Glaucoma and Driving License: How to Identify Patients at Risk of Revocation

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Abstract

Aim: To identify clinical criteria that are easily achievable with follow-up tests and can identify subjects not suitable for driving.

Patients and methods: We recruited 194 subjects with a clear diagnosis of glaucoma, with no other conditions that could affect the visual field (VF), and who performed a reliable VF examination. All patients underwent a full ophthalmologic evaluation and a questionnaire considering driving habits. An integrated visual field (IVF) was built using both monocular VF charts; the number of missed points (NoMP) within the central 20°, the average sensitivity (AS), and the better eye mean deviation (BEMD) were evaluated.

Results: A total of 128 subjects showed a valid driving license (DL); 61.7% of drivers did not show missed points within the central 20° of the IVF, 27.4% presented one to three missed points, and 10.9% had four or more missed points. Best corrected visual acuity (BCVA) was highly above the legal criteria.

Stratifying drivers by their BEMD (−7, −10, and −14 dB), we confirmed that the BEMD decrease corresponds to an increased NoMP and a decreased AS.

Conclusion: Better eye mean deviation can be useful in clinical practice to identify patients at increased risk of being unsuitable for driving. Nevertheless, it is important to set specific cut-offs based on on-road driving performance. IVF evaluation may also be implemented in perimeter analysis software so that the composition of IVF, the BEMD, and the AS could directly describe the patient's binocular VF, excluding recourse to the Esterman visual field test (EVFT).

Clinical significance: This new methodology will allow every physician—not just ophthalmologists—even if not an expert in evaluating a VF test, in assessing the ability to drive of glaucomatous patients.

Keywords: Cohort study, Driving license, Glaucoma, Public health, Vision field test.

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Introduction

Glaucoma is a chronic progressive neuropathy causing different types of VF defects of increasing severity.[1,2] This fact could have a severe impact on car driving, the most common means of transport in Europe,[3] and the responsibility of glaucomatous damage in car accidents is a central topic in the scientific literature.

Some studies rated drivers with bilateral glaucoma as significantly less safe,[4,5] reporting more driving and critical errors compared to subjects without glaucoma.[6,7] A further in-depth analysis showed that drivers with glaucoma have trouble in critical situations, that is, detection of peripheral obstacles, hazards, and reactions to unexpected events.[8]

Other investigators identified a connection between glaucoma and the motor vehicle collision (MVC) rate. A population-based study on 206 drivers with glaucoma showed a higher MVC rate, but there was no association of MVC rate with impaired visual acuity (VA) and contrast sensitivity.[9] Other studies support these findings, suggesting that vision screening for drivers' licenses, based primarily on VA, may miss fundamental aspects of visual impairment.[4,10] Some authors consider divided attention tests a more reliable index to assess the ability to drive compared to static exams, such as perimetric tests, and found the useful field of view (UFOV) as a better predictor of MVC.[11–13] However, UFOV is too expensive to be successfully used as a screening method. Crabb et al.[14] suggest that the relationship between visual function and driving is not

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straightforward, and careful consideration should be given when predicting patients' driving ability using their VF; in particular, they suggested that the influence of eye movement patterns in glaucoma patients should be considered, being significantly different from age-matched controls when observing a traffic scene.

For example, patients with advanced glaucoma must compensate for their VF defects with effective visual scanning; therefore, a simple VF examination alone cannot predict driving fitness.[15–17] Given their degree of adaptation and attentiveness, some authors even go as far

as saying that older people with glaucoma drive at least as safely as, if not more safely than, older people without glaucoma.[18]

Regarding the regulatory aspect, the European Union (EU) Directive 2009/112/CE established a set of psychophysical criteria for DLs,[19] particularly concerning the extension of the VF. Specifically, it should include 120° horizontally, with at least 50° both on the left and on the right, and 20° upwards and downwards; in addition, there should not be defects within the central 20°. The VF area accepted by the EU law corresponds to the one established by the UK's Driver and Vehicle Licensing Agency (DVLA), but the DVLA goes further and defines significant defects as "a cluster of four or more adjoining points that is either wholly or partly within the central 20° area".[20] Regarding Italy and other regions of the EU, no definition of significant defects is given. Furthermore, these standards are not equipment-specific, but today, the binocular EVFT is the most used test. EVFT, however, is not a diagnostic or follow-up test, so patients must undergo it in addition to all other examinations.

Concerning VA, the European law states that it should be higher than 0.7 Snellen, reachable adding the VA of the two eyes corrected, if necessary, but the worst eye should not report a VA inferior to 0.2 Snellen.

Saunders et al.[21] demonstrated a strong relationship between BEMD from the Humphrey field analyzer and the probability of not being legally fit to drive. They studied three cut-offs of BEMD (−7, −10, and −14 dB) that could be practical landmarks for visual disability in glaucoma patients; in particular, −7 dB as a margin to refer the patient for an EVFT and −14 dB for a high probability of being unfit to drive.

AIM OF THE STUDY

The aim of the study is to identify clinical criteria that are easily achievable with the patient's follow-up tests, which can identify subjects at increased risk of being unfit to drive cars. Only then will they be directed to further investigations. These clinical standards should also be suitable for implementing or substituting the current law's criteria after appropriate additional studies so that the law can be based on the clinic.

PATIENTS AND METHODS

In this observational study, we recruited patients referred to the glaucoma service of the ophthalmologic unit, ASST Sette Laghi University Hospital in Varese from January 2019 to July 2019. The study adhered to the tenets of the Declaration of Helsinki. The study was registered on ClinicalTrials.gov ID: NCT 04671550. A consent form was signed by all patients as for ASST Sette Laghi Hospital for data management for clinical and research purposes.

Enrolled subjects were 18 years old or older, with a clear diagnosis of glaucoma (of any type) and without any other conditions that could affect the VF (i.e., cataract or macular degeneration). All enrolled patients required a reliable VF examination (less than 15% false positive or false negative and no more than 33% loss of fixation) comparable to Humphrey Swedish interactive thresholding algorithm standard 24-2 or 30-2 and performed within the previous 6 months. We excluded patients who underwent a 10-2 test since the composition for the IVF was not suitable.

All patients who agreed to join in the study underwent a full ophthalmologic examination and verbally answered a questionnaire designed by the authors (Luca Landini, Simone Donati, and Maurizio Digiuni), as reported in Table 1. Ocular examination included BCVA measurement, slit lamp biomicroscopy, Goldmann's applanation tonometry, gonioscopy with a four-mirror lens, optical coherence tomography retinal nerve fiber layer and ganglion cell layer imaging, if necessary, and evaluation of the target intraocular pressure. VA was reported in Snellen chart according to the legal criteria used to establish the ability to drive; we converted it into the LogMAR scale for a better statistical analysis.

Two monocular VF examinations were combined to build the IVF, which is demonstrated by various DP Crabb papers[22–25] to represent an efficient surrogate for the EVFT. The same method described by Crabb was used; therefore, for an exhaustive explanation, refer to the bibliography. In short, each point on each monocular field was compared to its equivalent in the other eye, and we kept the best sensitivity data. Locations were dichotomized into groups with sensitivity ≥10 dB and <10 dB, representing whether a patient would see or miss a point in the EVFT test, respectively. To match even better the IVF with the EVFT, eight points of the inner 20° of the IVF were excluded since there are no direct equivalent points in the EVFT. Figure 1 better explains this process. In contrast to Crabb et al., we used Microsoft Excel® rather than Progressor® to build the IVF in an analogous mode. For each IVF, we considered the NoMP within the central 20° and the AS of all 60 points that constitute the 24-2 grid. We also collected the BEMD from the VF exam, that, as stated by Saunder et al.'s work[21] can be a useful indicator of visual disability.

Data collected for each patient were:

- Best corrected visual acuity for both eyes [oculus uterque visual acuity (OUVA)] assessed at 6 m and reported as the sum of VA of each eye expressed in fractional notation, from 1/20 to 10/10 (example: BCVA RE 10/10 + BCVA LE 10/10 = OUVA 20/20), as functional parameter and measurement unit considered by law.
- Best corrected visual acuity for the worse eye [worse eye visual acuity (WEVA)].
- Answers of the questionnaire.
- Better eye mean deviation.
- Integrated visual field with NoMP and AS.

Each data was input in an Excel® datasheet file, with a progressive number associated with each patient, age, and gender to describe the enrolled cohort.

Statistics

Analysis of variance was used to analyze differences among means, and linear regression was computed to study the relationship between two variables using MedCalc® 19.6.1 (MedCalc Software Ltd., Acacialaan 22, 8400 Ostend, Belgium).

Table 1: Questionnaire for patients

Have you ever had a DL?
When did you last renew your DL?
Are you currently in possession of a DL?
Do you usually drive a car?
How much confidence do you feel while driving a car? (from 1 to 10)
When will your DL expire?
During the renewal procedure, have you been asked about specific tests for glaucoma?
If you don't drive or don't have a DL, is it because of your sight?

RESULTS

Population

A total of 194 subjects fulfilled our inclusion criteria (98 males and 96 females), with a mean age of 72.16 (±11.60) years, as shown in Figure 2A.

Considering DL accomplishment, the population was divided, as shown in Figure 2B. Only 66% of subjects were current drivers. The remaining 66 subjects did not drive for different reasons; only seven (11%) answered that this decision was due to visual disability.

Drivers

Focusing on the driver group, the mean age was 69.38 (±11.33), with a male/female ratio of 1.8 (82 males and 46 females). The average NoMP on the IVF was 1.34 (±3.16).

Approximately 61.7% of drivers had no missed points, 27.4% showed one to three missed points, and 10.9% presented four or more missed points, so they would not meet Europe driving requirements. The mean AS was 25.70 (±4.51) dB. Considering the BCVA, the mean Snellen OUVA was 17.5/20 (±3.41), and the mean WEVA was 8.5/10 (±1.88).

Drivers are stratified by their BEMD using margins of −7, −10, and −14 dB as proposed by Saunders et al.,[21] and we obtained the data reported in Table 2.

The NoMP was significantly different ($p < 0.05$) in the last three groups of Table 2, confirming that the decrease in BEMD

corresponds to an increased NoMP. In the same way, the AS shows a reduction with BEMD decrease, with the first and fourth groups significantly different ($p < 0.05$) from the central two. OUVA presented a significant difference ($p < 0.05$) between the first and third groups (Fig. 3). The linear regression of the population otherwise confirmed the association between OUVA and BEMD decrease (Fig. 4D). The linear regression test also confirms the association between lowering BEMD and both the increased NoMP (Fig. 4A) and the decreased AS (Fig. 4B). No association was found between BEMD scores and self-reported driving confidence using the same test (Fig. 4C).

Applying Saunders' margins,[21] we dichotomized the driver cohort, and we obtained the results shown in Table 3.

Clinical Cases Examples

In Figure 5, we show clinical examples of eight different drivers with BEMD < −14 dB. This figure aims to better explain and underlie the advantages and disadvantages of BEMD thresholding.

DISCUSSION

The results of this study showed the need for a stricter control of DL renewal in patients with glaucoma since more than 10% of our cohort of drivers with glaucoma turned out to be unfit to drive, according to European law. Our study showed the possibility of an effective assessment of fitness to drive based only on
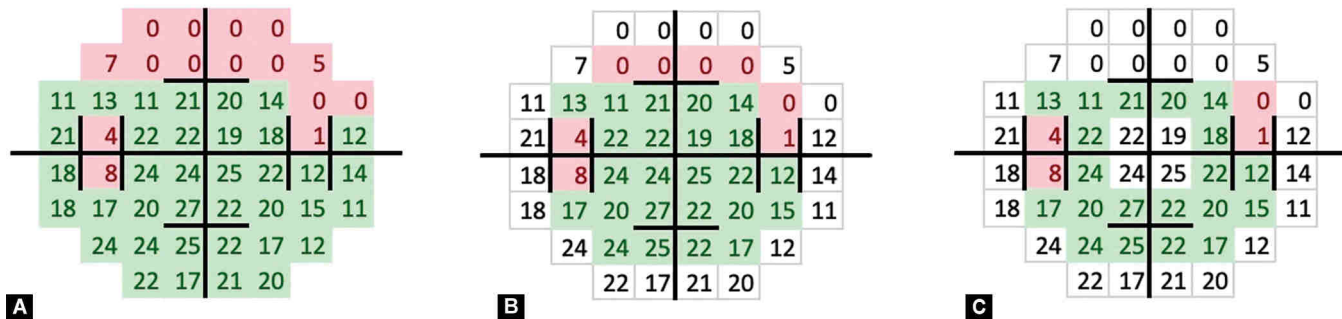
Figs 1A to C: Selection of the points that constitute the inner 20° of the IVF. (A) Base grid of the IVF, each of these points represents the higher sensitivity between left and right eye. The red ones are <10 dB, so they would not be seen in an EVFT test; (B) Only the inner 20° are highlighted; (C) Four central points and four superior points are excluded to better match this grid with the EVFT; in this particular case it involves a drop of the missed points from eight to four
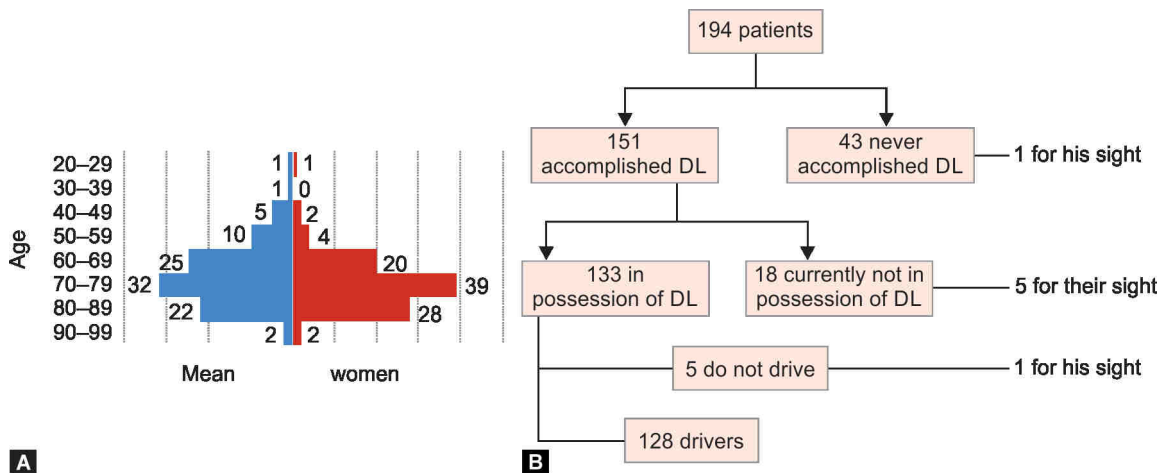
Figs 2A and B: Distribution of subjects. (A) Population pyramid; (B) Flowchart of the population considering DL accomplishment

Table 2: Stratification of the population based on BEMD values. We reported the frequency (absolute and %), mean age, mean number of unseen points (missed loci), mean AS of the IVFs, mean OUVA, mean WEVA, and mean self-reported confidence on a 1–10 scale

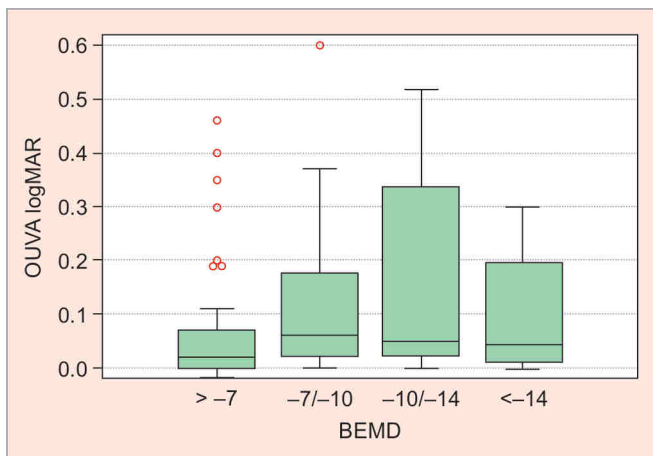| BEMD(dB)	Freq abs.	Freq %	Age	Number of missed loci	AS (dB)	OUVA (Snellen/20 and LogMAR)		WEVA (Snellen/10 and LogMAR)	Confidence (1–10)
>−7	100	78%	68.87 ± 11.48	0.28 ± 0.53	27.49 ± 2.26	18.08 ± 2.65	Snellen	8.68 ± 1.66	8.8 ± 1.15
						0.08 ± 0.13	LogMAR	0.05 ± 0.08	
7–10	9	7%	67.89 ± 11.37	1.33 ± 1.32	22.82 ± 2.05	15.22 ± 5.25	Snellen	7.88 ± 2.17	9.13 ± 1.25
						0.12 ± 0.15	LogMAR	0.15 ± 0.20	
10–14	11	9%	72.55 ± 10.88	5.18 ± 3.92	20.05 ± 2.24	14.91 ± 5.34	Snellen	8.06 ± 2.61	8.64 ± 1.12
						0.26 ± 0.58	LogMAR	0.16 ± 0.19	
<−14	8	6%	73.13 ± 10.47	9.38 ± 6.32	14.33 ± 5.56	16.38 ± 11.13	Snellen	7.25 ± 2.94	8.88 ± 1.13
						0.18 ± 0.21	LogMAR	0.10 ± 0.12	

Fig. 3: Box and Whisker plot of BCVA in each group of drivers, divided by BEMD cut-offs. The dots correspond to the outliers

the clinical tests they already undergo during the follow-up for glaucoma pathology.

In our study, we applied the selection criteria set by European law to a glaucomatous patients cohort, and we verified if patients with a license to drive matched these standards. In this respect, we considered the number of defects within the inner 20° of the binocular VF, the BCVA for both eyes, and for the worse eye, which are the standard limits mentioned by country regulations. To find new parameters that are easier to achieve, we analyzed BEMD and AS; BEMD is a simple index obtained from follow-up tests, AS is more difficult to obtain since it requires IVF creation.

In our cohort, more than 1 out of 10 drivers with glaucoma did not fulfill legal criteria for DLs in terms of the VF, and some had dramatic conditions. Concerning VA, the results are less worrying since only three drivers (2%) do not fulfill legal standards.

Considering all parameters, our data analysis identified a common trend among BEMD, AS, and NoMP; a high NoMP corresponds to a lower BEMD and a lower AS. BEMD and AS are closely related and indicate the global sensitivity of the VF. BEMD refers to a single eye and is a weighted average deviation of the values of sensitivity from a normal reference VF. AS otherwise refers to the IVF and is the mean of the sensitivity of each point. It is not surprising that two parameters so similar have a similar trend. The NoMP otherwise defines the extension of a critical area without providing a general understanding of the VF. Therefore, these parameters are complementary, and the worsening of one of them may predict deterioration of the others. A clinician should

base their evaluation on all these indexes, but the damage may be suspected by a modification of just one of them.

Regarding VA, our data confirmed that the lower the BCVA is, the greater the impairment to the VF. On the contrary, all groups stratified by BEMD values have an OUVA and WEVA within the legal criteria for fitness to drive (OUVA > 7/20 with WEVA > 2/10). Among the 128 drivers, only three drivers had a BCVA that did not fit legal criteria, and two of them were one-eyed. Moreover, good VA could coexist with tunnel-like vision, adding further diagnostic difficulty for the examiner. We can conclude, in overall agreement with other authors,[10,22] that to evaluate the fitness to drive, BCVA cannot be used as a single indicator but must be supported by a VF test.

We also analyzed the safety level perceived by glaucomatous drivers to evaluate the patients' self-assessment. Even if we applied an approximate method, the results suggest that there is no correlation between visual disability and self-reported confidence. This outcome is in accordance with another study that used the Driving Habits Questionnaire.[7] Thus, it should be mandatory that every subject who must renew their DL perform an in-depth visual function assessment since we cannot be aware of a possible disability.

Saunders et al.[21] proposed −7 dB as a useful landmark to refer the subjects for an EVFT test; we applied this cut-off value, and we identified 22% of our population. In this subgroup, the mean NoMP was 5.1 (±5.17). In contrast, the remaining 78% of subjects with a BEMD higher than −7 dB, showed a mean NoMP of 0.28 (±0.53) within the central 20°, so it was reasonable not to proceed with further investigation.

Shifting the margin to −10 dB, the probability of being legally unfit to drive increased, including the 15% of drivers in our cohort, with a mean NoMP of 6.95 (±5.35). Lowering the margin to −14 dB, only 6% of the enrolled subjects presented a lower BEMD, with a mean NoMP of 14.33 (±5.56).

This last group of patients showed an 88% likelihood of not meeting the European legal requirement for driving, even if they owned a DL and usually drove a car. These data were confirmed by the analysis of IVF from the same patients (Fig. 5). Only one patient (n° 169 in Figure 5) in this group was able to drive, with just two missing points but showing a BEMD of −14.80 dB. This discrepancy is due to a low MD in both eyes added to a specular symmetric defect in the VF: under the horizontal raphe in the left eye and above it in the right one (Fig. 6). This fact could represent a false positive in the detection of being legal unfit to drive. These types of defects could be found by analyzing the AS of the IVF; this patient showed an AS of 19.85 dB compared to the mean AS value of the whole group (14.33 dB).
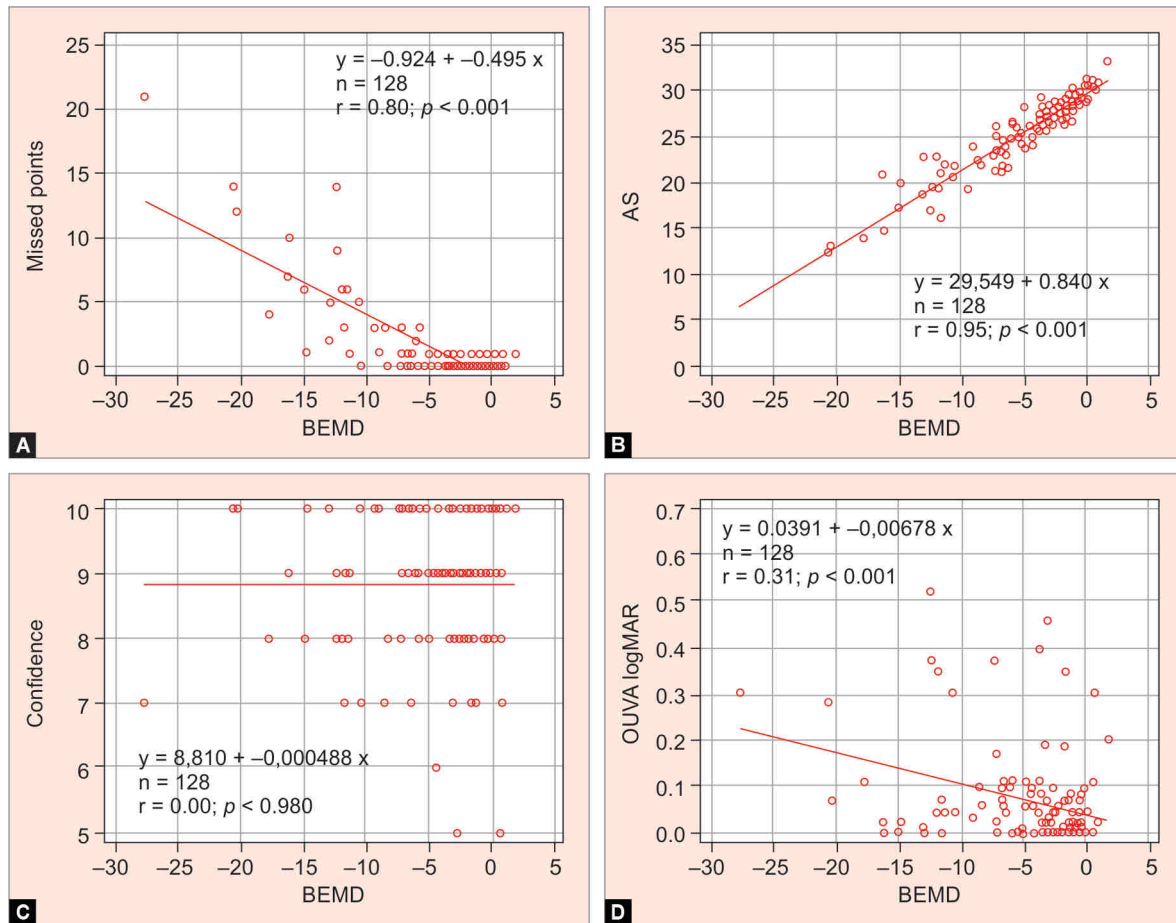
Figs 4A to D: Results of linear regression analysis: (A) Association between lower BEMD and increased NoMP; (B) Association between lower BEMD and lower AS; (C) No association found between BEMD and self-reported driving confidence in a 0–10 scale; (D) Association between lower BEMD and lower best corrected OUVA

Table 3: Partition of drivers' cohort based on BEMD values. The frequency (absolute numbers and %) is reported. This is the result of the application of different BEMD margins

	Frequency (n°)	*Frequency %*
Threshold BEMD = −7 dB		
>−7	100	78%
<−7	28	22%
Threshold BEMD = −10 dB		
>−10	109	85%
<−10	19	15%
Threshold BEMD = −14 dB		
>−14	120	94%
<−14	8	6%

This work is not void of limitations. In our data analysis, the prevalence of drivers with glaucoma unfit to drive was 6%, and although this percentage is high, there is reason to believe that it may be even higher.

Our study presented two main selection biases. First, we enrolled patients referred to the glaucoma service and, therefore, patients with disease awareness and ocular hypotensive therapy. Moreover, as we learn from the literature,[26,27] the number of subjects with undiagnosed glaucoma is approximately 50% of the population.

Therefore, the number of glaucomatous drivers could be reasonably higher. Second, we could not enroll patients with severe glaucoma who usually underwent Humphrey 10-2 procedures for follow-up. The 10-2 grid evaluates a smaller portion of the VF than 24-2, and building an IVF was not possible. Finally, it is likely that even some of those patients usually drive a car; therefore, the percentage of people unfit to drive could be even greater than we estimated.

Concerning methods, as we considered only clinical data, we did not compare the IVF to an actual binocular field, although the equivalence of these two tests is already demonstrated in literature[21–24] even if a binocular test appeared always less severe.

At last, we would like to clarify that this study is limited by not comparing VF results to risk of collision or simulated or on-road driving performance.

Conclusion and Clinical Significance

Considering the clinical application of the indexes we analyzed, BEMD represents a parameter already available for any patient with glaucoma, as it is automatically calculated by any computerized perimeter. BEMD cannot substitute an EVFT VF test alone; however, it can be useful in clinical practice to identify patients at increased risk of being unfit to drive. These or furthermore specific cut-offs should be legally set. In this case, every physician—not just ophthalmologists—even if not an expert to evaluate a VF test could assess the ability to drive. The examiner may suggest performing
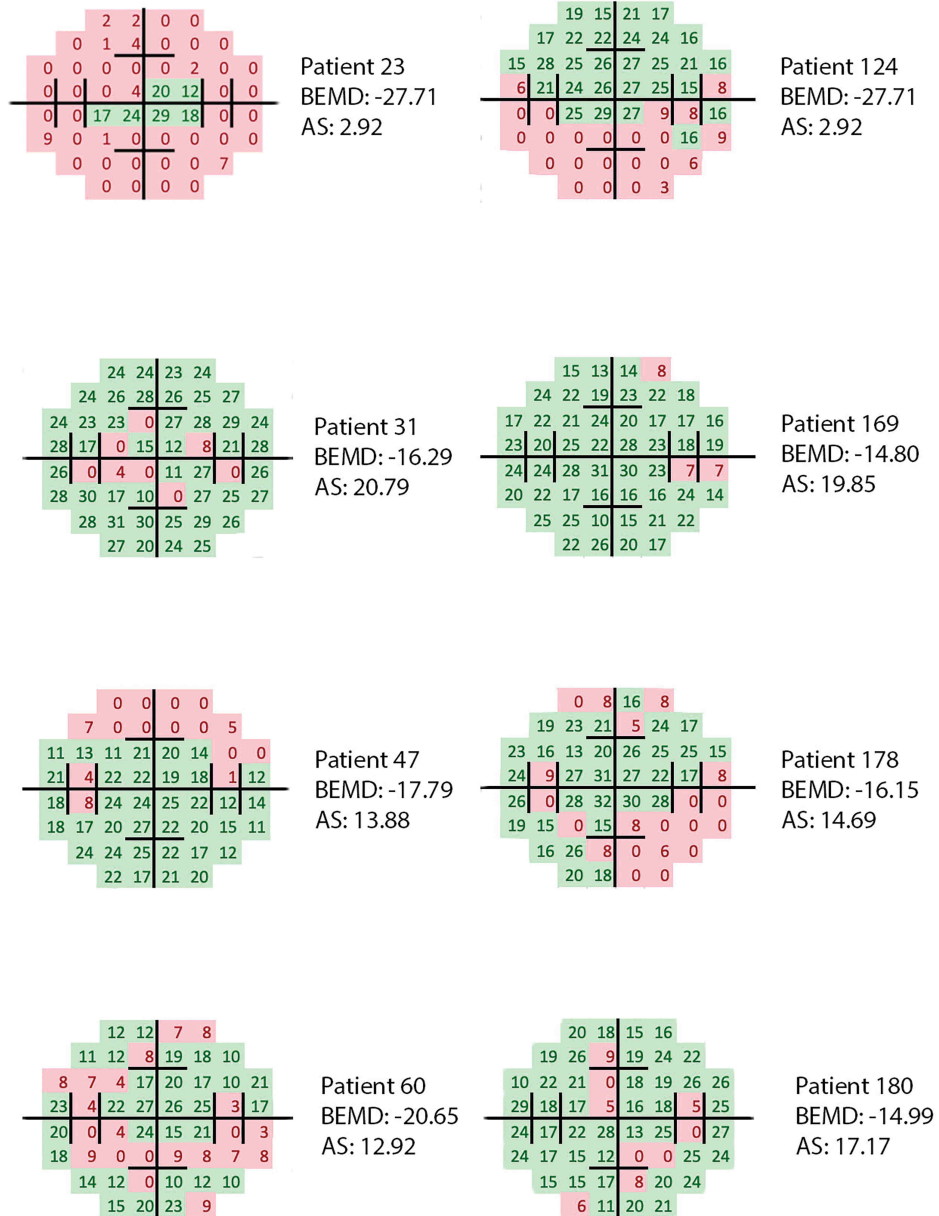
Patient 23
BEMD: -27.71
AS: 2.92

Patient 124
BEMD: -27.71
AS: 2.92

Patient 31
BEMD: -16.29
AS: 20.79

Patient 169
BEMD: -14.80
AS: 19.85

Patient 47
BEMD: -17.79
AS: 13.88

Patient 178
BEMD: -16.15
AS: 14.69

Patient 60
BEMD: -20.65
AS: 12.92

Patient 180
BEMD: -14.99
AS: 17.17

Fig. 5: Example of IVF in selected patients with BEMD <−14 dB

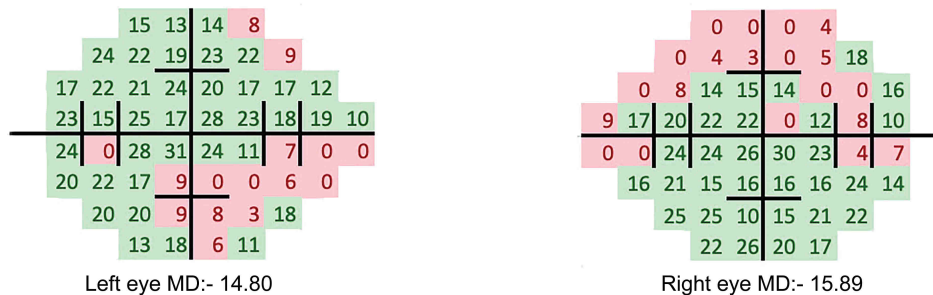Left eye MD:- 14.80

Right eye MD:- 15.89

Fig. 6: Monocular VFs of a studied patient (*n*°169 in Figure 5). This patient was able to drive, with just two missing points but showing a BEMD of −14.80 dB. This discrepancy is due to a low mean deviation in both eyes added to a specular symmetric defect in the VF as shown

an EVFT or acting by discouraging the patient from driving activity. Therefore, BEMD could be as easy to use as VA already is.

For glaucoma specialists, as proposed by other authors,[22–24] the implementation of IVF evaluation in perimeter analysis software may be a useful tool. Simply applying the follow-up test, the ophthalmologist could obtain all necessary parameters to assess patients' fitness to drive. BEMD, NoMP, and AS may be able to completely describe VF conditions. Moreover, patients could avoid further analysis, such as EVFT, which is not necessary for their treatment. The application of IVF with the road test-based cut-off and tolerability for BEMD and AS may be important to fully evaluate subjects' visual function. In this way, it would be possible to decrease the number of subjects owing a DL but unfit to drive. Nevertheless, we believe that Saunder's BEMD cut-offs of −7 and −14 dB may be immediately employed. The first is a rule-out to consider patients as likely fit to drive. The second is a rule-in to warn the patient that their driving performance can be severely impaired by their pathology and that they may also no longer fit the legal criteria for having a DL.

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