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Diagnostic Accuracy of the Amsler Grid Test for Detecting Neovascular Age-Related Macular Degeneration
A Systematic Review and Meta-analysis

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IMPORTANCE Patients with nonneovascular age-related macular degeneration (AMD) are encouraged to use the Amsler grid test for self-assessment to facilitate early diagnosis. The test is widely recommended, suggesting a belief that it signals worsening AMD, warranting its use in home monitoring.

OBJECTIVE To systematically review studies of the diagnostic test accuracy of the Amsler grid in the diagnosis of neovascular AMD and to perform diagnostic test accuracy meta-analyses.

DATA SOURCES A systematic literature search was conducted in 12 databases for relevant titles from database inception until May 7, 2022.

STUDY SELECTION Studies included those with groups defined as having (1) neovascular AMD and (2) either healthy eyes or eyes with nonneovascular AMD. The index test was the Amsler grid. The reference standard was ophthalmic examination. After removal of obviously irrelevant reports, 2 authors (J.B. and M.S.) independently screened the remaining references in full text for potential eligibility. Disagreements were resolved by a third author (Y.S.).

DATA EXTRACTION AND SYNTHESIS Two authors (J.B. and I.P.) independently extracted all data and evaluated quality and applicability of eligible studies using the Quality Assessment of Diagnostic Accuracy Studies 2. Disagreements were resolved by a third author (Y.S.).

MAIN OUTCOMES AND MEASURES Sensitivity and specificity of the Amsler grid for detecting neovascular AMD with comparators being either healthy control participants or patients with nonneovascular AMD.

RESULTS Of 523 records screened, 10 studies were included with a total of 1890 eyes (mean participant age ranging from 62 to 83 years). Sensitivity and specificity to diagnose neovascular AMD were 67% (95% CI, 51%-79%) and 99% (95% CI, 85%-100%), respectively, when comparators were healthy control participants and 71% (95% CI, 60%-80%) and 63% (95% CI, 49%-51%), respectively, when control participants were patients with nonneovascular AMD. Overall, potential sources of bias were low across studies.

CONCLUSIONS AND RELEVANCE Although the Amsler grid is easy and inexpensive to use for detection of metamorphopsia, its sensitivity may be at levels typically not recommended for monitoring. Coupling this lower sensitivity with only moderate specificity to identify neovascular AMD in a population at risk, these findings suggest that such patients typically should be encouraged to undergo ophthalmic examination regularly, regardless of any results of Amsler grid self-assessment.

Supplemental content and Journal Club Slides

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The introduction of intravitreal anti-vascular endothelial growth factor therapy for neovascular age-related macular degeneration (AMD) has dramatically changed the prognosis for the most prevalent cause of irreversible vision loss in the developed world.[1,2] A key factor for treatment success is early intervention before onset of irreversible subretinal fibrosis.[3-5] Treatment delay translates to significantly worse visual acuity, which has become especially apparent during the COVID-19 pandemic.[6-8] Thus, diagnostic tools for early detection of neovascular AMD are essential to preserve vision in patients with AMD.

Health professionals often recommend the Amsler grid, which was first described and popularized by the Swiss ophthalmologist Marc Amsler in the 1940s to 1950s as a tool to detect central vision metamorphopsia and relative scotoma.[9-11] Patients are told to use the Amsler grid daily for self-assessment to facilitate early detection of neovascular AMD. A perceived distortion of the grid should prompt contacting an ophthalmologist for a new examination that ideally would allow for fast detection of neovascularization and initiation of anti-vascular endothelial growth factor therapy. Theoretically, many prerequisites for an optimal early detection tool are fulfilled: The Amsler grid is inexpensive, easy to use, and usable without electronic devices, and it requires neither reading abilities nor specific language skills. However, patients with AMD without neovascularization can report subjective changes to the Amsler grid presumably due to large drusen or retinal atrophy, which can lead to unnecessary consultations and worry. More important, though, some patients do not visit their ophthalmologist in time because the Amsler grid seems normal to them, which then can delay diagnosis and potentially lead to worse visual treatment outcomes.[12] In this systematic review and meta-analysis, we evaluated the diagnostic test accuracy of the Amsler grid for the diagnosis of neovascular AMD.

Key Points

Question What are the sensitivity and specificity of the Amsler grid test for the diagnosis of neovascular age-related macular degeneration (AMD)?

Findings In this systematic review and meta-analysis of 10 studies, sensitivity and specificity of the Amsler grid to diagnose neovascular AMD vs nonneovascular AMD were low and moderate, respectively.

Meaning These findings suggest that the diagnostic accuracy of the Amsler grid for the detection of neovascular AMD is moderate when used in a patient population with an a priori risk of neovascular AMD, supporting that these patients should seek ophthalmic examination regularly, regardless of the results of Amsler grid test results.

Methods

Protocol and Registration

This systematic review and meta-analysis was designed in accordance with the items of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis of Diagnostic Test Accuracy Studies.[13] Our protocol was submitted to the International Prospective Register of Systematic Reviews (CRD42022332803). Conducting systematic reviews does not require institutional review board approval according to Danish law.

Eligibility Criteria

Participants, Setting, and Target Conditions

We considered any study that had 2 separate groups of eyes defined as having (1) neovascular AMD and (2) either healthy eyes or eyes with nonneovascular AMD. We did not enforce further restrictions on the definition of neovascular AMD. We defined the group of healthy eyes or eyes with nonneovascular AMD as eyes with no retinal abnormalities apart from other subtypes of AMD (early, intermediate, or late nonexudative AMD), since this comparison group also represents the general scenario when the Amsler grid is used in a population at risk of neovascular AMD.

Index Test

We considered any study that used the Amsler grid test as the index test. Eligible studies had to provide data qualified for diagnostic test accuracy calculation on the index test; that is, studies using the Amsler grid test as part of the screening or diagnosis, but without reporting any test statistics, were not considered eligible for this study.

Reference Standards

Eligible studies must have performed an ophthalmic examination or have obtained a diagnosis of the ophthalmic condition from previous examination. This process had to be performed for all participants in the analysis to avoid bias. However, we also acknowledge that fluorescein angiography, which is an invasive investigation using an intravenous contrast agent, is not routinely performed in patients without clinical suspicion of macular neovascularization. Therefore, we included studies in which fluorescein angiography was not systematically performed in patients with nonneovascular AMD.

Study Design

We included prospective and retrospective studies with diagnostic test accuracy estimates of the outcomes of interest, regardless of study design. Conference abstracts were considered if original data were reported. Single-case reports were not considered. For practical purposes, we considered only studies written in English, Danish, German, Norwegian, or Swedish.

Information Sources, Search, and Study Selection

One trained author (Y.S.) performed the literature search in 12 databases (PubMed, Embase, Cochrane Central, ClinicalTrials.gov, Web of Science Core Collection, BIOSIS Previews, Current Contents Connect, Data Citation Index, Derwent Innovations Index, KCI Korean Journal Database, Russian Science Citation Index, and SciELO Citation Index) on May 7, 2022 (eMethods in Supplement 1), screened titles

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and abstracts of all records, and removed duplicates and obviously irrelevant reports. Two authors (J.B. and M.S.) independently screened the remaining references in full text and reviewed the reference lists for additional eligible studies. Disagreements between the authors were discussed with a third author (Y.S.) for final decision.

Data Collection Process, Data Extraction, Risk of Bias, and Applicability

We extracted data regarding study design and characteristics, population characteristics (including age and sex), methodological details regarding index test and reference standard, and results regarding the diagnostic test accuracy of the Amsler grid (ie, true-positive [TP], false-positive [FP], true-negative [TN], false-negative [FN]) for detecting neovascular AMD. All data were extracted independently by 2 authors (J.B. and M.S.) using predesigned data extraction forms. Quality of eligible studies was evaluated using the recommended risk-of-bias tool for diagnostic accuracy studies, the Quality Assessment of Diagnostic Accuracy Studies 2,[14] which also evaluates the applicability. This assessment was made independently by 2 authors (J.B. and I.P.). Disagreements between the authors were discussed with a third author (Y.S.) for final decision.

Diagnostic Accuracy Measures, Synthesis of Results, and Meta-analysis

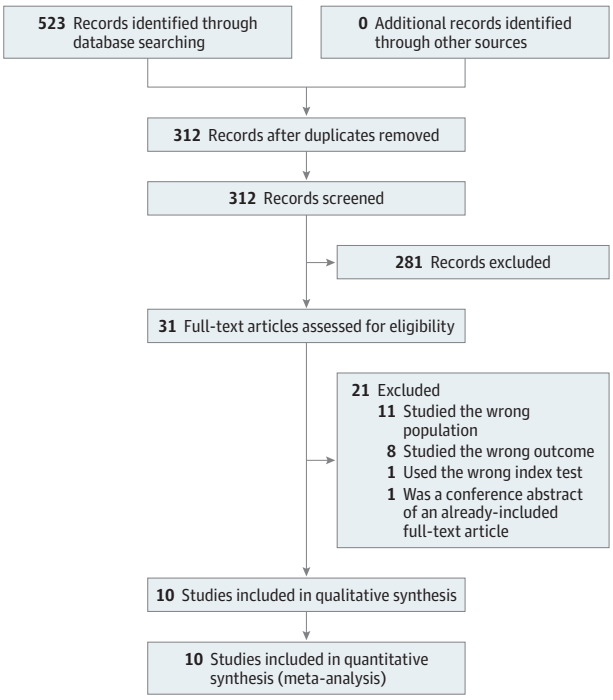
For all calculations, the unit of assessment was per eye. Our outcomes of interest were TP, FP, TN, and FN, which were used to calculate sensitivity (ie, TP / [TP + FN]) and specificity (ie, TN / [TN + FP]). These measures were calculated for the detection of neovascular AMD in 2 settings: (1) healthy control participants (ie, no retinal abnormalities) as the comparator and (2) nonexudative AMD as the comparator. We followed the *Cochrane Handbook for Systematic Reviews of Interventions* for methodological guidance.[15,16] Data were presented in 2 × 2 tables with 95% CIs for the calculated sensitivity and specificity. Because of the fundamental relationship and correlation between sensitivity and specificity, we analyzed results based on an approach to fit random effects using the hierarchical summary receiver operating characteristic model. This model accounts for the across-study variability and estimates summary accuracy measures of sensitivity and specificity. We used this model to interpret the summary sensitivity and specificity point to reflect the average observed accuracy.[17] Our calculations were made using MetaDTA, version 2.01.[17] Sensitivity analyses were made by excluding each study in turn and recalculating summary estimates to evaluate the robustness of the calculations.

Results

Study Selection

Our search identified 523 records, of which 211 were duplicates and 281 obviously irrelevant. The remaining 31 records were read in full text. Of these, 21 records did not fulfill our eligibility criteria and were excluded (**Figure 1**). Thus, 10 studies were eligible for qualitative and quantitative review.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-analysis Flow Diagram of Study Selection Process



Study Characteristics

The 10 studies included in our review collectively summarized data from 2524 eyes tested using the Amsler grid, of which 1890 eyes were of relevance for our analyses.[18-27] The studies were conducted between 2003 and 2015 and originated from Germany (n = 3),[19,20,27] the US (n = 3),[21,25,26] Brazil (n = 1),[18] Israel (n = 1),[22] and Poland (n = 1)[24]; 1 study was an international collaboration.[23] All were clinic-based studies. One study was a case-control study,[24] and the rest were cross-sectional. One study was retrospective in nature,[26] and the remaining were prospective. Three studies were multicenter studies,[20,22,23] and the remaining were single-center studies. Six studies had a criterion of a best-corrected visual acuity of at least 0.1 to 0.2 Snellen of the study eye for being eligible for participation.[18,19,22-24,27] Further study details are summarized in **Table 1**.

Studies collectively included 425 eyes with neovascular AMD, 1262 eyes with nonneovascular AMD, and 203 healthy control eyes. Definitions of neovascular and nonneovascular AMD were subject to variation across studies. Mean participant age ranged from 62 to 83 years, and women comprised 40% to 68% (males, 32%-60%) of the samples. Study-specific details on participant characteristics are summarized in eTable 1 in Supplement 1.

The reference test (ie, diagnosis of AMD subtype or having a healthy retina) was defined as a clinical examination. The clinical examinations included slitlamp biomicroscopy, fundus photography, optical coherence tomography (OCT), and fluorescein angiography; however, different diagnostic modalities were used, and the methodological details were disclosed variably across studies (**Table 2**). The index test (ie, the

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Table 1. Study Characteristics

Source	Study design	Participant eligibility	Participant recruitment		Funding
			Screened	Analyzed	
Isaac et al,[18] 2007, Brazil	Prospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic defined according to retinal status of AMD (no AMD, mild AMD, intermediate AMD, or neovascular AMD). Participants were included if BCVA ≥0.125 Snellen, no other forms of maculopathy, no presence of glaucoma or high myopia, and no recent ocular surgery.	NA	65 Eyes of 65 individuals	No funding
Kampmeier et al,[19] 2006, Germany	Prospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic defined as healthy age-matched control participants, patients with nonneovascular AMD, or patients with neovascular AMD. Participants were included if BCVA ≥0.2 Snellen, aged ≥50 y, and no other forms of maculopathy.	NA	140 Eyes of 174 individuals	Grant from a private foundation
Klatt et al,[20] 2006 Germany	Prospective, cross-sectional, multicenter, clinic-based study	Participants from 2 eye clinics with a diagnosis of intermediate AMD, classical CNV, or occult CNV. Other study groups included control participants without maculopathies and patients with macular hole, epiretinal membrane, or central serous chorioretinopathy. No further eligibility criteria were described.	NA	153 Eyes of 147 individuals[a]	NA
Koike et al,[21] 2015, US	Prospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic with a diagnosis of dry or exudative AMD. No further eligibility criteria were described.	NA	82 Eyes (number of individuals NA)	No funding
Loewenstein et al,[22] 2003, Israel	Prospective, cross-sectional, multicenter, clinic-based study	Participants from 2 eye clinics defined according to retinal status of AMD (no AMD, early AMD either with or without ≥6 large drusen, GA, or neovascular AMD). Participants were included if aged ≥50 y, BCVA ≥0.1 Snellen, no other retinal diseases, no optic nerve disease, and no significant media opacity.	NA	159 Eyes of 159 individuals	Unclear; however, some coauthors were financially involved with parts of the study
Goldstein et al,[23] 2005, international collaboration	Prospective, cross-sectional, multicenter, clinic-based study	Participants from 3 eye clinics defined according to retinal status of AMD (no AMD, early AMD, intermediate AMD, GA, or neovascular AMD). Participants were included if aged ≥50 y, BCVA ≥0.125 Snellen, no other maculopathies, no optic nerve disease, and no significant media opacity.	179 Individuals, of whom 29 were excluded as not fulfilling the eligibility criteria	150 Eyes of 150 individuals	Unclear; however, some coauthors were financially involved with parts of the study
Nowomiejska et al,[24] 2013, Poland	Prospective, case-control, single-center, clinic-based study	Participants from 1 eye clinic with wet AMD or age-matched healthy control participants. Additional eligibility criteria included BCVA ≥0.1 Snellen, no other retinal diseases, no glaucoma, no amblyopia, no strabismus, no prior intraocular surgery, and no refractive error greater than ±5 D.	NA	59 Eyes of 59 individuals	Grant from a university
Robison et al,[25] 2011, US	Prospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic with a diagnosis of dry or exudative AMD. Patients with GA or disciform scarring were not included. No further eligibility criteria were described.	NA	90 Eyes (No. of individuals was unclear)	Grant from a public foundation
Wiecek et al,[26] 2015, US	Retrospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic with a diagnosis of dry or exudative AMD obtained through electronic patient records. Other study groups included patients with epiretinal membrane, central serous chorioretinopathy, cystoid macular edema, and diabetic macular edema. No further eligibility criteria were described.	5661 Individuals	1495 Individuals randomly sampled. Each patient contributed 1 outcome regardless of the status in individual eyes.[b]	Grant from a public foundation and a university
Zorn et al,[27] 2005, Germany	Prospective, cross-sectional, single-center, clinic-based study	Participants from 1 eye clinic with a diagnosis of nonneovascular or neovascular AMD. Participants were included if BCVA ≥0.2 Snellen. No further eligibility criteria were described.	NA	97 Eyes of 97 individuals	NA

Abbreviations: AMD, age-related macular degeneration; BCVA, best-corrected visual acuity; CNV, choroidal neovascularization; GA, geographic atrophy; NA, not available.

[a] Of these eyes, 47 were excluded in the present review (23 with macula holes, 13 with epiretinal membrane, and 11 with central serous chorioretinopathy).

[b] Of these eyes, 587 were excluded in the present review (346 with epiretinal membrane, 53 with central serous chorioretinopathy, 116 with cystoid macula edema, and 72 with diabetic macula edema).

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Table 2. Methods of the Index Test and the Reference Test in Included Studies

Source	Index test method	Reference test method
Isaac et al,[18] 2007	White square grid on a black background. The test was supervised and performed using a +3.0-D addition to the participant's refraction at 33-cm distance from the participant's eye. All eyes were tested with undilated pupils. The test was considered positive in the presence of any scotoma, blurred lines, or metamorphopsia.	All participants were examined by 1 retina specialist, and the diagnosis was confirmed by a second masked examiner through fundus photography analysis. Fluorescein angiography was performed where CNV was suspected.
Kampmeier et al,[19] 2006	Black square grid on a white background. The test was supervised and performed using a +3.0-D addition to the participant's refraction at 33-cm distance from the participant's eye. Pupillary dilation status was not outlined. The test was considered positive in the presence of any scotoma or metamorphopsia.	All participants were examined using slitlamp biomicroscopy, fundus photography, optical coherence tomography, and fluorescein angiography.
Klatt et al,[20] 2006	Black square grid on a white background. The test was supervised and performed using a reading addition to the participant's refraction at 30-40-cm distance from the participant's eye. Pupillary dilation status was not outlined. The test was considered positive in the presence of any scotoma or blurred or displaced lines.	All participants were examined using slitlamp biomicroscopy, indirect ophthalmoscopy, fundus photography, and optical coherence tomography. In patients with intermediate AMD or any suspicion of CNV, fluorescein angiography was performed.
Koike et al,[21] 2015	Supervised Amsler grid test was performed but not specified in further detail.	Clinical examination included optical coherence tomography. Examination was not specified in further detail.
Loewenstein et al,[22] 2003	Supervised Amsler grid test was performed, but further details were not specified. The test was considered positive in the presence of any distortion, scotoma, or blurring.	Clinical examination included slitlamp biomicroscopy, fundus photography, and fluorescein angiography upon any suspicion of CNV.
Goldstein et al,[23] 2005	Black square grid on a white background. The test was supervised and performed using a +3.0-D addition to the participant's refraction at 33-cm distance from the participant's eye. Pupillary dilation status was not outlined. The test was considered positive in the presence of any scotoma, blurred lines, or metamorphopsia.	A retina specialist performed slitlamp biomicroscopy examination and stereoscopic macular color photography.
Nowomiejska et al,[24] 2013	Black square grid on a white background. The test was supervised and performed using a reading addition to the participant's refraction at 30 cm from the participant's eye. All were tested with undilated pupils. The test was considered positive in the presence of any blurred lines or metamorphopsia.	All participants underwent slitlamp biomicroscopy examination, applanation tonometry, dilated fundoscopy, and optical coherence tomography.
Robison et al,[25] 2011	White square grid on a black background. The test was supervised and performed at a reading distance at 30 cm from the participant's eye. Further details were not specified. The test was considered positive in the presence of metamorphopsia or any other central visual field disturbance.	All participants underwent clinical examination, including optical coherence tomography, scanning laser ophthalmoscopy, fundus photography, and fluorescein angiography.
Wiecek et al,[26] 2015	Supervised Amsler grid test was performed but not specified in further detail. A certified ophthalmologic technician replicated the patient's drawing/description on a computer-based grid for further analyses.	Details of the clinical examination were not specified.
Zorn et al,[27] 2005	Supervised Amsler grid test was performed but not specified in further detail.	All participants were examined with fundoscopy, stereoscopic macula color photographs, and fluorescein angiography.

Abbreviations: AMD, age-related macular degeneration; CNV, choroidal neovascularization; D, diopter.

Amsler grid) was performed with a white square grid on a black background in 2 studies[18,25] and a black square grid on a white background in 4 studies[19,20,22,24]; the test configuration was not specified in 4 studies.[21,22,26,27] Six studies outlined that the test was performed using a reading addition to the participant's refraction and at 30 to 40 cm from the participant's eye.[18-20,23-25] Detailed methodological descriptions of the index and reference tests used across studies are available in Table 2.

Results of Individual Studies, Risk of Bias Within Studies, and Applicability

Wiecek et al[26] evaluated the prevalence and patterns of metamorphopsia across macular diseases and determined that metamorphopsia in neovascular AMD was more centrally located in the Amsler grid. Other types of AMD were less likely to lead to metamorphopsia, and when they did, it was more commonly spread out on the grid.[26]

Six studies were designed to compare the diagnostic accuracy of the Amsler grid with preferential hyperacuity perimeter (PHP) for detecting neovascular AMD.[18-20,22,23,27] Isaac et al[18] found that the 2 methods were comparable but that PHP had slightly higher sensitivity than the Amsler grid. Kampmeier et al[19] determined that both methods revealed metamorphopsia and scotoma in early and late AMD but that PHP was more sensitive for geographic atrophy and neovascular AMD. Klatt et al[20] reported overall comparable results from the 2 methods but that the Amsler grid was superior for detecting intermediate AMD and classic choroidal neovascularization (CNV), whereas PHP was superior to the Amsler grid for occult CNV. Goldstein et al[23] concluded that PHP had greater sensitivity than the Amsler grid for detecting any AMD but that PHP also had many FP results and lower specificity. Both methods revealed that earlier stages of AMD were associated with metamorphopsia and positive Amsler grid or PHP findings.[23] Zorn et al[27] found that both methods had comparable diagnostic accuracy, especially for detecting metamorphopsia in the early stages of AMD, but that PHP was superior in detecting geographic atrophy. Loewenstein et al[22] compared diagnostic accuracy of the Amsler grid with

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Table 3. Results of the Diagnostic Test Accuracy Meta-analyses of the Amsler Grid Test for Detecting Neovascular Age-Related Macular Degeneration (AMD)

Source	No.					% (95% CI)	
	Eyes	TP	FP	FN	TN	Sensitivity	Specificity
Performance in a scenario where the comparator and control participants are those with no retinal pathology							
Isaac et al,[18] 2007	25	7	0	3	15	70 (40-89)	100 (80-100)
Kampmeier et al,[19] 2006	79	36	5	9	29	80 (66-89)	85 (70-94)
Klatt et al,[20] 2006	93	60	0	13	20	82 (72-89)	100 (84-100)
Koike et al,[21] 2015	NR	NR	NR	NR	NR	NR	NR
Loewenstein et al,[22] 2003	83	11	1	21	50	34 (20-52)	98 (90-100)
Goldstein et al,[23] 2005	52	10	0	9	33	53 (32-73)	100 (90-100)
Nowomiejska et al,[24] 2013	59	25	0	11	23	69 (53-82)	100 (86-100)
Robison et al,[25] 2011	NR	NR	NR	NR	NR	NR	NR
Wiecek et al,[26] 2015	NR	NR	NR	NR	NR	NR	NR
Zorn et al,[27] 2005	NR	NR	NR	NR	NR	NR	NR
Summary estimate	NR	NR	NR	NR	NR	67 (51-79)	99 (85-100)
Performance in a scenario where the comparator and control participants are those with nonneovascular AMD							
Isaac et al,[18] 2007	50	7	8	3	32	70 (40-89)	80 (65-90)
Kampmeier et al,[19] 2006	140	36	45	9	50	80 (66-89)	53 (43-62)
Klatt et al,[20] 2006	86	60	13	13	0	82 (72-89)	0 (0-23)
Koike et al,[21] 2015	82	22	16	11	33	67 (50-80)	67 (53-79)
Loewenstein et al,[22] 2003	108	11	13	21	63	34 (20-52)	83 (73-90)
Goldstein et al,[23] 2005	117	10	20	9	78	53 (32-73)	80 (71-86)
Nowomiejska et al,[24] 2013	NR	NR	NR	NR	NR	NR	NR
Robison et al,[25] 2011	63	23	9	6	25	79 (62-90)	74 (57-85)
Wiecek et al,[26] 2015	908	100	468	19	321	84 (76-90)	41 (37-44)
Zorn et al,[27] 2005	97	25	31	4	37	86 (69-95)	54 (43-66)
Summary estimate	NR	NR	NR	NR	NR	71 (60-80)	63 (49-51)

Abbreviations: FN, false-negative; FP, false-positive; NR, not relevant; TN, true-negative; TP, true-positive.

a macular computerized psychophysical test, a computerized method with similarities to the PHP, for detecting neovascular AMD. The authors found that the macular computerized psychophysical test detected more individuals with both early AMD and late AMD than the Amsler grid.

Three studies compared the diagnostic accuracy of the Amsler grid with other non-PHP modalities for metamorphopsia.[21,24,25] Koike et al[21] compared diagnostic accuracy of the Amsler grid with noise-field perimetry for detecting neovascular AMD and found the Amsler grid to have higher sensitivity and comparable specificity. Nowomiejska et al[24] compared diagnostic accuracy of the Amsler grid with M-charts for detecting neovascular AMD, with the M-charts having slightly higher sensitivity than the Amsler grid and both having comparable specificity. Robison et al[25] compared diagnostic accuracy of the Amsler grid with a 3-dimensional computer-automated threshold Amsler grid for detecting neovascular AMD and found that the latter detected cases of metamorphopsia in both dry and neovascular AMD otherwise not detected by standard Amsler grid.[25]

Our risk-of-bias evaluation of individual studies and the assessment of applicability are summarized in eTable 2 in Supplement 1. Patients were likely referred to and seen in the clinics because of symptoms, which introduced a risk of selection bias and challenged applicability of findings. All studies used supervised Amsler grid testing (Table 2), which deviates from its use in home monitoring. Therefore, the risk-of-bias evaluation revealed the highest risk of bias for the domains of patient selection and index test.

Diagnostic Test Accuracy of the Amsler Grid for Detecting Neovascular AMD

Study-specific data on diagnostic test accuracy in individual studies are available in **Table 3**. We summarized diagnostic test accuracy of the Amsler grid for detection of neovascular AMD in 2 scenarios. First, the comparator or control participants were those without retinal pathology. Here, we calculated a summary estimate of the diagnostic test accuracy to be 67% (95% CI, 51%-79%) sensitivity and 99% (95% CI, 85%-100%) specificity. Second, the comparator or control participants were those with nonneovascular AMD. Here, we calculated a summary estimate of the diagnostic test accuracy to be 71% (95% CI, 60%-80%) sensitivity and 63% (95% CI, 49%-51%) specificity.

Hierarchical summary receiver operating characteristic curves showed the association between sensitivity and specificity for the Amsler grid in both scenarios (**Figure 2**). Our sensitivity analyses of both scenarios showed robust estimates (eTable 3 in Supplement 1). In post hoc analysis, the Amsler grid test was more sensitive to classic vs occult CNV (eTable 4 in Supplement 1).

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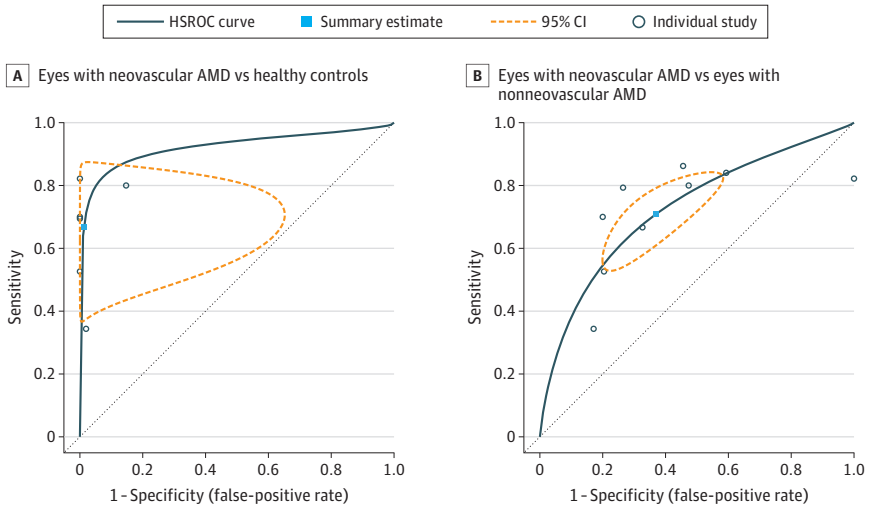
Figure 2. Hierarchical Summary Receiver Operating Characteristic (HSROC) Model Curve for Evaluating the Sensitivity and Specificity of the Amsler Grid Test in Detecting Neovascular Age-Related Macular Degeneration (AMD)



Discussion

In this systematic review and meta-analysis, we found that the Amsler grid test has sensitivity at levels typically not recommended for monitoring. Regarding specificity, when the Amsler grid was tested against healthy control participants, our summary estimate is as much as 99%, but when tested against patients with nonneovascular AMD, it missed 1 in 3 eyes with neovascular AMD. When the Amsler grid test is used for detection of neovascular AMD in a clinical setting, it is performed in patients with an a priori risk of neovascular AMD. These patients can have various stages of nonneovascular AMD (early AMD, intermediate AMD, or late nonexudative AMD with geographic atrophy) and possibly additional age-related macular conditions, such as epiretinal fibrosis, all of which can be associated with some level of metamorphopsia or scotomas that can lead to positive findings on the Amsler grid. Thus, it is not surprising that the Amsler grid will correctly classify only 63% of patients who have transitioned from dry to neovascular AMD.

Newer methods for evaluation of metamorphopsia exist, including computerized and smartphone application-based techniques with static or dynamic testing principles.[28] The dominant principle in dynamic testing is hyperacuity, and currently, commercially available devices include the ForeseeHome monitor (Notal Vision Inc) and the Alley (Oculocare) and myVisionTrack (Vital Art and Science) smartphone applications.[29-31] These methods have shown some promise but are not without limitations. In a meta-analysis, Faes et al[32] were unable to find statistically significant differences in the diagnostic test accuracy between the Amsler grid and PHP, the latter being a technological forerunner to the ForeseeHome monitor. The Home Monitoring of the Eye study found that a smaller decline in visual acuity from baseline to CNV detection could be achieved with the ForeseeHome monitor,[33] but self-monitoring compliance remains an issue for a meaningful number of patients.[34] Similar to the performance of the Amsler grid test, the first assessment of the Alley smartphone application in clinical practice found that the method was effective at discriminating AMD from no AMD, but discrimination between dry and wet AMD was moderate.[35] The downsides of computerized techniques include the need for more or less costly hardware and software, training, and possibly continued supervision by a technician. Older individuals with poor eyesight and who have not adapted to the digital age may be overly challenged by these newer modalities.[36] Examination times are also usually several minutes, much longer than that of the Amsler grid test. Adoption of computerized methods for metamorphopsia screening is still in an early phase, which could explain why only small gains in neovascular AMD detection have been proven presently. Further studies are warranted to uncover the potential of computerized methods for detection of metamorphopsia.

It should be noted that clinical application of the Amsler grid has its own challenges. The test can be performed incorrectly in many ways, such as without near correction, with binocular instead of monocular vision, or at a distance greater than what is recommended. These factors may worsen the diagnostic test accuracy. Challenges of using the Amsler grid may be better controlled through computerized methods for detection of metamorphopsia. Therefore, modern home monitoring technologies may outperform the Amsler grid, at least theoretically.

Fluorescein angiography and OCT angiography remain the best methods for detecting neovascular AMD.[37] From a screening perspective, increasing access to OCT alone can be expected to provide a significant improvement in detection of neovascular AMD.[38] The sensitivity of fundus photography (81%) is slightly lower than that of OCT (97.5%), whereas the specificity (89.5%) is slightly higher than that of OCT (85%); however, both are superior to that of the Amsler grid.[39,40]

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In some countries, optometry clinics provide posterior segment screening using imaging modalities such as fundus photography or OCT, after which images are interpreted in collaboration with retina specialists.[41-43] These initiatives bring retinal imaging closer to the patients, allow broader access to better diagnostic methods, and help with triaging patients by urgency.[41-43]

Limitations

Limitations of this study should be acknowledged. First, our review is based on studies that diagnosed neovascular AMD from 2003 to 2015. During this period, emerging widespread adoption of OCT in clinical practice allowed for a more detailed diagnosis and better disease definition and stratification, which may have contributed to differences in disease category definitions across studies. Second, the Amsler grid test was performed in a supervised manner in the reviewed studies, which may not reflect the performance of the Amsler grid test self-assessment for home monitoring. Third, retrospective studies may contribute to selection, ascertainment, and information biases. In our meta-analysis, only 1 study was retrospective,[26] and excluding this study did not change the estimates (eTable 3 in Supplement 1). Fourth, different distributions of CNV subtypes may explain differences across studies. In a post hoc analysis, the Amsler grid test was more sensitive to classic CNV than occult CNV (eTable 4 in Supplement 1). Although data do not exist on nonexudative CNVs, we speculate that the sensitivity of the Amsler grid for nonexudative CNVs is at best similar to that of occult CNV. Studies of Amsler grid test sensitivity for CNV subtypes may shed more light on this topic.

Conclusions

In conclusion, our findings suggest that the Amsler grid test should be used with caution for detecting neovascular AMD in eyes with an a priori risk of neovascular AMD. Although the Amsler grid test is inexpensive, readily available, easy to use, and independent of electronics or devices, it is important to note that when patients have signs of early or dry AMD and, thus, are at risk of developing neovascular AMD, the actual performance of the Amsler grid is not at a level typically recommended for monitoring. Although the Amsler grid may perform well in some cases, it may also provide a false sense of security in others. To date, to the best of our knowledge, no randomized controlled trial data exist on the effect of Amsler grid self-assessment for home monitoring on real-life outcomes in patients at risk for neovascular AMD. Thus, physicians recommending the Amsler grid self-assessment should also encourage patients to undergo ophthalmic examination regularly, regardless of Amsler grid results.

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REFERENCES

1. Finger RP, Daien V, Eldem BM, et al. Anti-vascular endothelial growth factor in neovascular age-related macular degeneration—a systematic review of the impact of anti-VEGF on patient outcomes and healthcare systems. *BMC Ophthalmol*. 2020;20(1):294. doi:10.1186/s12886-020-01554-2

2. Bloch SB, Larsen M, Munch IC. Incidence of legal blindness from age-related macular degeneration in Denmark: year 2000 to 2010. *Am J Ophthalmol*. 2012;153(2):209-213.e2. doi:10.1016/j.ajo.2011.10.016

3. Cheung CMG, Grewal DS, Teo KYC, et al. The evolution of fibrosis and atrophy and their relationship with visual outcomes in Asian persons with neovascular age-related macular degeneration. *Ophthalmol Retina*. 2019;3(12):1045-1055. doi:10.1016/j.oret.2019.06.002

4. Roberts PK, Schranz M, Motschi A, et al. Baseline predictors for subretinal fibrosis in neovascular age-related macular degeneration. *Sci Rep*. 2022;12(1):88. doi:10.1038/s41598-021-03716-8

5. Kim JH, Kim JW, Kim CG, Lee DW. Long-term treatment outcomes in type 3 neovascularization: focus on the difference in outcomes between geographic atrophy and fibrotic scarring. *J Clin Med*. 2020;9(4):1145. doi:10.3390/jcm9041145

6. Bloch SB, Lund-Andersen H, Sander B, Larsen M. Subfoveal fibrosis in eyes with neovascular age-related macular degeneration treated with intravitreal ranibizumab. *Am J Ophthalmol*. 2013;156(1):116-124.e1. doi:10.1016/j.ajo.2013.02.012

7. Lim JH, Wickremasinghe SS, Xie J, et al. Delay to treatment and visual outcomes in patients treated with anti-vascular endothelial growth factor for age-related macular degeneration. *Am J Ophthalmol*.

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2012;153(4):678-686, 686.e1-686.e2. doi:10.1016/j.ajo.2011.09.013

8. Kim J-G, Kim YC, Kang KT. Impact of delayed intravitreal anti-vascular endothelial growth factor (VEGF) therapy due to the coronavirus disease pandemic on the prognosis of patients with neovascular age-related macular degeneration. *J Clin Med*. 2022;11(9):2321. doi:10.3390/jcm11092321

9. Marmor MF. A brief history of macular grids: from Thomas Reid to Edvard Munch and Marc Amsler. *Surv Ophthalmol*. 2000;44(4):343-353. doi:10.1016/S0039-6257(99)00113-7

10. Amsler M. Earliest symptoms of diseases of the macula. *Br J Ophthalmol*. 1953;37(9):521-537. doi:10.1136/bjo.37.9.521

11. Augustin AJ, Offermann I, Lutz J, Schmidt-Erfurth U, Tornambe P. Comparison of the original Amsler grid with the modified Amsler grid: result for patients with age-related macular degeneration. *Retina*. 2005;25(4):443-445. doi:10.1097/00006982-200506000-00008

12. Gianniou C, Dirani A, Jang L, Mantel I. Refractory intraretinal or subretinal fluid in neovascular age-related macular degeneration treated with intraretinal ranibizumab: functional and structural outcome. *Retina*. 2015;35(6):1195-1201. doi:10.1097/IAE.0000000000000465

13. McInnes MDF, Moher D, Thombs BD, et al; PRISMA-DTA Group. Preferred Reporting Items for a Systematic Review and Meta-Analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. *JAMA*. 2018;319(4):388-396. doi:10.1001/jama.2017.19163

14. Whiting PF, Rutjes AWS, Westwood ME, et al; QUADAS-2 Group. QUADAS-2: a revised tool for the quality assessment of diagnostic accuracy studies. *Ann Intern Med*. 2011;155(8):529-536. doi:10.7326/0003-4819-155-8-201110180-00009

15. Higgins JPT, Thomas J, Chandler J, et al, eds. *Cochrane Handbook for Systematic Reviews of Interventions*. Version 6.3. Cochrane; 2019. Updated February 2022. Accessed July 18, 2022. https://training.cochrane.org/handbook

16. Macaskill P, Gatsonis C, Deeks JJ, et al. *Cochrane Handbook for Systematic Reviews of Diagnostic Test Accuracy*. Version 2.0. The Cochrane Collaboration, 2010. Accessed July 18, 2022. https://methods.cochrane.org/sdt/handbook-dta-reviews

17. Freeman SC, Kerby CR, Patel A, Cooper NJ, Quinn T, Sutton AJ. Development of an interactive web-based tool to conduct and interrogate meta-analysis of diagnostic test accuracy studies: MetaDTA. *BMC Med Res Methodol*. 2019;19(1):81. doi:10.1186/s12874-019-0724-x

18. Isaac DLC, Avila MP, Cialdini AP. Comparison of the original Amsler grid with the preferential hyperacuity perimeter for detecting choroidal neovascularization in age-related macular degeneration. *Arq Bras Oftalmol*. 2007;70(5):771-776. doi:10.1590/S0004-27492007000500009

19. Kampmeier J, Zorn MM, Lang GK, Botros YT, Lang GE. Comparison of Preferential Hyperacuity Perimeter (PHP) test and Amsler grid test in the diagnosis of different stages of age-related macular degeneration. Article in German. *Klin Monbl Augenheilkd*. 2006;223(9):752-756. doi:10.1055/s-2006-926880

20. Klatt C, Sendtner P, Ponomareva L, et al. Diagnostics of metamorphopsia in retinal diseases of different origins. Article in German *Ophthalmologe*. 2006;103(11):945-952. doi:10.1007/s00347-006-1381-0

21. Koike K, Hohenberger M, Wannamaker K, Trivedi RH, Kylstra JA. Noise field perimetry for screening central scotomas in age related macular degeneration. *Invest Ophthalmol Vis Sci*. 2015;56(7):3152.

22. Loewenstein A, Malach R, Goldstein M, et al. Replacing the Amsler grid: a new method for monitoring patients with age-related macular degeneration. *Ophthalmology*. 2003;110(5):966-970. doi:10.1016/S0161-6420(03)00074-5

23. Goldstein M, Loewenstein A, Barak A, et al; Preferential Hyperacuity Perimeter Research Group. Results of a multicenter clinical trial to evaluate the preferential hyperacuity perimeter for detection of age-related macular degeneration. *Retina*. 2005;25(3):296-303. doi:10.1097/00006982-200504000-00008

24. Nowomiejska K, Oleszczuk A, Brzozowska A, et al. M-charts as a tool for quantifying metamorphopsia in age-related macular degeneration treated with the bevacizumab injections. *BMC Ophthalmol*. 2013;13:13. doi:10.1186/1471-2415-13-13

25. Robison CD, Jivrajka RV, Bababeygy SR, Fink W, Sadun AA, Sebag J. Distinguishing wet from dry age-related macular degeneration using three-dimensional computer-automated threshold Amsler grid testing. *Br J Ophthalmol*. 2011;95(10):1419-1423. doi:10.1136/bjo.2010.194886

26. Wiecek E, Lashkari K, Dakin SC, Bex P. A statistical analysis of metamorphopsia in 7106 Amsler grids. *Ophthalmology*. 2015;122(2):431-433. doi:10.1016/j.ophtha.2014.09.006

27. Zorn MM, Kampmeier J, Botros YT, Lang GE. Comparison of preferential hyperacuity perimeter (PHP) test and Amsler grid test in the diagnosis of different stages of ARMD. *Invest Ophthalmol Vis Sci*. 2005;46(13):240.

28. Mohaghegh N, Ghafar-Zadeh E, Magierowski S. Recent advances of computerized graphical methods for the detection and progress assessment of visual distortion caused by macular disorders. *Vision (Basel)*. 2019;3(2):25. doi:10.3390/vision3020025

29. Chew EY, Clemons TE, Bressler SB, et al; AREDS2-HOME Study Research Group. Randomized trial of the ForeseeHome monitoring device for early detection of neovascular age-related macular degeneration. the Home Monitoring of the Eye (HOME) study design—HOME study report number 1. *Contemp Clin Trials*. 2014;37(2):294-300. doi:10.1016/j.cct.2014.02.003

30. Kaiser PK, Wang Y-Z, He Y-G, Weisberger A, Wolf S, Smith CH. Feasibility of a novel remote daily monitoring system for age-related macular degeneration using mobile handheld devices: results of a pilot study. *Retina*. 2013;33(9):1863-1870. doi:10.1097/IAE.0b013e3182899258

31. Islam M, Sansome S, Das R, et al. Smartphone-based remote monitoring of vision in macular disease enables early detection of worsening pathology and need for intravitreal therapy. *BMJ Health Care Inform*. 2021;28(1):e100310. doi:10.1136/bmjhci-2020-100310

32. Faes L, Bodmer NS, Bachmann LM, Thiel MA, Schmid MK. Diagnostic accuracy of the Amsler grid and the preferential hyperacuity perimetry in the screening of patients with age-related macular degeneration: systematic review and meta-analysis. *Eye (Lond)*. 2014;28(7):788-796. doi:10.1038/eye.2014.104

33. Chew EY, Clemons TE, Bressler SB, et al; AREDS2-HOME Study Research Group. Randomized trial of a home monitoring system for early detection of choroidal neovascularization Home Monitoring of the Eye (HOME) study. *Ophthalmology*. 2014;121(2):535-544. doi:10.1016/j.ophtha.2013.10.027

34. Yu HJ, Kiernan DF, Eichenbaum D, Sheth VS, Wykoff CC. Home monitoring of age-related macular degeneration: utility of the ForeseeHome device for detection of neovascularization. *Ophthalmol Retina*. 2021;5(4):348-356. doi:10.1016/j.oret.2020.08.003

35. Schmid MK, Thiel MA, Lienhard K, Schlingemann RO, Faes L, Bachmann LM. Reliability and diagnostic performance of a novel mobile app for hyperacuity self-monitoring in patients with age-related macular degeneration. *Eye (Lond)*. 2019;33(10):1584-1589. doi:10.1038/s41433-019-0455-6

36. Korot E, Pontikos N, Drawnel FM, et al. Enablers and barriers to deployment of smartphone-based home vision monitoring in clinical practice settings. *JAMA Ophthalmol*. 2022;140(2):153-160. doi:10.1001/jamaophthalmol.2021.5269

37. Usman M, Iqbal K, Ali MH, Nafees K. Features and diagnostic accuracy of optical coherence tomography angiography in neovascular age-related macular degeneration. *Cureus*. 2019;11(12):e6485. doi:10.7759/cureus.6485

38. Castillo MM, Mowatt G, Lois N, et al. Optical coherence tomography for the diagnosis of neovascular age-related macular degeneration: a systematic review. *Eye (Lond)*. 2014;28(12):1399-1406. doi:10.1038/eye.2014.214

39. Maruyama-Inoue M, Kitajima Y, Mohamed S, et al. Sensitivity and specificity of high-resolution wide field fundus imaging for detecting neovascular age-related macular degeneration. *PLoS One*. 2020;15(8):e0238072. doi:10.1371/journal.pone.0238072

40. Faridi A, Jia Y, Gao SS, et al. Sensitivity and specificity of OCT angiography to detect choroidal neovascularization. *Ophthalmol Retina*. 2017;1(4):294-303. doi:10.1016/j.oret.2017.02.007

41. Muttuvelu DV, Buchholt H, Nygaard M, Rasmussen MLR, Sim D. Danish teleophthalmology platform reduces optometry referrals into the national eye care system. *BMJ Open Ophthalmol*. 2021;6(1):e000671. doi:10.1136/bmjophth-2020-000671

42. Kern C, Fu DJ, Kortuem K, et al. Implementation of a cloud-based referral platform in ophthalmology: making telemedicine services a reality in eye care. *Br J Ophthalmol*. 2020;104(3):312-317. doi:10.1136/bjophthalmol-2019-314161

43. McCormick E. OCT rollout in every Specsavers announced. Optometry Today. Accessed August 15, 2022. https://www.aop.org.uk/ot/industry/high-street/2017/05/22/oct-rollout-in-every-specsavers-announced

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