Research Article

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Diagnostic protocol by ocular transpalpebral doppler of the ophthalmic artery in patients with cerebrovascular disease

Abstract

Introduction: The incidence of cerebrovascular diseases is related to the atherosclerotic process, which increases exponentially with age according to studies.

Objective: To propose a diagnostic protocol by transpalpebral ocular Doppler in patients with ischemic cerebrovascular disease.

Methodology: The research design is descriptive with a mixed approach. An initial diagnosis was made of the state of the application of ophthalmic artery Doppler ultrasound in patients with cerebrovascular disease through a survey applied to 13 imaging specialists belonging to the "Lucia Iñiguez Landín" Clinical Surgical Hospital that showed that specialists do not apply a diagnostic protocol in care settings.

Results: The proposed diagnostic protocol interprets from Imaging the usefulness of the transpalpebral Doppler of the ophthalmic artery not only as a selective exploration test, but also as a , but also as an instrument to assess the extent and severity of cerebrovascular disease. The proposed diagnostic protocol reveals the relevance of the proposed diagnostic protocol, taking into account the fundamental relationships that are established between the scientific method and the care practice. **Conclusions:** the solution route offers a new look at the training of medical imaging professionals in a given historical context and its transformation in correspondence with scientific and technological advances.

Keywords: imaging, cerebrovascular disease, diagnostic protocol, ocular doppler

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Introduction

The incidence of cerebrovascular disease is related to the atherosclerotic process, which increases exponentially with age according to studies. These have examined the relationship between the general modifications that occur in the biological aging process or alterations of the vascular wall and atherosclerotic disease.[1,2]

With an overall prevalence of 2.6 in persons over 20 years of age, it is estimated that in Europe the number of strokes per year is one million new cases for a population of 450 million, which means an annual incidence of 222 cases per 100 000 inhabitants. In Spain, according to data obtained in the IBERICTUS study, the non-age-adjusted incidence rate was 187 cases per 100,000 inhabitants in 2006. The Latin American population has a reported prevalence of between 1.7 and 6.5 per 1000 inhabitants.

According to the 2022 Cuban statistical yearbook published in 2023, there were 4874 deaths due to occlusive cerebrovascular disease in 2022, being higher in the male sex with 2533 deaths for a rate of 45.6 per 100,000 inhabitants, while in the female sex there were 2341 for a rate of 41.6 per 100,000 inhabitants.[3-6]

Atherosclerosis is responsible for the lesion that causes thrombotic strokes in 95% of cases.[3,4] The main lesion is the atheromatous plaque, which unfailingly evolves towards the gradual reduction of the vascular lumen. During the natural evolution towards occlusion, even before symptoms appear, hemodynamic disturbances occur whose intensity is directly related to the degree of carotid stenosis.

Coherent with the above, there are dissimilar techniques that from Imaging serve as predictive and prognostic tools for this nosological entity, among which is the Carotid Doppler Ultrasound, the latter is currently considered the first line study in the noninvasive evaluation of vascular structures. In comparison with other imaging techniques, it has certain advantageous characteristics: low cost, high availability, easy transfer of the equipment with the possibility of performing studies at the patient's bedside, reliability of the results and the possibility of visualizing the flows in real time to perform hemodynamic evaluations and physiological tests at the moment.

However, the use of Doppler at the level of the ophthalmic artery as the first intracranial branch of the internal carotid artery has not been sufficient, since the use of this technique is limited only to extracranial branches.

During the last decade the use of ocular ultrasound has promoted its usefulness to assess the ophthalmic arteries, and also as a valuable complementary tool for patients whose Doppler velocimetric evaluation of extracranial carotid branches is inconclusive. In these cases, the use of ophthalmic artery Doppler ultrasound reveals whether the results are adverse to the life of the patient with cerebrovascular disease, by relating the latter to the increase in peak velocity values.

Although there are different authors who reveal the importance of the use of this diagnostic technique in question, there is no need for a diagnostic protocol to guide the way forward from the practice, without establishing a dichotomy between the results in the flowmetric evaluation by Doppler ultrasound, and the biological dimension of the patient to be able to form a criterion and establish some recommendations.

All the aforementioned reveals the need to conceive tools that in an organized way allow investigating a certain clinical picture and transforming the surrounding reality in order to revert the health status of the ill patient. The analysis of the limitations shows that there are several causes that affect the diagnosis by transpalpebral ocular Doppler in patients with ischemic cerebrovascular disease.

These limitations have their expression in the medical practice that attempts against a quality care to the sick patient granting this fact social significance, therefore, the following scientific problem is revealed: How to improve the diagnosis by transpalpebral ocular Doppler in patients with ischemic cerebrovascular disease?

The object of the research is defined as: Imaging techniques approved by the National Health System for the management of chronic non-communicable diseases. Correspondingly, it is specified as field of action: Transpalpebral ocular Doppler in the management of patients with ischemic cerebrovascular disease.

Therefore, the objective of the research is to propose a diagnostic protocol by transpalpebral ocular Doppler in patients with ischemic cerebrovascular disease.

Methodology

The research design is descriptive with a mixed effect. The dependent variable is defined as: the diagnosis by transpalpebral ocular Doppler in patients with ischemic cerebrovascular disease. The independent variable is defined as the proposed diagnostic protocol that will establish an operational and functional way to transform the object of study allowing to analyze, explain and evaluate the elements that characterize it.

An initial diagnosis of the state of the application of ophthalmic artery Doppler ultrasound in patients with cerebrovascular disease was made through a survey applied to 13 imaging specialists belonging to the Hospital Clínico Quirúrgico ¨Lucia Iñiguez Landín¨¨. To calculate the reliability of the applied instrument, Cronbach's alpha coefficient was used assuming the criteria of George and Mallery (2003) to evaluate the results. In this case Cronbach's alpha coefficient was 0.81 (good) and the instrument showed to have content validity designed to evaluate the subject purpose.

The survey applied to Imaging specialists of the Clinical Surgical Hospital ¨Lucia Iñiguez Landín¨ showed that specialists do not apply a diagnostic protocol for Doppler ultrasound of the ophthalmic artery in patients with cerebrovascular disease in health care settings.

Different data, sources and theoretical and empirical methods were triangulated to find coincidences and discrepancies between the results. In addition, to socialize the information and contributions of the research, to assess the level of significance of the protocol, expert criteria were used to obtain consensus.

Result

Proposal for a diagnostic protocol by transpalpebral ocular doppler imaging of the ophthalmic artery in patients with ischemic cerebrovascular disease

Name of the protocol

Definition of the health problem: An ischemic cerebrovascular disease is an acute neurological injury that occurs as a result of cerebral ischemia. This condition may be due to occlusion of cerebral blood vessels by thrombosis or embolism or, occasionally, due to systemic hypoperfusion. Cerebrovascular disease (CVD) has an annual incidence of 17 million cases worldwide and is the second leading cause of death worldwide, the second most common cause of disability in adults, and its prevalence increases with age.

Ischemic stroke has three main causes: thrombosis, embolisms and systemic hypoperfusion resulting in ischemia and hypoxia. Thrombosis refers to the obstruction of arterial blood flow. If the occlusive material blocking a cerebral artery comes from another point in the circulation, it is called an embolism. The most frequent sources of emboli are the heart and atheromatous plaques or thrombi in the extracranial carotid and vertebral arteries.[6,7] There is a risk of CVD in hypertensive persons, smokers, persons with diabetes or heart disease, atherosclerosis, advanced age, and with a family history of CVD. Approximately 80%-85% of all cerebrovascular diseases are ischemic (15%-20% are hemorrhagic). Of the ischemic ones, approximately 80% are thrombotic (20% are embolic).[8-10]

Due to the great impact of this disease on patients' lives, both economically and socially, this research is motivated by the proposal of an imaging protocol by transpalpebral ultrasound of the ophthalmic artery in patients at risk of suffering it as a valuable complementary tool for those whose velocimetric evaluation by Doppler of extracranial carotid branches is not conclusive. In view of the above, it is assumed that ischemic cerebrovascular disease is acute neurological damage that occurs as a result of cerebral ischemia. This condition may be due to occlusion of cerebral vessels by thrombosis or embolism, or in some cases to systemic hypoperfusion.

At the Lucia Iñiguez Landín Clinical Surgical Hospital in Holguín, this disease is very frequent and therefore the proposal for the management of CVD from transpalpebral ultrasound of the ophthalmic artery is provided.

Clinical manifestations: Decreased or loss of muscle strength, Sudden numbness or weakness of the face, arm or leg (especially on one side of the body). Sudden confusion, difficulty speaking or understanding language. Sudden difficulty seeing with one or both eyes as well as gait, dizziness, loss of balance or coordination. Sudden severe headache with no known cause.[1,11,12]

Pathophysiology: Ischemic stroke may be due to occlusion of large cerebral vessels; the source of emboli may be the heart, the aortic arch, or other arteries, such as the internal carotid arteries. Small, deep ischemic lesions are most often related to intrinsic small vessel disease (lacunar strokes). Low-flow strokes are sometimes seen with severe proximal stenosis with insufficient collaterals that are challenged by episodes of systemic hypotension. Hemorrhages are the most frequent result of ruptured aneurysms or small vessels within the brain tissue. The variability in stroke recovery is influenced by collateral vessels, blood pressure, and the specific site, as well as the mechanism of vessel occlusion. If blood flow is restored prior to significant cell death, the patient may experience only transient symptoms.[13,14]

Population susceptible to the application of the protocol

Eligibility criteria: Patient from evaluation consultation for patients with a history of stroke with uncomplicated atherosclerosis risk factors (hypertension, diabetes mellitus, smoking, hyperlipidemia) and over age.

Exclusion criteria: Patients with associated oncoproliferative process. Patients with decompensated chronic diseases. Pregnancy. Dementia. Prostration. Decompensated dysrhythmias.

Planning for image acquisition during transpalpebral ocular Doppler assessment of the ophthalmic artery (AO)

The ophthalmic artery is identified in a cranial axial section at the orbital level through the optic orifice where it runs parallel to the homonymous nerve, which is taken as a reference, identified as a linear anechoic structure in the posterior pole of the eyeball. The ophthalmic artery is located at the nasal margin of the nerve, 1-2 cm posterior to the papilla. The central retinal artery and vein are identified in its course, while the posterior ciliary arteries are located on the nasal and temporal side of the nerve.

Technical aspects of measurement

- The study is started with the patient in the supine position with the head incorporated at 45 degrees and the eyes closed. Contact lenses should be removed in patients who wear them. Sterile contact gel is placed as a conductive substance on the closed eye, applying the transducer (7.5-10Mhz) without pressing, to avoid collapsing the anterior chamber, in which case the hand can be placed carefully on the patient's nose or forehead.

- In the specific case of transpalpebral ocular ultrasound, the acoustic power should be reduced to 64% in order to avoid the risk of producing iatrogenic lesions.
- The vessel should be identified with color Doppler and medium velocity scales (between 20 and 40 cm/s) should be used for selective vessel identification.
- The zoom must be sufficient for the area of interest to occupy >50% of the screen.
- The Doppler sample size should be equivalent to the diameter of the artery and should be placed in the center of the vessel.
- The Doppler study should be performed during the diastolic phase of the cardiac cycle.
- Care should be taken not to exert excessive pressure on the eyeball, as this may interfere artifactually with the velocimetric values.
- Estimate mean velocities after three measurements of similar characteristics for the, with an appropriate pulsed Doppler scale (PRF), occupying at least three-quarters of the y-axis, with the baseline in the lower quarter of the axis.
- The sweep speed should allow 5-10 waves to be displayed on the screen.
- The acquisition and measurement of the wave will be repeated three times, and for clinical purposes we will consider the best (most pulsatile) of the observations.

Identify according to velocimetric wave morphology the retrobulbar arterial vascular structures.

Conventionally, those flows that approach the transducer (in the cerebro-ocular direction) are represented in red, and inversely, those flows that move away from the transducer (in the oculocerebral direction) are represented in blue (Figure 1).

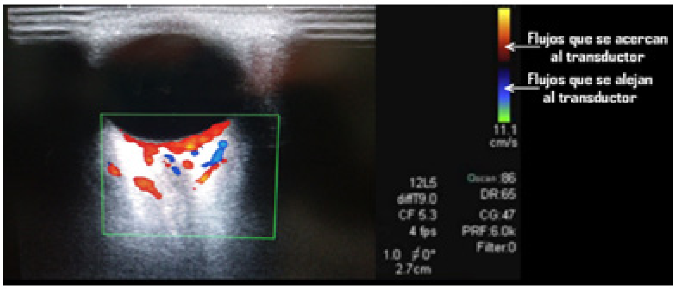


Figure 1 Direction of flow according to the color map.

Depending on the color map (Figure 1) any vascular structure approaching the transducer is impregnated with a positive value or red color and conversely those moving away, negative or blue color, so the arteries examined in our study were visualized in red color. In this way, we proceed to recognize the presentation of the ophthalmic artery in its medial (nasal) path with respect to the path of the optic nerve; the central retinal artery, contained as well as its accompanying vein, the central retinal vein, in the adventitial sheath of the optic nerve; and the short posterior ciliary arteries a few millimeters from the area of recognition of the central vessels.

Ophthalmic artery: flows similar to those of the internal carotid (low resistance), high systolic peak, dicrotic incisura and low diastolic flow (Figure 2).

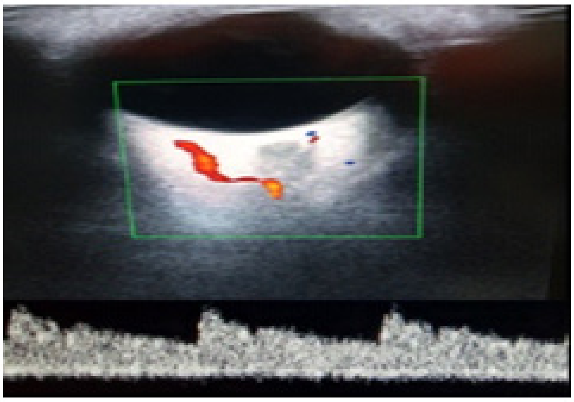


Figure 2 Spectrum of the ophthalmic artery.

Spectrum of the ophthalmic artery: The retinal vasculature is supplied by the ophthalmic artery (OA). The retina is one of the most metabolically active tissues in the body and consumes high levels of oxygen and nutrients. It therefore has a well-organized vascular system that is adapted to meet its metabolic requirements to ensure visual function.

Central retinal artery and vein: one arterial and one venous flow, anterograde and retrograde at 2 mm anterior to the optic nerve shadow (Figure 3).

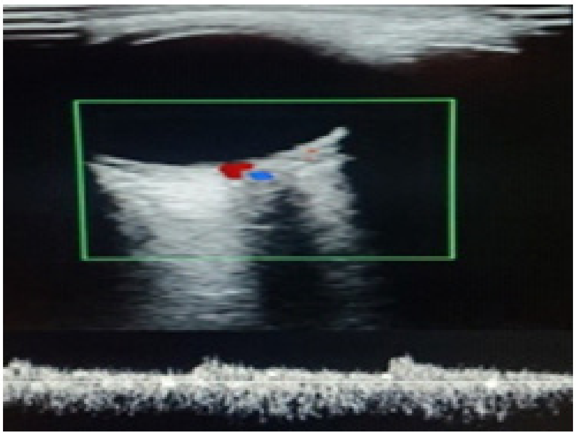


Figure 3 Central retinal artery and vein.

Spectrum of the central retinal artery and vein: In this order of ideas, the velocimetric evaluation of the spectrum allows discerning the vascular structure in question, which when it takes values between 25 and 45 cm/sec points to the presence of the ophthalmic artery that can vary, but if the velocity is similar or less than 10 cm/sec it is more likely to be over the central retinal artery that has lower velocities.

Retinal circulation is influenced to a lesser extent by blood pressure (BP) and postural changes due to its self-regulating capacity; however, it can be affected by increases in intraocular pressure (IOP). For this reason it is important not to exert pressure on the eyeball when applying the ultrasound probe as this would raise the IOP and alter the blood flow results.[15-17]

Ciliary arteries: arterial flow velocities are lower than those of the ophthalmic artery lateral to the optic nerve and have a uniform thickness (Figure 4).

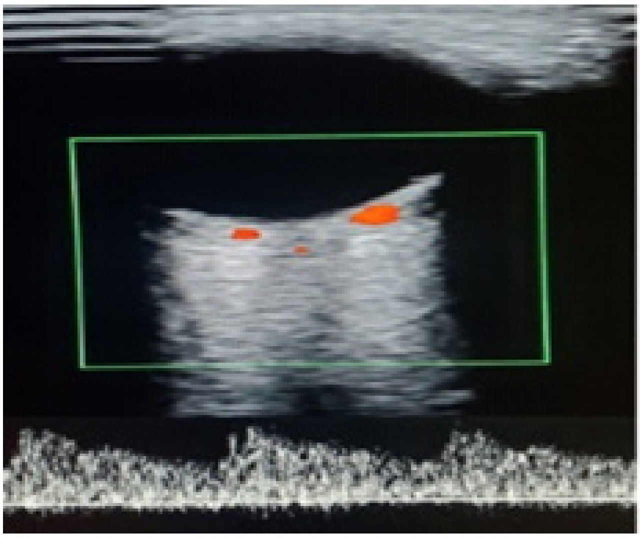


Figure 4 Spectrum of posterior ciliary arteries.

To estimate arterial velocimetric parameters

Normal flows of the ophthalmic artery, the spectral waves are classified as: low resistance waves; moderate resistance and high resistance. In the case of the ophthalmic artery, being the first branch of the internal carotid artery, there is contiguity in the circuit and its spectral wave is of low resistance, presenting continuous flow during diastole.[19]

Once the optimal image of the explored vessel is obtained, with the necessary anatomical knowledge, the spectral record is visualized for the calculation of the desired parameters, placing the sample volume selectively in each of these vessels; for example: velocity at peak systolic (maximum) in cm/sec (VPS); velocity at end diastole (minimum) in cm/sec (VDF); resistance index (IR) or Pourcelot index corresponding to the equation (Figure 5).

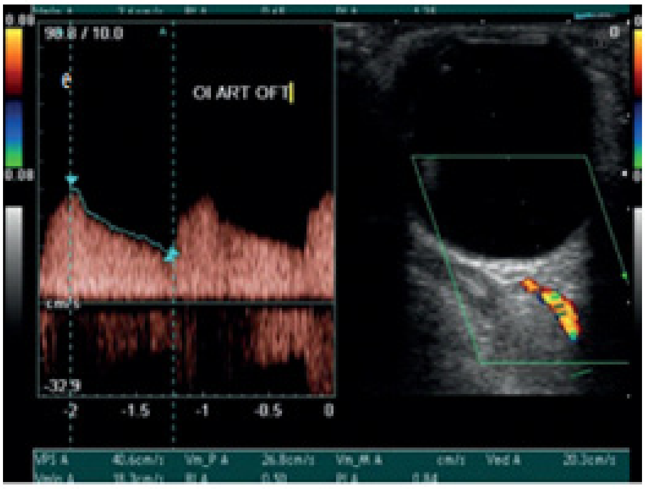


Figure 5 Estimation of arterial velocimetric parameters.

We can visualize the intracerebral circulation by means of four ultrasound windows that identify a specific vascular group according to the acoustic characteristics of each vessel, which are summarized in (Table 1).

Table 1 Reference sonographic parameters of retrobulbar arterial vascular structures (Argentine Society of Cardiology)[20]

Parameter	AO	ACR	Lateral ACP	Medial ACP
VSM (cm/sec)	45,3 ± 10,5 (31,4-39,6)	17,3 ± 2,6 (8,8-12,6)	13,3 ± 3,5 (9,8-11,4)	12,4 ± 3,4 (8,6-14,2)
VDP (cm/sec)	11,8 ± 4,3 (8,2-10,6)	6,2 ± 2,7 (2,0-4,0)	6,4 ± 1,5 (3,4-1,7)	5,8 ± 2,5 (3,3-4,9)
IR	0,74 ± 0,07 (0,73-0,81)	0,63 ± 0,09 (0,70-0,76)	0,52 ± 0,10 (0,63-0,68)	0,53 ± 0,08 (0,63-0,68)

Parameters used in clinical practice: Arterial pathology alters the physiological spectral wave curves in a characteristic way, and the recognition of these changes is useful for the diagnostic approach.

The main ones are listed below:

Loss of reverse flow and diastolic component: as atherosclerotic disease appears and progresses, the elasticity of the arterial wall is lost and is gradually manifested when reverse flow is lost in early diastole, in more advanced stages and in distal segments of arteries with significant stenosis there is a loss of complete diastole with monophasic flow.

Spectral wave broadening: the thickness of the spectral wave translates normal laminar flow in an artery without significant hemodynamic changes, the spectral broadening is due to turbulent flow that causes red blood cells to travel disorderly and turbulently through the artery, occupying the spectral window as turbulence increases.

Increased systolic and diastolic components at the site of stenosis: blood needs to travel at a higher velocity to pass the same volume through a smaller lumen, manifesting as spectral waves with a high peak. In advanced stages of stenosis, the diastolic velocity at the end of each cardiac cycle also increases.

Aliasing: when a stenosis becomes hemodynamically significant, the pattern of change consists of continuous turbulence at the site of the stenosis.

Decreased curve amplitude distal to the stenosis: Decreased and delayed arterial pulsations have been termed "pulsus parvus and tardus". The parvus tardus waveform is characterized by a small, smooth, rounded systolic peak and distal to severe atherosclerotic stenosis is observed.

Collateral arteries: Occlusion of an artery can lead to the formation of small tortuous collateral branches that do not follow normal patterns.

Bidirectional flow (To-and-Fro Flow): When flow travels into a blind channel (dissection, complete obstruction, neck of a pseudoaneurysm) it flows inward in systole and returns back to the artery in diastole. These alternating currents can be reflected in the lumen of a main artery and detected on spectral Doppler ultrasound.

Shunts: arteriovenous fistula causes high-flow, low-resistance waves with almost uninterrupted direct flow. There is coexistent venous wave pulsatility at the fistula site caused by tissue reverberation of the highly turbulent flow.

Doppler velocity measurements are the main indicators to evaluate and quantify the degree of stenosis in vascular Doppler ultrasound (VPS and VPS stenosis/pre-stenosis index), as long as the insonation angle is between 45 and 60º (preferably 60º for reproducibility in each study). The following is a referential pattern of wave morphology types (Figure 6).

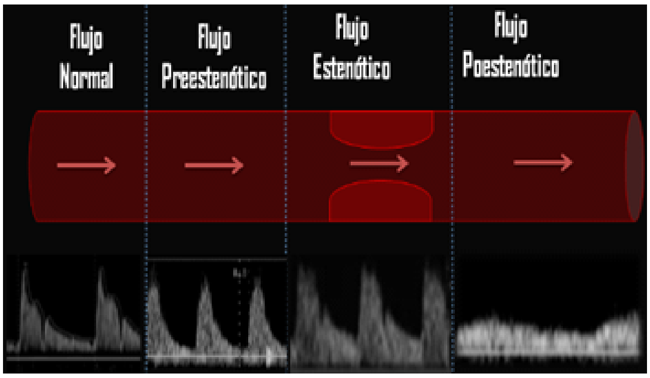


Figure 6 Referential pattern of wave morphology types of stenosis in ophthalmic artery.

The spectral wave characteristics in the presence of arterial stenosis at the ophthalmic level are:

- Elevated VPS at the stenosis site.
- Elevated end-diastolic or end-diastolic velocity (EDV) (mainly in vessels with low resistance).
- High ratio of PSV between the stenosis site with respect to the PSV of the previous segment (peak systolic velocity index).
- Color overlap.
- Spectral broadening of the Doppler wave.
- Post-stenotic flow characteristics.
- Post-stenotic turbulence.
- Acceleration time delay to peak systolic.

Final recommendations

This document was based on scientific evidence based on the experience of a panel of experts in vascular ultrasound. The grade of recommendation and level of evidence used for the final recommendations are described below:

Type of recommendation

- Class I: There is evidence and/or general agreement that a given procedure or treatment is beneficial, useful and effective.

- Class II: There is conflicting evidence and/or divergence of opinion about the usefulness or efficacy of the method, procedure and/or treatment.

- Class IIa: Weight of evidence/opinion is in favor of utility/ efficacy.

. - Class IIb: Utility/efficacy is less well established by evidence/ opinion.

- Class III: There is evidence or general agreement that the treatment, method/procedure is not useful or effective and in some cases may be harmful.

Level of evidence

- Level A: Data from multiple randomized clinical trials or meta-analysis.

- Level B: Data from a single randomized clinical trial or from non-randomized studies.

- Level C: Consensus of expert opinion or small studies.

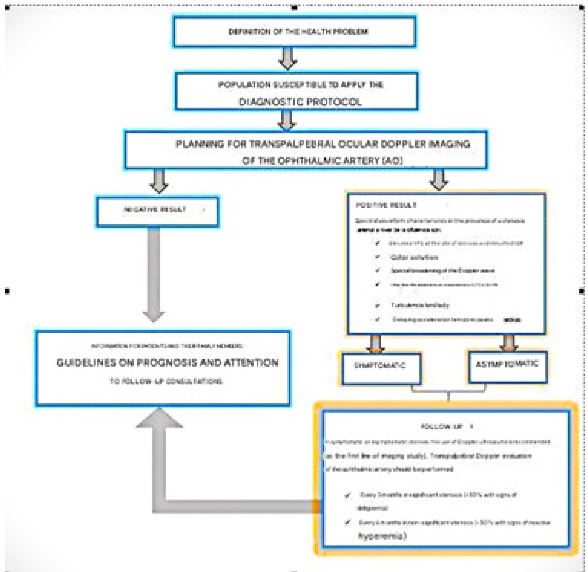
Recommendation	Class	Level of evidence
If there is ultrasound evidence of symptomatic or asymptomatic stenosis, the use of Doppler ultrasound is recommended (first line of imaging study) followed by the following order of angio-CT and angio-MRI for stenosis stratification.	I	B
Detection of the presence of atherosclerotic plaque by ultrasound as a risk modifier in cardiovascular risk assessment.	II	B
The use of Doppler ultrasound is recommended as the first-line imaging method when supra-aortic arteritis is suspected.	I	C

Follow-up

Patients with alterations in the transpalpebral Doppler evaluation of the ophthalmic artery should be evaluated every 3 months in significant stenosis (+50% with signs of oligoemia) and every 6 months in non-significant stenosis (-50% with signs of reactive hyperemia).

Information to patients and their families

General information should be provided on the diagnosis and treatment of your disease and the procedures you should undergo. Written informed consent as well as a medical report at discharge with the following sections: definitive diagnosis, prognosis guidelines and attendance to follow-up consultations.



Logic of the diagnostic protocol as a scientific result.

Assessment of the methodology by expert criteria

The Delphi method was used as one of the most reliable subjective methods for the evaluation of experts' criteria, as one of the most reliable subjective forecasting methods. It is a procedure for drawing up a picture of the evolution of complex situations, through the statistical elaboration of the opinions of the experts on the subject in question, with the following stages: elaboration of the objective, elaboration of the questionnaire, selection of the method of execution of the protocol and processing of the information. The elaboration of the objective was formulated in terms of assessing the proposed diagnostic protocol for the effectiveness expected to be achieved with its application during practice.

For the selection of the experts, the number of expert candidates was determined in accordance with the methodology of the Academy of Sciences of the former USSR, the level of competence of the experts was determined through the calculation of the competence coefficient K, for which a questionnaire standardized by Cruz and Martinez (2012) was applied in search of expertise in terms of knowledge on the subject and experience. The group was composed of 21 masters in Diagnostic Means, 5 doctors of science, 10 managers, 9 full professors, 15 assistant professors and 3 assistants, most of them with more than 20 years of experience in training.

In the questionnaire stage, the principles of communication theory were taken into account. After determining the level of competence of the experts, a survey was applied to those selected to evaluate the essential ideas of the proposed protocol.

Then, in two rounds, the questionnaire is circulated for the evaluation of aspects related to methodology. Opinions are expressed on an ordinal rating scale: very adequate (MA), quite adequate (BA), adequate (A), not very adequate (PA) and inadequate (I). The criterion is taken individually based on the delivery of a summary with the results of the research. Suggestions and recommendations are made to improve the proposal.

The proposal is recognized as novel and they insist on the importance of the use of the health VA by the Imaging teacher. Likewise, they consider the relationship between the evaluated aspects as very adequate, which allows emphasizing the coherence of the research results. These data are corroborated by the Delphi method and show the feasibility of the scientific results. In general, the experts consulted considered the proposed methodology to be very relevant, necessary and useful. The recommendations made by the experts are taken into account for its materialization in practice.

The scientific novelty is expressed in the approach for the integral management of patients with ischemic cerebrovascular disease with diagnostic alternatives from Imaging, constituting a body of knowledge that approaches the human being and the health-disease process in a holistic manner.

In terms of relevance and timeliness, its use is based on scientific grounds, with methods and techniques in the area of medical imaging that are integrated into the care protocols implemented in the institutions of the three levels of care.

Qualitative analysis of the cost-benefit-risk perception ratio: the cost-benefit-risk perception analysis as a process referring to the evaluation of the proposed diagnostic protocol shows convenience based on the costs and benefits derived from it, which from a preventive point of view limits the minimum consumption of medical supplies used in the management of these patients.

Conclusions

The proposed diagnostic protocol interprets the usefulness of the transpalpebral Doppler of the ophthalmic artery not only as a selective screening test, but also as an instrument to assess the extent and severity of cerebrovascular disease. The expert criterion reveals the pertinence of the proposed diagnostic protocol, takes into account the fundamental relationships established between the scientific method and the practice of care, offering a new look at the training of the professional specialist in medical imaging in a given historical context and its transformation in correspondence with the scientific and technological progress.

Acknowledgments

None.

Conflicts of interest

Authors declare that there is no conflicts of interest.

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