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Strabismus Measurements with Novel Video Goggles

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Purpose: To assess the validity of a novel, simplified, noninvasive test for strabismus using video goggles.

Design: Cross-sectional method comparison study in which the new test, the strabismus video goggles, is compared with the existing reference standard, the Hess screen test.

Participants: We studied 41 adult and child patients aged ≥6 years with ocular misalignment owing to congenital or acquired paralytic or comitant strabismus and 17 healthy volunteers.

Methods: All participants were tested with binocular infrared video goggles with built-in laser target projection and liquid crystal display shutters for alternate occlusion of the eyes and the conventional Hess screen test. In both tests, ocular deviations were measured on a 9-point target grid located at 0±15° horizontal and vertical eccentricity.

Main Outcome Measures: Horizontal and vertical ocular deviations at 9 different gaze positions of each eye were measured by the strabismus video goggles and the Hess screen test. Agreement was quantified as the intraclass correlation coefficient. Secondary outcomes were the utility of the goggles in patients with visual suppression and in children.

Results: There was good agreement between the strabismus video goggles and the Hess screen test in the measurements of horizontal and vertical deviation (intraclass correlation coefficient horizontal 0.83, 95% confidence interval [0.77, 0.88], vertical 0.76, 95% confidence interval [0.68, 0.82]). Both methods reproduced the characteristic strabismus patterns in the 9-point grid. In contrast to Hess screen testing, strabismus video goggle measurements were even possible in patients with comitant strabismus and visual suppression.

Conclusions: The new device is simple and is fast and accurate in measuring ocular deviations, and the results are closely correlated with those obtained using the conventional Hess screen test. It can even be used in patients with visual suppression who are not suitable for the Hess screen test. The device can be applied in children as young as 6 years of age. *Ophthalmology 2017;■:1–8 © 2017 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

Supplementary material available at www.aaojournal.org.

Measuring ocular alignment and motility is essential for the diagnosis of strabismus and diplopia, for follow-up of patients with acquired or congenital strabismus, and for surgical treatment decision making. A method for mapping ocular deviation should be easy to perform for both the patient and the examiner and repeatable under the same conditions, and the results of successive examinations should be comparable to each other objectively.

The different techniques to assess ocular deviation can be divided into objective methods, as for example the cover test, and subjective methods, such as the Maddox rod test.[1] However, all need active cooperation of the patient. Probably the most commonly used method in clinical practice is the prism cover test (PCT). However, the PCT is performed manually and measurements depend on the examiner's attention and professional experience. Therefore the PCT is not absolutely reliable and may be inconsistent between repeated measurements by the same examiner or between several different examiners.[2] Furthermore, the examiner must observe the ocular movements during covering and uncovering of the eyes and may miss very small movements[3] that would be important in cases with subtle cranial nerve palsies.

Several variants of subjective screen tests are used clinically to measure and document ocular deviations.[4] The Hess[5–7] and Lancaster[8,9] screen tests both use red–green glasses to break binocular fusion. In the Hess test, the patient has to indicate targets on a red grid. While the red grid is only visible with one eye through the green glass by color subtraction, the red laser pointer can only be seen with the other eye through the red glass by color addition (Video 1, available at www.aaojournal.org). In the Lancaster test, the examiner projects a red light streak with a flashlight onto a grid (invisible to the patient through the glasses), which the patient has to match with a green flashlight. This allows the examiner to also estimate ocular torsion. The Harms tangent

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screen[10] is a similar but more cumbersome test that serves to quantify the horizontal, the vertical, and additionally the torsional components of ocular misalignment. In contrast to the Hess and Lancaster screen tests, for the Harms test the head rather than the eyes is rotated into 9 different positions to achieve eccentric gaze.

With good patient cooperation, all these tests are accurate, but they lack objectivity because the patient must indicate the position of the light shown on the screen. Furthermore, these tests cannot be performed accurately in patients with visual suppression or abnormal retinal correspondence. The tests also require additional personnel and take up to 20 minutes to complete. Computerized versions have been developed, but they still have the same patient requirements and limitations, and the results are not always fully comparable.[11,12]

An accurate and objective method using binocular dual search coils in a 3-field magnetic system has been developed.[13,14] However, this method is semi-invasive, as it involves placing silicone rings on the patient's cornea, and can only be used in cooperating patients. Therefore, it is not practical in clinical routine, is rather costly, and is time consuming.

For these reasons, there has been an ongoing search for alternative, objective, and noninvasive strabismus recording techniques. Several video-based infrared eye-tracking devices exist, but choices of commercially available video recording systems suitable for strabismus are scarce.[15,16] Most video recording systems are not tailored to clinical strabismus measurements, as they do not include all the components necessary for these measurements.

Therefore, we developed a pair of novel portable strabismus video goggles, which include a head-fixed laser target display and liquid crystal display (LCD) shutters for binocular dissociation. In the current study, we compared the performance of our new strabismus video goggles with the standard Hess screen test (Video 1, available at www.aaojournal.org).

Methods

Ethics

The study was approved by the ethics committee of the canton of Zurich (KEK-ZH-Nr. 2014-0481) and by SwissMedic (2014-MD-0028). The study adhered to the ethical standards laid down in the Declaration of Helsinki for research involving human subjects, and written informed consent was obtained from all participants or their parents. The study was registered at ClinicalTrials.gov (NCT02228070) and the study device was registered in the European database of medical devices (EUDAMED CIV-14-09-012767).

Subjects

Subjects were recruited between July 2015 and July 2016 from the Department of Ophthalmology at the University Hospital Zurich. Included were 41 patients and 17 healthy volunteers (total 58 subjects) aged 6 to 81 years (median, 37 years). The patients had various forms of ocular misalignment, such as congenital or acquired paralytic strabismus (4 third, 16 fourth, and 5 sixth nerve palsies), comitant strabismus (12 esotropia and 1 consecutive exotropia), and 3 various diagnoses (Miller Fisher syndrome, thyroid eye disease, meningioma with orbital apex syndrome). The 17 healthy volunteers did not have any known ocular misalignment or motility deficits. Exclusion criteria were noncooperating patients, patients unable to perform the standard tests (e.g., owing to hearing problems or other disabilities), uncorrected visual acuity of less than 0.05 (20/400) in either eye, anomalous retinal correspondence, eccentric fixation, extreme angles of strabismus (larger than 60 prism diopters), and severe limitation ($<15°$) of ocular movements. Three patients were unable to undergo Hess screen testing because of visual suppression but completed video-oculography. Three patients had to be excluded from the analysis for technical reasons.

Examination Procedure

All subjects underwent complete ocular examinations, visual acuity measurements, cover and alternate cover tests, alternate PCT, double Maddox test, and Lang stereoacuity test,[17] as well as Hess screen testing and video-oculography. All tests were performed by the same study team and were done under the same light conditions.

Hess Screen Test. A standard Hess screen test was used with a red grid printed onto a gray tangent screen, located at a distance of 0.5 m from the subject (Video 1, available at www.aaojournal.org).[5] Fixation targets on the 9-point grid were located at $0\pm15°$ horizontal and vertical eccentricity of a Hess coordinate system with non-nested, head-fixed horizontal and vertical rotation axes. During the test subjects were seated in front of the screen with the head on a chin rest and wore glasses with a red filter in front of one eye and a green filter in front of the other eye. The eye with the green filter sequentially fixated on the 9 different locations on the grid, which could not be seen by the eye with the red filter. The latter eye, however, guided the pointing of a red laser light by the patient, which could not be seen by the eye with the green filter. The red light was moved by the patient to the perceived points on the grid and the examiner noted the deviation on the grid of each point on a paper chart. The filters were then switched between the eyes and the procedure was repeated. The horizontal and vertical difference between the locations of the red light and the target positions on the red grid correspond to the phoria, the ocular misalignment in the absence of binocular fusion. The results on the paper charts were scanned and digitized using MATLAB software (MATLAB R2014b, 2014, The MathWorks Inc, Natick, MA).

Video-oculography. Binocular video goggles with a head-fixed target display were designed specifically for this study and built with rapid prototyping (Fig 1; Video 1, available at www.aaojournal.org).[18] Binocular eye position was recorded at 36 Hz with lightweight digital infrared video cameras (Firefly MV, Point Grey Research Inc, Vancouver, British Columbia, Canada). The images of the eye were deflected to the cameras with hot mirrors to provide an unobstructed view to the presented targets. The eyes were illuminated by infrared light-emitting diodes (LED) (TSUS502, Vishay Intertechnology, Malvern, PA), which were invisible to the subject to allow for recording even in complete darkness. The LED was run at 20 mA to keep infrared radiation far below exposure risk levels.[19] Binocular horizontal and vertical eye positions were calculated from the video images.[20] The area of the pupil was detected using image thresholding to estimate eye position based on the center of gravity of the pupil area.[21] Targets in a $0\pm15°$ 9-point grid were projected with a head-mounted class 1 mini-laser on a turret onto a screen at 0.5 m distance. The laser target was sufficiently bright to be visible by subjects with low uncorrected vision. The turret rotated horizontally, and different lasers mounted in the