Characterization of Temporal bone in CT Images using Texture Analysis

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Abstract: *This study concern to characterize the Temporal bone were definingto Fluid, Mucosal, Sclerotic and Soft tissues density using texture feature extractionand extract classification features from CT images. The texture analysis technique used to find the gray level variation in CT images. analyzing the image with Interactive Data Language IDL software to measure the grey level variation of images. The results show that texture analysis give classification accuracy of temporal boneto fluid 86.3%, mucosal 98.2%, sclerotic 99%, While the soft tissue density showed a classification accuracy 92.2%. the overall classification accuracy of temporal bone area 93.6%. These relationships are stored in a Texture Dictionary that can be later used to automatically annotate new CT images with the appropriate temporal bonearea names.*

Keywords: Temporal bone, Chronic Otitis Media, Computed Tomography, Texture Analysis

1. Introduction

Chronic otitis media (COM) is a longstanding inflammation of the middle ear cleft without reference to a etiology or pathogenesis. Due to the strategic location of the tympanomastoidcompartment, separated from the middle and posterior cranial fossa by the thinnest of bony partitions, otitis media has the potential for intracranial extension [1].

Hence, it becomes very important to know the location and extent of the disease before proceeding to surgical treatment. Radiological examination of the temporal bone helps us to achieve this objective. It i s important to differentiate between the two types of COM: The chronic mucosal disease and the chronic otitis media with cholesteatoma because of higher risk of complications associated with the cholesteatoma group which can lead to life threatening conditions. Early recognition of the disease is important to adopt a surgical procedure to save the patient from loss of hearing and to prevent grave intracranial complications. The present work, has been undertaken to study the role of High Resolution Computed Tomography (HRCT) of temporal bone as a diagnostic modality in COM[1].

The computed tomography (CT) of temporal bones demonstrates with large accuracy the presence of abnormal tissue in the middle ear, but cannot define whether this tissue with soft parts density represents or not the presence of a cholesteatoma.[2]

The definition of COM is based on clinical and pathological features. COM is traditionally characterized by the presence perforations, cholesteatoma, recurrent ear discharge, and hearing loss. Histopathologically it is defined by the presence of middle ear inflammation, associated with irreversible tissue damage, regardless of the presence of tympanic membrane perforations [3]. The disease often evolves in a continuum. Abnormalities that at first caused mild or minimal symptoms, such as simple retractions, for example, can progress to severe changes, such as retraction pockets and destructive cholesteatomas.

This continuum model [4,5,6] explains the development of COM in a progressive manner. According to this theory, effusion, perforations, and cholesteatomas represent different pathological stages of the same disease.

The evolution of this continuum can be seen in the contralateral ear (CLE). When tubal dysfunction is the trigger of COM, there is a high probability of impairment of both ears, although in different intensity. Some studies point to a tendency of bilateral involvement in inflammatory pathologies of the middle ear.

Computed tomography (CT) is an excellent methodto visualize bone and pneumatized spaces. It is thereforethe best diagnostic method to evaluate the involvement oftemporal bone structures resulting from chronic inflammation.

There are well-documented findings of COM in CTstudies [7]. Modern techniques of helical image acquisitionand high-resolution cuts allow the evaluation of smallerstructures more accurately.

A comprehensive understanding of the role of theCLE in the evaluation of patients with COM is essential,especially when viewing otitis media from a continuumperspective. We believe that the study of the CLE can provideclues to the pathophysiology of the primary ear disease(ear with full-blowndisease),serve as a parameter oftubalfunction, and contribute to the therapeutic planning.

CT scanning excels in the evaluation of bone and air space anatomy and disorders. Because CT scans are more accurate in identifying many soft tissue abnormalities and are much less prone to artifacts, they have largely replaced polytomography, there is also less radiation to the lens with CT scans than with

polytomography. CT has the advantage of producing images with higher contrast and a better spatial resolution [8].

Computed tomography (CT) is necessary for all patientssuspected of having complications of otitis media. CTscan is a reliable method for studying the status of themastoid air cell system, middle ear, internal auditorymeatus (IAM), and also intracranial complications of otitismedia. [9,10] Treatment of COM is surgical (tympanoplasty with or without mastoidectomy). Havingenoughknowledge of the middle ear before the surgerycan helpthesurgeon choose the

optimal surgical procedure and achieve appropriate results [11].

Evaluation of the temporal bone is difficult because of its complex anatomy containing multiple small structures within a moderately compact area. Further information revealed by three dimensional images gives a better understanding of temporal bone anatomy and advances the capability to evaluate related disease, thus optimizing surgical planning [12].
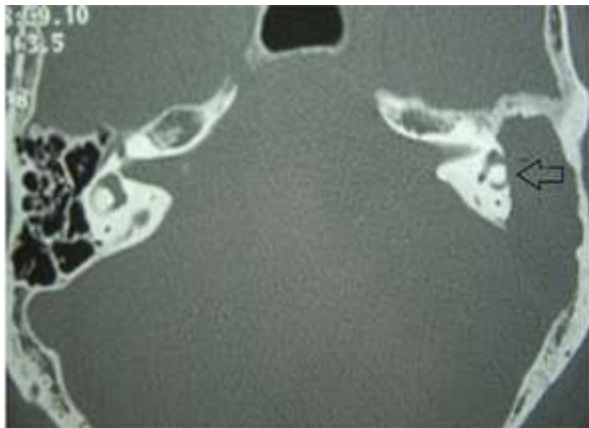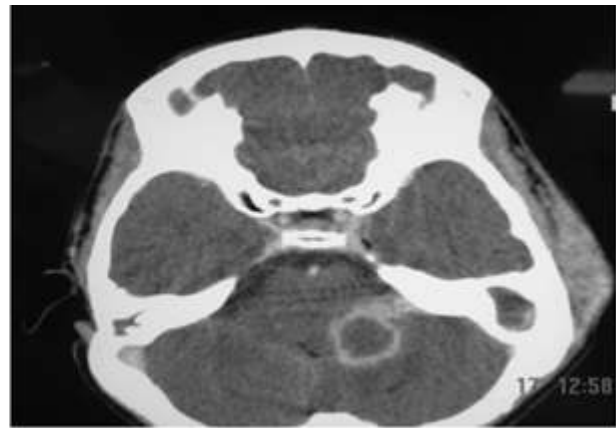
(A) (B)

Figure: (A) show temporal bone CT, axial view, the arrow shows erosion of the lateral semicircular canal on the left. (B) brain CT with contrast, axial view and soft tissue window, show cerebellar abscess on the left

2. Statistical Methods

First Order Statistics: FOS can be used as the most basic texture feature extractionmethods, which are based on the probability of pixel intensity values occurringin digital images. The parameters in the followingstatistical formulas are xi, the intensity value of pixel i, N, the total numberof pixels, maxV , the maximum intensity value within a patch and Hi, thehistogram of an image patch.

Mean: Calculates the mean intensity value of all pixels. In Matlab the functionμ= mean2(IP) can be used to compute this feature.

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Standard Deviation
The standard deviation of all the intensity values of a patch is used as atexture feature. The corresponding Matlab function is σ= std2(IP).

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

Coefficient of variation
The coefficient of variation can be seen as the relative standard deviation. Itis calculated by dividing the standard deviation with the mean value.

$$c_v = \frac{\sigma}{\mu}$$

Skewness
Another statistical measure which is used for texture analysis is skewness. Itmeasures the symmetry of a distribution curve of pixel intensity occurrencesas seen in a histogram. The function
$\Upsilon 1=$ skewness(IP) can be used tocompute the skewness in Matlab.

$$\gamma_1 = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^3}{\left(\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2\right)^{\frac{3}{2}}}$$

Kurtosis
The kurtosis measures the atness of a histogram relative to a normal distribution.A curve has a high kurtosis when it has a clear peak close to themean value. The Matlab function for the kurtosis is $\Upsilon 2=$ kurtosis(IP).

$$\gamma_2 = \frac{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^4}{(\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2)^2} - 3$$

Entropy

The entropy of a gray-scale image is a measure of intensity value randomness.It is calculated from the histogram counts of an image giving a probability p of certain pixel values occurring in the image.

$$s = -\sum(p.*log2(p))$$

2.1 Materials: CT scanner machine

GE 8 slice MDCT scan.**Scanning parameters:** 120-140 kV, 200 -220 mAs. **tubespecification:** focal spot 0.6mm *0.6mm and anode heat dissipation 400kuH/min, anode heat storage capacity4.0 MHU. **Gantry specification:**Rotation speed 360° in 0.30,1,1.5 second,tilt +/-30 ° and aperture 70 cm.**Detector specification** :Scan type eight (option) ,spiral or axial, slice thickness 0.5,1.0,1.5, 3.0,5.0and 10 mm,scan mode 0.50:1 /1.5:1.Algorithm (option)standard ,soft tissue ,bone and edge enhancement , matrix 512*512and 20 cm field of view.

2.2 Technique and Protocol

Scan to evaluate the organ of hearing and balance was obtained. Thin slices without overlapping wereused to ensure optimal resolution, the whole skull was not imaged, and just the required part of the temporalbone was included. The two temporal bones images are magnified and imaged separately .This to make possibledifferentiation between small structures like the ossicles, cochlea and semicircular canals. CT scans wereperformed including protocol of axial images from the area of temporal bone with patient in supine position,head first. Reconstruction used to obtain coronal views of temporal bone. No preparation for patient who'sundergone CT temporal bone was done. Analyzing the images with Interactive Data Language IDL software to measure the grey level variation of CT images, classify the CT temporal bone to Fluid, Mucosal, Sclerotic and Soft tissues density the features of the classified regions of the whole images (as raw data) were classified furthers using linear discriminate analysis.

3. Results
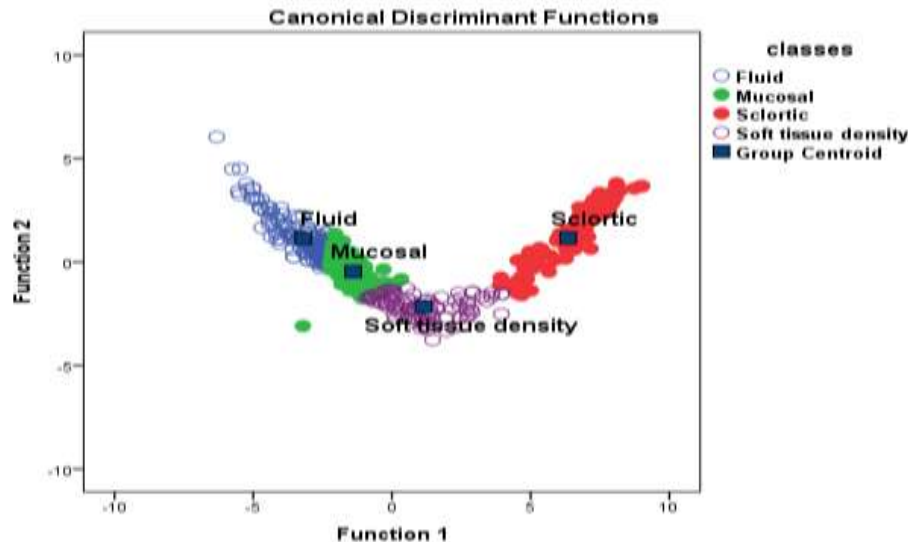
Figure 1: Scatter plot demonstrates the distribution of four Classes according to their textural feature using linear discriminate analysis functions

The classification showed that the temporal bone wasclassified well from the rest of the tissues although ithas characteristics mostly similar to surrounding tissue.

Table 4-1: A confusion matrix shows the classification accuracy of the original classes versus the predicted membership according to linear discriminant functions (multiple linear regression equation)

| Classes		Predicted Group Membership				Total
	Original groups	*Fluid*	*Mucosal*	*Sclortic*	*Soft tissue density*	
%	*Fluid*	**86.3%**	*13.8%*	*0.0%*	*0.0%*	*100.0%*
	Mucosal	*0.0%*	**98.2%**	*0.0%*	*1.8%*	*100.0%*
	Sclortic	*0.0%*	*0.0%*	**99.0%**	*1.0%*	*100.0%*
	Soft tissue density	*0.0%*	*7.8%*	*0.0%*	**92.2%**	*100.0%*

93.6% of original grouped cases correctly classified.

Table (1) show classification score matrixgenerated by linear discriminate analysis and the overall classification accuracyof temporal bone 93.6%, were the classificationaccuracy of fluid86.3%, mucosal98.2%,sclortic 99%, While the soft tissue density showed aclassification accuracy 92.2%.
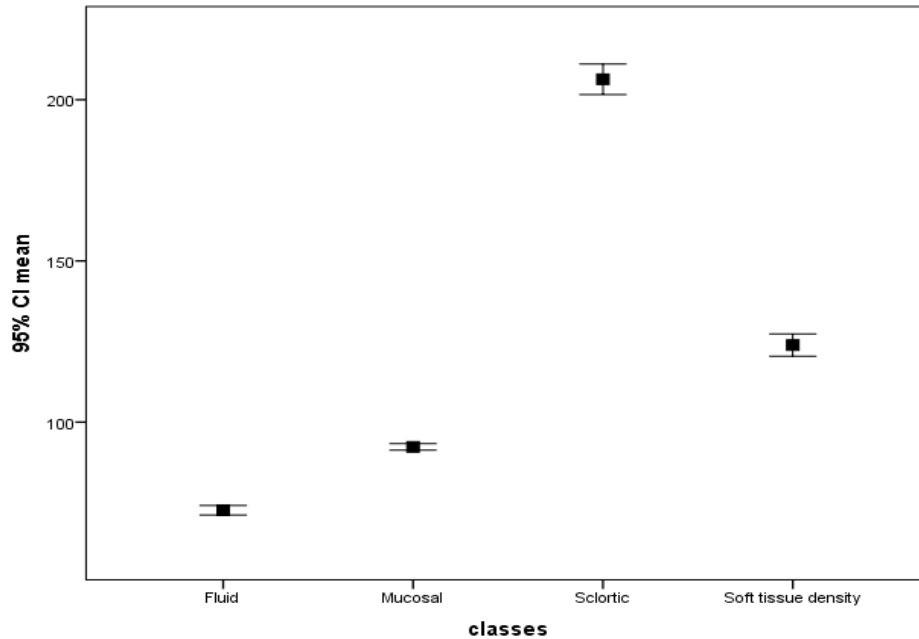
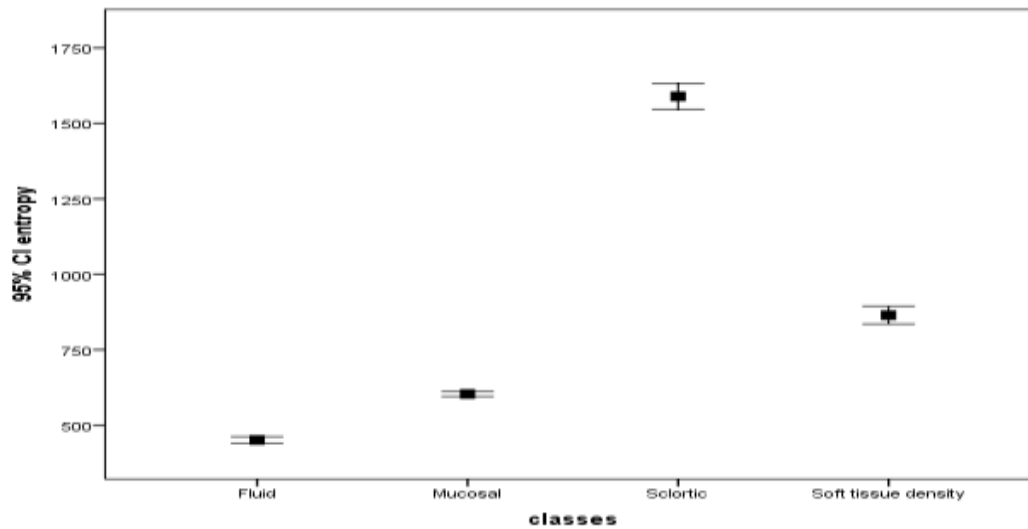

Figure 3: Show error bar plot for the CI mean texturalfeatures that selected by the linear stepwise discriminatefunction as a discriminate feature where it discriminates between all features. From the discriminate power point of view in respect to the applied features the mean candifferentiate between all the classes successfully.
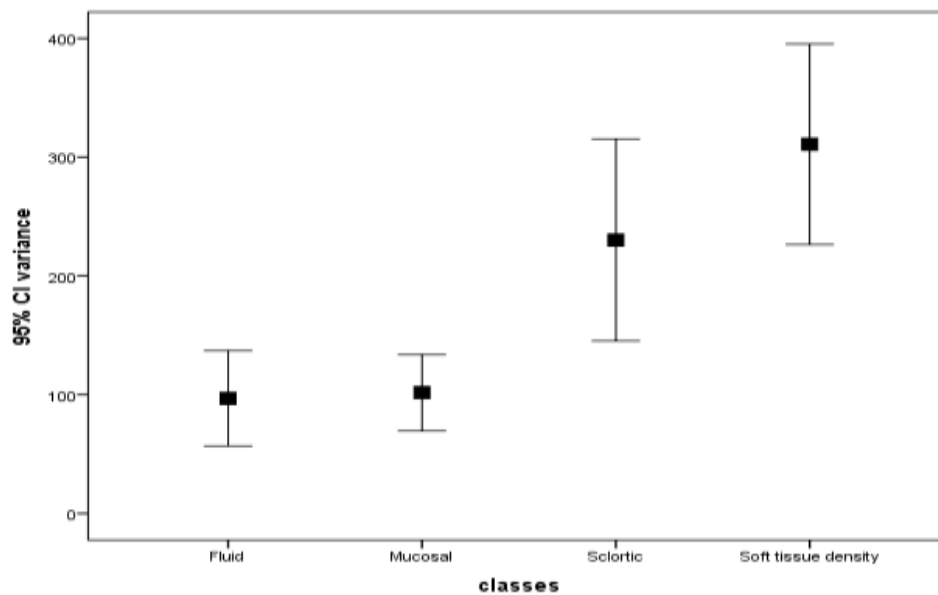
Figure 4: Show error bar plot for the CI variance textural featuresthat selected by the linear stepwise discriminate function as adiscriminate feature where it discriminates between allfeatures.
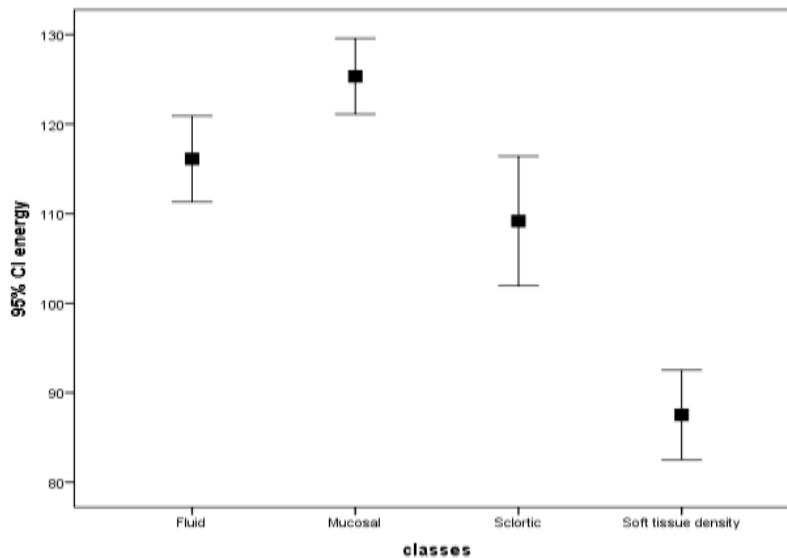
Figure 4 show error bar plot for the CI energy textural featuresthat selected by the linear stepwise discriminate function as adiscriminate feature where it discriminates between allfeatures.

Figure 4: Show error bar plot for the CI entropy textural featuresthat selected by the linear stepwise discriminate function as adiscriminate feature where it discriminates between all features.

4. Conclusion

The classification processes of CT Temporal bone were defining the otitis media to Fluid, Mucosal, Sclerotic and Soft tissues density and carried out using Interactive Data Language (IDL) program as platform for the generated codes. The result of the classification showed that the temporal bone areas were classified well from the rest of the tissues although it has characteristics mostly similar to surrounding tissue.

Several texture features are introduced from *FOS* and the classification score matrix generated by linear discriminate analysis and the overall classification accuracy oftemporal bone area classify to fluid 86.3%, mucosal 98.2%, sclerotic 99%,While the soft tissue density showed a classification accuracy 92.2%.The overall classification accuracy of temporal bone area 93.6%.

Using Linear discrimination analysis generated aclassification function which can be used to classify otherimage into the mention classes as using the following multiregressionequation;
Fluid, Mucosal, Sclerotic and Soft tissues density
Fluid = (mean × 23.7) + (variance × 0.006) + (energy × -0.099) + (entropy × -2.703) -247.54
Mucosal = (mean × 26.1) + (variance × 0.006) + (energy × -0.109) + (entropy × -2.97) -303.93
Sclerotic = (mean × 26.7) + (variance × 0.007) + (energy × -0.104) + (entropy × -2.97) -387.66
Soft tissues density = (mean × 28.4) + (variance × 0.009) + (energy × -0.17) + (entropy × -3.22) -362.83

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