The European Research Journal 2023;9(2):285-290 Original Article

DOI: 10.18621/eurj.1073259 *Radiology*

Evaluation of optic nerve by histogram analysis on MRI in patients with isolated optic neuritis

Seda Nida Karaküçük[1], Adil Doğan[1], Murat Baykara[2], Selma Urfalıoğlu[3]

[1]Department of Radiology, Kahramanmaraş Sütçü İmam University School of Medicine, Kahramanmaraş, Turkey; [2]Department of Radiology, Fırat University School of Medicine, Elazığ, Turkey; [3]Department of Ophthalmology, Kahramanmaraş Sütçü İmam University School of Medicine, Kahramanmaraş, Turkey

ABSTRACT

Objectives: We aimed to evaluate the Magnetic Resonance Imaging (MRI) histogram texture analyzis of the optic nerve by comparing patients of isolated optic neuritis with a healthy control group and to provide objective information without using contrast in the diagnosis of the disease.

Methods: A total of 40 patients, including 20 patients with isolated optic neuritis (13 females, 7 males) and 20 healthy controls (11 females, 9 males), were included in the study. Non-contrast brain MR images of the patient and control groups were analyzed retrospectively. In the coronal T2-weighted MRI sequence of both groups, the Region of Interest (ROI) was placed in the extraocular anterior 1/3 of the optic nerve of both eyes. Numerical data were obtained using histogram analysis and the data were evaluated in the MATLAB program. The data were compared statistically, in addition, sensitivity and specificity were determined by Receiver Operating Characteristic (ROC) curve analysis.

Results: As a result of histogram analysis, a significant difference was found between the mean values in the healthy and affected eye of the patients with isolated optic neuritis and the mean values of the control group ($p < 0.05$). A significant difference was found in standard deviation, minimum, maximum, median, variance values between both groups. ROC analysis was performed for mean value, AUC = 0.943 and when threshold value was selected as 354.258 Haunsfield Unit, two groups could be differentiated with 84.2% of sensitivity and 92.1% of specificity. We can say that patients with isolated optic neuritis also have histological effects on the clinically asymptomatic eye.

Conclusions: Histogram analysis can be used in the diagnosis of the patients with isolated optic neuritis without the need to use contrast in their MRI. In addition, histological effect can be detected in the eye that does not show clinical symptoms with histogram analysis.

Keywords: Optic neuritis, histogram analysis, texture analysis

Optic neuritis (ON) is characterized by inflammation of the optic nerve which is mainly idiopathic demyelination. Also, many causes including ischemic, metabolic, nutritional, hereditary, toxic, traumatic, paraneoplastic and radiation induced events [1]. Clinical presentation of the optic neuritis is mostly visual loss, periocular pain and dyschromatopsia of triple semptoms, and some patients may suffer from visual

Received: ***February 24, 2022;*** *Accepted:* ***July 18, 2022;*** *Published Online:* ***October 11, 2022***

How to cite this article: *Karaküçük SN, Doğan A, Baykara M, Urfalıoğlu S. Evaluation of optic nerve by histogram analysis on MRI in patients with isolated optic neuritis. Eur Res J 2023;9(2):285-290. DOI: 10.18621/eurj.1073259*

e-ISSN: 2149-3189

Address for correspondence: *Seda Nida Karaküçük, MD., Assistant Professor, Kahramanmaraş Sütçü İmam University School of Medicine, Department of Radiology, Avşar Yerleşkesi, Batı Çevreyolu Blv. No: 251, 46050 Onikişubat, Kahramanmaraş, Turkey. E-mail: drsedanida@gmail.com, Phone: +90 344 300 34 34*

field defects and swelling or atrophy of the optic nerve [2, 3].

Treatment planning and prognosis will depend on the etiology in patients with optic neuritis. In order to identify differential diagnosis, clinical history, visual field perimetry, optical coherence tomography (OCT), Magnetic Resonance Imaging (MRI) and serologic testing are used [4].

MRI is an important test that can be used in the diagnosis of the disease, and it excludes other diagnoses. MRI findings are shown enlarged of the affected segment of the optic nerve, high-signal-intensity lesions in the optic nerve on T2-weighted MRI and typically as contrast uptake in a contrast-enhanced T1 sequence with fat suppression [5].

The texture analysis technique is a mathematical calculation of the the signal properties, the position and density of pixels in an digital images and how many pixels in the image have a certain gray level value. This provides objective information about the basic structure and pathological process of tissue [6]. Histogram analysis is part of the tissue analysis method that is increasingly used in recent years. This has been successfully applied in the differentiation of pathological tissues from many intact tissues such as brain, liver, breasts, thyroid and lungs [7-11]. In addition, histogram texture feature analyzis was used to evaluate the optic nerve in patients with Multiple Skleroz (MS) [12].

In this study, we aimed to evaluate the MRI histogram texture analysis of the optic nerve in patients with isolated optic neuritis without MS, having an objective knowledge in the diagnosis of the disease without using contrast.

METHODS

This study was conducted retrospectively, and informed consent from the patients wasn't used because MRI is used in the diagnosis of the disease in clinical practice at our hospital. An ethical approval (approval number-date 13/18.03.2020) was obtained from our hospital ethical committee.

Our study was designed as a case control, and the patient group will consist of patients who applied to our hospital's ophthalmology clinic and diagnosed with isolated optic neuritis.

The control group consists of patients with brain MR images who have applied to our hospital for any reason. A total of 40 patients including 20 patients with isolated optic neuritis diagnosis and 20 healthy control group were included in the study. The diagnosis of isolated optic neuritis was made in the ophthalmology clinic according to the history and examination findings, considering the age of the patient. The exclusion criteria of patients, Multiple sclerosis, behçet, inflammatory syndromes, glaucoma, ophthalmic surgery history, and orbital mass.

Study Design and Image Processing

Optic nerves were evaluated from coronal T2-weighted MRI sequence in brain MRI images in patients and control groups.

For standardization, the extraocular anterior 1/3 part of the optic nerve was measured. A round-shaped Region of Interest (ROI) was inserted by a single radiologist, by manual drawing, surrounding the optic nerve (Workstation: 27 inch iMac computer, Apple Inc. Cupertino, 88 California, using ROI from). ROI was placed in the optic nerve of the other intact eye, as well as the clinically affected eye of the patients (Fig. 1).

Similarly in the control group, an ROI was placed

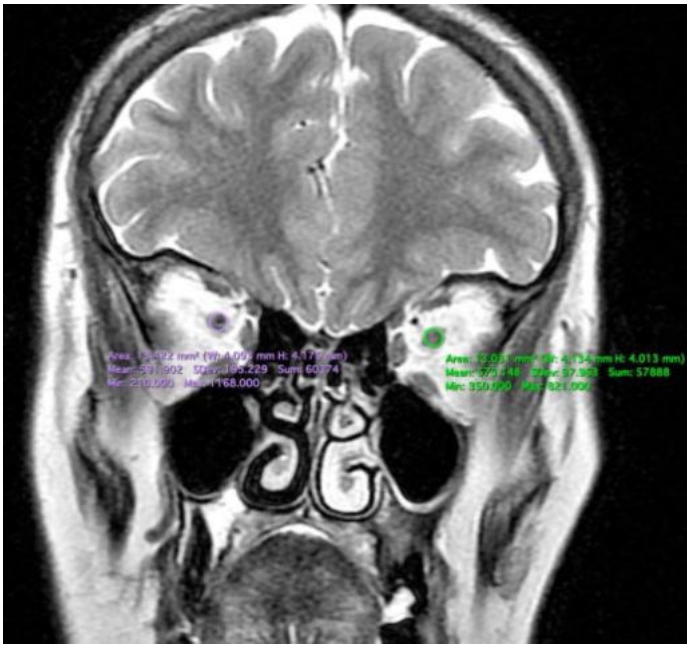

Fig. 1. A round-shaped Region of Interest (ROI) was inserted by a single radiologist, by manual drawing, surrounding the optic nerve.

in the extraocular anterior 1/3 of the optic nerve in two eyes.

The area of all ROI's ranged from 10 mm^2 to 20 mm^2 on the optic nerve. The ROI calculation was exported to an XML (Extensible Markum Language) file.

MRI Examination

Cranial MRI examinations were performed using 1.5T MRI with a cranial coil (Philips Ingenia 1.5T, Eindhoven 2015, the Netherlands); The following parameters were used in coronal T2-weighted: time of repetition (TR) 4827 ms, time of echo (TE) 100 ms, slice thickness 5 mm, interslice gap 1 mm, field of view 23×23 cm, matrix 356×221, and number of excitations (NEX) 2.00.

Statistical Analysis

Histogram analysis from ROI's were performed using a (Matrix laboratory, MathworksInc, Natick, ABD) computer program. As a result of the analysis, mean, standard deviation (SD), minimum, maximum, median, variance, entropy (disorder), uniformity (homogeneity), skewness and kurtosis parameters were calculated from these values. ROI values were transferred numerical data and Mann Whitney u test was used to compare between the patient and control group. The specificity and sensitivity were determined by performing Receiver Operating Characteristic (ROC) curve analysis. Chi-square test was used for gender comparison between the two groups, and the mann withney u test was used for age comparison. All statistical analyses were made with SPSS, version 25.0 (IBM Statistics for Windows, version 25, IBM Corporation, New York, U.S.A.). Statistically, $p < 0.05$ was considered significant.

RESULTS

In the patient group, 18 patients had clinical symptoms in one eye, while 2 patients had symptoms in both eyes.

The mean age of the study population (40 patients) was 40.5 years (min: 14, max: 57). There was no statistically significant difference between the ages of the patient and control groups ($p > 0.05$).

The patient group (13 females, 7 males) and the control group (11 females, 9 males), no significant difference was found between the two groups in terms of gender ($p > 0.05$).

In the histogram analysis performed on the optic nerve in both eyes in the patient group, the mean was 603.81 + -177.62 Haunsfield Unit (HU), in the healthy control group, the mean was 255.38 + 54.71 HU, and mean values in optic neuritis patients were found to be significantly higher compared to the control group ($p < 0.05$). As shown in Table 1, a significant differ-

Table 1. The analysis of histogram parameters of the normal and optic neuritis

	Optic neuritis (n = 38) mean ± SD	Control (n = 38) mean ± SD	*p value*
Mean *	603.81 ± 177.62	255.38 ± 54.71	**< 0.001**
Standart Deviation *	164.83 ± 51.54	61.36 ± 20.88	**< 0.001**
Minimum*	305.45 ± 143.36	142.61 ± 64.160	**< 0.001**
Maximum*	1069.29 ± 312.01	427.18 ± 100.43	**< 0.001**
Median*	578.07 ± 172.71	249.69 ± 53.17	**< 0.001**
Variance*	29758.87±15984.47	4190.02 ± 2700.07	**< 0.001**
Entropy	6.08 ± 0.24	6.06 ± 0.14	0.736
Size%L	14.14 ± 3.77	15.32 ± 3.41	0.182
Size%U	16.16 ± 3.08	15.26 ± 2.57	0.238
Size%M	69.68 ± 5.56	69.40 ± 5.04	0.823
Kurtosis	3.32 ± 1.38	3.31 ± 0.97	0.506
Skewness	0.59 ± 0.47	0.44 ± 0.50	0.245
Uniformity	0.21 ± 0.05	0.21 ± 0.06	0.625

SD = Standard Deviation

*Statistically significant difference, $p < 0.005$

ence was found in mean, standard deviation, minimum, maximum, median, variance values between both groups ($p < 0.05$).

No significant difference was found between the optic nerve histogram analysis values in the right and left eyes in both groups. In addition, ROC curve analysis was performed for mean value, AUC = 0.943, and when the threshold value was selected as 354.258 HU, 84.2% of sensitivity and 92.1% of specificity could be differentiated from patient-normal (Fig. 2).

DISCUSSION

Texture analysis allows the pixels in the image to be evaluated with mathematical expressions, independent of the experience of the radiologist [13, 14]. Reaching the diagnosis with objective information increases the accuracy of the diagnosis. The use of histogram analysis, which is a new method in patients with isolated optic neuritis, will contribute to the early diagnosis and the course of the prognosis. In our study, we can distinguish the patients from the healthy patient group with high sensitivity and specificity with mean histogram values.

However, in studies in the literature, similar parameters such as entropy, skewness, kurtosis were examined using histogram analysis in patients with isolated optic neuritis but mean values were not mentioned. Mean values measure the overall grayscale intensity and increase with higher signal intensity [15].

In histogram analysis, radiological modalities such as ultrasonography, computed tomography and magnetic resonance imaging can be used. MRI, one of the radiological modalities, is frequently used in histogram analysis due to its high tissue resolution [6].

In the literature, MRI was used in histogram analysis studies in neuroradiologically brain tumors, migraine, acute stroke, focal cortical dysplasia, Alzheimer's, epilepsy and multiple sclerosis patients [16, 17]. We used MRI images in our study in accordance with the literature.

Entropy shows the irregularity in pixel distribution. Liu *et al*. [18] it is observed that patients with optic neuritis can differentiate with high sensitivity and specificity in entropy and energy parameters by performing histogram analysis of the optic nerve in contrast-enhanced and non-contrast MR images [18]. In our study, we kept the study design different by not including contrast images, so we think that our entropy values did not show difference.

There is a close relationship between optic neuritis and MS. Some of the patients diagnosed with isolated optic neuritis develop MS in the following years [19,

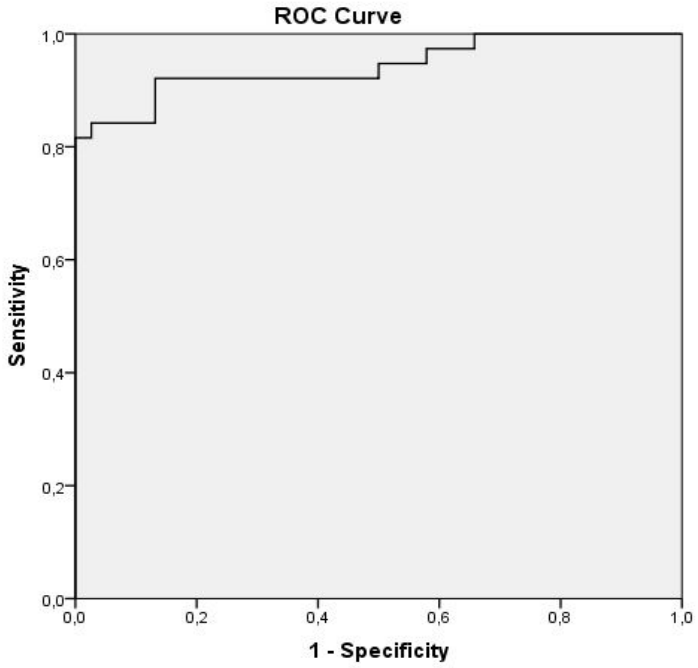

Fig. 2. ROC analysis of mean values.

20]. Even in 70% of the patients diagnosed with MS, acute optic neuritis is seen as the first symptom [21]. Therefore, early diagnosis of optic neuritis is very important in MS diagnosis, treatment planning and prognosis.

Contrast-enhanced MR is used in routine practice in the diagnosis of patients with optic neuritis, but the use of contrast is an invasive method. It is difficult to get the correct diagnosis in optic neuritis without using contrast. Tissue analysis, which is a non-invasive method, can be helpful in diagnosis by showing early histological changes. Histogram analysis was very successful in distinguishing the affected eye from the healthy eye. Hence the use histogram analysis is an important advantage in the patients whose use of contrast is contraindicated.

In addition, with histogram analysis, we can observe histological changes that are invisible to the naked eye. In patients with isolated optic neuritis, it can often cause symptoms in one eye clinically. When the opposite eye is viewed with the naked eye on the MRI images of these patients at the time of diagnosis, it is usually seen as normal. In the literature, there is a study done by adding diffusion tensor imaging to MRI to show the effect of the opposite eye [22]. However, taking additional sequences to routine imaging increases the duration and cost of the exposure. In our study, we can say that although there was no symptom in the contralateral eye at the time of diagnosis, the optic nerve in the contralateral eye was subclinically affected when histogram analysis was performed. This shows that although there is no clinical symptom, early initiation of treatment is important for the prognosis of the disease.

Limitations

The study has some limitations. Since the study is retrospective, the number of patients was limited.

CONCLUSION

Histogram analysis can be used in the diagnosis of patients with isolated optic neuritis without the use of contrast.

Authors' Contribution

Study Conception: SNK; Study Design: SNK, SU, AD; Supervision: SNK, SU; Funding: N/A; Materials: SU; Data Collection and/or Processing: AD, MB, SU; Statistical Analysis and/or Data Interpretation: MB, AD; Literature Review: SNK, MB, AD; Manuscript Preparation: SNK, AD and Critical Review: SNK, MB, SU.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The authors disclosed that they did not receive any grant during conduction or writing of this study.

REFERENCES

1. Kanda T, Miyazaki A, Zeng F, Ueno Y, Sofue K, Maeda T, et al. Magnetic resonance imaging of intraocular optic nerve disorders: review article. Pol J Radiol 2020;85:e67-81.
2. Dooley MC, Foroozan R. Optic neuritis. J Ophthalmic Vis Res 2010;5:182-7.
3. Hoorbakht H, Bagherkashi F. Optic neuritis, its differential diagnosis and management. Open Ophthalmol J 2012;6:65-72.
4. Bennett JL. Optic Neuritis. Continuum (Minneap Minn) 2019;25:1236-64.
5. Petzold A, Wattjes MP, Costello F, Flores-Rivera J, Fraser CL, Fujihara K, et al. The investigation of acute optic neuritis: a review and proposed protocol. Nat Rev Neurol 2014;10:447-58.
6. Castellano G, Bonilha L, Li LM, Cendes F. Texture analysis of medical images. Clin Radiol 2004;59:1061-9.
7. Jian ZC, Long JF, Liu YJ, Hu XD, Liu JB, Shi XQ, et al. Diagnostic value of two dimensional shear wave elastography combined with texture analysis in early liver fibrosis. World J Clin Cases 2019;7:1122-32.
8. Kwon MR, Shin JH, Hahn SY, Oh YL, Kwak JY, Lee E, et al. Histogram analysis of grey scale sonograms to differentiate between the subtypes of follicular variant of papillary thyroid cancer. Clin Radiol 2018;73:591.e1-591.e7.
9. Chitalia RD, Kontos D. Role of texture analysis in breast MRI as a cancer biomarker: a review. J Magn Reson Imaging 2019;49:927-38.
10. Cauley KA, Fielden SW. A Radiodensity histogram study of the brain in multiple sclerosis. Tomography 2018;4:194-203.
11. Chabat F, Yang GZ, Hansell DM. Obstructive lung diseases: texture classification for differentiation at CT. Radiology 2003;228:871-7.
12. Dogan A, Baykara M. The evaluation of the optic nerve in multiple sclerosis using MRI histogram analysis. Ann Med Res 2020;27:780-3.
13. Lubner MG, Smith AD, Sandrasegaran K, Sahani DV, Pickhardt PJ. CT texture analysis: definitions, applications, biologic correlates, and challenges. Radiographics 2017;37:1483-503.

14. Zhang S, Chiang GC, Magge RS, Fine HA, Ramakrishna R, Chang EW, et al. Texture analysis on conventional MRI images accurately predicts early malignant transformation of low-grade gliomas. Eur Radiol 2019;29:2751-9.
15. Razik A, Goyal A, Sharma R, Kandasamy D, Seth A, Das P, et al. MR texture analysis in differentiating renal cell carcinoma from lipid-poor angiomyolipoma and oncocytoma. Br J Radiol. 2020;93:20200569.
16. Shin HJ, Kwak JY, Lee E, Lee MJ, Yoon H, Han K, et al. Texture analysis to differentiate malignant renal tumors in children using gray-scale ultrasonography images. Ultrasound Med Biol 2019;45:2205-12.
17. Kassner A, Thornhill RE. Texture analysis: a review of neurologic MR imaging applications. Am J Neuroradio 2010;31:809-16.
18. Liu HJ, Zhou HF, Zong LX, Liu MQ, Wei SH, Chen ZY. MRI histogram texture feature analysis of the optic nerve in the patients with optic neuritis. Chin Med Sci J 2019;34:18-23.
19. Rizzo JF, III, Lessell S. Risk of developing multiple sclerosis after uncomplicated optic neuritis: a long-term prospective study. Neurology 1988;38:185-90.
20. Francis DA, Compston DA, Batchelor JR, McDonald WI. A reassessment of the risk of multiple sclerosis developing in patients with optic neuritis after extended follow-up. J Neurol Neurosurg Psychiatry 1987;50:758-65.
21. Leocani L, Guerrieri S, Comi G. Visual evoked potentials as a biomarker in multiple sclerosis and associated optic neuritis. J Neuroophthalmol 2018;38:350-7.
22. Chen Z, Lou X, Liu M, Huang D, Wei S, Yu S, et al. Assessment of optic nerve impirment in patients with neuromyelitis optica by MR diffusion tensor imaging. PLoS One 2015;10:e0126574.