USING CONTRAST STRETCHING TECHNIQUE TO ENHANCE VISIBILITY OF LOW CONTRAST LIVER LESIONS IN COMPUTED TOMOGRAPHY: PHANTOM STUDY

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Abstract - Contrast stretching technique plays an essential role in image processing for humans and computer vision. It is performed for medical image processing to aid medical practitioners in making more informed diagnoses. This study aimed to enhance liver lesions visibility in computed tomography (CT) applications via post processing contrast stretching technique. A phantom contains 16 cylindrical lesions with four different diameters (5, 8, 10 and 15 mm) and iodine concentrations (4.2, 4.4, 4.6 and 4.8 mg iodine /mL) were scanned via four CT scan protocols with energies of 80, 100, 120 and dual energy (140 and 80 kVp). The contrast stretching technique was modified to enhance the acquired images using ImageJ software program. The contrast, contrast noise ratio and statistical analysis measurements were performed to evaluate the quality of pre and post processed CT images. The results showed that contrast and visibility of the scanned lesions was improved with modifying contrast stretching technique. The lesions visibility was found to be at its highest quality when it is acquired at 80 kVp protocol and further post-processed by the contrast stretching technique. Statistically, paired t-test results showed there were significant increases in the contrast and contrast noise ratio values for the liver lesions enhanced with the contrast stretching technique, particularly at 80 kVp protocol (P values < 0.05).

Keywords - Computed Tomography; Liver Lesions; Lesions Enhancement; Contrast stretching Technique

I. INTRODUCTION

Computed tomography (CT) scan is a medical imaging modality uses X-ray with computer to construct detailed images about the scanned region. CT image depends on the CT numbers differences to discriminate between normal and abnormal regions [1, 2]. Liver has specific physical and attenuation characteristics helping to provide more diagnostic details in CT examinations.

However, contrast of CT image is still considered to be relatively insensitive in the detection of liver lesions, particularly when these lesions have CT numbers close to the normal liver background (low contrast lesions). Contrast stretching technique often modifies to change the range of pixel values for enhancing the image quality. This method work to remap grayscales of input image so that the grayscales of output image resulting in the enhancement of subjective image quality [3, 4].

Detection of liver lesions at contrast material enhanced CT is directly related to lesion to liver contrast. Therefore, measurements as contrast (Cn) and contrast to noise ratios (CNR) are often utilized to evaluate image quality and liver lesions visibility in CT liver examinations [5-7]. As verified by the results of several published studies, the administration of iodine contrast material enhances the lesion to liver contrast of liver lesions [5, 7, 8]. The low contrast liver lesions are occupied a relatively narrow range of pixels intensity values. Therefore, modifying contrast stretching technique to expand the pixels intensity of scanned area may provide a larger portion of the displayed pixels intensity range helping to improve the visibility of the low contrast lesions. Therefore, this research was aimed to improve the visibility of low contrast liver lesions using optimal contrast enhancement techniques.

II. MATERIALS AND METHODS

Phantom Design

This research study is required a specific phantom to be designed for investigating the methods of enhancement for low contrast liver lesions. A liver phantom was developed with dimensions of 30 cm (major axis) x 20 cm (minor axis) x 10 cm (thickness) to mimic intermediate patient of approximately 72-85 kg [9]. Liver lesions with different CT numbers were prepared by diluting the iodinated contrast material (Omnipaque 350, GE Healthcare, China) via distilled water. The phantom constructed with 16 cylindrical holes of four different diameters (5, 8, 10 and 15 mm) and four different concentrations of iodinated solutions (4.2, 4.4, 4.6 and 4.8 mg I/mL). Figure 1 shows the sketch of constructed phantom with distributions of the simulated lesions.

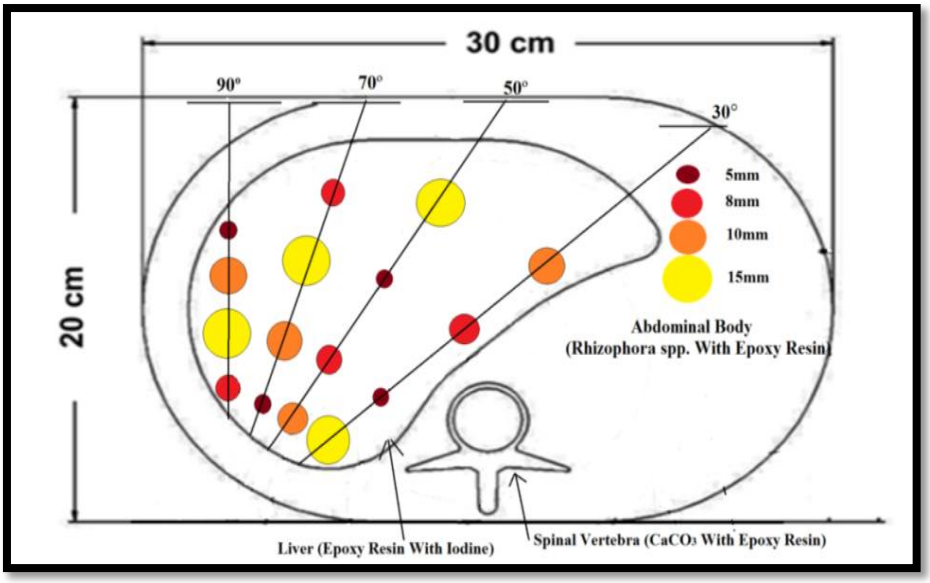


Figure 1: Sketch drawing of the liver phantom showing the simulated liver lesions distribution

Scanning Parameters

The scanning process in this research was performed at Department of Radiology, Hospital Perubatan dan Pergigian Termaju, Malaysia. The phantom was scanned via four CT scan protocols with different tube voltages. The tube voltages of 80,100, 120 and mixed energy (80&140) kVp were set with a suitable tube current time values to achieve the target radiation dose level. The reference radiation dose levels of scanned protocols were performed among the clinical settings for liver CT protocols [10].

Image Quality and Analysis

ImageJ version 1.8.0 bundled with 64-bit Java was used to measure the pixel intensities at specific regions of interest (ROIs) for the pre and post processing CT images. Also, the ImageJ was used in image enhancement processing by modifying contrast stretching technique. Pixel intensity values were measured by drawing circular ROIs in the lesions and the background. 15 mm lesions at four ROIs (ROIlesions 1–4) with constant area approximately (64 mm²) were utilized for lesions contrast measurements (Figure 2). The 15 mm was selected to obtain enough number of pixels as well as ensure sufficient confidence margin measurements. The figure also shows three constant ROIs (260 mm²) placed in three different locations in the liver background (ROI_{liver} 1–3). The contrast (Cn) and contrast noise ratio (CNR) measurements were performed to evaluate liver lesions visibility in pre-processing and post-processing images following Equations: 1 and 2. Then, the contrast stretching was modified as post processing technique to enhance the Cn and CNR of the scanned lesions. All the acquired images were converted to 8 bit image type (0-255 gray scale pixel values), and then post-processing technique was modified. Statistically, paired t-test using the SPSS, version 23.0 (IBM, New York, USA) was performed for investigation of differences in means of Cn and CNR among pre and post processing images. The probability (p) value equals to 0.05 is considered as the significant level value

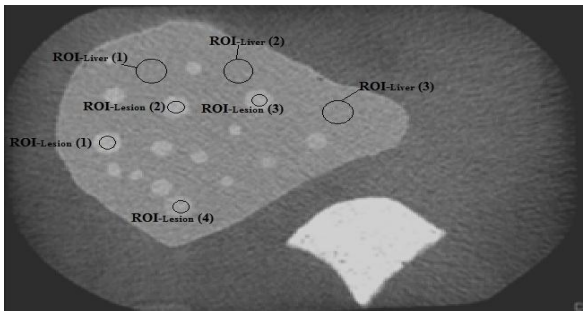


Figure 2: Cross-sectional image showing the region of interests of lesions ($ROI_{lesions}$ 1–4) and liver background (ROI_{liver} 1–3)

$$Cn = ROI_{lesion} - ROI_{liver} \quad (1)$$

$$CNR = (ROI_{lesion} - ROI_{liver}) / SD_{noise} \quad (2)$$

where ROIlesion and ROIliver are the mean pixel intensity of the lesion and liver background, respectively. SDnoise is the image noise defined by the average standard deviation for liver background.

III. RESULTS AND DISCUSSION

Table 1 shows measurements of Cn, SD and CNR for the acquired images before and after modifying contrast stretching technique. The results showed that the lesions visibility was improved by increasing their Cn and CNR values. The Cn and CNR of pixel intensity values were increased effectively compared with those values measured before enhancing. Image with 80 kVp had the highest Cn and CNR differences between the scanned lesions within 61 to 111.1 and 1.6 to 2.4 pixel intensity, respectively. It is important to note, that the measurements of lesion four with 120 kVp protocol were not reported in the table 1, since the lesions cannot be delineated by human eye.

However, the Cn and CNR measurements confirmed the ability of contrast stretching method to improve the visibility of liver lesions.

Figure 3 shows the scanned transverse images with and without contrast stretching method. As shown in images, the lesions visibility was improved effectively. All lesions visibility was improved to be more delineated by human eye. This enhancing refers to increase the differences between pixel intensities values between the lesions and the background. Statistically, all results for four groups of lesions were confirmed that the contrast stretching technique was enhanced the Cn values of the lesions significantly (all P values < 0.05).

The differences between CNR values were statistically significant in 80 kVp protocol (P value = 0.002) and 100 kVp protocol (P value = 0.04), and no significant differences were observed in other protocols (P values > 0.05). In summary, the qualitative and quantitative results concluded the utility of contrast stretching technique to enhance the low contrast liver lesions visibility, especially for lesions scanned with low tube voltages (80 and 100 kVp).

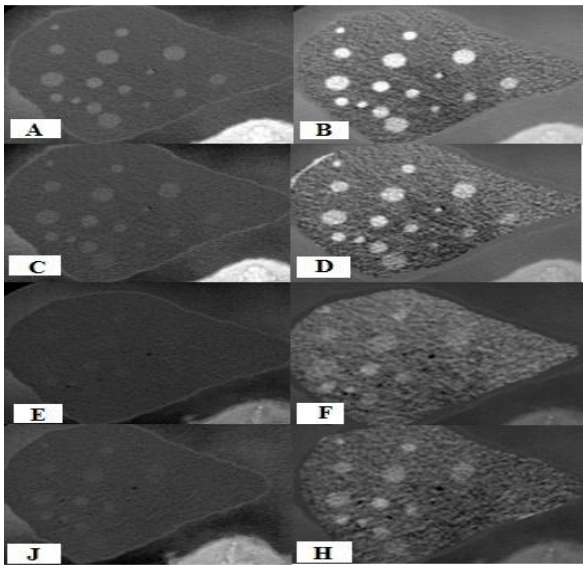


Figure 3: Eight CT images of the scanned phantom enhanced by contrast stretching technique: pre-processing (A) and postprocessing (B) images with protocol 80 kVp; preprocessing (C) and postprocessing (D) images with protocol 100 kVp; preprocessing (E) and postprocessing (F) images with protocol 120 kVp; preprocessing (J) and postprocessing (H) with protocol (80 and 140 kVp)

		Pre-Processing			Post-Processing (contrast stretching)		
Protocol	Lesion	Contrast (Cn)	Noise (SD liver)	Contrast Noise Ratio (CNR)	Contrast (Cn)	Noise (SD liver)	Contrast Noise Ratio (CNR)
(80 kVp)	1	19.8	2.8	7.1	130.9	14.8	8.8
	2	15.8	2.8	5.6	118.1	14.8	8
	3	12.8	2.8	4.6	98.5	14.8	6.7
	4	8.8	2.8	3.1	69.8	14.8	4.7
(100 kVp)	1	12.9	2.4	5.4	105.4	14.5	7.3
	2	10.4	2.4	4.3	90.9	14.5	6.3
	3	8.8	2.4	3.7	63.4	14.5	4.4
	4	4.1	2.4	1.7	33.1	14.5	2.3
(120 kVp)	1	4.8	2.1	2.3	58.2	14.6	4.00
	2	3.6	2.1	1.7	37.0	14.6	2.5
	3	2.4	2.1	1.1	29.5	14.6	2.0
	4	_	_	_	_	_	_
(80&140 kVp)	1	10.5	2.2	4.8	81.2	14.2	5.7
	2	8.8	2.2	4.0	55.3	14.2	3.9
	3	6.4	2.2	2.9	47.9	14.2	3.4
	4	3.7	2.2	1.7	30.7	14.2	2.2

Table 1: Lesions to liver contrast (Cn), liver noise (SD), and contrast noise ratio (CNR) measurements for the liver lesions for pre-processing and postprocessing images using contrast stretching technique

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