M-Mode ultrasonography in ocular emergencies

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***Abstract*: M-Mode, or time-motion display, allows a single beam to emit from the ultrasound transducer along a defined track in conjunction with a recorder that captures all motions that occurs along the path. This mode allows high temporal resolution, thus affording the examiner an excellent view of subtle motions. Clinically, this mode is ideal for capturing vessel diameter changes, movement of cardiac valves, and detecting fetal heartbeats.**

The use of the M-mode or time-dependent intensity modulated ultrasound technique for ophthalmologic investigations are described here. This technique provides the investigator with a means for monitoring structural changes in the eye during physiologic or pharmacologic experimental conditions, or a combination of both, and is particularly useful in studying optically inaccessible structures. The technique has been used to study accommodation changes in axial length and lens thickness as well as the rate of such changes and to study vascular pulsations and choroidal thickness changes at the rear wall of the eye.

***Keywords:* Orbital Ultrasonography (USG), Electromyogram (EMG), Visual Evoked Response (VER), Ocular Ultrasonography, M- Mode ultrasonography, Ocular emergencies**

I. INTRODUCTION

M-Mode ultrasonography is a diagnostic tool that evaluates the health of the muscles and the nerves that control them by measuring muscle electrical activity. This test is most commonly performed to determine the cause of muscle weakness and identify cases that are caused by neurologic disorders such as carpal tunnel syndrome, peripheral neuropathy and other primary muscle disorders. (1-9)

During the test, transducer is placed on the skin over the targeted muscle, where it detects electrical activity while the muscle is at rest and when it is contracting. This test is usually performed in conjunction with a nerve conduction velocity test, Electromyography (EMG) and Evoked Response tests.

Normal results of an M -Mode ultrasonography test indicate muscles that do not produce any electrical activity while at rest and progressively increases with contraction. After the test, patients may experience feelings of numbness on the affected muscle.

An evoked response study is a diagnostic procedure that measures electrical activity in the brain as it responds to signals from the sight, sound and touch senses. This allows doctors to assess hearing or sight (especially useful when performed on infants), diagnose optic nerve disorders or detect tumors within the brain or spinal cord.

There are several different types of evoked response studies available that can test for different problems. The three major tests include:

- **Visual Evoked Response (VER) Test** - This test diagnoses problems within the optic nerve by placing electrodes on the scalp as the patient watches patterns appear on a screen. The electrical responses are then recorded.
- **Brainstem Auditory Evoked Response (BAER) Test** - The BAER test detects a patient's ability to hear and is also effective in detecting brain stem tumors and diagnosing multiple sclerosis. During this test, electrodes are placed on the scalp and earlobes and subtle noises are delivered to one ear.
- **Somatosensory Evoked Response (SSER) Test** - This test detects abnormalities within the spinal cord by attaching electrodes to the wrist, knee and other locations. A mild electrical signal is then sent to these areas and the brain's response is recorded.

The following conditions are less easily differentiated but may cause abnormal results (1-9)

- Optic neuropathy – this can be due to damage of the optic nerve from a number of causes, including: a blockage of the nerve’s blood supply, nutritional deficiencies, or toxins. As the nerve is damaged, electrical signals do not conduct properly. Examples include diabetes in the advanced stages which can be associated with damage to the blood vessels and nerves supplying the eyes, or toxic amblyopia which is a condition of the eyes associated with decreased vision, due to a toxic reaction in part of the optic nerve.
- Tumors or lesions compressing the optic nerve – if the optic nerve is compressed, the pathway for conduction is affected and an abnormal VEP is seen.
- Glaucoma – patients who suffer from glaucoma have increased intraocular pressure (ie pressure inside the eye). This can result in damage to the optic nerve, leading to prolonged VEPs.
- Ocular hypertension (high pressure) – this refers to any situation in which the pressure in the eye is higher than normal. There are no signs of glaucoma,

but patients may be at increased risk of developing glaucoma later in life.

M- Mode Ultrasound tomography (MUST) use ultrasound waves for creating images. In the first measurement step a defined ultrasound wave is generated with typically Piezoelectric ultrasound transducers, transmitted in direction of the measurement object and received with the same ultrasound transducers. While sound is traversing and interacting with the target tissue the ultrasound wave is changed and carries new information about the object. After being recorded the information from the modulated waves can be extracted and used to create an image of the object in a second step. Unlike X-ray which provides limited information, ultrasound provides multiple facets of the tissue. When attenuation must be managed, either because a target is too bright or too dark, power can be increased or decreased either throughout the entirety of the image or at specified depths. Gain increases will add power to combat attenuation by increasing the brightness. Unlike conventional ultrasound sonography, which uses phased array technology for beam formation , the M-Mode systems utilize unfocused spherical waves for imaging. MUST systems aim for advanced quantitative imaging , either by synthesizing ("stacking") 2D images or by full 3D aperture setups. (Figure 1) 3D ultrasonography in the ambulatory and critical care setting has become an invaluable diagnostic tool for patients presenting with traumatic or atraumatic vision loss and ocular emergencies. In expert hands, sonographic bedside evaluation is intuitive, easy to perform, and can accurately diagnose a variety of pathologies. Also, they are fast in data collection as it does not require time-consuming mechanical movements. Ocular emergencies which can be diagnosed using MUST include detachment or hemorrhage of the retina, choroid or vitreous, lens dislocation or subluxation, globe rupture, commotio retinae, retrobulbar hematoma, ocular and orbital foreign bodies, infections, cellulitis, inflammation, tumors, orbital compartment syndrome and increased optic nerve sheath diameter which can be assessed in the setting of suspected increased intracranial pressure. Over the last two decades, a large number of scientific publications have documented that 3D ultrasound in emergent or critical care settings are an accurate diagnostic tool and expands and improves emergency diagnosis and management. (10-13)

II. DISCUSSION

Clinical examination and electroretinography will rule out ocular disorders but problems of the sensory and higher visual pathways can only be investigated by preferential looking (PL) or visual evoked potential (VEP) methods. As the former can result in very arbitrary outcomes in children with severe cortical visual impairment (CVI), the latter method has been the only method available. As in several centers, it has been the authors' practice to supplement clinical assessment and electroretinography with M- Mode ultrasonography, in the belief that this contributes both diagnostic and prognostic information.

A normal flash VEP being a gross response indicates little about the spatial and contrast processing functions of visual pathways' and therefore it is quite possible that it may be unaffected when such spatial contrast mechanisms are significantly impaired. The VEP is particularly useful in detecting past optic neuritis. This refers to inflammation of the optic nerve, associated with swelling and progressive destruction of the sheath covering the nerve, and sometimes the nerve itself. As the nerve sheath is damaged, the time it takes for electrical signals to be conducted to the eyes is prolonged, resulting in an abnormal VEP. This may be seen in multiple sclerosis – one of the most common causes of optic neuritis (as above). Abnormal VEP's are seen in multiple sclerosis patients due to the presence of optic neuritis.

While these tests are effective in detecting abnormalities within the sensory functions, they often cannot determine the cause of the abnormality, so additional testing may be required. The M-Mode ultrasonography is a good negative predictor suggesting that it conveys information on the viability of pathways to support subsequent development of vision/acuity, despite the fact that it does not intrinsically correlate with such function. As to the conclusions which can be drawn from an abnormal flash response, it is highly unlikely that the gross pathway dysfunction would not embrace those of the macula too and, therefore, it is reasonable to suggest that visual acuity would be severely affected. It is therefore conceded that the M-Mode ultrasonography will be a powerful investigation tool.

The application of an "M"-mode technique (intensity modulated ultrasonograms recorded on a real time axis similar to those used for recording heart valve motion) to the study of ocular dynamics would seem to be of value. The ideal system for monitoring oculofacial emergencies should, of course, not disturb the eye, and yet be sensitive enough to provide useful information. The M-mode system in fact, offer negligible disturbance to the ocular system and still is a sensitive monitor. (Figure 2)

III. CONCLUSIONS

Diagnostic ultrasound is a powerful, minimally-invasive tool that improves the diagnostic accuracy of clinical examinations when employed at the bedside. Understanding ultrasound physics is critical to image acquisition, image optimization, image interpretation, and ultimately clinical integration. Once aware of ultrasound principles and how they are used to manipulate sound waves, sonographers can optimize the clinical utility of diagnostic ultrasound.

Specifically, the ability to discern normal from pathologic findings also requires understanding of how sound waves interact with different tissues and how primary ultrasound functions are used to best display the differentiation. Sonographers who examine patients without applying ultrasound physics principles at the bedside competently will struggle to leverage the technology for timely and accurate diagnosis. (14)

We recommend that patients with suspected oculofacial injuries should undergo careful ultrasound examination by appropriately trained ophthalmologists.

Declaration of Helsinki:

This review is adhered to the ethical principles outlined in the Declaration of Helsinki as amended in 2013. (https://www.wma.net/what-we-do/medical-ethics/declaration-of-helsinki/).

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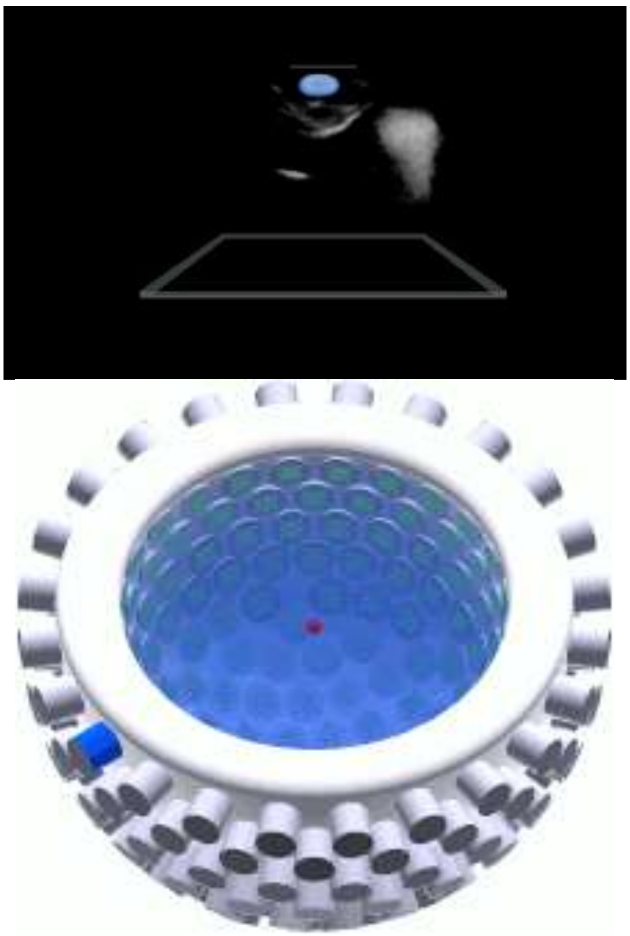

Figure 1: Measurement procedure of a 3D USCT: semi-spherical water filled measurement container lined with ultrasound transducer arrays in cylindrical housings (transducer elements as green dots). Centrally placed a simple object (red). Spherical wave emitted (semi-transparent blue), all other transducers gather data. Wave-front interacts with object and re-emits a secondary wave (semi-transparent purple). Repeated iteratively for all transducers.

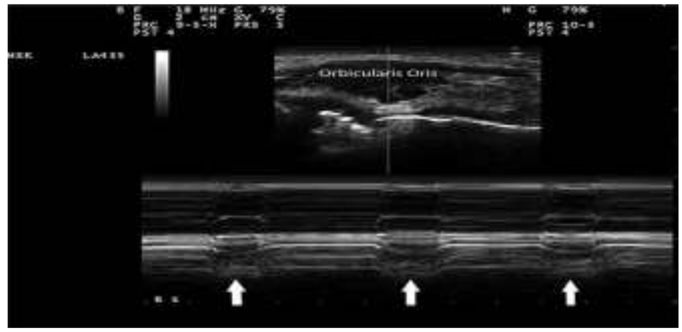

Figure 2: M-mode ultrasound of orbicularis oris muscle in a patient with synkinesis. The image was captured while the patient blinked her eye. Top of the figure shows B-mode image of the transverse view of the orbicularis oris muscle with the position of the M-mode beam (vertical line) over the muscle. M-mode trace at the bottom of the figure shows contraction of the orbicularis Oculi (white arrows) during eye blinking.

REFERENCES

[1] Adams R, Victor M. Brown R. et al. Special Techniques for Neurologic Diagnosis, Adams and Victor's Principles of Neurology – 8th Ed. The McGraw-Hill Companies, Inc.; 2005

[2] Atilla H, Tekeli O, Ornek K: Pattern electroretinography and visual evoked potentials in optic nerve diseases. J Clin Neurosci 2006 Jan; 13(1): 55-9

[3] Huszar L. Clinical Utility of Evoked Potentials E-medicine [serial online]. 2006 [cited 31st July 2007]. Available from URL: http://www.emedicine.com/neuro/topic69

[4] Krarup C. Electrophysiology of the central and peripheral nervous systems, Oxford Textbook of Medicine – 4th Ed. Oxford University Press; 2003

[5] Misulis K, Fakhoury R. Spehlmann's evoked potential primer. 3rd ed. Butterworth Heinemann.

[6] Neurophysiology (2005), Journal of Neurology, Neurosurgery and Psychiatry: Neurology in Practice. 76; 11:18

[7] Nuwer, MR. Fundamentals of evoked potentials and common clinical applications today. Electroencephalogr Clin Neurophysiol 1998; 106:142.

[8] Odom JV, Bach M, Barber C, et al (2004). Visual evoked potentials standard (2004) Documenta ophthalmologica. Advances in ophthalmology. 108 (2): 115-23.

[9] Deuschl E. Recommendations for the Practice of Clinical Neurophysiology: Guidelines of the International Federation of Clinical Neurophysiology. 2nd ed: Elsevier, 2000.

[10] Khazaei H, Khazaei D, Ashraf D, Mikkilineni S, Ng JD. Overview of Orbital Ultrasonography. Ann Ophthalmol Vis Sci. 2022; 5(1): 1028.

[11] Khazaei H, Khazaei D, Brundage D, Mikkilineni S, Dailey RA. Facial Ultrasonography in acquired facial lipoatrophy. Inter J. Research and Scientific Innovation (IJRSI). 2021; 9:48-51.

[12] Khazaei H, Khazaei D, Ashraf D, Mikkilineni S, Ng JD. Ultrasonographic Characteristics of the Facial Nerve in Patient with Bell's Palsy. Ann Ophthalmol Vis Sci. 2022; 5(1):1029.

[13] Hadi Khazaei. M.D., M.S., M.C.R.*, Alireza Mobaseri. M.D, Danesh Khazaei, John D Ng. M.D, M.S, Dr. G. Seethapathy, MS, MRCS, FRCS Ed, FRCOphth, "ORBITAL Ultrasonography a diagnosis tool in early cellulitis" International Journal of Research and Scientific Innovation (IJRSI) vol.9 issue 7, pp.127-130 July 2022

[14] Grogan SP, Mount CA. Ultrasound Physics and Instrumentation. [Updated 2022 Apr 5]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan- Available from: https://www.ncbi.nlm.nih.gov/books/NBK570593/