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Central visual field in glaucoma: An updated review

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Abstract:

Evaluation of central vision in glaucoma is important due to its impact on patients' quality of life and activities of daily living such as reading, driving, and walking. The 10-2 visual field (VF) assessment remains a mainstay in the functional analysis of central vision in glaucoma diagnosis and progression. However, it may be underutilized in clinical practice. Monitoring of disease progression especially in advanced cases, glaucoma evaluation in certain ocular disorders such as high myopia, disc hemorrhage, low corneal hysteresis, and certain optic disc phenotypes, as well as earlier detection of central VF damage, are certain conditions where additional monitoring with the 10-2 pattern may provide complementary clinical information to the commonly utilized 24-2 pattern. In addition, the development of artificial intelligence techniques may assist clinicians to most effectively allocate limited resources by identifying more risk factors to central VF damage. In this study, we aimed to determine specific patient characteristics that make central VF damage more likely and to assess the benefit of incorporating the 10-2 VF in various clinical settings.

Keywords:

Artificial intelligence, central visual field, glaucoma, quality of life

Overview

Glaucoma is a leading cause of irreversible blindness globally.[1-3] The hallmark of glaucoma is the gradually progressive damage to the optic nerve head and retinal ganglion cells, leading to progressive visual field (VF) loss.[3,4] Timely diagnosis and assessment of disease progression is a pressing unmet need for the management of glaucoma that can lead to significant visual disability or blindness if inadequately treated.[3,5] Prompt diagnosis and evaluation of disease progression, followed by taking remedial action can halt further VF damage in glaucoma leading to a better quality of life for patients, avoiding the subsequent need for advanced medical interventions, and substantially reducing the costs to patients and health care systems.[6,7]

Many clinicians rely on a combination of a VF test with a 6° grid (e.g., the 24-2 test) along with an optical coherence tomography (OCT) scan of the disc, as well as fundus photos and clinical examinations of the disc to diagnose and evaluate disease progression in glaucoma.[8] Approximately half of all retinal ganglion cells are located within the macular region and due to the magnification phenomenon, over 90% of the primary visual cortex is engaged in processing information obtained from the central 10° of VF.[9-11] Contrary to the common notion that central VF remains unaffected until the more advanced stages of glaucoma, recent evidence suggests the possibility of central VF damage even at earlier disease stages.[8,12-22] For the optimal detection of such damage, strategies that concentrate test points at 2° increments in the central 10° (i.e., 10-2 strategy that comprises 68 individual points over the central 10° of VF) of the VF are preferred, as the 24-2 strategy inadequately samples the central field and the corresponding macular function.[12,13,18,19,23]

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Importance

Timely detection and appropriate characterization of central VF damage is of utmost importance in the clinical management of glaucoma due to its impact on patients' quality of life and activities of daily living such as reading, driving, and walking.[24] In addition, damage to the central VF increases the risk of psychiatric comorbidities among glaucoma patients including depression.[7,9,25,26] Prior studies have demonstrated that impairment in vision-related quality of life depends both on the overall severity and the location of VF damage in glaucoma patients.[9,25,26] Blumberg and colleagues suggested that patients with disproportionately lower quality of life scores compared to the magnitude of 24-2 VF damage may have undetected central VF damage by the 24-2 strategy.[9] Furthermore, global indices of central VF damage have shown a stronger association with vision-related quality of life metrics compared to more peripheral VF indices obtained by the 24-2 test strategy.[9,25,26] Moreover, 10-2 mean deviation (MD) has been shown to be significantly correlated with facial recognition in open-angle glaucoma patients.[27]

Increased central VF test points being evaluated by the 10-2 test strategy also enable a more precise characterization of the patterns of central VF damage. The applications of artificial intelligence (AI) techniques to extract these patterns from large datasets of glaucoma patients show promise to provide prognostic advantage in terms of functionality and quality of life outcomes in glaucoma patients.[28-30] The main purpose of the current review was to identify the individual patient characteristics that increase the likelihood of central VF damage and to evaluate the utility of including 10-2 test strategy in different clinical settings.

Advanced Glaucoma

The public health economic burden of patients with advanced glaucoma is more than 4 times compared to that of patients at earlier disease stages.[6] Little residual damage and small amount of progression at the advanced stage have remarkable consequences affecting a patient's visual function and quality of life.[25,31,32] However, monitoring progression at the advanced stage remains a challenging task in both glaucoma clinical practice and research. Based on the existing literature, the preserved visual capacity in the advanced stage largely corresponds to the central VF areas,[17,33] where the majority of the peripheral 24-2 VF test points are already severely depressed, and therefore much more variable, limiting the test ability to reliably detect further glaucomatous progression.[34] Gardiner *et al*. demonstrated that any change in measured test points below 15–19 dB cannot be reliably differentiated from chance.[35]

The concept of "measurement floor" is another limitation to effectively evaluate glaucoma progression at the advanced stage from a structural standpoint. In brief, OCT-provided metrics at the ONH and the macular areas are shown to correlate with the severity of VF damage up to a certain threshold (i.e. measurement floor) beyond which they remain relatively stable. This structural floor is partly explained by the remaining thickness of the glial tissue and also by the limitations in the axial resolution of the currently available OCT technologies.[36-39] Prior studies have reported that OCT metrics approximately reach a floor at 44.9–53.7 μm for retinal nerve fiber layer (RNFL) thickness and 55–70 μm for macular Ganglion cell complex thickness measurements.[40]

Considering the above limitations and to more precisely assess the remainder of the visual capacity in advanced glaucoma, the 10-2 test strategy is one of the most commonly used modalities in clinical practice and research. As Weber *et al*. have previously described, the preserved central VF in advanced glaucoma is limited to a "centro-coecal isle" with the largest extension to the lower temporal quadrant and a small upper nasal step representing the intact papillomacular bundle which is more precisely captured by the 10-2 test strategy.[33] Rao *et al*. found that in eyes with severe baseline VF loss, the rate of decline in MD is greater when the 10-2 test strategy is employed compared to that of the 24-2 test strategy.[41] This observation is likely due to the fact that most of the peripheral points have already reached their "floor" in advanced glaucoma. An inability to detect further deterioration in peripheral test locations would mask the ongoing damage in the central locations when the MD is estimated by averaging the sensitivity loss across all points on a 24-2 VF. With only a central island of field remaining in advanced glaucoma, they suggested that further VF progression would stand out better when the central VF is evaluated with greater resolution using the 10-2 strategy. This rationale has been the fundamental assumption of many studies to evaluate correlates and characteristics of VF progression in advanced glaucoma based on the 10-2 test strategy.[42-46]

Early Glaucoma

Contrary to the conventional notion that central VF damage occurs mostly in the advanced stages of glaucoma, recent studies have shown that it can also occur early in the disease process.[8,12-22,47] In a previous study, Park *et al*. demonstrated that among 91 eyes with evidence of glaucomatous optic neuropathy and 24-2 VF MD ≥−6 dB, 68 eyes (74.7%) had a parafoveal scotoma detected on the 10-2 test.[19] While studying the patterns of VF defects in different stages of glaucoma, Germano *et al*. found that 28% of eyes with early glaucoma had VF defects within the central 5°.[47] Traynis and associates

found that abnormal 10-2 VFs (53%) were nearly as common as abnormal 24-2 VFs (59%) in patients with early glaucoma defined as 24-2 VF MD ≥ −6 dB.[12] In a study evaluating the role of 10-2 VF test in the different stages of glaucoma and glaucoma suspects, Tomairek *et al*. found that central VF defects were detected by the 10-2 strategy in 60.7% of cases with early and moderate glaucoma.[21] Moreover, Leung have recently used a novel imaging technology that integrates the thickness and reflectance information on widefield OCT images to demonstrate that papillofoveal and papillomacular bundle defects commonly occur in early glaucoma (24-2 VF MD ≥ −6 dB) and are associated with central VF defects at their corresponding VF locations.[48]

Evident central VF damage in early glaucoma on the 10-2 test strategy may be missed by the 24-2 test pattern. Traynis *et al*. found that approximately 16% of eyes with glaucomatous optic neuropathy and/or early glaucoma had central defects on the 10-2 test that were undetected on the 24-2 test.[12] Two previous studies of early glaucoma patients reported defects detected by the 10-2 test without evidence of central 10° involvement on the 24-2 test pattern in around 30%–80% of the study population.[21,22] In addition, De Moraes *et al*. demonstrated that the 10-2 test revealed VF damage in 35% of ocular hypertensives, 30% of suspected glaucoma, and 61% of early glaucoma eyes with relatively intact 24-2 VF appearance.[13] Given the previous evidence on the association of baseline central VF damage with more rapid subsequent VF progression,[49,50] these findings have important clinical implications for the risk assessment and management of glaucoma patients since individualized implementation of 10-2 strategy could aid in identifying patients who might benefit from treatment intensification.

Factors that Affect Central Visual Field Involvement

In this review, we have highlighted the importance of assessing certain patient populations at risk of central VF progression in glaucoma with the presence of an apparently intact central 24-2 test points. While it may be beneficial to assess certain subgroups with additional 10-2 testing, studies have shown that not all patients will benefit from this supplemental test. In an observational study, west and associates studied early glaucoma patients (median MD: −2.31 dB and − 1.75 dB in 24-2 and 10-2 tests, respectively) and healthy subjects who were administered both the 24-2 and 10-2 VF tests to study the clinical utility of the 10-2 VF. In patients with abnormal VF results, West *et al*. demonstrated an overlap of 60%–86% in pattern deviation and total deviation between the 10-2 and 24-2 VF, while having only insignificant differences in area under the receiver operating characteristics curve.[51] In addition, prior studies have found the MD of the 10-2 and 24-2 VF to be significantly correlated.[18,21] In one of these studies, Sullivan-Mee *et al*. also demonstrated that 82% of eyes with 10-2 VF loss also demonstrated abnormalities in the central 10° of the 24-2 VF test.[18] These studies highlight the need for individualized treatment not all patients will benefit from additional testing with the 10-2.

There are practical limitations in the assessment of central VF damage for all patients with an established or suspected glaucoma diagnosis in busy clinical settings,[52] highlighting the importance of tailoring the management based on individual risk factors. With that respect, several prior studies have identified the characteristics that might increase the likelihood of central VF damage development or progression.

Optic disc phenotypes

Several previous studies have divided optic disc phenotypes into the following four categories: focal ischemic (FI), generalized cup enlargement, myopic glaucomatous (MY), and senile sclerotic (SS) with each phenotype being associated with several distinctive clinical features.[53,54] These phenotypes are among the characteristics shown to be associated with the presence of central VF damage in glaucoma patients.[53,54] To elaborate more on the clinical implications of this classification, Ekici *et al*. identified that the severity and prevalence of central glaucomatous VF damage vary between these phenotypes, with the FI and MY phenotypes more likely to be associated with concurrent central VF damage, particularly in early disease.[55] Risk stratification of patients based on optic disc phenotypes may assist clinicians inefficient reallocation of 10-2 assessments.

Disc hemorrhage

The presence and location of optic disc hemorrhage (DH) is another important clinical characteristic that affects the probability of the presence and progression of central VF damage in glaucoma patients.[56-58] It has been previously reported that DH occurs more frequently in glaucoma patients (4%–13%) compared to healthy subjects (0%–1%).[59,60] The ocular hypertension treatment study has shown that patients with DH are 3.7 (95% confidence interval [CI], 2.1–6.6) times more likely to develop primary open-angle glaucoma when considering baseline predictive factors.[61] Specifically, DH in the superotemporal and inferotemporal regions had more subsequent structural and functional deterioration compared with the eyes with DHs in the temporal quadrant and nasal area.[56-58]

Considering that DHs are associated with the presence of central VF damage, prior studies evaluated possible

associations between DH and progression of central VF defects. In a longitudinal study over an average span of 9 years, Shukla *et al*. demonstrated that glaucoma eyes with DH experienced more rapid 10-2 MD decline compared to eyes without DH.[62] However, such a faster rate of progression was not detected when considering solely the central points of the 24-2 test grid, highlighting the importance of 10-2 in monitoring central VF progression. DHs that were in the inferotemporal area were more related to central VF loss. The inferotemporal optic nerve region receives axons from the macular vulnerability zone[17] as well as areas outside the macular region, typically, damage to these fibers leads to paracentral VF defects or nasal steps. In a cohort study investigating the rate of central VF loss after DH, David *et al*. demonstrated that the rate of 10-2 MD loss is three times greater than eyes without a history of DH. Furthermore, they noted that glaucomatous eyes with DH are more likely to have central VF progression, as opposed to peripheral VF progression.[63] Similarly, Kono *et al*. found that normal tension glaucoma eyes with DH are more likely to have VF progression within the central 10°, compared to normal tension glaucoma eyes without DH.[64] Considering the higher prevalence and likelihood of progression of central VF damage in glaucoma patients with DH, clinicians should carefully scrutinize the central VF in any patient with DH, preferably with testing including the 10-2 VF. Figure 1 shows a case of a glaucoma patient with DH in the left eye. While 24-2 appeared normal, RNFL defects can be seen in the macula. 10-2 VF revealed a typical glaucomatous defect in the inferonasal field.

Myopia

Myopia is among the clinical characteristics associated with glaucoma and its prevalence has been estimated to increase to nearly 5 billion people globally by 2050.[65] In a large meta-analysis of 48,161 individuals, it has been shown that myopes are nearly twice as likely to develop open-angle glaucoma (odds ratio [OR]: 1.92, 95% CI: 1.54–2.38).[66] Furthermore, Shen *et al*. demonstrated that each one diopter decrease in the spherical equivalent of refraction is associated with a 10% increase (95% CI: 1.08–1.12) in the risk of developing primary open-angle glaucoma.[67]

In addition, prior studies investigated myopia as a possible risk factor for glaucomatous central VF damage. Araie *et al*. evaluated the influence of myopia on the central VF in normal tension glaucoma and primary open-angle glaucoma eyes, finding that myopic power had a significant positive correlation with the depression in the lower cecocentral area in both of these glaucoma classifications.[42] Similarly, Mayama *et al*. and associates found that in advanced-stage, open-angle glaucoma patients with high IOP, higher

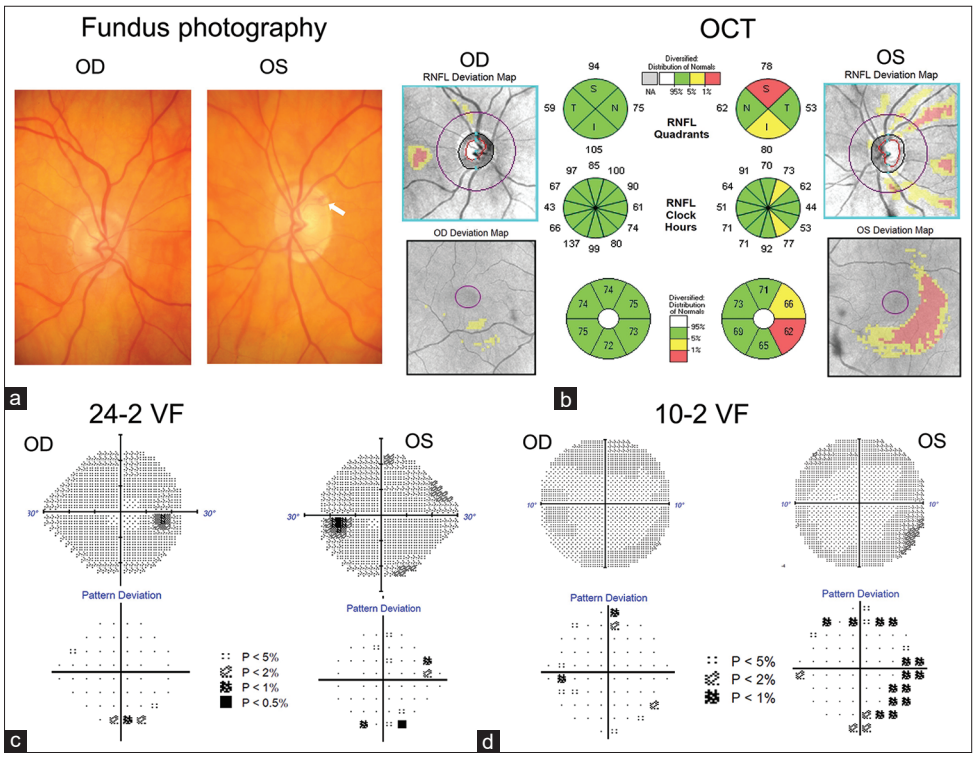

Figure 1: An 82-year-old, female patient with glaucoma. (a) Stereo fundus photography showed optic disc excavation in the right eye (OD) and optic disc excavation and disc hemorrhage (pointed by the white arrow) in the left eye (OS), (b) Optical coherence tomography result was normal for OD. Retinal nerve fiber layer thinning in the superior and inferior temporal sectors was observed for OS, with corresponding temporal thinning in the macula, (c) 24-2 visual field (VF) was within normal limits for OD, while scattered defects outside of the central 4 points was observed for OS, (d) 10-2 VF was within normal limits for OD but showed inferior nasal defects corresponding to the disc hemorrhage in OS

degrees of myopia are associated with damage to the lower cecocentral VF.[43] It has also been revealed that myopic glaucoma is associated with central and paracentral scotomas more often, as a result of increased RNFL defects involving the papillomacular bundle.[44-46] Kimura *et al*. demonstrated that in early glaucoma, high myopia was significantly associated with the nearest RNFL defect occurring within the papillomacular bundle area (OR: 3.72, 95% CI: 1.64–8.45) and the presence of paracentral scotomas (OR: 3.08, 95% CI: 1.14–8.33).[45] Due to the higher prevalence of central VF loss in glaucoma patients with myopia, further testing with the 10-2 strategy could be clinically advantageous. Figure 2 depicts a myopic glaucoma suspect with normal 24-2 VF, but abnormal 10-2 VF confirmed by the presence of macular retinal fiber defects in macula.

Low corneal hysteresis

Corneal biomechanical properties have been evaluated as a risk factor for glaucoma. Multiple studies have shown significant associations between lower corneal hysteresis (CH) and increased likelihood of glaucoma and glaucoma progression.[68-75] In one of them, Kaushik *et al*. and associates found CH measurements to be significantly less in primary open-angle glaucoma (7.9 mmHg, 95% CI: 6.9–8.8) and normal tension glaucoma (NTG) (8.0 mmHg, 95% CI: 7.2–8.8) patients, compared to healthy subjects (9.5 mmHg, 95% CI: 9.2–9.8).[69] With respect to central VF progression in glaucoma, Kamalipour *et al*. followed glaucoma and glaucoma-suspect patients over an average span of 5 years and showed that lower baseline CH was significantly associated with an increased risk of central VF progression (OR: 1.35 per 1 mmHg decrease in CH, $P < 0.001$).[68] In the same study, a subanalysis of early glaucoma patients (baseline 24-2 MD ≥ −6 dB) was conducted, demonstrating lower CH and its association with central VF progression even in early glaucoma patients. As a result of the higher rate of central VF progression in glaucomatous eyes with lower CH, additional testing with 10-2 strategy may be beneficial for further risk assessment.

Presence of macula optical coherence tomography defects

Macular OCT has been used for the detection and monitoring of glaucoma, particularly in early and advanced glaucoma. Ganglion cell–inner plexiform

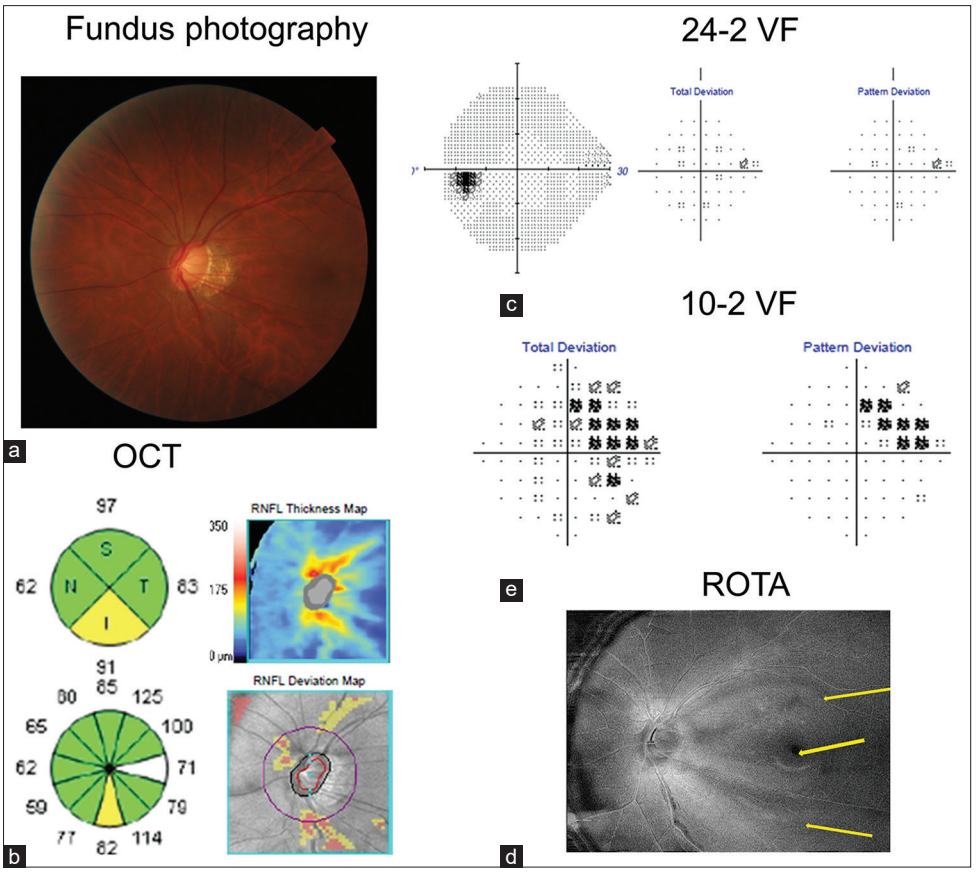

Figure 2: A 54-year-old, female patient with glaucoma suspect and myopia (−6.5 D). (a) Stereo fundus photography showed optic disc rim thinning in the left eye (OS), (b) Optical coherence tomography result was normal for OS, without any "outside normal limit" sectors, (c) 24-2 visual field (VF) was within normal limits, (d) 10-2 VF showed typical supranasal defects, (e) Retinal nerve fiber layer optical texture analysis confirmed narrow superior and inferior papillomacular retinal fiber layer defects as well as papillofoveal defects (yellow arrows)

layer (GCIPL) changes in macula OCT can be detected even before any detectable change in 24-2 VF or RNFL OCT. Park *et al*. showed that any central 12 points depressed <5% on 24-2 VF that spatially corresponds to macular GCIPL thinning is highly associated with the presence of parafoveal scotoma on 10-2 VF.[19]

The current clinical paradigm to clinically assess for structural abnormalities is based on RNFL and macula thickness by OCT. However, in a previously mentioned study, Leung and associates have developed a new algorithm, RNFL optical texture analysis (ROTA). Through evaluation of the tissue reflectance in conjunction with thickness, ROTA is capable of reporting the trajectories of papillomacular and papillofoveal bundles – which cannot be detected by traditional OCT. ROTA has shown promising results in pinpointing the precise location of damage and could be a powerful tool for predicting functional VF damage based on structural data.[48,76] After the application of ROTA on eyes with early glaucoma, Leung and associates found that papillofoveal and papillomacular bundle defects were common even in early glaucoma and were associated with central VF loss on the 24-2 VF.

Newer Patterns

In an effort to reconcile the under-sampling of the central VF in the 24-2 VF pattern, the 24-2C was developed. This pattern contains additional test points in the central 10° distributed based on the most frequently damaged locations.[77] Recent studies have shown that while the 24-2C pattern was approximately four times more likely to detect central VF damage than the 24-2 pattern, the 10-2 pattern outperforms the novel 24-2C by returning more clusters of defects and yielding a higher rate of structure-function concordance [Figure 3].[52,77] Future studies are needed to explore the importance of the 10 additional points for disease progression and the interpretation of the results for clinicians. The additional test points in the 10-2 pattern provide the highest resolution and should be utilized extensively to further characterize defects as compared to the 24-2C.

Artificial Intelligence and Central Visual Field

In recent years, the applications of AI in general (and deep learning models in particular) in medicine has led to the introduction of numerous automated diagnostic modalities. AI techniques have many implications in machine vision tasks including image classification with the performance sometimes higher than that of humans[78] and unsupervised identification of different patterns that exist in large datasets of images. A widespread use of different imaging modalities in ophthalmology research and clinical practice makes this medical subspecialty a major area for the implementation of these novel algorithms to assist in diagnosis and improve the currently used image analysis techniques.[79]

To date, the majority of AI applications related to the central VF in glaucoma can be classified into two main domains supervised and unsupervised learning tasks. For the supervised learning tasks, many studies have evaluated the prediction of the severity and pattern of central VF damage using highly reproducible structural OCT images. Driven by the conceptual relevance of the macular information to the central VF, several previous studies have developed and validated deep learning algorithms to predict the global and pointwise 10-2 test indices using macular OCT data as the input.[28,80,81] In general, the proposed models have dramatically improved the estimates of functional loss based on structural data. Christopher *et al*. developed several deep learning models using macular OCT information from different layers and proposed a final model utilizing combined information of all layers with the highest accuracy for estimating 10-2 MD ($R^2 = 0.82$, mean absolute error [MAE] = 1.9 dB).[81] However, the mentioned study did not provide pointwise estimates of accuracy. Several other studies have tried to fill in this gap by developing AI models capable of predicting individual 10-2 VF test points. Xu *et al*. and Hashimoto *et al*. proposed deep learning models that were capable of estimating the entire 10-2 VF map with the absolute mean prediction error of 2.7–2.8 dBs over the entire field which is quite promising.[28,80] More recently, a study by Kamalipour *et al*. proposed a deep learning model using the ONH circular scans to estimate the entire 10-2 VF map.[82] The authors used a large dataset of more than 5000 RNFL OCT scans to inform their models and achieved an MAE of 2.88 dB for estimating 10-2 MD. The clinical relevance of this finding cannot be overemphasized since circular ONH OCT scan is the most commonly used structural imaging modality in glaucoma practice and research. Another impressive finding was that both the ONH-based and the macular-based deep learning simulations of the central VF yielded shared characteristics for the prediction accuracy of different 10-2 regions. The reported prediction accuracy has been higher in the temporal inferior area of the central VF which has been previously described by Weber *et al*.[33] as the relatively preserved central isle of VF especially at the advanced stage of glaucoma. Not being bound by the inherent linear structure-function relationship assumption, having a wide flexibility to learn complex patterns from the labeled data itself, and making use of a much larger proportion of the structural data account for the observed remarkable improvement of the AI models compared to the traditional statistical modes of analysis.[28,29,80,83] If visual function can be estimated

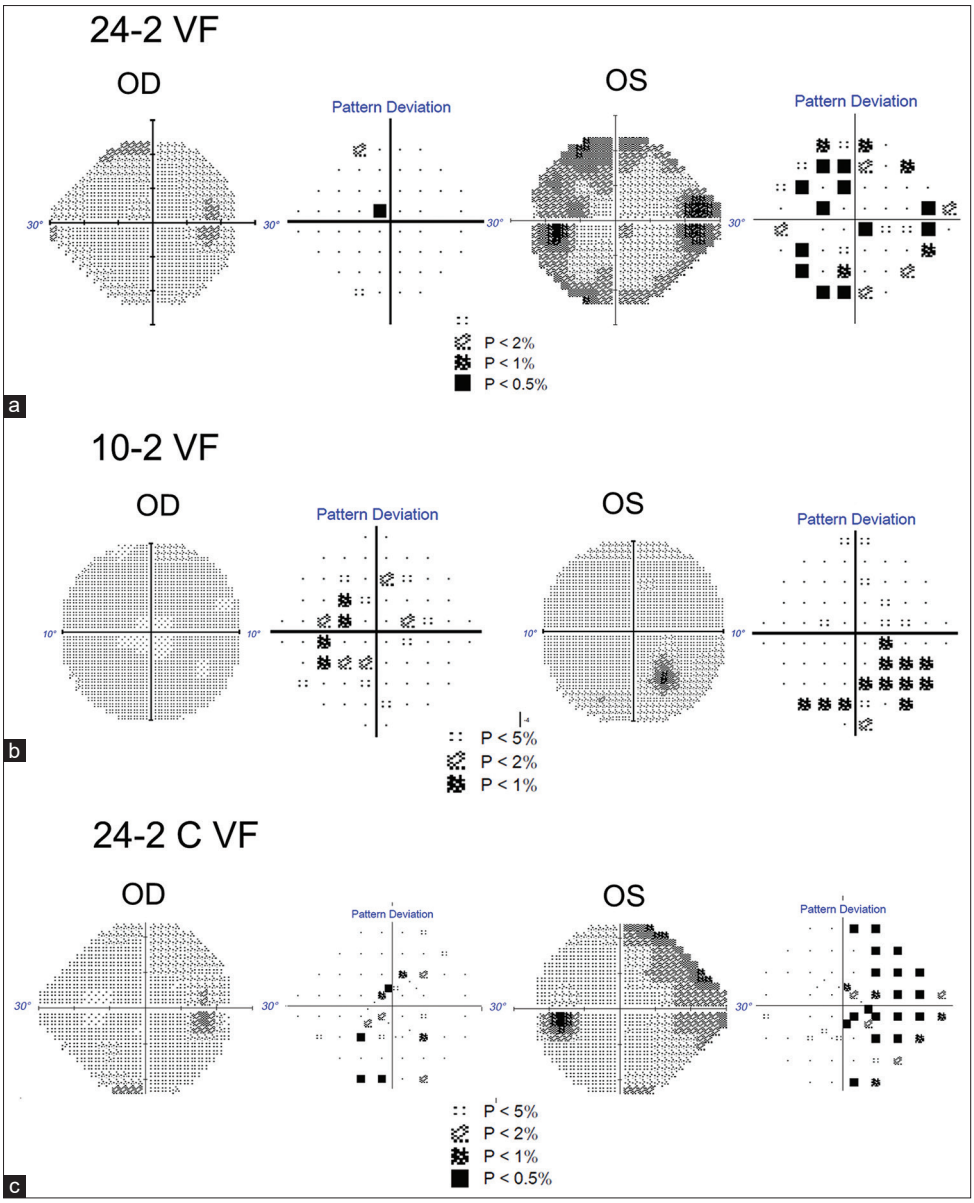

Figure 3: 24-2, 10-2 and 24-2C visual field (VF) of the same patient in Figure 1 after 7 years, which showed glaucoma progression and bilateral paracentral defects. Images of the right eye (OD) and the left eye (OS) were shown on the right and left side of each panel, respectively. (a) 24-2 VF showed central scotoma and superior defects in OD and inferior nasal step and inferior paracentral scotoma in OS, (b) 10-2 VF showed progressive paracentral defects in OD, and the inferior nasal defects observed 7 years ago in OS also progressed, (c) 24-2 C VF showed changes consistent with the 10-2 VF and provided more details of the paracentral scotoma.

accurately from standard deviation OCT imaging, clinicians can identify disease earlier and can determine progression more quickly. This leads to more effective individualized targeting that not only can help to reduce testing in patients unlikely to be experiencing functional loss, it also can be used to increase testing for those glaucoma patients at the greatest risk of functional loss based on OCT estimates with substantial savings in patients' and staff's time and the costs associated with VF testing. However, even with the recent advancements in AI, this is yet to be accomplished partly due to the inherent limitations of estimating function from the structural data including the concept of "floor effect" and the variability of the VF data itself that would act as prediction label for these models especially at the severe stage.[84]

Unsupervised learning strategies are the second major category of AI applications to improve the characterization of central VF damage in glaucoma. As opposed to supervised learning, unsupervised learning strategies do not require any labeled data for model training where the task is to identify different coexisting patterns within the data structure itself.[85-87] This becomes especially important in phenotyping the spatial patterns of central VF damage at different severity stages of glaucoma. In a cohort study of 1103 eyes with end-stage glaucoma (24-2 MD ≤-22 dB),

Wang *et al*.[88] included a total of 2912 10-2 VF tests and used archetypal analysis to identify spatial subtypes of defects on the 10-2 test grid in advanced glaucoma. They were able to characterize 14 distinct patterns of end-stage central VF damage in glaucoma and found that the initial central VF loss in glaucoma is more likely to be nasal loss. They suggested these identified patterns might be related to different subtypes of the disease. Moreover, they were able to identify one of the initial nasal loss patterns that is more likely to progress to total loss. In a separate study, Wang *et al*.[30] evaluated the patterns of central VF damage among the disease severity spectrum using archetypal analysis. For this purpose, they found 17 distinct patterns of central VF damage extracted from a total of 14,000 10-2 VF tests. They divided the identified patterns into isolated superior loss, isolated inferior loss, diffuse loss, and other loss patterns. It was notable that the majority of their described patterns were consistent with the more vulnerable zones of damage previously described by Hood *et al*.[16,17] and only one of them affected the less vulnerable inferotemporal zone. They demonstrated that considering the spatial patterns of central VF loss improves the prognostic models for the risk assessment of glaucomatous central VF progression in glaucoma. These AI methods provide the framework to quantitatively assess where each patient falls in terms of their individualized spatial patterns of damage. This approach shows promise in identifying the effects of demographic, ethnicity, and genetic subtypes of disease and thereby moving towards a personalized medicine approach for glaucoma management.

When to Order 10-2 Visual Field?

Considering the advantages offered by the higher resolution 10-2 test strategy, a critical question for clinicians is when and how frequently this test should be administered to glaucoma patients given that both central and peripheral VF tests may provide useful data depending on different individual scenarios. It has been suggested that simultaneous performance of both 24-2 and 10-2 tests might be valuable in a more comprehensive characterization of the extent and locations of VF damage.[7,52,89,90] On the other hand, it remains crucial to more effectively allocate the limited clinical time and resources and also to limit patient and staff exposure to communicable diseases.[52,91] Moreover, since VF testing is a time-consuming process, concurrent administration of both of these test strategies in a single session can fatigue patients and lead to variable or unreliable results.[81,92] Therefore, it becomes essentially important to risk-stratify patients based on the probability of central VF damage and attempt a more detailed assessment of the central vision only when the likelihood of detecting this damage justifies the required resources. For example, glaucomatous eyes with any abnormal 24-2 VF points on the central 10-degree region that are depressed <0.5% or <5% that correlates to macular GCIPL thinning have shown to be associated with parafoveal scotoma on 10-2 VF.[19] The ocular characteristics discussed above such as certain optic disc phenotypes, low CH, myopia, and eyes with DH may also aid clinicians in stratifying patients who may benefit most from additional 10-2 VF testing. The authors of this paper suggest evaluating all glaucoma patients with 24-2 VF, peripapillary OCT as well as macular OCT and further evaluated with a 10-2 VF test if the patient has the above risk factors.

Limitations

Similar to any testing modality in clinical settings, there are certain limitations with the 10-2 VF assessment that must be considered. First, although static automated perimetry VF testing is the standard of care for monitoring VF in glaucoma, there are limitations inherent to this approach. Testing variability may limit the utility of standard automated perimetry (SAP) to effectively assess the progression of VF.[93] Studies have shown this variability increases in more severely damaged areas, possibly confounding VF results, making it more difficult to discern between VF test–retest variability or true VF damage.[94-96]

Second, as a limited recourse and time, it might not be feasible to order 10-2 testing routinely for all glaucoma patients. This testing should be allocated to those with the highest risk, indicating the need for an individualized approach. The recent implementation of AI techniques has shown much promise in accurately estimating and predicting VF results from ONH or macular OCT images.[28,29,80] AI methods have also been utilized to quantitatively evaluate central VF damage patterns, which may help to identify relationships between patient characteristics and certain patterns of VF damage in the near future.[30,88] A recent study has shown that 10-2 VF can be estimated from the 24-2 VF with high accuracy using AI algorithms.[85] The progress of AI applications regarding 10-2 VF merits further research to continue exploring potential methods to more effectively allocate the 10-2 VF to patients with the highest likelihood of central VF damage.

Conclusion

The 10-2 VF assessment remains a powerful tool for the assessment of the central VF and aids in providing a more extensive picture of visual function in glaucoma. However, the current implementation of the 10-2 in the common clinical practice requires further enhancement– contrary to the conventional notion that central VF remains undamaged until advanced glaucoma, central VF has been shown to be affected through

various spectrums of glaucoma damage, especially in early stages.[8,12-22,47] For the most accurate assessment of the central VF, the 10-2 strategy is recommended, however, common clinical practice typically only incorporates a 6° test grid (e.g., 24-2) which have been shown to under-sample the central 10°.[12,13,18,19,23] Undetected early central VF damage has significant implications in glaucoma patients (e.g., quality of life, potential treatment intensification, more frequent assessments).[7,9,13,24-26,49,50,68] While it is not feasible in busy clinical settings to administer a 10-2 VF test for every patient,[52] clinicians must reallocate this limited resource to those with the highest likelihood of central VF damage due to a combination of different clinical risk factors. In the near future, clinicians may soon begin to utilize promising AI methods that may serve as additional tools for risk assessment. Although the current applications of AI with regards to 10-2 VF show promise, further research is necessary to more effectively and efficiently utilize the 10-2 VF assessment.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient guardian has given her consent for her images and other clinical information to be reported in the journal. The patient guardian understands that her name and initials will not be published and due efforts will be made to conceal identity, but anonymity cannot be guaranteed.

Data availability statement

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

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Conflicts of interest

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