LUPUS SCIENCE & MEDICINE™

Ultrasonographic assessment of optic nerve: does it help in lupus-induced optic neuropathy?

Amira Elsonbaty ,[1] Doaa M Mahmoud ,[2] Sara Alattar ,[3] Ahmed Hosny Shaaban ,[4] Abdallah El-Sayed Allam [5]

To cite: Elsonbaty A, Mahmoud DM, Alattar S, *et al*. Ultrasonographic assessment of optic nerve: does it help in lupus-induced optic neuropathy?. *Lupus Science & Medicine* 2025;**12**:e001358. doi:10.1136/lupus-2024-001358

Received 30 September 2024
Accepted 7 January 2025

[1]Department of Rheumatology, Rehabilitation and Physical Medicine, Assiut University, Assuit, Egypt
[2]Department of Neurology and Psychiatry, Assiut University Hospital, Assiut, Egypt
[3]Department of Ophthalmology, Assiut University Hospital, Assiut, Egypt
[4]Department of Ophthalmology, Assiut University Student's Hospital, Assiut University Faculty of Medicine, Assiut, Egypt
[5]Physical Medicine, Rheumatology & Rehabilitation, School of Medicine, Tanta University, Tanta, Egypt

Correspondence to
Dr Amira Elsonbaty;
dramiramelsonbaty@gmail.com

ABSTRACT

Objective Evaluating the potential role of neuromuscular ultrasonography (NMUS) in assessing optic nerve affection in patients with systemic lupus erythematosus (SLE), compared with healthy controls and other conventional strategies in diagnosing optic neuropathy.

Methods We conducted an observational cross-sectional study comparing patients with SLE and a healthy group. We measured the optic nerve diameter (OND) and optic nerve sheath diameter (ONSD) and calculated the OND/ONSD ratio and side-to-side difference. An ophthalmologist examined all lupus patients and visual evoked potential (VEP) was performed to help evaluate the rule of NMUS in lupus-induced optic neuropathy.

Results In this study, we include 140 subjects, 65 lupus patients and 75 controls. Significant enlargement was present among lupus patients OND and ONSD (p= 0.017, 0.004, respectively) in comparison to controls; ultrasonographic evaluation had a high specificity when compared to ophthalmological evaluation and VEP reaching 89.6% and 88.1%, respectively, but with very low sensitivity.

Conclusion Ultrasonographic evaluation of the optic nerve may add significant value to the diagnosis of optic neuropathy in patients with SLE and should be considered a complementary tool to other conventional methods.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Systemic lupus erythematosus (SLE) can induce optic neuropathy, which is difficult to be diagnosed using traditional methods alone. Neuromuscular ultrasonography (NMUS) has been investigated as a promising tool for evaluating optic nerve involvement across various conditions.

WHAT THIS STUDY ADDS

⇒ This study offers practical insights into using NMUS to evaluate optic nerve involvement in patients with SLE. The findings revealed a notable increase in both optic nerve diameter and optic nerve sheath diameter in patients with SLE compared with healthy controls. The ultrasonographic assessment demonstrated high specificity but lower sensitivity when compared with ophthalmological evaluations and visual evoked potential (VEP) tests.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Ultrasonographic evaluation of the optic nerve significantly can significantly aid the diagnosis of optic neuropathy in patients with SLE. NMUS should be regarded as an adjunct to conventional diagnostic methods, potentially improving the early detection and management of optic neuropathy in SLE.

INTRODUCTION

Ocular affection occurs in 30% of systemic lupus erythematosus (SLE) patients, with optic neuropathy being one of the most devastating manifestations in such patients. However, if diagnosed early, they could dramatically respond to treatment.[1 2]

Optic neuritis and ischaemic optic neuropathy were reported in the case of lupus-induced optic nerve affection.[3]

Women aged 20–40 years are more susceptible to optic neuropathy. Patients usually present with eye pain that is worsened with eye movement and reduction of visual acuity up to no light perception, which is usually reversible, especially if treated early. Also, it may cause either central or peripheral visual field defects, affection of colour perception and flashing light visualisation. Various diagnostic protocols were proposed for optic neuropathy evaluation depending mainly on ophthalmological evaluation and Visual evoked potential (VEP). In some instances, optical coherence tomography (OCT) and brain MRI with or without contrast may be helpful.[4–6]

In some cases, no ophthalmoscopic changes could be detected, as in cases of optic nerve trunk affection, which may add difficulty in diagnosing such conditions and make the diagnosis completely patient-dependent.[7]

Thus, introducing neuromuscular ultrasonography (NMUS) evaluation for retrobulbar optic nerve diameter (OND), being bedside, quick, non-invasive, easily applicable and a low-cost modality, has been considered a

promising technique. It was used in cases with intracranial hypertension with comparable results to conventional techniques.[8–11] Moreover, to 3T MRI, assuming it had a reproducible, good measurement accuracy with an inter/intraobserver agreement.[12]

Many studies proposed an ultrasonographic role in the evaluation of optic neuritis.[4 7 13–18]

Lacking of a gold standard technique for definite diagnosis of optic neuropathy opened the field for new techniques to be added to increase the sensitivity and specificity of proposed diagnostic protocols. Also lack of studies in the field of autoimmune rheumatic diseases was compelling and captured our interest to use the optic nerve ultrasonography in SLE; moreover, we aimed at introducing different variables of ultrasonographic scanning technique that might add benefit for earlier diagnosis of patients with lupus-induced optic neuropathy.

PATIENT AND METHODS

Subjects and methods

This is an observational cross-sectional study. Verbal consent, free and informed, was obtained from both patients and healthy subjects included in the study. Patients or public were not involved in design, conducting, reporting, nor dissemination plans of our research.

Inclusion criteria

Adult patients with SLE, who fulfilled Systemic Lupus International Collaborating Clinics classification criteria for SLE,[19] either attended the outpatient clinic or inpatient ward, with and without symptoms of optic nerve affection during 2022, were included. Another group of apparently healthy subjects not known to have any chronic disease or neuropathy-associated complaints (depending on thorough history including present illness, chronic complaints, therapeutic and family history, most of them were from paramedical personnel) was added to this study.

Exclusion criteria

Any patient with optic neuropathy due to causes other than lupus was excluded from the study: for example,

- Post-traumatic neuropathy.
- Purely degenerative neuropathy.
- Diabetic neuropathy.
- Toxic neuropathy.
- Neuropathies related to infections.
- Drug-induced neuropathy, eg, quinine and some antibiotics, ethambutol.
- Infections, eg, measles, mumps, Lyme disease, etc.
- Other autoimmune diseases like sarcoidosis, Bechet's disease.

Clinical evaluation

Detailed history, systemic examination and investigations were done for all lupus patients. Hence, Systemic Lupus Erythematosus Disease Activity Index—2K (SLEDAI—2K)[20] was used to evaluate patient's disease activity.

Ophthalmological examination

An expert ophthalmologist evaluated all lupus patients. Ophthalmic evaluation included a full history and clinical examination with biomicroscopic slit lamp and indirect ophthalmoscopy. Patients with suspicious signs or symptoms underwent further testing, including visual field examination, OCT (macula and peripapillary RNFL) and MRI.

Clinical features suggestive of optic neuropathy included visual loss, periocular pain exaggerated by eye movements, relative afferent pupillary defect, reduced contrast sensitivity and impaired colour vision. Patients were considered to have definite optic neuritis if they had all mentioned clinical criteria plus one positive paraclinical test (OCT, MRI or visual field) or two positive paraclinical tests in the absence of periocular pain. Possible optic neuropathy was suspected in the presence of two or more of the clinical criteria plus abnormal optic disc appearance on fundus examination (including pale or swollen optic disc).[6 21]

Neurophysiological study

The electro-neurophysiological device 'NIHON KOHDEN' (Neuropack M1, MEB-9200 EMG unit four channels) was used in our study. VEP of both eyes was performed for patients with SLE.

Neuromuscular ultrasonography

Ultrasound (MyLab Seven eHD; Esaote SpA, Italy) with linear array high frequency (11–18 MHz) transducer was used for assessing the optic nerves of both eyes of the patients and the healthy subject group, with the probe placed over the outer superior quadrant of the closed eye with eliminating the thermal index.

As shown latter in figure 1, optic nerve sheath diameter (ONSD) and OND were measured 3 mm behind the

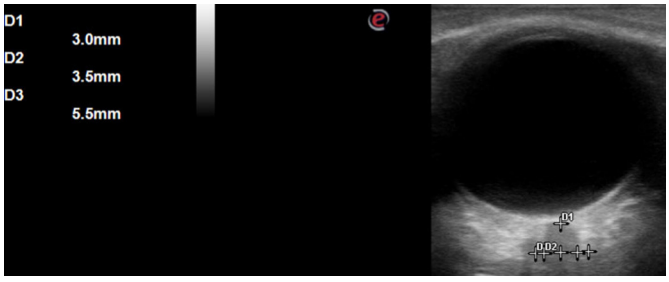

Figure 1 Transbulbar sonography of the optic nerve shows OND (D2) and ONSD (D3) that were measured as identified protocols. Here you can see the optic nerve as a markedly hypoechoic tubular structure with a hyperechoic sheath surrounding it. OND is measured by adjusting the cursor 3 mm behind the retina (marked at D1 site) and just at the edges of the nerve hypoechoic area we adjust the 2 marks of cursor while ONSD is measured by adjusting cursor mark just outside the hyperechoic margins of the nerve. OND, optic nerve diameter; ONSD, optic nerve sheath diameter.

retina; the average of three readings was used. OND/ONSD ratio, side to side difference was calculated as well.

Another expert rheumatologist in the ultrasonography evaluated all sonar images and was blinded for other clinical data.

Statistics

The collected data were analysed using the IBM SPSS Statistics, V.25 (IBM Corporation, New York). The mean and SD were used to describe most of the quantitative data, while frequency and percentage % were used for summarising the qualitative data. Either Student's t-test or Mann-Whitney test were applied when appropriate according to testing the normal distribution of all quantitative data.

For categorical data, χ^2 test was used for comparing significance between different proportions. P value <0.05 was considered to be statistically significant.

Cross tabulation was used to estimate the sensitivity and specificity of ultrasonographic measures compared with the traditional techniques including both the ophthalmological evaluation and VEP to find the benefit of using NMUS in detecting Optic neuropathy among lupus patients.

Correlation analysis between OND, ONSD and personal parameters (age) and clinical parameters (disease duration, SLEDAI-2k) were done using person's correlation test, with significance p<0.05 where r>0.5–1 means moderate to strong correlation and r<0.5—0 means weak correlation.

RESULTS

One hundred forty subjects, including 65 adult patients with SLE and 75 healthy subjects, joined this study. No significant difference was found between patients and controls concerning age or gender (p>0.05). The baseline characteristics of both groups are shown in table 1. Most of the patients were between moderate to high disease activity.

Ophthalmologic evaluation of lupus patients confirmed optic neuropathy in 21 patients, and another 12 patients were suspected of having subclinical optic neuropathy and highly suggestive for follow-up. In comparison, VEP assumed the affection of 10 patients. Finally, NMUS suggested the affection of 10 patients.

Mean±SD of OND, ONSD, OND/ONSD ratio were 4.48±1.03, 6.23±1.21, 0.71±0.57, respectively, in healthy subjects, mean±SD of Right Eye OND was 4.21±1.07, ONSD was 5.91±1.23 while Left Eye OND was 4.15±1.02, ONSD was 5.71±1.17.

Student's t-test was used to compare different parameters of both lupus patients and controls with a significant enlargement of OND and ONSD in patients (p=0.017, 0.004, respectively) with insignificant difference of OND/ONSD ratio among both groups (p=0.30). Mann-Whitney test was used in comparison of OND and ONSD side to side difference among both groups, which revealed insignificant difference, all of which are shown in table 2.

Mean+2 SD of healthy subjects' values were considered the cut-off value of the measured ultrasound parameters.

Table 1 Baseline characteristics of the studied groups

Items		SLE group n=65	Healthy subjects n=75	P value
Age in years (mean±SD)		35.1±9.8	32.3±10	0.28
Gender	Female n (%)	61 (93.8%)	66 (88%)	0.24
	Male n (%)	4 (6.2%)	9 (12%)	
Disease duration (mean±SD)		8.2±4.7	NA	
SLEDAI–2k (n(%))		N0=25 (38.5%) Mild=14 (21.5%) Moderate=17 (26.2%) High=7 (10.8%) Very high=2 (3.1%)	NA	
Optic neuropathy diagnosis among patients with SLE by:				
Ophthalmological evaluation		Affected: 29 eyes in 21 pts (32.3%) Suspected: 15eyes in 11 pts (16.9%)		
VEP		15 eyes in 10 pts (15.4%)		
Ultrasonographic evaluation		17 eyes in 10 pts		

p<0.05 is significant. Student's t-test and χ^{2*} were applied when appropriate.
n, number of subjects; NA, not applicable; SLE, systemic lupus erythematosus; SLEDAI, Systemic Lupus Erythematosus Disease Activity Index; VEP, visual evoked potential.

Table 2 Statistical data results among both studied groups

Items	Healthy subjects	Cases	P value
OND (mean±SD) in mm^2	n=150 4.18±1.05	n=130 4.48±1.03	0.017
ONSD (mean±SD) in mm^2	n=150 5.81±1.20	n=130 6.23±1.21	0.004
OND/ONSD ratio (mean±SD) in mm^2	n=150 0.73±0.18	n=130 0.71±0.57	0.30
OND side to side difference (median and QR) in mm^2	n=75 0.4+0.7 (0–2.2)	n=65 0.5+0.8 (0–2.2)	0.334*
ONSD side to side difference (median and IQR) in mm^2	n=75 0.5+0.7 (0–2.2)	n=65 0.5+0.7 (0–2.2)	0.230*
	Sensitivity		**Specificity**
ONSD	► 13.3% (compared with VEP) ► 0% (compared with ophthalmological evaluation)		► 98.3% (compared with VEP) ► 96% (compared with ophthalmological evaluation)
Combined ultrasonographic parameters	► 33.3% (compared with VEP) ► 17.2% (compared with ophthalmological evaluation)		► 89.6% (compared with VEP) ► 88.1% (compared with ophthalmological evaluation)

p<0.05 is significant.
*Student's t-test was used except Mann-Whitney test was used. For sensitivity and specificity, crosstab was used.
n, number of subjects; OND, optic nerve diameter; ONSD, optic nerve sheath diameter; VEP, visual evoked potential.

Both ophthalmological evaluation and VEP were used as standard techniques to compare the sensitivity and specificity of ultrasonographic evaluation, where VEP with p100 latency more than 110.8 was considered abnormal according to different literature,[22 23] and any patient who had clinical features suggestive of optic neuropathy plus one positive paraclinical test (OCT, MRI or visual field) or two positive paraclinical tests in the absence of periocular pain as previously detailed in methodology section was considered to have definite ophthalmologic affection.[6]

Cross-tabulation was used and showed that the sensitivity of combined ultrasonographic evaluation (including ONSD, OND, OND/ONSD ratio, and side-to-side difference added parameters results) to be 33.3% compared with VEP with specificity of 89.6%. It decreased to 17.2% sensitivity and 88.1% specificity compared with ophthalmological evaluation. When we calculated the sensitivity and specificity of ONSD alone, the most previously used ultrasonographic value, they were markedly decreased, as shown in table 2. Moreover, we compared VEP to the standard ophthalmological evaluation to find that it had 13.8% sensitivity and 89.1% specificity. Our greatest challenge was lack of gold standard technique to confirm optic neuropathy diagnosis, so we added the validated approaches to measure the sensitivity and specificity of new ultrasound technique.

A Pearson's correlation test was used to correlate OND and ONSD to age, disease duration and disease activity index (SLEDAI-2K), where we found no correlation between them.

DISCUSSION

Optic neuropathy is the most common manifestation of neuro-ophthalmic lupus, both optic neuritis and ischaemic optic neuropathy are reported, and they may lead to progressive vision loss. In 50% of cases, complete blindness may occur especially if patients were not diagnosed early. Previous literatures reported optic nerve involvement in 1% of patients with SLE.[1 24 25]

Ultrasonographic assessment of the optic nerve was suggested to be of great value in intracranial hypertension, with most of these papers concluded the presence of a larger ONSD in such patients.[8–11]

Other studies postulated ultrasonographic role in evaluating optic neuritis with special focus to multiple sclerosis (MS) and diabetes mellitus.[4 7 14–18]

In Kattan *et al*, 40 MS patients were compared with 28 matched age and sex controls, where they concluded the presence of significantly smaller OND and ONSD in MS patients. However, there was no significant difference among patients with or without present or previous optic neuritis.[26] Moreover, the same results were recorded by other studies.[27 28]

While in Sánchez *et al*, only OND was measured in 63 MS patients with a significant smaller diameter in patients compared with controls. In MS, this smaller diameter could be explained by the increased axonal loss of the affected nerves.[17]

Also, a significantly smaller OND was found in 49 pts with glaucoma compared to 90 controls when measured by the B-scan ultrasonography technique.[14]

This smaller size could be attributed to optic nerve atrophy that occurs in glaucoma, which was revealed in studies that examined the histological appearance of glaucomatous optic nerve cross-section and found a decreased diameter of the cross-section and decreased count of nerve fibres in comparison to healthy controls.[29]

In a very recent study that was published during revision of our manuscript, ONSD was found to be significantly larger in nine patients of giant cell arteritis (GCA) when compared with 21 patients with no GCA. This study is important as the pathology of optic nerve affection in patients with autoimmune vasculitis is very similar to the patients with SLE, and they observed findings that align closely with those of our study results.[13]

In our study, 32.3% of patients were diagnosed with optic neuritis after complete ophthalmological evaluation. Optic nerve ultrasonographic assessment for both lupus patients and healthy controls was applied, and we measured more than one parameter in a trial to increase the efficacy of data that could be obtained using this technique. Most of the previous literature either used ONSD or OND measures in their studies. However, we used both measures in bilateral eyes and calculated the OND/ONSD ratio and side-to-side difference. We found a significant enlargement of ONSD and OND in the patients when compared with the controls, with an insignificant difference between the OND/ONSD ratio and side-to-side difference, which can be explained by different pathophysiology of nerve affection in lupus.

Inconsistent with our results, Gerling *et al* found a significant increase in OND when measured by B-scan ultrasonography in patients with unilateral idiopathic optic neuritis in comparison to the unaffected side of the same patients and patients with anterior ischaemic optic neuropathy.[16]

We also measured the sensitivity and specificity of combined ultrasonographic parameters evaluation compared with the traditional methods of optic neuropathy diagnosis, including both the ophthalmological evaluation and VEP. It showed high specificity and low sensitivity to these techniques, yet sensitivity was much better than the usually measured parameter (ONSD) alone. Moreover, on measurement, the sensitivity and specificity of VEP technique in comparison to the standard ophthalmological evaluation, it showed 13.8% sensitivity and 89.1% specificity, indicating the need of adding all these techniques together in patients suspected to have optic neuropathy as full ophthalmological evaluation; despite being the most sensitive and specific technique, yet as we previously mentioned it can miss cases with optic nerve trunk affection.

Some papers studied possible correlation between OND and different parameters including age, disease duration, disease severity and progression.

In Beatty *et al*, OND was inversely related to age of both controls and glaucomatous patients, and this finding was consistent with previous studies that reported the decrease of axonal count of human optic nerve with age shown in histological cut sections.[14 30]

On studying MS, De Masi *et al* found a negative correlation between OND, ONSD and both disease duration and assessment of disability using the Expanded Disability Status Scale (EDSS). While Candeliere *et al* found negative correlation between OND, ONSD and only disease duration with no correlation to EDSS.[27 31]

In the other side, Kattan *et al* found no correlation between OND, ONSD of MS patients and neither age, duration of the disease nor EDSS.[26]

In our study on SLE, we found no correlation also between both OND, ONSD with either age, disease duration or activity index (SLEDAI-2K).

In conclusion, Neuromuscular ultrasonographic assessment of the optic nerve is a valuable technique that should be added to the routine evaluation of patients with suspected optic neuropathy. Several parameters, including (ONSD, OND, OND/ONSD ratio, side to side difference) may increase the sensitivity and specificity of this technique.

A more significant number of patients with SLE should be included in future studies, and we recommend producing multicentre-based reference values for OND for each population and both age and gender-based to help further studies evaluating different diseases. Using dot cursor setting, enlarging images before measuring, adjusting gain settings according to the used ultrasonography machine and performing interobserver and intraobserver variability studies are highly advised for future studies to enhance precision and validating measurement accuracy.

Contributors AE: conceptualisation, data curation, formal analysis, investigation, methodology, project administration resources, software supervision, visualisation, writing—original draft, guarantor. DMM: investigation, methodology, project administration resources, visualisation. SA: investigation, methodology, project administration resources, visualisation. AHS: methodology, software, visualisation, writing—review and editing. AE-SA: methodology, project administration, supervision, validation, visualisation, writing—review and editing.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by the Committee of Medical Ethics, Faculty of Medicine, Assiut University under the IRB number 04-2023-300128. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request.

ORCID iDs
Amira Elsonbaty http://orcid.org/0009-0006-3903-3864
Doaa M Mahmoud http://orcid.org/0000-0002-0685-6227

Sara Alattar http://orcid.org/0000-0002-4628-063X
Ahmed Hosny Shaaban http://orcid.org/0009-0001-8575-4607
Abdallah El-Sayed Allam http://orcid.org/0000-0002-7432-1793

REFERENCES

1 Lin YC, Wang AG, Yen MY. Systemic lupus erythematosus-associated optic neuritis: clinical experience and literature review. *Acta Ophthalmol* 2009;87:204–10.
2 Singerman LJ, Jampol LM. *Retinal and Choroidal Manifestations of Systemic Disease*. Williams & Wilkins, 1991.
3 Giorgi D, Balacco Gabrieli C. Optic neuropathy in systemic lupus erythematosus and antiphospholipid syndrome (APS): clinical features, pathogenesis, review of the literature and proposed ophthalmological criteria for APS diagnosis. *Clin Rheumatol* 1999;18:124–31.
4 Behbehani R. Clinical approach to optic neuropathies. *Clin Ophthalmol* 2007;1:233–46.
5 Wilhelm H, Schabet M. Diagnostik und therapie der optikusneuritis. 2015.616–26.
6 Petzold A, Fraser CL, Abegg M, *et al*. Diagnosis and classification of optic neuritis. *Lancet Neurol* 2022;21:1120–34.
7 Kaneko A, ed. A new contact b-scan ultrasonic apparatus for the ophthalmological diagnosis. In: Ultrasonography in Ophthalmology: Proceedings of the 8th SIDUO Congress; 1981
8 Haratz K, Viñals F, Lev D, *et al*. Fetal optic nerve sheath measurement as a non-invasive tool for assessment of increased intracranial pressure. *Ultrasound Obstet Gynecol* 2011;38:646–51.
9 Lin J-J, Chen AE, Lin EE, *et al*. Point-of-care ultrasound of optic nerve sheath diameter to detect intracranial pressure in neurocritically ill children - A narrative review. *Biomed J* 2020;43:231–9.
10 Mehrpour M, Oliaee Torshizi F, Esmaeeli S, *et al*. Optic nerve sonography in the diagnostic evaluation of pseudopapilledema and raised intracranial pressure: a cross-sectional study. *Neurol Res Int* 2015;2015:146059.
11 Raghunandan N, Joseph M, Nithyanandam S, *et al*. Role of ultrasonographic optic nerve sheath diameter in the diagnosis and follow-up of papilledema and its correlation with Frisén's severity grading. *Indian J Ophthalmol* 2019;67:1310–3.
12 Rangel-Castillo L, Gopinath S, Robertson CS. Management of Intracranial Hypertension. *Neurol Clin* 2008;26:521–41.
13 Baalbaki H, Dubé D, Ross C, *et al*. Optic Nerve Sheath Measurement on Ultrasound: A Novel Diagnostic Test for Giant Cell Arteritis. *ACR Open Rheumatol* 2024;6:662–8.
14 Beatty S, Good PA, McLaughlin J, *et al*. Echographic measurements of the retrobulbar optic nerve in normal and glaucomatous eyes. *Br J Ophthalmol* 1998;82:43–7.
15 Dehghani A, Giti M, Akhlaghi MR, *et al*. Ultrasonography in distinguishing optic neuritis from nonarteritic anterior ischemic optic neuropathy. *Adv Biomed Res* 2012;1:3.
16 Gerling J, Janknecht P, Hansen LL, *et al*. Diameter of the optic nerve in idiopathic optic neuritis and in anterior ischemic optic neuropathy. *Int Ophthalmol* 1997;21:131–5.
17 Pérez Sánchez S, Eichau Madueño S, Rus Hidalgo M, *et al*. Usefulness of optic nerve ultrasound to predict clinical progression in multiple sclerosis. Neurologia (Engl Ed) 2021;36:209–14.
18 Vitiello L, De Bernardo M, Cornetta P, *et al*. Bedside Ocular Ultrasound Evaluation of Pediatric Optic Neuritis. *J Emerg Med* 2019;57:883–4.
19 Petri M, Orbai A-M, Alarcón GS, *et al*. Derivation and validation of the Systemic Lupus International Collaborating Clinics classification criteria for systemic lupus erythematosus. *Arthritis Rheum* 2012;64:2677–86.
20 Gladman DD, Ibañez D, Urowitz MB. Systemic lupus erythematosus disease activity index 2000. *J Rheumatol* 2002;29:288–91.
21 Silpa-archa S, Lee JJ, Foster CS. Ocular manifestations in systemic lupus erythematosus. *Br J Ophthalmol* 2016;100:135–41.
22 Hughes JR, Stone JL, Fino JJ, *et al*. Usefulness of different stimuli in visual evoked potentials. *Neurology* 1987;37:656–62.
23 Mustafa Y, Elbarbary H, El-Refaaey M, *et al*. Visual Evoked Potential in Idiopathic Intracranial Hypertension. *J Clin Exp Ophthalmol* 2019;10:2.
24 Luboń W, Luboń M, Kotyla P, *et al*. Understanding Ocular Findings and Manifestations of Systemic Lupus Erythematosus: Update Review of the Literature. *Int J Mol Sci* 2022;23:12264.
25 Man BL, Mok CC, Fu YP. Neuro-ophthalmologic manifestations of systemic lupus erythematosus: a systematic review. *Int J Rheum Dis* 2014;17:494–501.
26 Al Kattan MM, Labib AA, Ismail RS, *et al*. Assessment of the optic nerve and its arterial supply by ultrasound imaging in multiple sclerosis patients. *Egypt J Neurol Psychiatry Neurosurg* 2019;55:1–6.
27 Candeliere Merlicco A, Gabaldón Torres L, Villaverde González R, *et al*. Transorbital ultrasonography for measuring optic nerve atrophy in multiple sclerosis. *Acta Neurol Scand* 2018;138:388–93.
28 Carraro N, Servillo G, Maria Sarra V, *et al*. Optic nerve and its arterial-venous vascularization: an ultrasonologic study in multiple sclerosis patients and healthy controls. *J Neuroimaging* 2014;24:273–7.
29 Jonas JB, Schmidt AM, Müller-Bergh JA, *et al*. Optic nerve fiber count and diameter of the retrobulbar optic nerve in normal and glaucomatous eyes. *Graefes Arch Clin Exp Ophthalmol* 1995;233:421–4.
30 Balazsi AG, Rootman J, Drance SM, *et al*. The effect of age on the nerve fiber population of the human optic nerve. *Am J Ophthalmol* 1984;97:760–6.
31 De Masi R, Orlando S, Conte A, *et al*. Transbulbar B-Mode Sonography in Multiple Sclerosis: Clinical and Biological Relevance. *Ultrasound Med Biol* 2016;42:3037–42.