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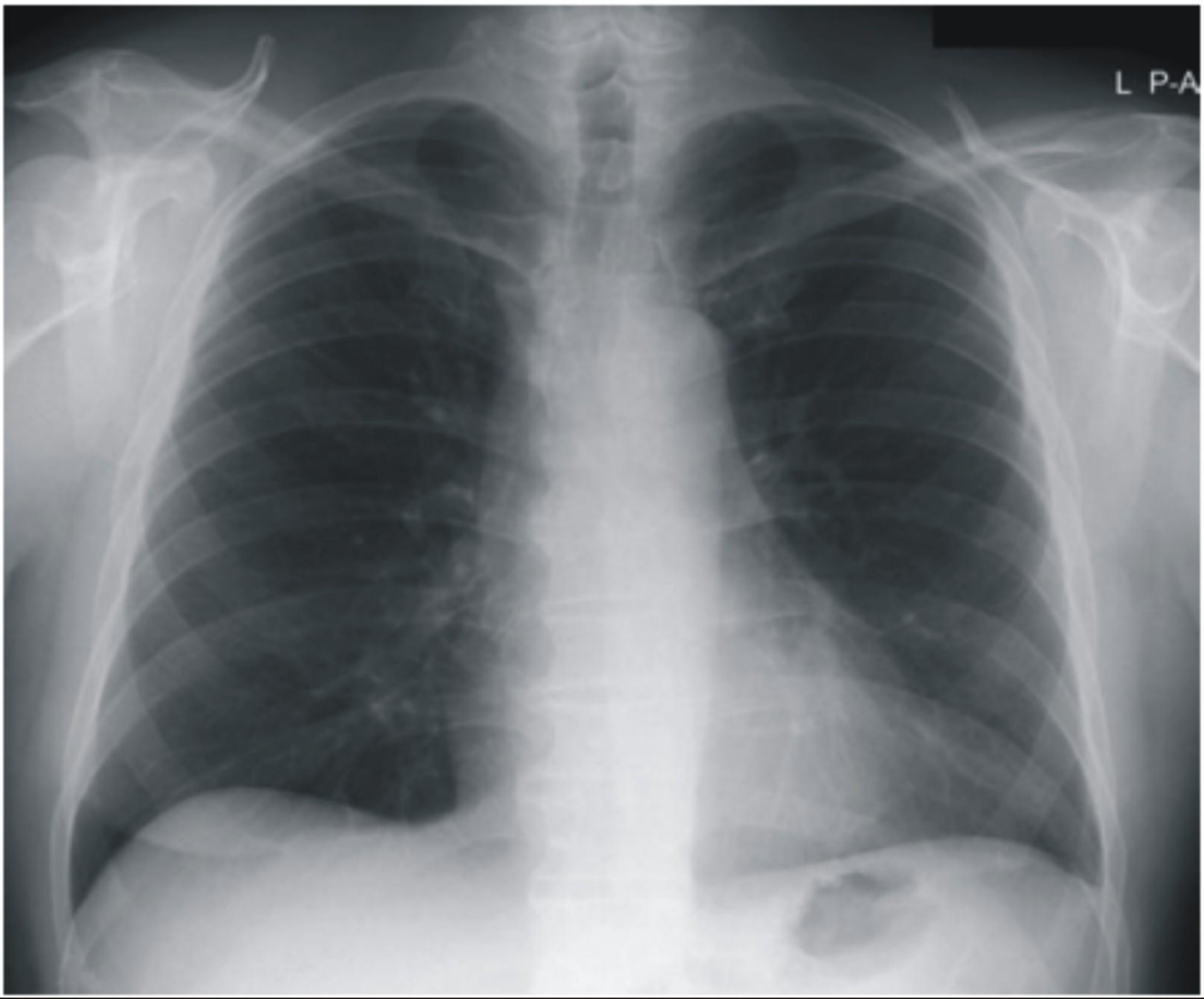

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Comparative analysis of image enhancement techniques for uterine fibroid ultrasound

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ABSTRACT

Background: The Ultrasound image is a vital diagnostic tool in the preliminary clinical assessment of many diseases, especially in Obstetrics and Gynecology. However, poor ultrasound image quality often leads to the inaccurate diagnosis of diseases such as uterine fibroids. Many researchers have proposed various methods for improving ultrasound image quality.

Objective: To explore by comparison of four image enhancement techniques, the best approach for the enhancement of uterine fibroid images towards achieving better diagnosis and proper management of the disease..

Methodology: The study assessed and compared the performance of four (4) different image enhancement techniques namely; Contrast stretching, Gamma correction, Histogram equalization (HE) and Contrast limited adaptive histogram equalization (CLAHE) on uterine fibroid ultrasound image Twenty (20) Ultrasound images from thedatabasewere downloaded and processed in MATLAB (2015a version) using image processing toolbox. Based on histogram distribution and statistical features (Mean, Standard Deviation and Entropy), the enhanced images were evaluated and compared.

Results: The results show that Contrast stretching performed better based on Histogram distribution while CLAHE shows superior performance on Statistical features

Conclusion: Contrast stretching and Contrast limited adaptive histogram equalization (CLAHE) have demostrated good performance in enhancement of uterine fibroid ultrasound image

Keywords: Ultrasound image, uterine fibroid, image enhancement, MATLAB.

INTRODUCTION

Image enhancement in ultrasound is an essential field in image processing and has made manyresearchers to focused on it in recent years. The Ultrasound image is a highly utilized tool for diagnostic imaging purposes, especially in women's health. Image enhancement of ultrasound continues to be a challenge to date [1, 2]. Medical practitioners are getting reliant on ultrasound for diagnosis purposes because of it advantages such as convenience, easy access, instantaneous imaging and most importantly, its relative safety compared to ionizing radiation imaging modalities [3-7].

Ultrasound image is produced by sending an ultrasound impulse, generated by a handheld transducer, into the body. The ultrasound wave interacts with the various tissue and organs of the body, is reflected back, and the echo is picked up by the sensor and converted it into an electrical signal that is later converted into ultrasound image.

Image enhancement is a prominent field of research, and there are scores of published studies on image enhancement of ultrasound image. Some researchers have put forward new algorithms while others modified and applied other algorithms to test their performance on various medical imagesof different clinical cases. Literature has shown that medical image processing relies on the type of the image or the medical condition in the image.[8].

Wang et al. [9] proposed enhancement algorithms of the breast ultrasound image based on fuzzy logic techniques. When tested on a variety of breast ultrasound images, the methods showed detailed features of the diseased part (pathology) on the image and with avoidance of over enhancement. It was asserted that the algorithms will be useful as an application in computer aided diagnosis.

Zhang et al. [10] suggested an image enhancement algorithm for B-mode ultrasound image based on multi-scale retinex theory (MSR). Quality estimation using three metrics of lightness, contrast, and entropy was done. The effects of five kinds of methods including HE, wavelet image denoising, homomorphic filtering, Single-Scale Retinex (SSR) algorithms and MSR are compared. The outcome shows that the proposed approach can improve visual grade of the image and helpclinician in disease diagnosis.

Zain et al. [3] compared ultrasound image enhancement of bone fracture by applying Average, median and Wiener filters. Among the three techniques, it was discovered that Weiner filtering performs well than Average and median filter in showing the bone fracture without eliminating the edges. Gupta et al. [11] performed enhancement of musculoskeletal ultrasound image by means of adaptive statistical methods.

The research employs Weibull adaptive contrast enhancement, gamma correction, and classical histogram equalization. Gamma correction was discovered to outperform the others. Konya et al. [12] proposed a new method for de-noising image and enhancing local details in the ultrasound image. Bilateral filter which preserved edge changes after filtering is utilized to remove noise. The image is first to undergo de-noising then follow by Rayleigh contrast limited adaptive histogram equalization.The proposed method have demonstrated improved visualization of the processed image.

Material and methods

Ultrasound image acquisition

A total of 20 ultrasound images with uterine fibroid are downloaded from the database [13]. All the images were of 300x225 dimensions, 96dpi both in horizontal and vertical resolution and had a bit depth of 24.

Tools for Data Analysis

The images are uploaded are uploaded into MATLAB software (version8.5.0197613, 2015a) for analysis. MATLAB also has a separatetoolbox for image processing application, which provided simpler solutions for many of the problems encountered in the research.

Image enhancement techniques implemented

We implemented four different image enhancement techniques on uterine fibroid ultrasound image using MATLAB image processing toolbox [14]. Their enhancement performance was evaluated based on histogram distribution and some statistical metrics of mean, standard deviation and entropy. The enhancement techniques are were Contrast stretching (CS), Gamma correction (GC), Histogram Equalization (HE) and Contrast limited adaptive Histogram Equalization (CLAHE).

All the original images were converted to grayscale images from RGB form using "rgb2gray" command before processing. The statistical metrics or values of the original and enhanced image were tabulated, and the variation noted. Histograms of the original and enhanced images were presented alongside the corresponding images.

Discussion

This study examined the performance of four different image enhancement techniques on uterine fibroid ultrasound images by statistical and histogram analysis.

The results of the statistical metrics as shown in Table 1 and presented on the bar chart (Fig.5-7) indicates that there is an increase in Mean and standard deviation of all the four enhanced image with histogram equalization having the highest value of mean (i.e. high brightness) and Contrast Stretching having the highest standard deviation which indicates more contrast and image details.

On the other hand, Contrast limited Adaptive histogram equalization has shown a significant increase in the value of Entropy, which signifies more information contain in the image. However, other three techniques have shown a decrease in Entropy value, with contrast stretching and Histogram Equalization showing a significant decrease while Gamma correction shows a minimal decrease in Entropy value compare to the original image.

By Histogram assessment (Fig. 1-4), Contrast stretching seems to have better histogram distribution of intensity values of the image without over enhancement of the image and the fibroid tumor is well outlined. Gamma correction seems to have minimal effect on the histogram distribution of intensity values in the image, and therefore, the fibroid image is not well outlined but the overall brightness of the image increased. There is the almost linear distribution of histogram toward the brighter end of the intensity values in the image, and thus, the image appears very light even though the fibroid is seen more enhanced than in the original image. Histogram distribution in CLAHE shows a dispersion but more toward the darker region of the intensity values. However, the overall image contrast and visualization of the fibroid is seen to improved compared to the original image.

There are different types of contrast enhancement methods and as well, there are different types of digital images [15]. Therefore, there is no general method that uses on all types of images. The methods used for one of the images types may not give good results when used with another type of image. For instance, Histogram Equalization was found to perform excellently on X-ray images in contrast adjustment but in our study we observed it performed poorly regarding maintaining image details while enhancing the fibroid image. Also, we have learned from the literature that the image enhancement is problem oriented. For instance, Gupta et al. [11],

In his study “Musculoskeletal ultrasound image contrast enhancement” found that gamma correction performed better than Weibull and histogram equalization. However, this is in contrast to Hafiza et al. [16] findings where Histogram equalization is said to perform better on Kidney ultrasound image enhancement than the others. However, in our study, we found CLAHE to perform superiorly than gamma correction, histogram equalization, and contrast stretching.

Results

A: Histogram Distribution

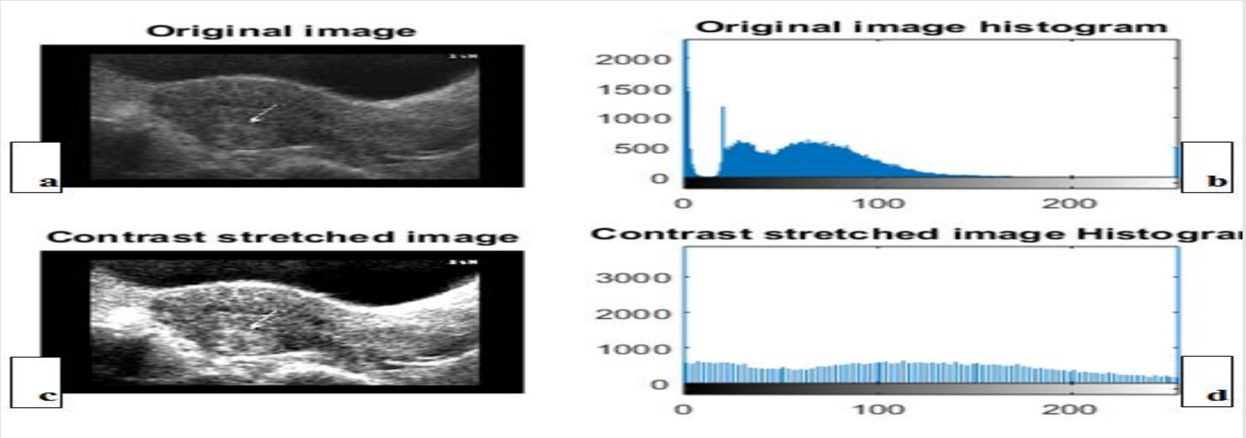

Figure 1: Contrast Stretching (a) Original image, (b) Histogram of Original image, (c) Contrast stretched image, and (d)Histogram of Contrast stretched image

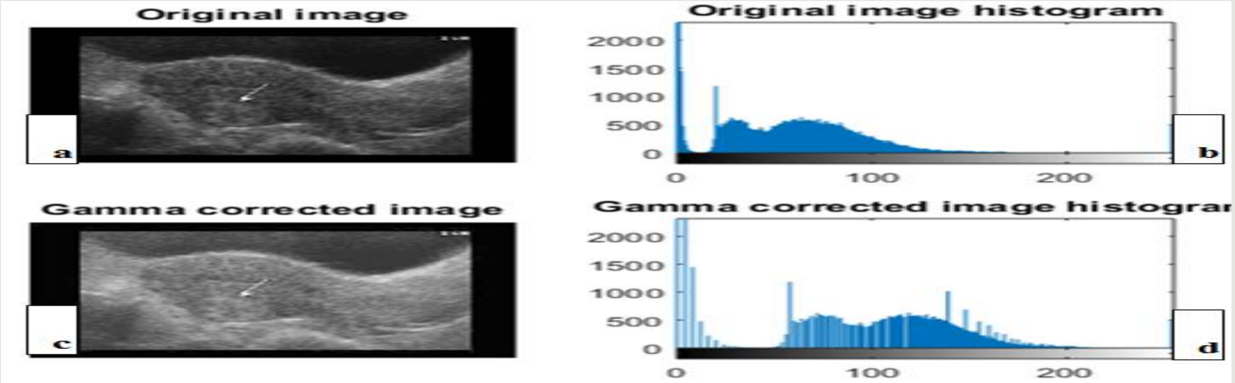

Figure 2: Gamma Correction (a) Original image, (b) Histogram of Original image, (c) Gamma corrected image (d) Gamma corrected image Histogram

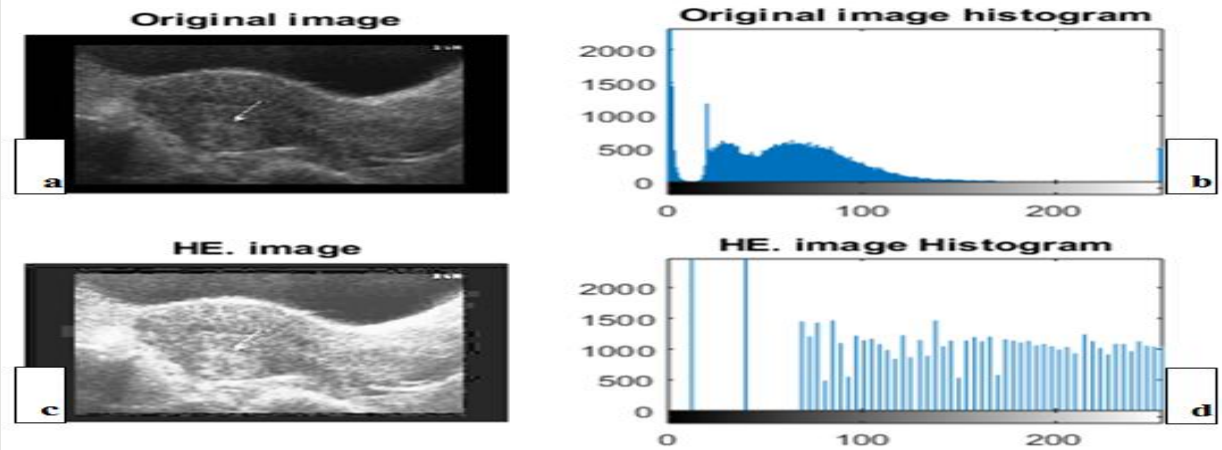

Figure 3: Histogram EqualizationOriginal image, (b) Histogram of Original image, (c) HE enhanced image (d)) HE enhanced image Histogram

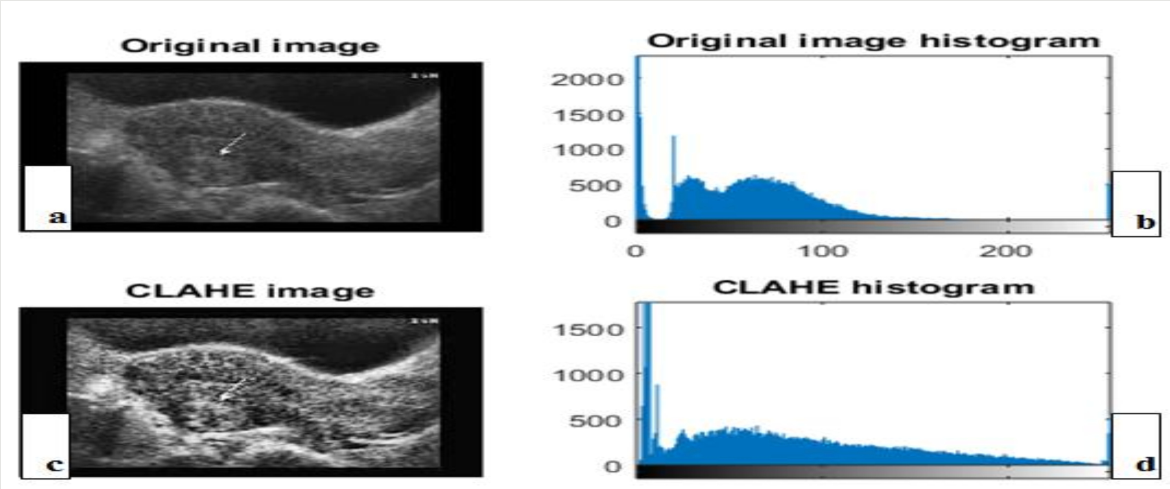

Figure 4: Contrast Limited Adaptive Histogram Equalization (CLAHE):(a) Original image, (b) Original image Histogram, (c) CLAHE enhanced the image and (d)) CLAHE enhanced image Histogram.

B: Statistical Metrics

Table 1: Average Values of Mean, Standard Deviation(SD) And Entropy of The Original image (OI) and Enhanced Images (CSI,GCI,HEI,CLAHEI)

METRICS	OI	CSI	GCI	HEI	CLAHEI
MEAN	47.527	78.74	75.01	128	73.32
SD	47.9665	87.52	60.11	73.39	66.81
ENTROPY	5.7505	4.37	5.7255	4.76	6.7

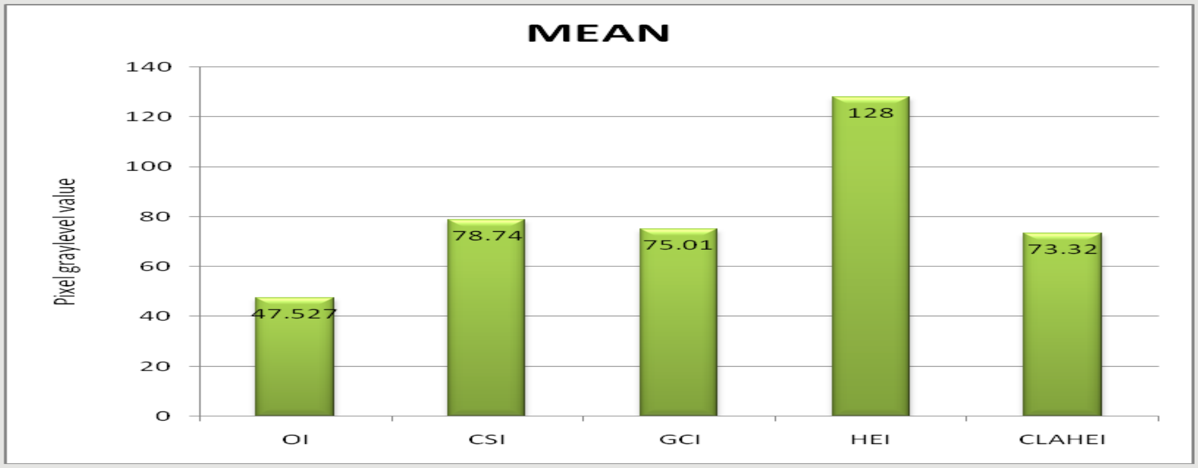

Figure 5: Mean Values of original and Enhanced Images

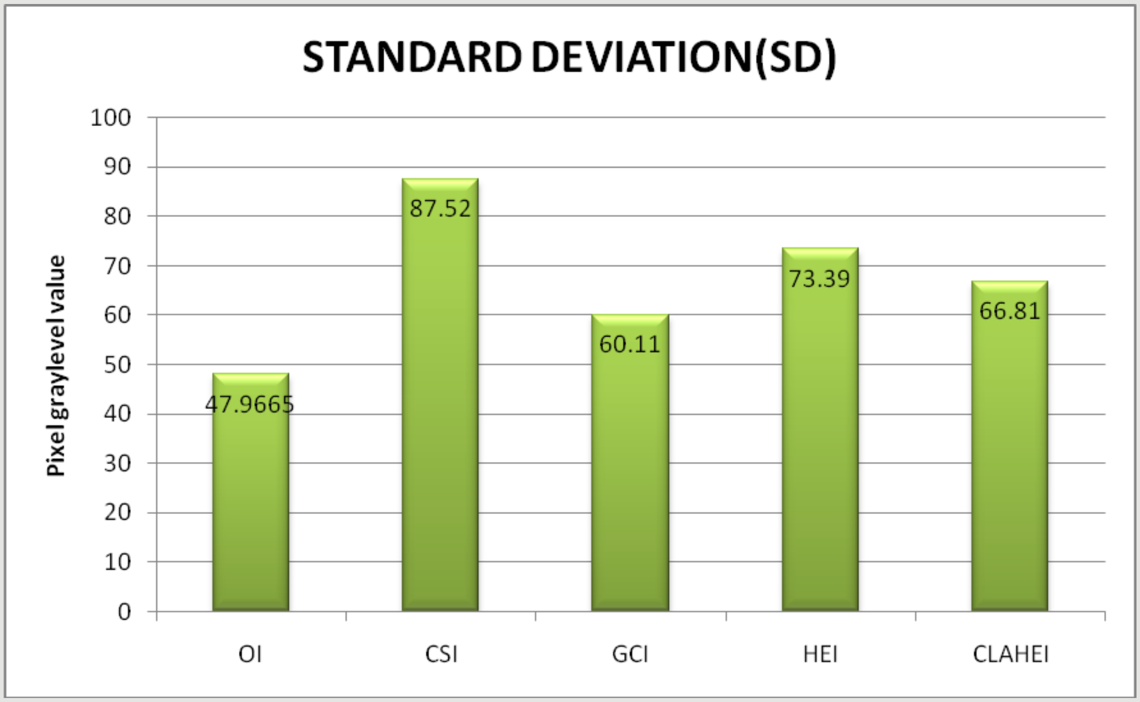

Figure 6: Average Standard Deviation (SD) Values of Original and Enhanced Images

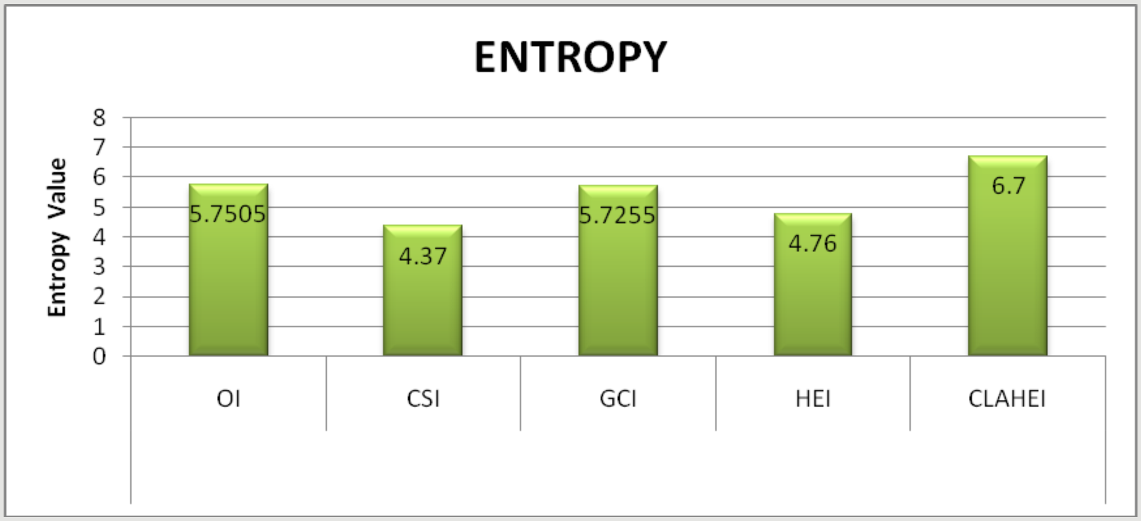

Figure 7: Average Entropy Values of Original and Enhanced Images

Conclusion

Ultrasound scanning is used to diagnose various human health disorders especially in Obstetrics and gynecology. However, poor ultrasound image quality often present difficulty in proper diagnosis of such diseases. Hence, the need for image enhancement to aid better diagnosis. We applied and compared the performance of four image enhancement techniques on uterine fibroid ultrasound image namely: Contrast stretching, Gamma Correction, Histogram Equalization and Contrast Limited Adaptive Histogram Equalization (CLAHE). The enhanced images are analyzed by histogram distribution and three statistical features MEAN, STANDARD DEVIATION AND ENTROPY. Based on the results obtained, it is clear that contrast stretching demonstrated better histogram distribution while enhancing the visualization of the fibroid. However, CLAHE shows both high entropy and standard deviation which signifies that the uterine fibroid visualization is well enhanced without much loss of image information like in Histogram Equalization and Gamma correction. Further study is desired in noise reductionand edge detectionof uterine fibroid as we observed from this study that even though the tumor visualization is enhanced but it edges are not clearly distinct from the surrounding uterine tissue and noise is amplified.

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