Journal of Medicinal and Nanomaterials Chemistry 6 (2024) 12-19

SPC

**Journal of Medicinal and Nanomaterials Chemistry**

*Journal homepage: https://jmnc.samipubco.com/*

Original Research Article

# Fractal pattern similar to hepatocellular carcinoma (FPS-HCC) in the mandelbrot set

Ashraf Heidaripour[1,*], Erfan Tayebi[2]

[1] *Department of Chemistry, Khajeh Nasir Toosi University of Technology, Tehran, Iran*
[2] *Research Center Karaj Moallem, Karaj, Iran*

**ARTICLE INFORMATION**

Received: 27 October 2023
Received in revised: 28 November 2023
Accepted: 22 December 2023
Available online: 23 December 2023
Checked for Plagiarism: **YES**

DOI: 10.48309/JMNC.2024.1.2

**KEYWORDS**

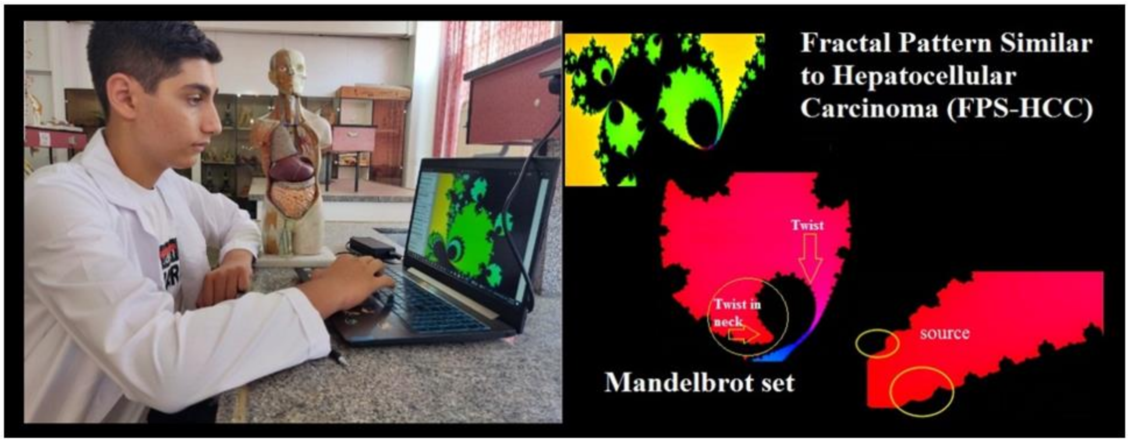
HCC
Fractal pattern
Mandelbrot
FPS-HCC
Cancer
Carcinoma

**ABSTRACT**

Hepatocellular carcinoma (HCC) is one of the deadliest types of cancer. The HCC is the most common (80%) of all primary liver cancers with mortality rate of 4.5 per 100 000 person/year. Early diagnosis of HCC can be an important factor in reducing mortality and timely treatment. One of diagnosis methods is the microscopic study of suspected cancer tissue and histopathology. In histopathology, tissue changes are investigated over time and the results are reported based on patterns. Since this comparison is often done visually and with the doctor's own diagnosis, it is not without errors. Therefore, HCC must be diagnosed early, and this is not possible except by carefully studying the liver tissue. In this way, HCC cancer should be detected from its early days and from liver tissue changes. This work requires identifying changes in liver tissue from a cellular perspective and studying the fractal patterns resulting from these changes. In this research, a fractal pattern similar to hepatocellular carcinoma (FPS-HCC) has been found in the Mandelbrot collection, which is an achievement in the recognition of fractal patterns of HCC. The study and source of the FPS-HCC paves the way for early recognition of HCC cancer.

Corresponding author, email: ashrafheidaripour@gmail.com (A. Heidaripour).

**Graphical Abstract**




## Introduction

The most common type of cancer is carcinoma. Carcinoma starts in the cells that make up the skin or the tissues that cover the organs. According to the US National Institutes of Health, carcinomas are responsible for 80 to 90 % of cancer cases [1,2]. The diagnosis of carcinoma requires physical examinations, diagnostic tests, monitoring the disease process, magnetic resonance imaging (MRI), laboratory tests, tumor sampling, endoscopy, surgery, or genetic tests [2]. However, HCC is still not detectable in the early stages and new diagnostic methods should be added to the field of cancer diagnosis. In the last two decades, it has been found that the shape of cancerous cells follows a fractal pattern in the early stages [3].

Distinguishing these patterns can prevent the progression of the carcinoma [4]. Researchers have provided evidence that cancerous structures exhibit fractal patterns. For example, the fractal pattern of the hippopotamus has been reported in the cancerous tissue of human gastrointestinal system [5].

*Mathematical patterns in cancerous cells*

Igor Sokolov observed firstly fractal patterns when he was studying the surface of mucous cells with nanometer precision [6, 7]. Although the source of carcinoma is still unknown, there are fractal patterns in the cancerous tissues that are related to disordered systems [7, 8]. In 2021, Pierre-Maxence-Vaysse research group reported a real-time lipid patterns to classify viable and necrotic liver tumors based on microscopic patterns, which can be used as an emerging tool for rapid diagnosis. Although they did not explicitly talk about fractal patterns, they discussed mathematical patterns similar to HCC. By the observed histopathological changes in HCC, they identified a common pattern of cancer in humans according to Figure 2 [9].

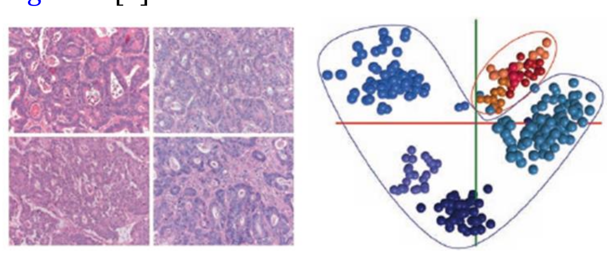


**Figure 1.** The HCC simulation results in a mathematical pattern [7]

*Patterns of cancerous cells in the Mandelbrot set*

The difference between cancerous and healthy cells is in their irregular shape. For this reason, the connection between cancerous cells decreases and when they reach an abnormal volume, they enter the stage of metastasis. At a glance, the disorder appears to be irregular in liver cancerous cells. But upon further investigation, structural patterns can be seen in cancerous cells that are similar to the fractal patterns on the boundary of the Mandelbrot set [9-15].

According to Figure 2, the Mandelbrot set has various components, including: secondary Head, Head, Body, and a boundary that extends around [10]. By Zooming in the boundary of Mandelbrot set, a series of small Mandelbrot sets can be seen that are growing. A Mandelbrot set also has several variable parameters, including center, width, grid, depth, and cmapindex. In this research, we named the area that connects the small Mandelbrot to the larger Mandelbrot as the neck area (Figure 2). The function that produces the Mandelbrot set is actually a simple mathematical function ($zk_{+1}=z_k^2 +z_0$) in the complex space. This function produces an infinitely large set for some values and in the case of iteration, which has no end. If the solution is limited to an absolute value number, the Mandelbrot set is obtained [11].

By carefully studying the fractal patterns can be found that is types of cancer. This research is an innovative effort to find the structural similarity between fractal patterns in Mandelbrot and HCC cancer cell tissue.

## Experimental

*The experimental part consists of two parts:*

*Infinite trajectories in HCC pattern*

Mathematically, there are two trajectories (path) in real (X) and imaginary (Y) complex space (Figure 3). A finite path that returns to the starting point (red dots).While an infinite path creates always moves away from the starting point (blue points). As an analogy, the healthy cells have a finite growth period and cancer cells have an infinite growth period it can be assumed (assumption) that mathematically, cancer cells follow an infinite path [8].

In this section, an assumption is proposed that a series of mathematical functions from the Mandelbrot set can be defined as indicators in cancer cells. In the next step, the most similar pattern to the structure of HCC is found in the Mandelbrot set and identified. Then the behavior of the selected pattern is compared with the assumed mathematical model.

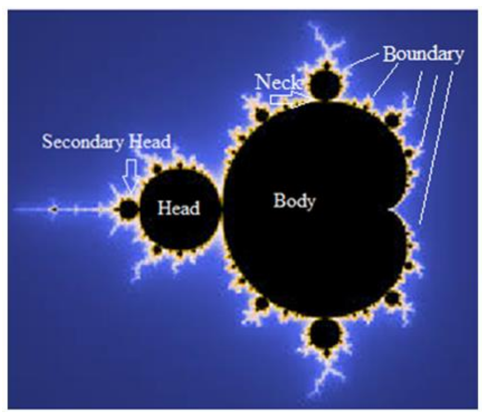



**Figure 2.** Components of the Mandelbrot set

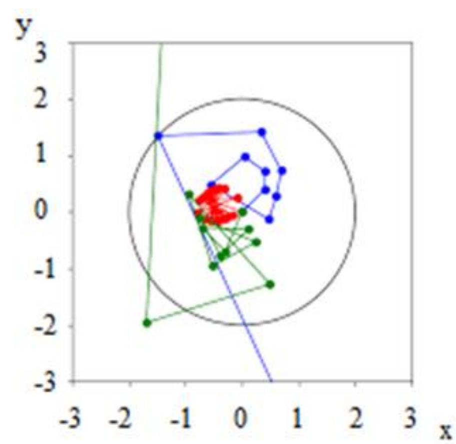



**Figure 3.** Mathematical representation of finite and infinite path

*Finding similar pattern to the HCC structure in the Mandelbrot set*

The nested growth pattern is one of the unique characteristics of cancerous tissue in HCC cancer. One of the characteristics of this type of cancer tissue is sufficient differentiation between nucleus and cytoplasm. Also, the cancer cells have cytoplasm with many grains, round and prominent nuclei with dispersed chromatin. With the onset of HCC disease, the amount of cytoplasm generally decreases and the volume of the nucleus increases [13]. All these features must be present in the chosen pattern.

## Result and Discussion

*Fractal Pattern Similar to HCC (FPS-HCC)*

A nested growth pattern is one of the unique characteristics of cancer cells in the HCC with sufficient differentiation between nucleus and cytoplasm. To find a similar fractal pattern, all patterns were evaluated in the Mandelbrot set. Several patterns consistent with the HCC were found, but the most similar pattern was seen in the first image of Figure 4b. This pattern was found from the successive enlargements at the junction of the Head and Body in the Mandelbrot set. By further zooming, another image can be seen that is very similar to the structure of the HCC (Figure 4c).

This image was examined more carefully due to its high appearance similarity with HCC. In this way, it has a structure similar to the structure of HCC, that is, large nuclei, cell compaction in parts of the tissue, and convolutions in the cellular tissue (Figure 4).

As seen in Figure 5, in the Mandelbrot set, somewhere between the Head and Body (inside the ellipse), there is a region that looks like a zipper (image1). With successive zooming, which can be seen in image 2 to 6, the desired image can be reached. For better understanding, the target areas are marked with yellow circles. As seen in the image 6, this structure is very similar to the HCC. The coordinates of this area were found with the help of web software, which are:

x=-0.749949324, y=-0.010508967, Depth= 4500, Zoom= 1.535222233.

We named this region of the Mandelbrot set as the Fractal Pattern Similar to HCC (FPS-HCC).

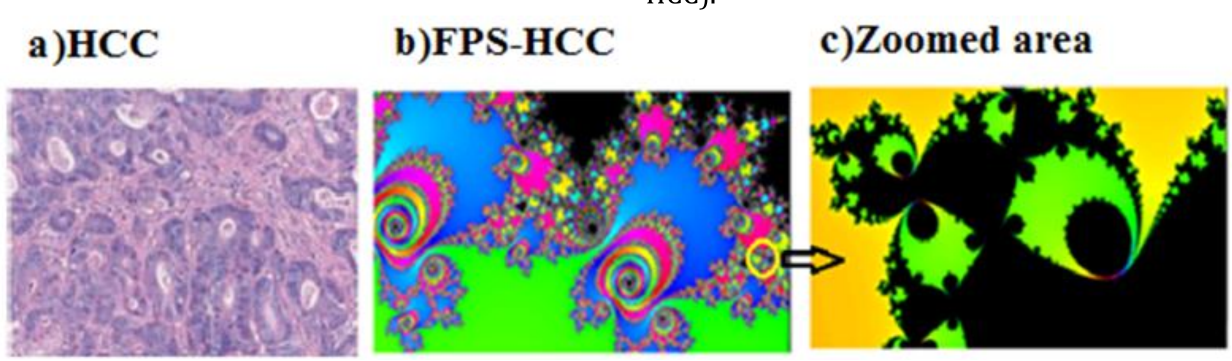



**Figure 4.** a) HCC, b) Fractal Patterns Similar to HCC (FPS-HCC), c) Zoomed area from FPS-HCC

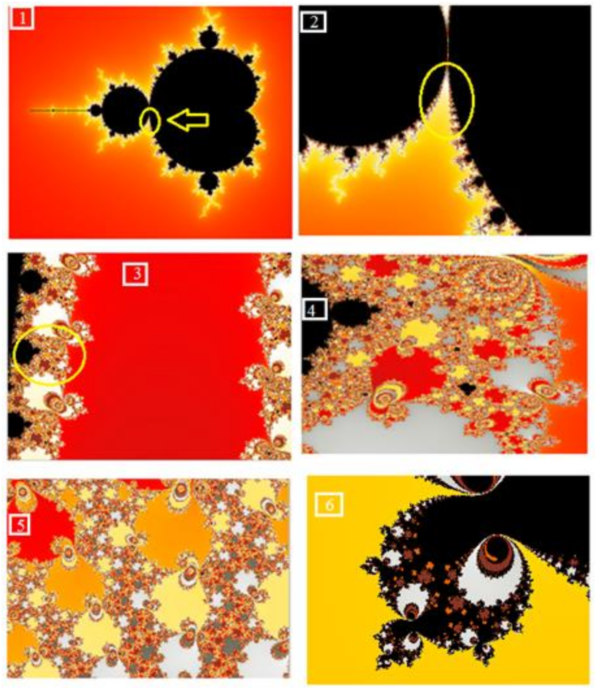



**Figure 5.** Successive zooming in the Mandelbrot set with certain coordinates

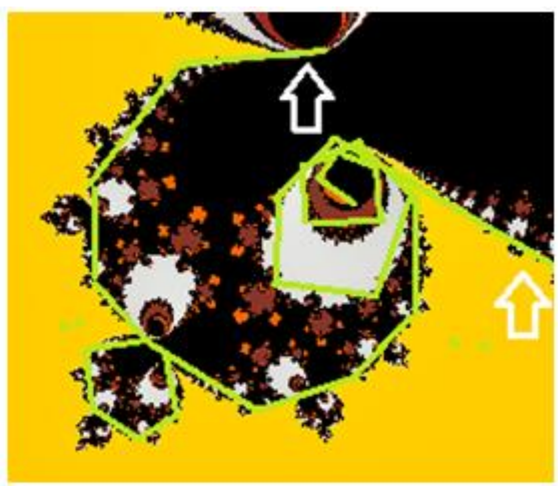


**Figure 6.** Explosive and infinite trajectory in FPS-HCC

*Testing of assumption in the use of infinite trajectories*

The selected pattern FPS-HCC has a successive twist and turn. During this twisting, a shape similar to the HCC pattern is created, which is stretched to the sides and constantly gets bigger. Similarly, nested structures are formed by twisting and arching. The trajectory that creates this structure is an explosive and infinite trajectory similar to mathematical function with infinite path in complex space. Therefore, it seems that the selected pattern of FPS-HCC is quite reasonable with the preliminary mathematical hypothesis that assumes an infinite trajectory to describe the behavior of cancerous cells.

*Zooming in on the FPS-HCC pattern to find its origin*

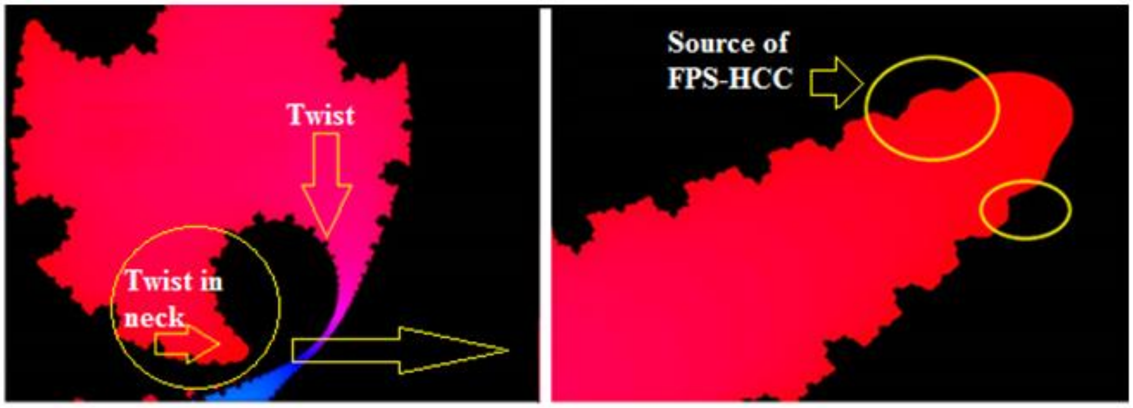



**Figure 7.** Magnification of the FPS-HCC pattern to find the source

By studying on the FPS-HCC pattern, its origin can be found. As seen in Figure 7, after successive zooming in the area with coordinates x=-0.749949324, y=-0.010508967, the source of the FPS-HCC structure is found. According to the left image of Figure 1, a twist in the neck area is responsible for creating the FPS-HCC structure. Unlike other symmetrical Mandelbrot set, in the FPS-HCC is seen asymmetric Mandelbrot set which has a wrapping in the neck area during growth. By magnifying in the twist area, the source of FPS-HCC structure can be easily seen (right image), which includes the growth of an asymmetric triangular structure. This structure grows gradually and has a special structure. Therefore, it can be said that asymmetric and couching in the neck area is an important factor in the formation of FPS-HCC structure.

*Relationship between the FPS-HCC and the HCC source*

According to the source found for the structure of FPS-HCC, it seems that the creation of such a structure in the liver is also a sign of the beginning of HCC. In this way, any twisting in the cells of the liver tissue caused by various factors is a warning for the beginning of HCC. This twisting may start with the formation of triangular and angular cells. Several factors may cause these changes in the appearance of cells, which are not discussed in this research, but briefly, a few can be mentioned:

1. Over weight and excess pressure on the liver tissue which results in twist in cells.
2. The pressure of the other organs around the liver tissue due to the hard work or exercise.
3. Inappropriate mobility and sitting that leads to stress in the liver tissue.
4. The effect of genes on the creation of specific patterns in the liver tissue that results in twist in the liver tissue.
5. The impact of various environmental factors such as magnetic waves, ambient temperature, and any factor that causes deformity and complexity in the liver tissue.

## Conclusion

Hepatocellular carcinoma (HCC) is a common liver cancer that has a high percentage among all types of liver cancer. The death rate in this disease is very high because of lethality of the HCC and its late diagnosis. In the results of histopathology, it has been determined that in HCC, the liver tissue undergoes special structural pattern, which include a change in the ratio of cytoplasm to the nucleus and an increase in the size of the nucleus. It has been found that in HCC, certain patterns are observed in the cell tissue, which is more like fractal patterns. The Mandelbrot fractal set is one of the fractal structures that have many patterns in its border areas. Upon further investigation, in the border area between the head and body area, there is a section that looks like a zipper. By zooming in on this area, a pattern very similar to HCC can be reached (FPS-HCC). In terms of structure, it is similar to a tissue full of dense cells with large nuclei, where the cells are twisted. The source that creates the FPS-HCC was further investigated.

The source found shows a structure of the Mandelbrot complex with a twist in the neck region. It seems that HCC can be prevented or diagnosed in time by identifying the factors that lead to the structural development of FPS-HCC.

**Acknowledgment**

The authors would like to sincerely thank all those who provided them with the laboratory results. They would like to thank the student research of Moallem for providing them with laboratory space. The authors are grateful to those who gave spiritual support and would like to thank Mrs. and Mr. Tayebi who sincerely and enthusiastically helped reach the goals of the research.

**Orcid**

*Ashraf Heidaripour*: 0000-0003-0223-5383
*Erfan Tayebi*: 0009-0004-4393-8012

**References**

[1]. Baish J.W., Jain R.K. *Cancer Res.*, 2000, **60**:3683 [Google Scholar], [Publisher]

[2]. Lee Y.T., Wang J.J., Luu M., Noureddin M., Kosari K., Agopian V.G., Rich N.E., Lu S.C., Tseng H.-R., Nissen N.N. *JNCI: J. Natl. Cancer Inst.*, 2021, **113**:1531 [Crossref], [Google Scholar], [Publisher]

[3]. D'Anselmi F., Valerio M., Cucina A., Galli L., Proietti S., Dinicola S., Pasqualato A., Manetti C., Ricci G., Giuliani A. *Int. J. Biochem. Cell Biol.*, 2011, **43**:1052 [Crossref], [Google Scholar], [Publisher]

[4]. Nanou A., Crespo M., Flohr P., De Bono J.S., Terstappen L.W. *Cancers*, 2018, **10**:416 [Crossref], [Google Scholar], [Publisher]

[5]. Grizzi F., Spadaccini M., Chiriva-Internati M., Hegazi M.A., Bresalier R.S., Hassan C., Repici A., Carrara S. *WJG*, 2023, **29**:4036 [Crossref], [Google Scholar], [Publisher]

[6]. Liebovitch L.S., Shehadeh L.A. *Tutrorials in contemporary nonlinear methods*, 2003, **24**:178 [Google Scholar]

[7]. Delides A., Panayiotides I., Alegakis A., Kyroudi A., Banis C., Pavlaki A., Helidonis E., Kittas C. *Anticancer Res.*, 2005, **25**:2141 [Google Scholar], [Publisher]

[8]. Jiang K., Al-Diffalha S., Centeno B.A. *Cancer Control*, 2018, **25** [Crossref], [Google Scholar], [Publisher]

[9]. Vaysse P.-M., Grabsch H.I., van den Hout M.F., Bemelmans M.H., Heeren R.M., Damink S.W.O., Siegel T.P. *Lab. Invest.*, 2021, **101**:381 [Crossref], [Google Scholar], [Publisher]

[10]. Shiah A., Ong K.K., Musielak Z.E. *Fractals*, 1994, **2**:111 [Crossref], [Google Scholar], [Publisher]

[11]. Peitgen H.-O., Jürgens H., Saupe D. *Fractals for the classroom: part two: complex systems and mandelbrot set.* Springer Science & Business Media, 2012. [Google Scholar],

[12]. Devarasetty M., Dominijanni A., Herberg S., Shelkey E., Skardal A., Soker S. *Sci. Rep.*, 2020, **10**:9832 [Crossref], [Google Scholar], [Publisher]

[13]. Calderaro J., Ziol M., Paradis V., Zucman-Rossi J. *J. Hepatol.*, 2019, **71**:616 [Crossref], [Google Scholar], [Publisher]

[14]. Wang Q., Chen N., Yu C., Wei Z., Li Z., Jin Z. *JBUON*, 2019, **24**:1408 [Google Scholar]

[15]. Michallek F., Sartoris R., Beaufrère A., Dioguardi Burgio M., Cauchy F., Cannella R., Paradis V., Ronot M., Dewey M., Vilgrain V. *Insights Imaging*, 2022, **13**:1 [Crossref], [Google Scholar], [Publisher]

**How to cite this manuscript**: Ashraf Heidaripour*, Erfan Tayebi. Fractal pattern similar to hepatocellular carcinoma (FPS-HCC) in the mandelbrot set. *Journal of Medicinal and Nanomaterials Chemistry*, 2024, 6(1), 12-19. DOI: 10.48309/JMNC.2024.1.2