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Dr. Ramya Rathan
Asst. Professor,
Dept. of Anatomy,
Gulf Medical University,
Ajman, UAE

Dr. Shridhar R
Prof and Head,
Dept. of Computer Science,
*SRKMV Arts and Science College, Coimbatore, India.

Dr. Latha KC
Lecturer, Dept. of Water and Health, JSS University,
Mysore, India.

Dr. S Balasubramanian
Director Research,
JSS University, Mysore, India

Correspondence:
Dr. Ramya Rathan
Asst. Professor,
Dept. of Anatomy,
Gulf Medical University,
Ajman, UAE

Endometrial cancer detection using fractal based texture analysis: A box counting Algorithm

Dr. Ramya R, Dr. Shridhar R, Dr. Latha KC and Dr. Balasubramanian S

Abstract
Introduction: The aim of the present study is to relate morphologic features of endometrial adenocarcinoma to grade and depth of myometrial invasion using fractal analysis. Our final goal is to see whether surface growth patterns of this neoplasm possess fractal properties and to investigate whether the fractal dimension, which is thought to represent partly the local biologic behavior of the tumor, differs according to grade or stage of the disease.
Methods: A method was developed in the Visual Basic for extracting the suspicious region from the MRI based on texture. For the extracted image, the fractal dimension was calculated using Box-counting method. Fractal analysis was applied using the fractal analysis software after the MRI image was turned to gray scale. Surface of the tumor growing into the endometrial cavity was selected as region of interest (ROI) for each photograph. The fractal dimension of the ROIs was calculated by box-counting method with this software. Statistical t- test was calculated.
Results: From these results, it is concluded that:
1. Fractal Dimension can be used when the cancer is in the advanced stage.
2. Fractal dimension is Insensitive when the cancer is in the initial stage.
Conclusion: The measurement of fractal dimension is helpful in discriminating the lesions. Fractal dimension has been applied to identify micro-calcifications and tumours in the tissues of the body. Through this method, the size, location and seriousness of the abnormality or suspicious regions are estimated for better diagnosis

Keywords: Endometrial Adenocarcinoma, Visual Basic, Fractal Dimension

1. Introduction
Radiology is considered as one of the most active and technologically advanced field in medicine. The medical imaging has advanced to such a stage where it is possible for early detection and diagnosis of the disease. Researchers and medical oncologists in collaboration with computer scientists have investigated Computer Aided Diagnosis (CAD) systems which will offer more objective evidences and accurate high diagnostic rates. Several such methods for accomplishing the non-invasive method are applied to medical images. One of the most popular methods is the fractal dimension based on the fractal theory of Mandelbrot (1967) [1]. The fractal geometry proved to be of a great interest for the digital image processing and analysis in an extremely wide area of applications, especially in medicine and has been used to detect small tumours, micro-calcification in mammograms, tumors in brain and to diagnose blood cells and human cerebellum (Buczko and Mikolajczak, 2005) [2]. The aim of the present study is to relate morphologic features of endometrial adenocarcinoma to grade and depth of myometrial invasion using fractal analysis. Our final goal is to see whether surface growth patterns of this neoplasm possess fractal properties and to investigate whether the fractal dimension, which is thought to represent partly the local biologic behaviour of the tumor, differs according to grade or stage of the disease.

2. Materials and Methods

MRI images from the patients who were diagnosed with endometrial carcinoma were collected. With the help of the radiologist and oncologist, the images were segregated into normal, fibroid and malignant. A method was developed in the Visual Basic for extracting the suspicious region from the MRI based on texture. For the extracted image, the fractal dimension was calculated using Box-counting method. The image was scanned from left to right and top to bottom and was brought to the system as a JPEG file. The JPEG image was used for further analysis.

Fractal analysis was applied using the fractal analysis software after the MRI image was turned to grey scale. Surface of the tumour growing into the endometrial cavity was selected as region of interest (ROI) for each photograph. The fractal dimension of the ROIs was calculated by box-counting method with this software. Statistical t- test was calculated between two independent samples viz. the fractal value of normal endometrial cells and carcinoma affected cells. The total number of MRIs of endometrial carcinoma collected was thirty four with different stages. This was tested against six control images. The fractal value was calculated using box counting method and then the mean value was calculated. The mean values were used for analysing the t-test.

3. Results

The fractal value of the MRI Image is calculated and presented in the Table 1. The fractal values were calculated for seven groups including the normal images of the MRI of the endometrium. From the table, we observed that the mean fractal value between each group differed and these values were subjected to statistical analysis and the results were presented in Table 2.

The normal images were compared with the malignant ones, and a significant difference was found at 1% probability level. From this, we observed that the calculated fractal value between the malignant and normal images is different which could be used as a measure to diagnose the MRI images of the cancer of the endometrium.

Statistical t-test was calculated between two independent samples (malignant and normal). The calculated t value is 5.510 for 5 degrees of freedom and found significant at 1% probability level. We have also calculated the paired t-test between normal and malignant groups, and the results are presented in Table 2. From the results it was observed that the normal versus stage 1 is significant at 1% probability level, similarly normal v/s stage 3 B is also significant at 1% probability level. However, there is no significant variation between normal and stage 1A, 1C and 2A. From these results it was inferred that the fractal analysis is insensitive to diagnose the initial stage of the cancer which is evident from the non-significant value. From these results, it is concluded that:

1. Fractal Dimension can be used when the cancer is in the advanced stage.
2. Fractal dimension is Insensitive when the cancer is in the initial stage.

To understand the above, Fig 1 was plotted which showed the fractal value in the Y- axis and the stages in the X-axis which showed that:-

1. The fractal value of tumour growth in endometrial carcinoma in different stages is not uniform.
2. It increases in trend in the first 2 stages and later starts decreasing.
3. Once the fractal value starts increasing for the second time, it can be assumed that, it has reached a level of Metastasis.

4. Discussion and Conclusion

The mean fractal value for stage 1A is 1.5991 whereas in stage 3 B the mean value is 1.822. The maximum fractal value seen in stage 1C was 1.85967. The observation we made was unique since the fractal values increased from stage 1A to 1C and then it gradually decreases. This is due to the initial slow phase of growth while the disease is in the primary stage. Once the volume of growth reaches an asymptotic level the nutrient supply to the cancerous cells are limited. This observation was done by Kim *et al*., (2006) [3] in vascular angiogenesis. In our study, there was an increase from 15.6% to 16.29% from stage 1a to 1c. From stage 1c onwards it is decreasing from 16.29% to 12.79%. In stage 3a it further decreases to 6.86%. In stage 3b it again increases up to 13.93%. The second increase in stage 3 is due to necrosis and ulceration according to Kikuchi [4].

Garuti *et al*., 2001 [5] reported that the morphology of adenocarcinoma was unrelated to both the stage and grade, but the study of Kikuchi *et al*., 2004 [4] reveals that the mean fractal dimension of G3 endometrial adenocarcinoma was significantly higher than that of G2(p=0.003) and although not statistically significant the value of G3 was greater than G1(p=0.10), and then G1 and G2 group (p=0.006).There is a unique distribution, however, the study of Kim *et al*., (2006) [3] on blood vessels stated that the fractal value displayed with reduced rate of increase at earlier and later tumor growth stages, due to the distinct characteristics in vessel length and density. Further, they stated that the fractal analysis displayed a sigmoid pattern. In view of this, we have plotted our curve using the data.

Fractal properties are used to differentiate the tumor from healthy tissue and the segmentation within the image, but it is impossible to compare fractal properties between images. Veenland *et al*., 1996) [6]. Chen *et al*., (1990) [7] and Lee *et al*., (2005) [8] have stated that the fractal properties alone are not sufficient for effective texture segmentation and suggested the use of fractal features in texture classification.

The measurement of fractal dimension is helpful in discriminating the lesions. Fractal dimension has been applied to identify micro-calcifications and tumours in the tissues of the body. Through this method, size, location and seriousness of the abnormality or suspicious regions are estimated for improved diagnosis. Our fractal methods provide insight into tumour morphology and become a useful tool for analysing complex irregular tumour growth patterns mathematically. From the results mentioned above, we can conclude that both the points are valuable ones, while applying fractal dimension to assess the differences between normal and malignant image with respect to the MRI Images of Endometrium only.

Table 1: The calculated Fractal values of the MRI and Fibroid images

Stages	Mean Fractal Value(Cancer)
1A	1.5991
1B	1.8435
1C	1.8597
2A	1.8037
3A	1.7089
3B	1.8220
Fibroid Images	1.42272
Controls	1.64

Table 2: The t-test analyses of the calculated Fractal values

		Paired Differences					T	df	Sig. (2-Tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of The Difference				
					Lower	Upper			
Pair 1	Stg1a - Control	.0113300	.1233697	.0551726	-.1418537	.1645137	.205	4	.847
Pair 2	Stg1b - Control	.2751867	.0411753	.0237726	.1729015	.3774718	11.576	2	.007
Pair 3	Stg1c - Control	.2945575	.1052375	.0526187	.1271012	.4620138	5.598	3	.011
Pair 4	Stg2a - Control	.2211225	.1129929	.0564965	.0413255	.4009195	3.914	3	.030
Pair 5	Stg3a - Control	.1460500	.0464673	.0207808	.0883532	.2037468	7.028	4	.002
Pair 6	Stg3b - Control	.1929840	.0775654	.0346883	.0966739	.2892941	5.563	4	.005
Pair 7	Mean- Control	-.20008200	.07591054	.03394822	.29433738	.10582662	-5.894	4	.004

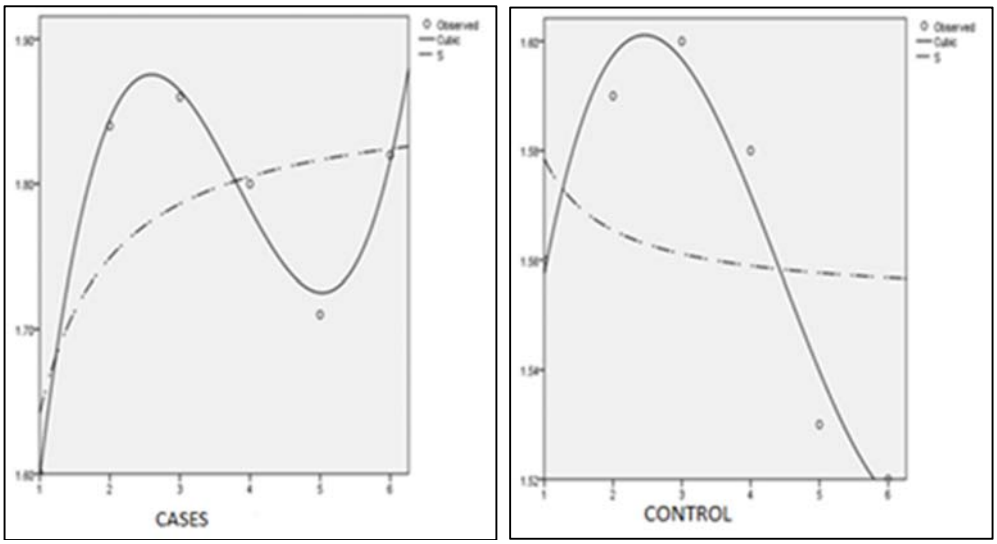

Fig 1: Graph representing Fractal values versus stages

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