessing the effectiveness of blended images and iodine maps in dual energy analysis.

Basic principles

To produce the best possible image, it is necessary to decrease the noise in the image and to increase contrast in order to be able to detect abnormalities.

In CT imaging, higher energy (135 kVp) scanning gives a better signal to noise ratio whereas lower energy (80 – 100 kVp) imaging generally produces enhanced contrast between materials. The best image would therefore be a combination of these two methods, thus decreasing the noise while maintaining the best possible contrast detail.

Dual energy can create a blended image for routine clinical diagnosis. A blended image is typically produced through a linear combination of the high energy image and the low energy image. This, however, generates a less than optimal image due to the noise of the low energy image and lower contrast detail in the 135 kVp image. Therefore,

Scan Condition	
Tube voltage	80/135 kVp
Tube current	570/100 mA
Rotation speed	0.5 s/r
Slice × Rows	0.5 mm × 80
Scan FOV	40 cm
HP	11.4
Backside exposure	OFF

Contrast Condition	
Concentration	370 mg I/cc
Injection duration	50 and 80 ml
Injection speed	2.5 ml/s

Reconstruction Condition	
Reconstruction kernel	FC13
AIDR 3D	strong

Table 1: General protocol conditions

a pixel by pixel blending function was developed which uses the greater contrast detail of iodine in the 80 kVp image. At the same time, low-intensity values such as water benefit from the 135 kVp image due to its low noise properties. The combination of these images can be described as a ratio between these two images which is based on the noise characteristics needed for diagnosis as well as on the amount of contrast available in the images.

Blended image = (1-ratio) low kVp image + ratio high kVp image

The automatic optimization of this ratio is important to the overall quality of the blended image. The workflow for the blended image is shown in Figure 1. Each image is evaluated on a per voxel basis. The comparison of the mass attenuation coefficients between the water and the contrast medium allows calculation of the ratio necessary for combining the energy images. The blending curve is actually based on a sigmoidal curve. A combination of the 135 kVp and the 80 kVp image is used to produce a kVp equivalent image of 120 kVp (see Fig. 2).

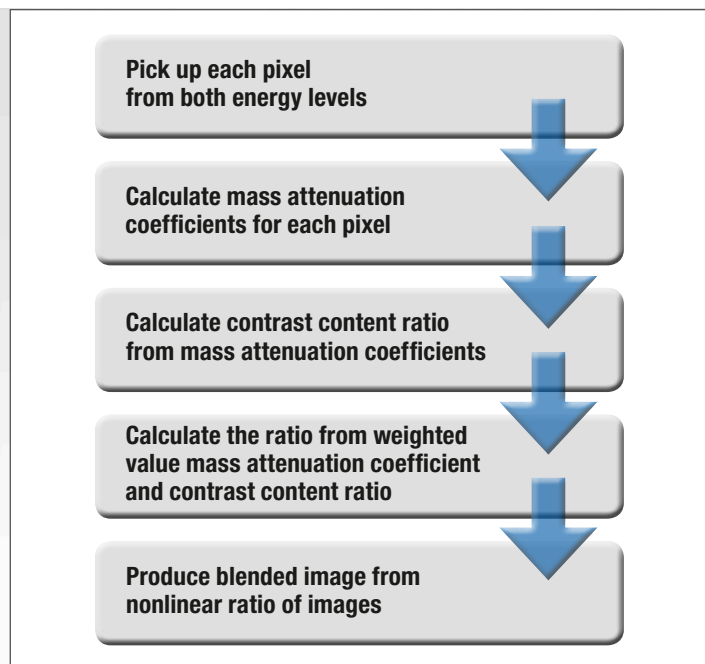The decomposition of the dual energy data produces an iodine map which allows the physician

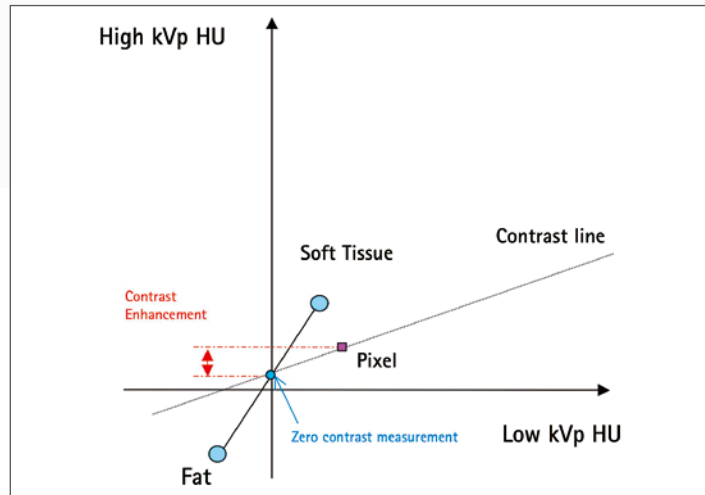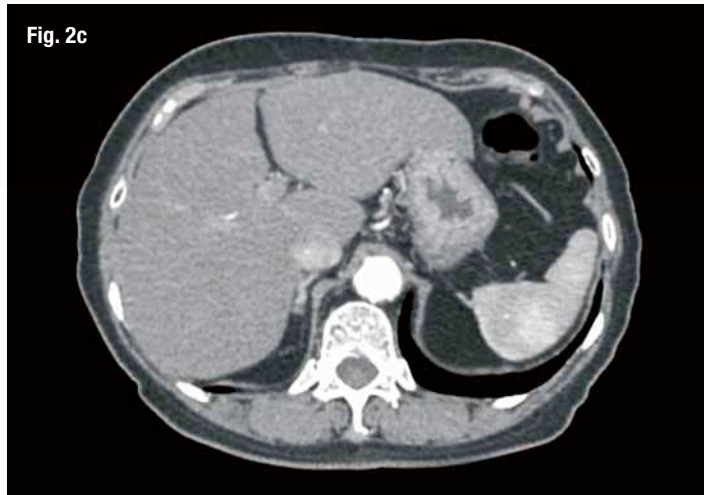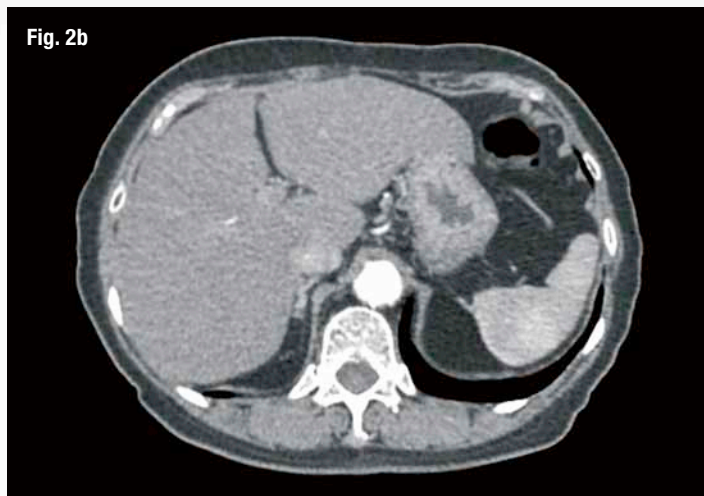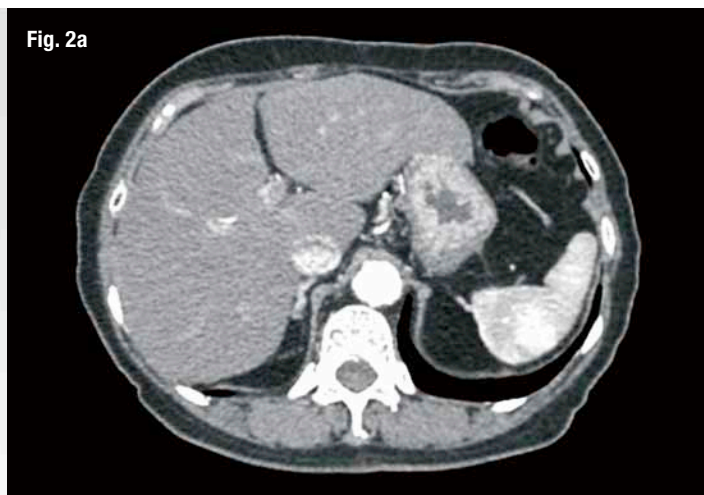Fig. 1: Calculation workflow of blended image

Fig. 3: Decomposition

Fig. 2: 80 kVp original image (a). Blended image (b). 135 kVp original image (c).

to evaluate the distribution of iodine within the organ post scanned.

In Figure 3 the pixel values from the high energy data sets and the low energy data sets can be plotted on the y-axis and x-axis respectively. The HU for pixels with contrast (high density) form a so-called contrast line. Similarly, the lower density pixels of tissue and fat form a tissue fat line.

A zero contrast measurement is determined from the intersection of the contrast and tissue lines along the y-axis. The difference between the pixel value HU on the high energy image and the zero contrast measurement determines the amount of enhancement which is shown as a color map overlay.

Material and methods
Dual energy data sets were acquired on an

Aquilion PRIME using the single source dual energy helical scan mode. This scan mode applies the high kV at the first part of the rotation and lower kV on the conjugate views and maintains a low pitch. This allows for near simultaneous acquisition of data to minimize movement between energy levels. Another approach to perform a single source dual energy helical scan is to acquire two consecutive helical scans, each acquiring a different energy

Case 1: Hypervascular liver tumor
Dual energy scans were performed in the late arterial phase to assess hepatoma recurrence. Dual energy technique allowed for a reduction in the amount of contrast with better conspicuity of small lesions from the combination of blended images and iodine maps (Figure 4).
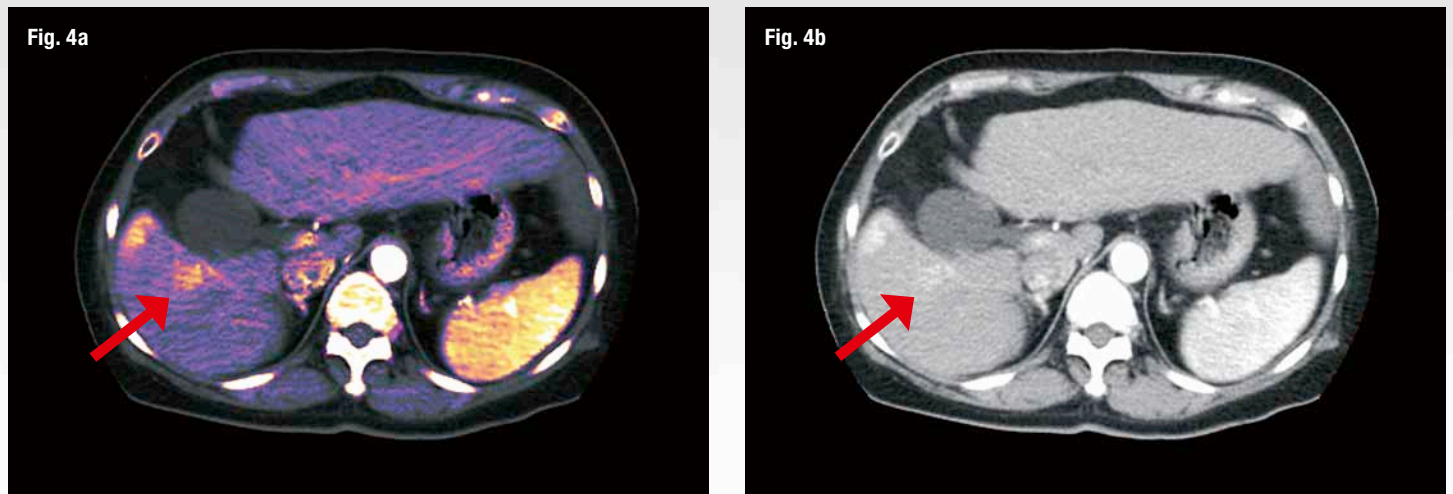

Fig. 4: Hypervascular liver tumor in late arterial phase, 50 % fusion image of iodine map and blended image (a). Blended image of selected 120 kVp (b).

Case 2: Necrotic tumor
A dual energy scan was performed in the late arterial phase to visualize this lesion. The blended image provides the low noise level of 135 kV and the improved contrast enhancement of 80 kV. Still the differentiation between necrotic areas and enhanced areas is difficult in this image. The fusion image of the iodine map and the blended image allows us to differentiate the necrotic areas from the areas of enhancement in the late arterial phase.
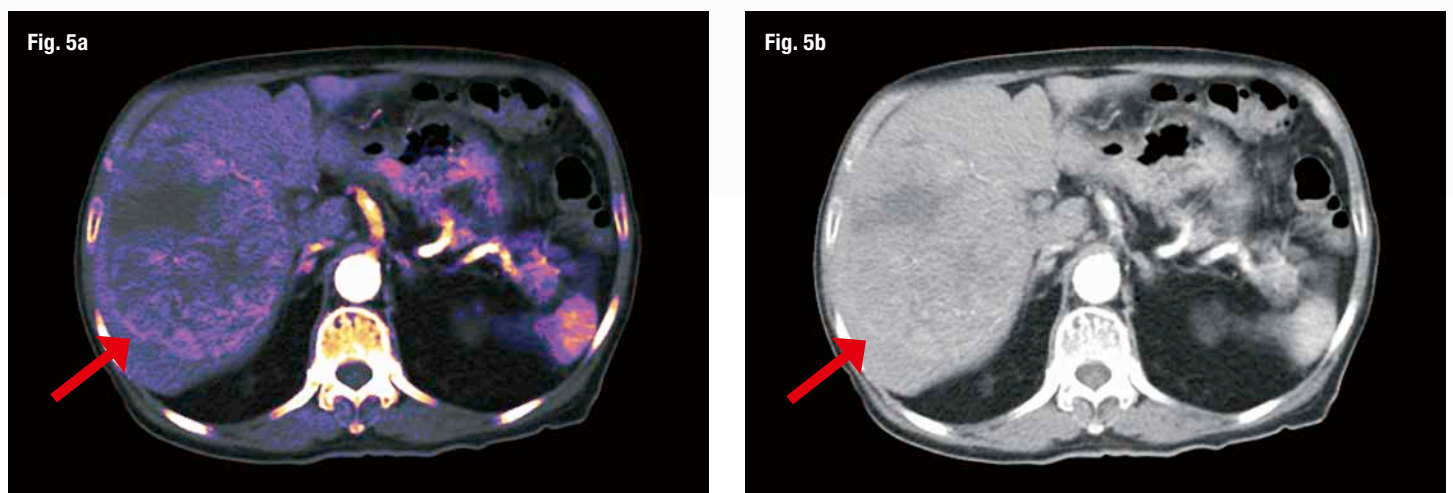

Fig. 5: Necrotic tumor in late arterial phase 50 % Fusion image between iodine map and blending images (a). Blended image of selected 120 kVp (b).

level and pitch. Performing this "go and go" dual energy helical scan with two big time difference and two different helical runs, however, will result in mismatch of patient position and therefore reduces diagnostic accuracy.

Furthermore, the tube currents were adjusted in such a way that the noise levels of both images matched, a point that fast kV switch fails to do. This matched noise level is very important to achieve high accuracy dual energy diagnostic results. Finally, the FOV was set to 50 cm for both energy scans assuring correct comparison between two images, as opposed to the dual source dual energy which utilizes two different FOVs.

Conclusion

Our initial experience shows that the blended image and iodine mapping strongly promise to improve the conspicuity of lesions in the abdomen and the overall specificity of the images and area of enhancement. We have demonstrated the diagnostic utility of full FOV dual energy helical scans with one helical run and matched noise levels. These fundamental principles on Toshiba's dual energy mode ensure high diagnostic accuracy.

References

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