Cite as: Karolczak-Kulesza M, Rudyk M, Niestrata-Ortiz M: Recommendations for ultrasound examination in ophthalmology. Part II: Orbital ultrasound. J Ultrason 2018; 18: 349–354.

Submitted: 16.07.2018
Accepted: 13.10.2018
Published: 31.12.2018

Recommendations for ultrasound examination in ophthalmology. Part II: Orbital ultrasound

Małgorzata Karolczak-Kulesza[1,2], Małgorzata Rudyk[3], Magdalena Niestrata-Ortiz[4]

[1] *Biomedical Engineering, Faculty of Mechanical Engineering and Management, Poznan University of Technology, Poznan, Poland*
[2] *Pro Bono Clinic, Poznan, Poland*
[3] *Department of Ophthalmology, Poznan University of Medical Sciences, Poznan, Poland*
[4] *Imperial College NHS Trust, Western Eye Hospital, London, UK*

Correspondence: Małgorzata Karolczak-Kulesza, Pro Bono Clinic, Leszczyńska 5a, 60-115 Poznan, Poland; e-mail: m.k.kulesza@wp.pl

DOI: 10.15557/JoU.2018.0051

Keywords
orbital ultrasonography, method of standardized echography acc. Ossoinig, ophthalmic indications for ultrasonography in ophthalmology

Abstract

Pathological processes within the orbits are a heterogeneous group of diseases of various etiologies, clinical pictures and therapy models. Due to poor access to the orbits in a clinical examination, imaging plays a significant role in both diagnosis and treatment monitoring in patients with an orbital pathology. One of such imaging modalities is ultrasonography. It is relatively well-available, rapid and safe for the patient. This paper enumerates indications for an orbital ultrasound scan, including functional ocular disorders (vision disorders, mobility disorders), autoimmune diseases, inflammatory conditions, proliferative processes, and others. The authors present Ossoinig's standardized method which encompasses topographic, qualitative and kinetic echography, and may facilitate orbital ultrasound examinations. Moreover, the article shows management standards for ultrasound imaging of orbital pathologies with an emphasis on the relevance of equipment selection, scanning technique (transducer position, transocular technique, paraocular technique) and patient preparation for the examination, and indicates appropriate elements of an examination report. The authors discuss the ultrasound presentation of the orbital structures in physiological conditions and selected orbital pathologies, such as pseudotumor, thyroid orbitopathy, cancerous tumors of the optic nerve, and others. The ultrasonographic characteristics of the presented pathologies are shown taking into account A and B scans. Attention was paid to the evaluation of angle kappa in the A scan in echographic assessment of the orbits. Furthermore, the authors include referential values for extraocular muscle thickness and quantitative measurement of the severity of thyroid ophthalmopathy based on Ossoinig's muscle index.

Nomenclature of eye and orbital ultrasound

Ultrasonography is a very helpful tool in the diagnosis of orbital pathologies. It is indicated, for instance, in: exophthalmos, globe mobility disorders, globe displacement, lacrimal gland swelling, endocrine orbitopathy, suspicion of muscle inflammation or scleritis, orbital injury, optic disc edema, choroidal folds, sudden refraction changes (hyperopia, astigmatism), episcleral vein dilation, and eye globe and orbital pain of unclear etiology[1,2].

Ossoinig's standardized echography may be helpful in orbital ultrasonography[1,3]. According to this method, the stages of an ultrasound scan should be: **screening** for lesion detection (A + B scans); **topographic echography** for characterization of a lesion in terms of location, shape, margins, and extension (A + B scans); quantitative **echography** for assessment of the internal structure of a lesion, its reflectivity and absorbance/attenuation of ultrasound waves (A scan); **wave attenuation** (absorption) evaluated on the basis of angle kappa, which is an acute angle between a time line and a line joining the

Fig. 1. *Transocular and paraocular techniques*

peak of descending echoes: angle kappa >45° denotes high echo attenuation, angle kappa =45° represents moderate echo attenuation, and angle kappa <45° indicates low echo attenuation; **kinetic echography** for information about lesion mobility, its elasticity/strain, and vascularity (A + B scans). This evaluation also involves the use of color Doppler.

Sonographic techniques used in the diagnosis of orbital pathologies

Two prominent techniques are used for orbital ultrasound: transocular or paraocular[3,4] (Fig. 1).

The transocular technique is used to evaluate the eye globe, extraocular muscles and spaces located in the muscular cone containing the optic nerve. The scan is usually conducted though closed eyelids. An examination with open eyelids is conducted by placing the transduced directly onto the cornea and conjunctiva after administration of an anesthetic drop into the conjunctival sac. This technique enables the measurement of the globe length (axial length, AL) that can be used, for instance, for the calculation of the strength of intraocular implants before a cataract surgery and for comparative biometry, which is significant e.g. in the case of pseudoexophthalmos, resulting from a considerable difference in the axial length of the globe (A scan). Using this method, one can also measure the thickness of the extraocular muscles and pathological structures in the above-mentioned areas (A and B scans) as well as the optic nerve (A and B scans).

In the **paraocular technique**, the ultrasound beam omits the globe. This method is mainly used for the assessment of structures located beyond the muscular cone and—with the immersion technique implemented – also for the assessment of changes located anterior to the equator, including lacrimal gland pathologies. Orbital ultrasound is performed in three sections: sagittal, longitudinal and transverse.

Assessment of individual orbital structures

The knowledge of a normal presentation of orbital structures is indispensable in ultrasonography and detection of potential pathologies. One should always compare both orbits in a low-sensitivity test (T – 20 dB), with the same globe and probe position and with the same equipment (preferably by a single examiner)[3,4].

In the **B scan**, with a sagittal central (C) probe position, the orbit's shape resembles a triangle. Its base is the posterior wall of the globe (white arrow in Fig. 2) with a prominent echogenic sclera. In the triangle, there is the optic nerve (yellow arrow in Fig. 2), which is strongly hypoechoic and divides the medium-reflectivity fat tissue into two parts (to the shape of the letter "W"). The sides of the triangle are made by two bony walls of the orbit, which, together with the muscles, are better visualized using longitudinal views (L) when the ultrasound beam is perpendicular to them.

The orbital apex is difficult to see on US due to the depth of ultrasound beam penetration and proximity of bone structures. In the **A scan**, the echogram of a healthy orbit presents a dense group of echoes which start with a high initial peak and a series of the remaining spikes of a rapidly decreasing amplitude. Angle kappa in the healthy orbit is >45°. In the site corresponding with the optic nerve, echo attenuation is observed (Fig. 3).

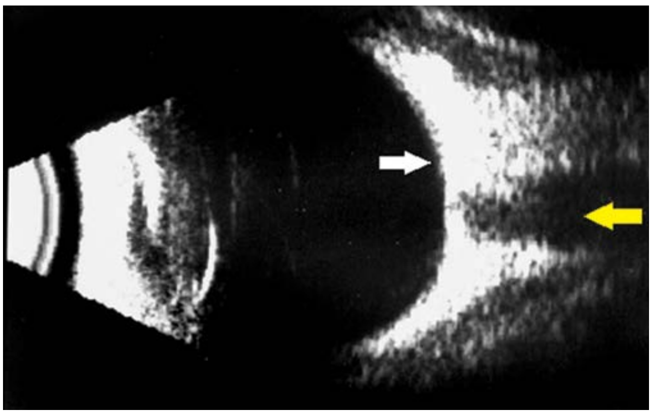

Fig. 2. *Sagittal section through the globe and optic nerve in the B scan. White arrow: posterior globe wall; yellow arrow: the optic nerve*

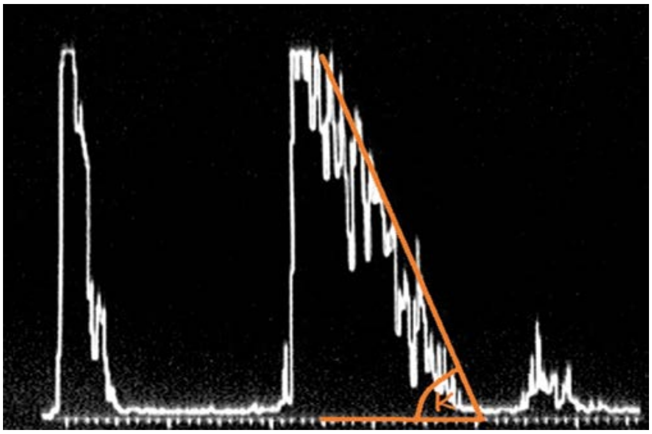

Fig. 3. *A scan of the orbit of a healthy person with marked angle kappa*

Moreover, the A scan is also used for the assessment of extraocular muscle thickness. During the examination, the patient is asked to gaze straight ahead and maintain the globe position at 0°. The probe is applied on the opposite side with the ultrasound beam running perpendicular through the posterior and anterior aspects of the examined muscles. The measurements are made by comparing dimensions of individual muscles in both orbits (Tab. 1) and by summing up the measurements of all muscles in each orbit; the Ossoinig muscle index should be calculated as well (summed up extraocular muscle thickness measurements divided by the number of the summed up muscles) (Tab. 2).

In normal orbits, the differences in thickness values between individual muscles are not greater than 0.5 mm, and differences in the sum of muscle thickness values between two orbits do not exceed 1.2 mm. These values are very similar in both orbits of the same patient. That is why a comparative scan of both orbits is of particular importance.

The optic nerve is evaluated firstly in a sagittal, longitudinal and transverse B scan, with globe position at 0°. The location, borders, shape, size, and echogenicity are examined, and the contralateral nerve is compared. Subsequently, the A scan is conducted by applying the probe to the globe equator temporally, opposite the medial rectus (to the conjunctiva of the region of the lateral canthus of the palpebral fissure). By changing the probe's inclination angle, making the ultrasound beam run through the optic nerve, one is capable of taking measurements in different sections between the globe and orbital apex (typically at a distance of of the orbital apex).

The normal optic nerve in the A scan is viewed as four peaks: two external and higher, representing nerve sheaths, and two internal and lower, indicating the nerve

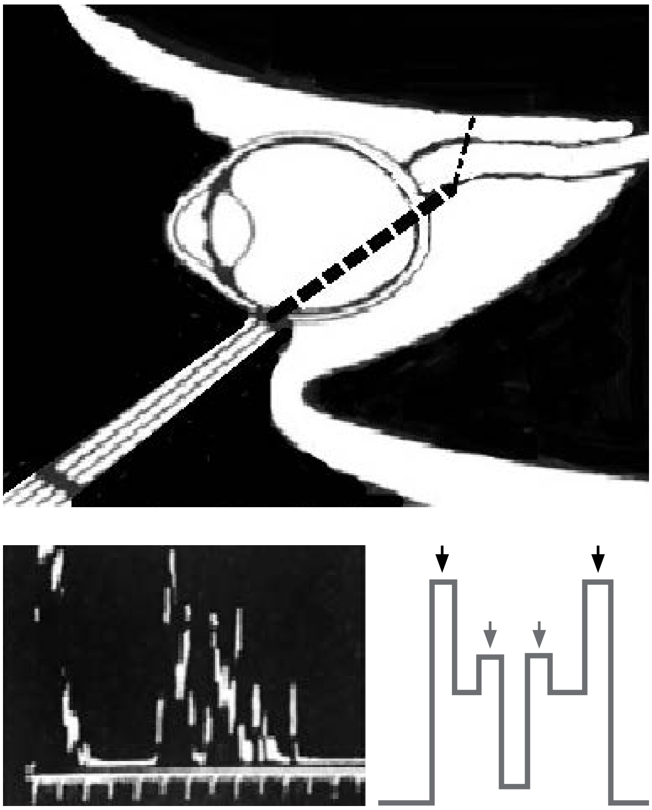

Fig. 4. *Optic nerve meas rement technique in the A scan. Normal optic nerve in the A scan (diagram): black arrows – dura mater; grey arrows – pia mater*

Muscle	Size (mm)*,**	Differences between orbits (mm)
Superior rectus and levator palpebrae superioris	3.9–6.8	0.8
Lateral rectus	2.2–3.8	0.4
Inferior rectus	1.6–3.6	0.4
Medial rectus	2.3–4.7	0.5
Sum	11.9–16.9	1.2

* Values <95. percentile
** Measurement taken in the central part of the muscle

Tab. 1. *Thickness of the extraocular muscles according to Byrne and Ossoinig[3,4]. In a low-sensitivity test, values over the 95th percentile are considered abnormal*

<5 – normal	Normal
4.5–5.5	Mild ophthalmopathy
5.5–6.5	Moderate ophthalmopathy
>6.5	Severe ophthalmopathy

Tab. 2. *Ossoinig's[3] muscle index (see text for description)*

tissue (Fig. 4). The diameter of the optic nerve is usually 3.5 ± 0.6 mm.

The lacrimal gland is evaluated by placing the transducer in the region of the upper palpebra temporally and directing it horizontally and vertically using an immersion technique or a large amount of gel (so-called gel pouch). In the A scan, the lacrimal gland is characterized by a collection of regular high-reflectivity echoes and low wave attenuation (acute angle kappa). The B scan shows a homogeneous structure of high reflectivity and smooth outlines.

Selected orbital pathologies – clinical features and ultrasound presentation

Idiopathic orbital inflammatory syndrome (*pseudotumor*) is a non-infectious and non-neoplastic inflammatory process that can involve some or all orbital tissues. It can be bilateral in children, while adults present mainly the unilateral form. In the A scan, it is characterized by a regular internal structure, low reflectivity, hard consistency and distinct outlines. In the B scan, it presents as an extraocular lesion of visible borders and moderate-to-low echogenicity[5] (Fig. 5).

Thyroid orbitopathy is the most common cause of extraocular muscle pathology. The muscle alteration secondary to thyroid pathology is usually bilateral and asymmetrical. In the A scan, the muscle acoustic structure is regular; it may be irregular with considerable muscle enlargement, with reflective internal echoes, representing perivascular inflammatory changes within a given muscle. The internal reflectivity is moderate-to-low. The borders are well-delineated (in the inactive phase) or blurred (in the active phase). The B scan shows muscle enlargement both in the transverse and longitudinal views (sometimes assuming a pear-like shape), with medium echogenicity and slightly blurred margins. In the active phase, one may also observe fluid under the capsule of Tenon (Fig. 6, Fig. 7)[5].

Cavernous hemangioma is a benign vascular tumor. In the orbit, it is typically located within the muscular cone. The typical histological structure (vascular spaces filled with blood) produces an adequate ultrasonographic presentation. In the A scan, this translates into high reflectivity and good delineation. Decreased peaks inside the lesion never reach the baseline due to the presence of blood in the cavernous spaces. In the B scan, hemangioma presents as a round well-delineated hypoechoic lesion with moderately echogenic connective tissue septa within the tumor mass (Fig. 8, Fig. 9)[5].

Optic nerve pathologies

In the diagnosis of optic nerve pathologies, the A scan seems to be of particular importance. This method enables differentiation between optic neuritis, increased intracranial pressure, optic nerve tumors, compression neuropathy and optic nerve atrophy (Fig. 10).

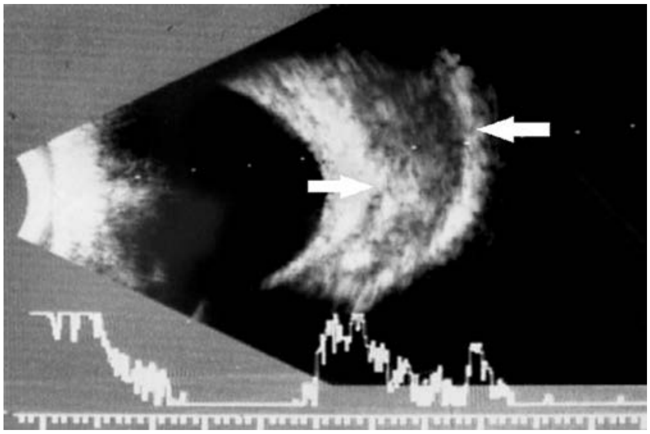

Fig. 5. *Orbital pseudotumor in ultrasonography (A and B scans). The arrow marks the lesion*

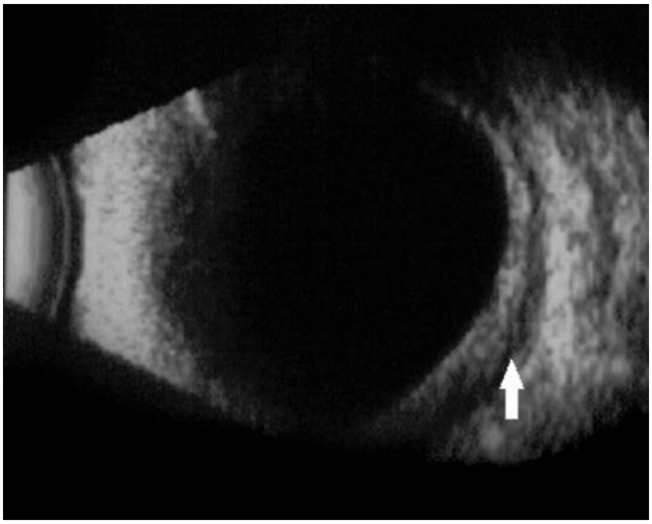

Fig. 6. *Thyroid ophthalmopathy, active phase. The arrow marks fluid under the capsule of Tenon*

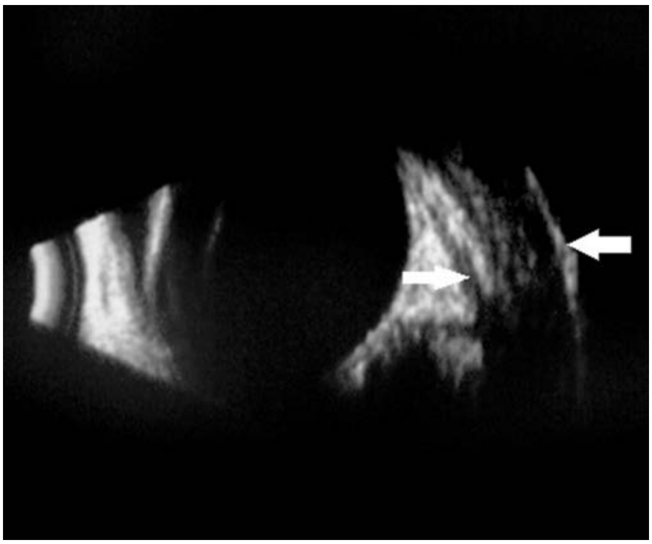

Fig. 7. *Thyroid ophthalmopathy, inactive phase. The arrow marks an enlarged muscle with well-delineated borders*

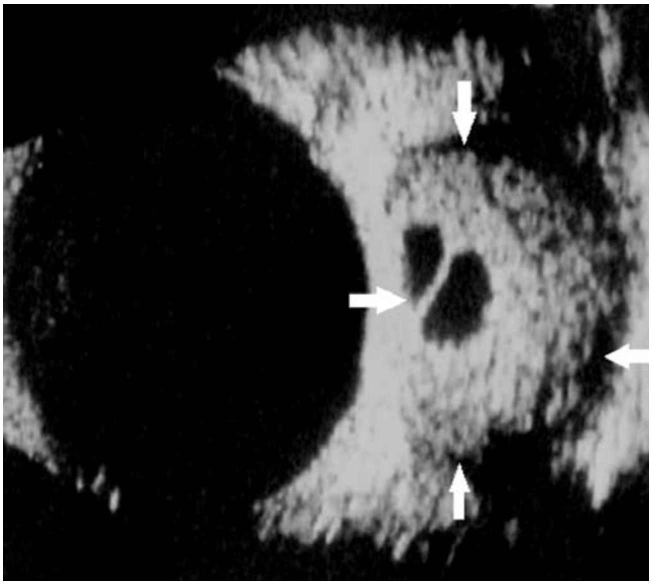

Fig. 8. *Orbital cavernous hemangioma (B scan). Arrows mark the borders of the lesion*

Optic nerve meningioma can be viewed in the A scan as a regular or irregular well-delineated internal structure of medium reflectivity and hard consistency. The B scan presents this tumor as a hypoechoic or moderately echogenic mass that increases the acoustic shadow of the optic nerve (Fig. 11)[6].

Conclusion

The ultrasound scan is a readily available first-line examination in the diagnosis of orbital pathologies. Appropriate performance of an ultrasound scan is crucial for establishing a correct diagnosis, creating a management algorithm for the diagnostic process and monitoring the therapeutic process in patients with orbital pathologies. Ossoinig's standardized echography, which arranges the order of procedures during an ultrasound examination, may be helpful. Maintaining appropriate examination conditions is very important

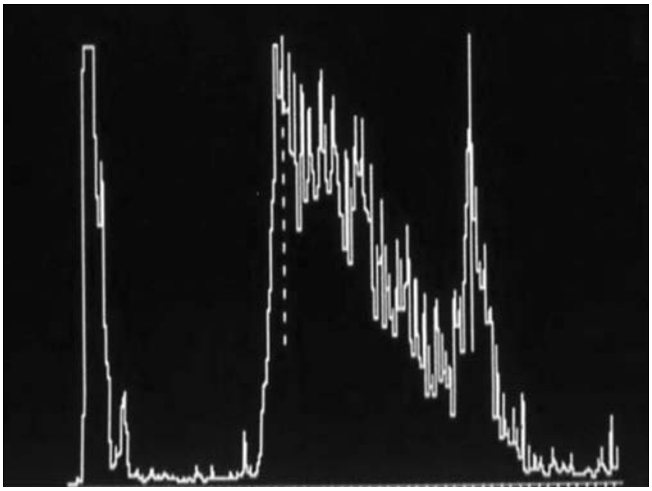

Fig. 9. *Orbital cavernous hemangioma (A scan)*

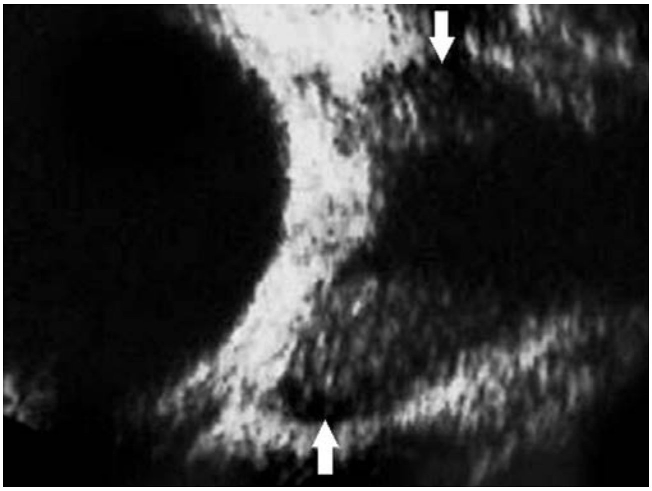

Fig. 11. *Optic nerve meningioma in the B scan. Tumor outlines marked with arrows*

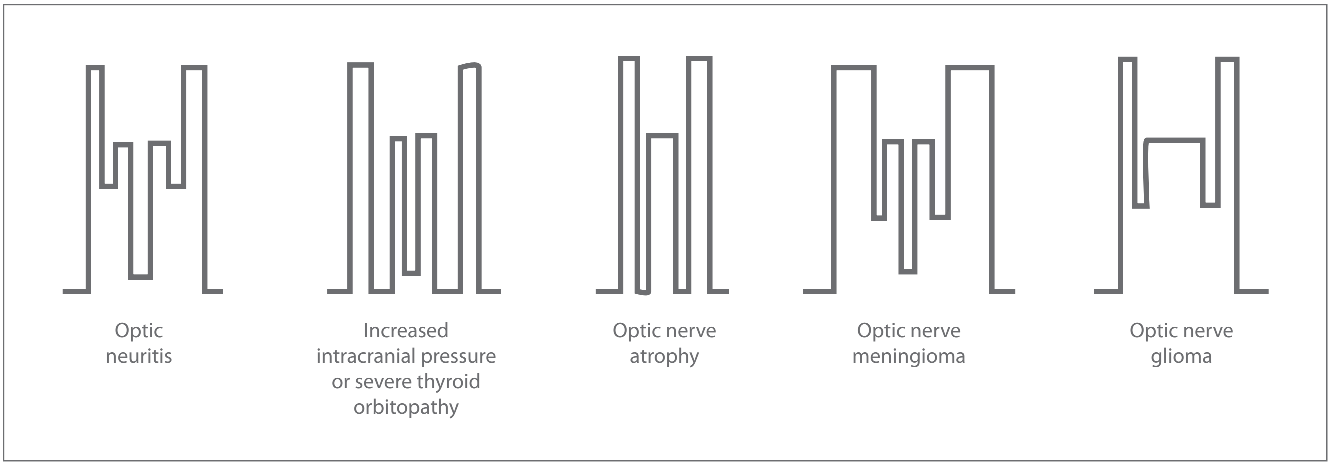

Fig. 10. *Differential diagnosis of selected optic nerve pathologies in the A scan*

in patient monitoring. For instance, the scan should be performed in the same conditions (preferably by the same examiner), with a specified probe and patient's globe position and using the same techniques and equipment.

Conflict of interest

Autorzy nie zgłaszają żadnych finansowych ani osobistych powiązań z innymi osobami lub organizacjami, które mogłyby negatywnie wpłynąć na treść publikacji oraz rościć sobie do niej prawo.

References

1. Sushil K, Ruchi G: Diagnostic Ultrasonography of the Eye. All India Ophthalmological Society, CME Series 2011; 24.
2. Kendall C, Prager TC, Cheng H, Gombos D, Tang RA, Schiffman JS: Diagnostic ophthalmic ultrasound for radiologists. Neuroimag Clin N Am 2015; 25: 327–365.
3. Ossoinig KC: Ophthalmic standardized echography. Course compendium. September 2001; 19– 22. Regensburg. Copyright September 2001 by K.C. Ossoinig M.P., Iowa City.
4. Hasenfratz G, Mardin C: Ultraschalldiagnostik in der Ophthalmologie (standardiesierte Echographie). Teil 2: Erkrankungen der Orbita – Ultraschallbiomikroskopie-Diagnostik. Ophthalmologe 2014; 111: 1085–1100.
5. Urs R, Ketterling JA, Silverman RH: Ultrafast Ultrasound Imaging of Ocular Anatomy and Blood Flow. Invest Ophthalmol Vis Sci 2016; 57: 3810–3816.
6. Poloschek CM, Lagreze WA, Ridder GJ, Hader C: Klinische und neuroradiologische Diagnostik bei Orbitatumoren. Ophthalmologe 2011; 108: 510–518.