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The Efficacy of B-Mode and Color Doppler Ultrasound in Evaluation of Various Intraorbital Disorders

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ABSTRACT

This review aims to present studies evaluating B-mode and color Doppler ultrasound as innovative techniques for ocular inspection and to furnish information regarding various intraorbital illnesses. Orbital ultrasonography is a swift and noninvasive procedure that has great sensitivity in visualizing an orbital mass; nevertheless, its specificity in the differential diagnosis of orbital lesions is limited, especially when malignancy is a concern. The evaluation of ocular illnesses necessitates several diagnostic strategies to reconcile the advantages and disadvantages of each technique. B-mode ultrasonography is a straightforward, quick, and objective technique for the quantitative evaluation of pupillary function.

KEYWORDS: ultrasonography, ocular illnesses.

1. Introduction

The eye's superficial position and cystic structure render ultrasonography optimal for ocular imaging. This is a straightforward, non-ionizing, cost-effective, real-time imaging method that offers detailed cross-sectional anatomy of the entire globe [1]. It can be conducted safely in an outpatient setting without the administration of

anesthetics or sedatives. In proficient hands, there is a strong association between sonological and clinicopathological data, even without a specialized eye scanner [2].

It is non-hazardous, atraumatic, and essential for assessing orbito-ocular lesions, particularly when opaque media are present. Sonography can successfully diagnose vitreoretinal disorders, ocular inflammatory illnesses, and intraocular masses. Ultrasound is highly beneficial for evaluating the orbit, excluding the globe [3].

Ultrasound enhances tissue diagnostics owing to its superior spatial and temporal resolution relative to CT or MRI. Ultrasonography aids in determining the kinetic properties of tumors, including their consistency and vascularity, with color Doppler technology. Colour Doppler flow imaging (CDFI) aids in the diagnosis and monitoring of orbital space-occupying lesions [3].

The evaluation of pupillary shape and size, together with the pupillary light reflex (PLR), is a common diagnostic method in ophthalmological and neurological assessments. The clinical assessment of pupillary function often involves measuring pupillary diameters (PD) and evaluating the pupillary light reflex (PLR) using a penlight [4]. The precise clinical evaluation of pupillary function may be hindered by eyelid retraction difficulties caused by edema, noncompliance, ambient light conditions, and the examiner's proficiency. Furthermore, subjective assessments of pupil diameters lack the reliability necessary for longitudinal inter-rater comparisons. Alternative techniques for the objective evaluation of pupillary function encompass advanced diagnostic tools such as video assessment or infrared pupillometry devices. Nonetheless, these tools are infrequently accessible beyond specialist centers [5]. B-mode ultrasonography is a straightforward and readily accessible noninvasive imaging modality. Ocular ultrasonography for the assessment of pupillary function has only been documented in one patient with ocular injuries [6].

2. Review:

Ultrasound is a traditional diagnostic instrument for the morphological assessment of ocular pathology. Doppler ultrasound's capacity to acquire quantitative vascular flow measurements introduces novel diagnostic opportunities, facilitating statistical analysis and enhancing diagnostic differentiation in conditions like glaucoma, which appears to involve vascular factors [7].

Primary open-angle glaucoma is, as per the World Health Organization (WHO), the predominant cause of preventable irreversible blindness globally. It is induced by optic neuropathy, marked by the acquired permanent loss of retinal nerve fibers that constitute the optic nerve (ON). Axonal loss in glaucoma transpires years prior to the detection of significant changes in the visual field (VF). Once the changes transpire, visual field loss is irreversible; thus, early diagnosis of glaucoma is essential for averting progressive vision deterioration. [8].

Glaucomatous damage is subtle and challenging to identify structurally until the disease has progressed significantly, owing to the extensive normal variability in the optic disc and the retinal nerve fiber layer (RNFL). The clear correlation between optic nerve head perfusion and retrobulbar circulation, which is readily accessible by

ultrasound, positions color Doppler imaging (CDI) as a promising method for assessing early alterations in vascular flow associated with glaucoma. The application of CDI has been substantiated in assessing moderate and advanced glaucoma patients, reliably identifying variations in flow velocity and heightened resistive index in these individuals compared to healthy controls [9]. Nonetheless, the utility of CDI as a mechanism for the early detection and progression of glaucoma has not been rigorously investigated. To our knowledge, only Calvo et al. [10] have incorporated glaucoma suspects or individuals with early-stage glaucoma. In all studies, the orbital CDI characteristics have been associated with the onset or advancement of glaucoma, as assessed using structural criteria evaluated over an extended duration. We have conducted a logistic discrimination function (LDF) to forecast progression utilizing ocular artery (OA) and central retinal artery (CRA) data. Zeitz et al. [11] and Martínez and Sánchez [12] investigated the predictive effect of CDI for glaucoma advancement in established glaucoma patients. Both studies included the cup-to-disc ratio alongside visual field testing and changes in visual field to assess glaucoma development [11,12].

Plange et al. reported [13] higher flow velocities and lower RI and PI in SPCAs within the No-Progression group; however, these differences lacked statistical significance. Conversely, certain studies indicate diminished circulation in these arteries among glaucoma patients, and Zeitz et al. [11] observed decreasing blood flow velocities in the SPCA correlated with glaucoma development. The small diameter of these vessels precludes individual measurements, necessitating varied insonation angles for their investigation due to their orientation. Moreover, the extensive variability in their measures exceeds that of other vessels, as previously suggested [14]. The increased size and more accessible locations of the OA and CRA facilitate easier and more reproducible measurements using Doppler ultrasound. The vascular supply of the external retina is directly reliant on the short posterior ciliary arteries (SPCA), which are branches of the ophthalmic artery (OA). Consequently, it is plausible that variables influencing the flow characteristics of the OA and central retinal artery (CRA) may similarly affect the SPCA, but direct proof of this is technically more challenging. Consequently, we believe that more extensive research may reveal substantial changes in the CDI characteristics of SPCAs. Other investigators [10] observed no differences between patients with stable and decreasing visual fields for the CRA. The varied designs and sampling of the studies, along with the diverse procedures employed, complicate the comparison of outcomes. We identified substantial discrepancies in certain CDI parameters, as noted by prior researchers. The Resistance Index (RI) possesses several advantages over alternative parameters, as it incorporates both systolic and diastolic velocity values and is the most reproducible metric in Doppler ultrasound [10,14]. CDI is a noninvasive technique that facilitates the examination of vascular implications in glaucoma. The reliability and precision of OBF measurements are inconsistent and contingent upon the uniformity of techniques and methodological design [14].

Hafiz MA et al. examined 50 patients using B-scan and determined it to be significantly accurate in detecting orbital masses, encompassing neoplastic and inflammatory diseases [15]. Glasier CM et al. investigated 26 infants and children

with orbital and ocular pathology through ultrasound and concluded that high-resolution ultrasound examination of the eye and periorbital tissues can be easily conducted with commonly available equipment, often revealing subtle structural abnormalities not detectable by CT or MRI [16]. Ukponmwan CU et al. identified a 92.3% correlation between clinical and ultrasonographic diagnoses. SB Adebayo et al. evaluated 29 patients to determine if ocular B-scan ultrasonography aids ophthalmologists in diagnosis, observing that ultrasound findings affected management decisions in 95% of cases [17]. Zhang et al. investigated 288 cases of orbital diseases utilizing CDI ultrasound and concluded that CDI effectively reveals color blood flow in orbital conditions, particularly in tumors with abundant vascular tissue and orbital vascular disorders, when used alongside B-mode ultrasound, CT, or MRI [18]. Scott IU et al. identified a 96% correlation between the final clinical or pathological diagnosis and the ultrasonographic diagnostic in their investigation [19]. JA Fielding's study found that ultrasound exhibits a sensitivity of 92% in identifying ophthalmic diseases [20]. Itani KM et al. determined that ultrasonography had a 100% success rate in identifying orbital masses [21]. Accurate diagnosis was achieved in 78% of patients by ultrasonography, 52% through clinical assessment, and 55% using radiologic testing. Ferrer E et al. examined 79 ocular disorders in 52 patients and determined that ophthalmic ultrasonography is a significant adjunct for the clinical evaluation of diverse ocular and orbital conditions [22]. Parchand S et al. examined 130 patients and determined that ultrasound exhibited an overall sensitivity and specificity of 92.31% and 98.31% for detecting rhegmatogenous retinal detachment, and 96.2% and 100% for posterior vitreous detachment, respectively, while achieving 100% accuracy for vitreous hemorrhage, preretinal bleed, and vitreous exudates [23].

The modification in OBF dynamics is well acknowledged in glaucoma. Numerous research conducted in the past two decades have demonstrated that vascular variables may significantly contribute to the etiology of glaucoma as a result of a failure in ocular blood flow autoregulation. Furthermore, while increased intraocular pressure (IOP) is a recognized significant risk factor for glaucoma, evidence indicates that many patients experience disease progression despite treatment reductions in IOP [24,25], rendering IOP an inadequate predictor for progression. The current investigation revealed no significant variations in intraocular pressure (IOP) between patients with glaucoma progression and those without; nonetheless, notable discrepancies were identified in several orbital CDI characteristics between the two groups. A reduction in flow velocities, along with an increase in pulsatility and resistive indices measured by orbital CDI, was observed in patients with progressive glaucoma compared to those who stay stable. The findings indicate that orbital hemodynamics analyzed using CDI may serve as a significant biomarker to differentiate glaucoma patients at an elevated risk for progression. Doppler ultrasound may facilitate the implementation of more assertive clinical care in ambiguous patients with elevated progression risk. While the existing data does not permit the establishment of definitive velocity parameters to delineate the threshold between normal and pathological dynamics, it does indicate a discernible difference in the mean velocities of the two groups. However, there is an overlap between the patient groups due to the extensive range of measured values, a phenomenon also observed in other functional and structural glaucoma tests currently utilized in

clinical practice. Calvo et al. [10] established that a RI value exceeding 0.75 in the OA, after a 48-month follow-up, correlated with glaucoma progression in individuals suspected of having glaucoma.

The temporal and nasal sectors, two of the six divisions of the HRT3 for the papilla, have reduced sensitivity in identifying glaucomatous alterations [23,24]. The superior and inferior regions of the optic nerve head, however, have been utilized to evaluate first indicators of glaucoma progression. This may pertain to the denser retinal nerve fiber layer bundles in the superior and inferior areas and the less dense bundles in the temporal and nasal regions, facilitating the HRT's ability to detect and measure alterations in the vertical axis more effectively. To enhance accuracy and eliminate bias, the temporal and nasal sectors were omitted from the statistical analysis based on these data [24].

Nonetheless, ultrasound demonstrated significant efficacy in localizing orbital masses, rendering it a valuable instrument for preliminary noninvasive evaluation or, in urgent situations, for excluding the existence of an orbital mass, particularly in the differential diagnosis of thyroid disorders, orbital inflammations, and orbital neoplasms. Moreover, it is an acceptable protocol to direct intraoperative biopsy or fine-needle aspiration [20, 21].

Despite advancements in radiological imaging technologies [22], each imaging pattern presents a unique differential diagnosis, making orbital lesions frequently challenging to diagnose [23]. A pathological analysis of a tissue biopsy is necessary for an accurate, precise, and comprehensive diagnosis, as well as for optimizing clinical therapy and estimating prognosis [24]. While there are no tests available to supplant histological testing, the finding indicates that orbital ultrasound may function as a noninvasive complement to clinical diagnosis for confirming and localizing an orbital mass; however, it cannot yield a definite diagnosis.

The assessment of ocular disorders necessitates several methodologies. Improving the precision of ultrasound in the United States through the utilization of contrast-enhanced ultrasound (CEUS) and integrating these methodologies with computed tomography (CT) and magnetic resonance imaging (MRI) might significantly aid in the preoperative evaluation for the biopsy of orbital lesions. Furthermore, a comprehensive medical history will assist in establishing an accurate diagnosis, corroborated by biopsy [25,26].

3. Conclusion:

The sutides in this review indicate that orbital hemodynamics, as investigated by CDI, may serve as a biomarker for the prediction of glaucoma progression, particularly in OA and CRA, where the LDFs have achieved high specificities. Additional research with a larger sample size is required. In order to facilitate the comparison of results, researchers should endeavor to establish uniform methodologic standards for orbital Doppler US. Orbital CDI would be a critical diagnostic method, as retrobulbar hemodynamic alteration may serve as a risk factor for glaucoma progression even in the early stages of the disease, when the visual

field remains unaltered and a classical risk factor such as IOP is unaffected. The results of this test could be used to determine the appropriate intensity of therapeutic interventions in conflicting cases. Also, the assessment of the PLR with B-mode ultrasound is a cost-effective, innovative, and widely available method for documenting routine clinical pupillary testing. The PLR and its dynamic component, the PCT, can be directly measured using B-mode ultrasonography of the eye.

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