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Vergleich der Ergebnisse aus Untersuchungen mit dem Tübinger Mobilkampimeter (TMC) und dem Octopus 101 Perimeter an Patienten mit fortgeschrittenen Gesichtsfeldausfällen

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Comparison of advanced visual field defects, measured with the Tuebingen Mobile Campimeter (TMC) and the Octopus 101 perimeter

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ABSTRACT

Purpose: To compare the results of the visual field testing of advanced visual field defects (VFDs) measured with a conventional perimeter (Octopus 101; O-101) and a new portable testing device, the Tuebingen Mobile Campimeter (TMC).

Methods: Thirty seven subjects (18 to 75 years old), 13 with advanced arcuate scotomas, 12 with VFD respecting the vertical meridians, 6 with concentric constriction and 6 healthy individuals were included. Subjects were first tested with the Octopus 101 as reference instrument, 30°-NO grid, 192 stimuli, 10 cd/m² background luminance, stimulus Goldmann size III = 26' and 320 cd/m² stimulus luminance. This was followed by testing with the TMC the same day with 84 stimuli as a subset of the O-101 grid, stimulus size 34', luminance 320 to 370 cd/m², background luminance 8 to 20 cd/m².

Pointwise accuracy (proportion of concordant locations), sensitivity and specificity were estimated into 95% confidence intervals (CI) by averaging individual logits. Both examination durations were compared.

Results: The TMC results are highly concordant with the results assessed with the Octopus 101 for all four defect classes. All 37 patterns were correctly recognized by the TMC examiner, so that lower limits of CI were for accuracy 91 %, sensitivity 89 % and specificity 54 %. For the entire sample, the percentage of discordant points, perceived with the TMC but not with the O-101, among all discordant points was 35 % (CI: 30 % to 40 %). Analysed by VFD pattern, the average pointwise accuracy was highest in healthy (97.9 %; CI: 97 % to 98.5 %), and lowest in arcuate scotomas (80.6 %; CI: 77.3 % to 83.5 %). Average pointwise sensitivity was highest in concentric constriction (94.5 %; CI: 82.9 % to 98.4 %), lowest in healthy individuals (59.1 %; CI: 26.3 % to 85.3 %). Average pointwise specificity was highest in healthy (98.1 %; CI: 96.6 % to 98.9 %), lowest in concentric constriction (77.4 %; CI: 62.1 % to 87.7 %).

Mean patient examination time was 4.6 min with the TMC and 9.8 min with the Octopus 101.

Conclusion: The results indicate that the TMC is a feasible device for documented detection of visual field loss.

Key words: Visual field – screening method – perimetry – campimetry – portable – concentric – grid

Introduction

The current “state of the art” for portable, screening visual field testing is the rough estimate of confrontation testing (Trobe et al. 1981). However, this procedure is characterized by a comparatively low retest-reliability (Trobe et al. 1981) and scotoma size is often underestimated (Johnson & Baloh1991). Confrontation test in comparison to automated perimetry provides low sensitivity in visual field loss due to parasellar tumors, glaucoma and compressive optic neuropathies (Johnson & Baloh 1991). Confrontation testing is often insensitive unless a moderate to dense defect is present (Shahinfar et al. 1995).

Under certain circumstances, like in emergency or intensive care units, patients are unable to perform a long lasting and extensive visual field test sitting in front of a conventional perimeter. In such cases, it would be helpful to examine and document the visual field efficiently with a screening device with a higher validity and reliability than the confrontation test (Norden 1989). Campimetry (visual field examination on a flat surface) can be a useful solution in this situation as the background area can be comparatively small when examining the central field in short distances. There have been some trial devices, but up to now, the variability of room light conditions with a direct impact to the background luminance of the instrument was a major drawback limiting the usefulness of these devices.

The aim of this study was to test the applicability of a newly developed portable campimetric visual field screening device with built in background illumination by comparing its results with those of a conventional perimeter.

Materials and Methods

Subjects: 31 patients visiting the neuro-ophthalmologic outpatient service of the Tuebingen University Eye Hospital (13 male, 18 female; age range 18 to 75 years) with one of three different types of VFDs who met the inclusion criteria were enrolled in the study. An additional six voluntary healthy subjects (4 male, 2 female; age range 24 to 55 years) with normal eye

examinations were included. All subjects were examined with both perimetric methods (for details see Table 1): thirteen patients with advanced arcuate scotomas,(Aulhorn stage III-IV (Aulhorn & Karmeyer 1977) caused by glaucoma or anterior ischemic optic neuropathy (AION), 12 patients with VFDs respecting the vertical midline at least in one eye due to chiasmal or postchiasmal lesions of the visual pathway, 6 patients with concentric constriction of the visual pathway due to tapetoretinal degeneration and 6 healthy subjects.

The study was approved by the local independent ethics committee and the protocol adhered to the tenets of the Declaration of Helsinki.

Patients were included if they were at least 18 years old, rested and relaxed, able to understand and perform the examination and to review and sign an informed consent. Ophthalmologic inclusion criteria included spherical ametropia of ∗< 8 D∗, a cylindrical ametropia of∗< 3 D∗, a central distant visual acuity of > 0.5 (10/20), and isocoria under varying luminance condition with a pupil diameter of > 3 mm.

Patients were excluded from the study if they had a history of intraocular trauma or inflammation, eye surgery (except intraocular lens implantation without any known complication), amblyopia, nystagmus, albinism, macular degeneration, manifest squint (strabismus), double vision, use of miotic drugs, or a medical history of diabetes mellitus, current arterial hypertension (RR >180/>90 mmHg), drug intake potentially affecting reaction time (e.g. sedatives), alcohol, nicotine or caffeine consumption less than 2 hours before the perimetric examination.

Healthy subjects were included if they fulfilled the same general requirements and had a normal ophthalmological and neurological history. Ophthalmological criteria of the healthy subjects were spherical ametropia of <∗8 D∗, cylindrical ametropia of <∗2 D∗ and central distant visual acuity of > 1.0 (20/20) for age group ≤ 60 years, > 0.8 (16/20) for age group 60 to ≤ 70 years and 0.63 (12/20) for age group > 70 years, respectively. The near visual acuity (Birkhäuser reading text) had to be ≥ BIRKH. 1.0 for age group ≤ 60 years, ≥ BIRKH. 0.8 for age group 60 to ≤ 70 years, ≥ BIRKH. 0.6 for age group > 70 years. Apart from that, pupils had to be isocoric with a diameter of > 3mm, the anterior segments and the fundus (examination with undilated pupils

after the perimetry) had to be normal. An intraocular pressure (IOP) ≤ 22 mmHg was required and the ocular motility and the LANG(-I) stereo test had to be normal (see Table 1).
Every subject underwent a mandatory visual field examination with the Octopus 101 (both eyes) during their visit.
Within the next three hours, only one eye, the more advanced one or in case of symmetric defects the randomized one, was examined with the TMC. Randomisation used a balanced, blocked list and sealed opaque envelopes opened by a third person. The examiner (A.B.) was masked as to the nature of the visual field defect of the patient**.**

Octopus 101: The reference standard instrument was the Octopus 101 (Haag-Streit AG, Koeniz, Switzerland) with an automated static three zone perimetric strategy: 30°-NO grid with 192 stimulus locations (see Figure 2a), initial luminance level of 2.5dB above the 5% reference value of local differential luminance of age-related normals, background luminance 10 cd/m², stimulus size Goldmann III = 26'. The maximum stimulus luminance during the test was 320 cd/m² for all stimulus locations to test for absolute defects.

Tuebingen Mobile Campimeter: A sand-blasted semi-transparent plexiglass-screen in a mat light grey frame (31x22cm), a well adjusted position of the bright energy-saving lamps and the dimming device in front of the lights assisted to reduce the inhomogeneity of the screen. In addition to the rechargeable batteries inside the handle, the TMC was equipped with mains voltage supply (6 Volt) to ensure constant conditions during the entire study. A thin rim trial lens holder was integrated in the bridge-chin support construction used for age-related adequate near correction for the distance of 21 cm.
For the Tuebingen Mobile Campimeter (Figure 1), a subset of the Octopus 30°-NO grid was printed on a Din A 4 foil: the TMC grid consisted of 84 concentrically arranged test locations (Figure 2c) with condensation towards the center. The stimuli had an offset with respect to the horizontal and vertical meridian within the 30° visual field. The stimulus locations at the TMC

grid were exactly identical to the ones on the Octopus grid, adjusted to the size of the TMC screen (Figure 2a,b,c). Each test location was labeled with an unambiguous identification number.
The background luminance ranged between 8 cd/m² in the corners and 20 cd/m² in the lower middle of the screen, depending on the light scatter. The stimulus size was 34' and the stimulus luminance 320-370 cd/m² (the diameter of the field of measurement of the luminance meter (Minolta luminance meter LS-100/LS-110; Minolta camera Co. Ltd Osaka Japan) was greater than the stimulus point which may have resulted in a variation of the measured data).

Examination procedure: For the examination with the TMC, the subject's eye was centred with the instruction to fix the four red dots in the center of the campimetric screen while the non-examined eye was occluded. Appropriate thin rim near correction glasses were provided if necessary. The TMC grid, printed on a transparent foil, was fit in the frame facing the examiner's position. The room was darkened completely. The examiner presented the test points at random with the preset intensity level and marked each location on the grid according to the patient's responses. Additional stimuli were presented in the center position to survey the subject's fixation and false negative responses. Responses were prompted with the light source turned off to check for false positive responses. Quality control stimuli were interspersed in the measurement stimuli in a randomised fashion. The examiner could additionally monitor the subject's fixation during the examination by looking over the upper rim of the presentation screen. She would ask for better cooperation when needed.
After the examination the transparent sheet had to be turned around the horizontal axis to achieve the standardized view. (Figure 3)

Scotoma classification: The visual field defects measured with the TMC and the Octopus 101 were classified according to a classification system used in the clinical routine by an experienced perimetrist (Schiefer & Wilhelm 1995; Schiefer et al. 2005) as normal or nerve fiber bundle defect, concentric constriction, or defect respecting the vertical meridian.

Statistics

Analysis of the perimetric results: First, the 84 identical stimulus points of the Octopus 101 grid and the TMC grid (Figure 2b) were counted separately. Only absolute scotomas were considered as “not perceived”, relative scotomas at the O-101 were handled as “perceived”. The analysis of the results was performed as follows:

The proportion of all stimuli perceived concordantly and discordantly with TMC and Octopus 101 among all 84 points was calculated. The proportion of discordant points which were perceived *with the TMC* but not with the O-101 among *all the discordant points* was calculated to know whether the TMC examination shows more points as normal or defective than the O-101.

In a second run, the relative defects assessed with the Octopus 101 were assigned to subgroups (in 5 dB steps) and were counted separately according to their depth and compared to the absolute perception of the stimuli with the TMC.

Statistical analysis: The Octopus 101 was taken as the reference standard method for the calculation. The following parameters summarise individual visual fields:

Accuracy: Number of stimulus locations concordantly perceived or concordantly not perceived with both devices divided by the total number of 84 tested locations. *Sensitivity*: Number of stimulus locations concordantly detected as “not perceived” (scotoma) with both devices divided by the number of test locations tested defective with the Octopus 101. *Specificity*: Number of stimulus locations concordantly detected as “perceived”/normal with both devices divided by the number of test locations perceived with the Octopus 101.

There are two possibilities for *discordantly* perceived stimulus locations: stimulus point perceived with the Octopus and not perceived with the TMC or stimulus point not perceived with the Octopus and perceived with the TMC.

The proportion of discordant points perceived with the TMC only, was estimated (in analogy to the sign-test) into an exact (Clopper-Pearson) 95%-confidence interval (CI) for each defect classification and the total without adjustment for multiplicity.

Sensitivity, specificity, and accuracy were computed per person and their median and unadjusted 95%-reference interval and CI estimated via the logit transform for the whole sample and each diagnostic group.

Record of the examination time: The net test duration time at the TMC was assessed in 33 of 37 examinations. The test duration time at the Octopus 101 was taken automatically by the software. Additionally, the average time per stimulus presentation was calculated, compared by computation of individual ratios, and estimated in CIs assuming normality, which was checked by normal-quantile plot.

Results

Classification: All visual fields measured with the TMC were assigned to scotoma categories identical to those seen with the Octopus 101 If our sample was representative, lower limits of CI were for accuracy 91%, sensitivity 89% and specificity 54%.

Concordant responses: For the entire sample the median pointwise accuracy was 89.4 % (CI: 85.8 % to 92.2 %), the median pointwise sensitivity was 84.8 % (CI: 76.5 % to 90.6 %), and the median pointwise specificity was 87.4 % (CI: 82.7 % to 90.9 %) (see Table 2). If analysed by patient per defect pattern, the median pointwise *accuracy* was highest in healthy individuals (97.9 %; CI: 97 % to 98.5 %), and lowest in patients suffering from RNFL loss (80.6 %; CI: 77.3 % to 83.5 %); the median pointwise *sensitivity* was highest in concentric constriction (94.5 %; CI: 82.9 % to 98.4 %), and lowest in healthy subjects (59.1 %; CI: 26.3 % to 85.3 %). The median pointwise *specificity* was highest in healthy subjects (98.1 %; CI: 96.6 % to 98.9 %), and lowest in patients with concentric constriction (77.4 %; CI: 62.1 % to 87.7 %).

Discordant responses: The percentage of discordant stimulus locations, which were perceived with the TMC but not with the Octopus, among all discordant points for the entire sample was 35 % (143/411; CI: 30 % to 40 %).

In each defect class, except healthy subjects, there were significantly more discordant points that were perceived with the Octopus 101 but not with the TMC than the other way round.

Relative defects: Considering the relative defects, 82 % (195/237) of the stimulus locations with a luminance level of 5 dB below the age related normative value at the Octopus 101 were perceived with the TMC. Defects of 10 dB luminance level below the age related normative value at the Octopus 101 were perceived with the TMC in 63 % of the locations (69/110). Only 41 % (36/86) of the relative defects which were 15 dB below the age related normative value were perceived with the TMC. This fraction remained at 43 % (3/7) for those relative defects that were 20 dB below the age related normative value. There were no relative defects within the 84 test locations at the Octopus that were 25 dB below the age related normative value.

Examination time: The mean examination time at the Octopus-101 using the 192 stimuli grid was 10.5 min, (range 8 to14.0 min) in the 31 patients and 6.2 min (range 6 to 7 min) in the 6 normal seeing subjects. Division by the considerably different numbers of stimulus presentations results in a mean time of 1.6 s per presentation (CI 1.6 s to 1.7 s) in both groups.

The mean examination time at the TMC was 4.7 min, (range 2.2 to 5.7 min) in 28 patients and 3.9 min in 5 control subjects (range 2.2 to 5.0 min), with a mean 2.6 s for each question (CI 2.5 to 2.7 s). Time per presentation was 61 % (CI 53 % to 69 %) longer with the TMC than with the Octopus.

For analysis of examination time for each defect class at the TMC and Octopus 101 see Table 5.

Discussion

Historically, uncomplicated, portable instruments were used for the first trials to develop visual field screening devices. Over time, these instruments have been enhanced and improved. Both, cupola perimeters (Goldmann 1945; Beck et al. 1985) and campimetric conventional devices, allow a more accurate examination and follow-up of visual field defects, but are not transportable (Gloor 1993; Straub et al. 1995).

Various approaches have been used to assess visual fields at the bedside. These were manual or half automated devices (Mandahl 1994); Bynke & Heijl 1976; Anicho & Yager 2001), capable of evaluating visual fields more accurately than the conventional confrontation tests (Bass et al. 2004) and of demonstrating valid and retest-reliable results. Several efforts were made to develop a portable, low cost and uncomplicated screening method with a campimetric screen, as these instruments are room saving and easy to handle. For glaucoma screening or for the use in developing countries (Anicho & Yager 2001), static (Mutlukan et al. 1993) or oculo-kinetic perimetry (Damato 1985) devices were supplied with campimetric screens to serve as portable instruments. Several examiners prefer this rectangular design of the screen as examination set-up, as it is easy to handle and to store in a case (Bass et al. 2004; Heijl & Krakau 1975; Mutlukan & Spaeth 2001).

Further developed screening devices include static and kinetic perimetric, pupillary and desaturation tests with different types of portable instruments (Lee et al. 2003; Trobe et al. 1981; Damato 1985; Vistec Technologies 2005; http://www.oculus.de) virtual examination with headset (Hollander et al. 2000; Bräuning et al. 1997) or campimetric screens (Mutlukan & Spaeth 2001; Heijl & Krakau 1975; Anicho & Yager 2001). To our knowledge, apart from the oculus centerfield perimeter, none of these has yet to become a commercially available standard procedure.

The screening devices are supposed to ensure low examination times (Mutlukan & Spaeth 2001; Lee et al. 2003; Damato et al. 1993; Hollander et al. 2000). In our study, the TMC examination of one eye (84 stimulus locations) takes on average, a reasonable 4.6 minutes.

Due to manual handling of the stimulus light and the documentation of the perception on the foil, the time needed per stimulus point is longer than with the Octopus 101.

The perimetric grid used in the TMC with 84 stimuli is a subset of the Octopus 101 stimulus arrangement. The selection of these stimulus locations constitutes a compromise between examination duration and spatial resolution (Aulhorn & Karmeyer 1997). Several stimulus presentations within the assumed blind spot are used to assess the fixation quality similar to the procedure after Heijl and Krakau (Heijl & Krakau 1975). Unlike most devices, which use rectangular grids (Lee et al. 2003; Mutlukan & Spaeth 2001; Anicho & Yager 2001), the TMC utilizes test points that are arranged concentricly with an offset along the vertical and horizontal meridians. In contrast to a rectangular stimulus pattern, the polar arrangement should be better suited to assess the configuration of arcuate scotomas and concentric constriction while the stimulus offset in regard to the meridians should also allow examination of the vertical and horizontal borders of chiasmal or postchiasmal visual field defects (Stürmer 1985).

The TMC results are highly concordant with the results assessed with the Octopus 101 for all four defect classes. The high accuracy and the fact that the defect classifications were identical between the Octopus 101 and the TMC, indicate that the spatial resolution of the TMC grid seems to be adequate. This is also very important in emergency units where acute visual field defects such as chiasmal and postchiasmal lesions have to be discriminated from chronic visual field defects such as RNFL loss. The accuracy was highest in areas of either unequivocally defective or unequivocally healthy test locations, whereas it was lowest in the border regions of defects and in the vicinity of the blind spot.

Concerning the discordant responses, the results indicate that more stimulus points were “not perceived” with the TMC than with the O-101, which indicates that the TMC examination shows more absolute scotomas than the O-101. In no instance did discordance change the conclusion of the type of visual field defect indicating that this will be an excellent screening tool.

The additional analysis of the relative defects at the Octopus 101 (which were flagged as "perceived" with the Octopus 101 in the preceding analysis) shows that shallow relative defects are rather perceived with the TMC than deeper relative defects.

With the TMC it is easily feasible to further assess the exact outline of an absolute defect by simply applying a manual kinetic technique i.e. by manually moving the stimulus (perpendicularly) towards the assumed visual field border.

There are still some efforts being made to improve the handling of the TMC. During this pilot study, the TMC was developed with a mains voltage supply for luminance stability reasons. However, the instrument is now more evenly illuminated by rechargeable batteries, which are integrated into the handle. Additionally, to achieve a more homogenous background luminance of about 10 cd/m², we may replace the plexiglass screen with a self-illuminated LCD-screen, which would still be transparent for stimulus projection or even to use a modified laptop with an attached touchpad. In that case the lights for background illumination which are momentarily fixed to the bridge could be abolished. This would reduce the instrument's weight and improve portability. Finally, a study with patients confined to bed should be performed with the further improved model to evaluate its applicability as a true bedside method.

In conclusion, the TMC appears to be a highly accurate, portable method for bedside perimetry. In this series, all patient VFDs were identified and accurately characterized and additionally the detailed results of this method favourably compared to the gold standard, more rigorous, more time consuming, non portable visual field results of the Octopus 101.

Table 1. Visual field defect (VFD) pattern, number of patients, gender, age range and examined eye of the study subjects

	No. of subjects	Gender Male (m): female (f)	Age range [years] Median (25% ; 75%quartile)	Examined eye right : left
VFD respecting the vertical meridian	12	6 : 6	18 to 68 44.5 (33 ; 56)	7 : 5
Arcuate scotoma	13	5 : 8	31 to 75 66 (57 ; 73)	3 : 10
Concentric constriction	6	2 : 4	26 to 60 31.5 (28 ; 60)	4 : 2
Healthy	6	4 : 2	24 to 55 37 (26 ; 54)	3 : 3
Total	37	17 : 20	18 to 75 54 (32 ; 66)	17 : 20

Table 2. Visual field defect (VFD) pattern, number of patients and accuracy, sensitivity and specificity computed per person; estimation of the median over all subjects of each defect class (RI: 95 % Reference Interval, CI: 95 % Confidence Interval)

	No. of subjects	**Accuracy** [%] **mean** 95% RI 95% CI	**Sensitivity**[%] **mean** 95% RI 95% CI	**Specificity**[%] **mean** 95% RI 95% CI
VFD respecting the vertical meridian	12	**91.2** 60.5 to 98.6 85.6 to 94.7	**89.0** 62.0 to 97.5 83.3 to 92.9	**91.0** 64.7 to 98.2 86.1 to 94.3
Arcuate scotoma	13	**80.6** 67.2 to 89.4 77.3 to 83.5	**75.3** 5.3 to 99.4 47.7 to 91.0	**81.1** 39.8 to 96.5 71.9 to 87.8
Concentric constriction	6	**86.2** 51.1 to 97.4 75.0 to 92.8	**94.5** 43.3 to 99.7 82.9 to 98.4	**77.4** 36.1 to 95.4 62.1 to 87.7
Healthy	6	**97.9** 95.5 to 99.1 97.0 to 98.5	**59.1** 11.4 to 94.2 26.3 to 85.3	**98.1** 94.9 to 99.3 96.6 to 98.9
Total	37	**89.4** 52.8 to 98.5 85.8 to 92.2	**84.8** 21.4 to 99.1 76.5 to 90.6	**87.4** 44.2 to 98.4 82.7 to 90.9

Table 3. The proportion of positive discordant points i.e. perceived with the TMC but not with the O-101 among all discordant points estimated for each defect class separately and for the entire sample.

	Positive discordant among discordant points [%] mean (CI)	absolute numbers of test points
VFD respecting the vertical meridian	31 (22 to 41)	33/107
Arcuate scotoma	40 (33 to 47)	86/217
Concentric constriction	26 (16 to 37)	20/78
Healthy	44 (14 to 79)	4/9
Mean	35 (30 to 40)	143/411

Table 4. Number and distribution of relative defects at the Octopus 101 compared to the perception of stimuli with the TMC

	Total number of relative defects at the Octopus	Relative defects at the Octopus 101 perimeter with the following levels below age-related normative value				
		5dB	10dB	15dB	20dB	25dB
Stimuli perceived with the TMC	303 (68.8%)	195	69	36	3	0
Stimuli **not** perceived with the TMC	137 (31.1%)	42	41	50	4	0
Total	440 (100%)	237	110	86	7	0

Table 5. Examination time: results of the Tübingen Mobile Campimeter (TMC) and the Octopus 101 perimeter (O-101) for each visual field defect pattern and for each test point.

	Number of examinations		**Mean examination time [min]** CI Range		**Mean examination time [s]** ***for each test point*** CI Range	
	TMC	**O-101**	**TMC**	**O-101**	**TMC**	**O-101**
VFD respecting the vertical meridian	10	12	4.7 4.2 to 5.3 2.2 to 5.7	9.6 8.5 to 10.6 8.0 to 13.0	2.7 2.5 to 2.9 2.0 to 3.0	1.6 1.5 to 1.6 1.5 to 1.8
Arcuate scotoma	12	13	4.9 4.5 to 5.2 3.7 to 5.7	11 10.0 to 12.0 8.0 to 14.0	2.7 2.5 to 2.9 2.2 to 3.0	1.6 1.6 to 1.7 1.5 to 1.8
Concentric constriction	6	6	4.3 3.7 to 4.9 2.3 to 4.8	11.3 9.9 to 12.8 10.0 to 13.0	2.5 2.1 to 2.9 2.0 to 3.0	1.6 1.5 to 1.7 1.5 to 1.8
Healthy	5	6	3.9 2.9 to 4.9 2.2 to 5.0	6.2 5.7 to 6.6 6.0 to 7.0	2.3 1.7 to 2.9 1.9 to 3.1	1.6 1.5 to 1.7 1.5 to 1.8
Total	33	37	4.6 4.3 to 4.8 2.2 to 5.7	9.8 9.0 to 10.6 6.0 to 14.0	2.6 2.5 to 2.7 1.9 to 3.1	1.6 1.6 to 1.6 1.5 to 1.8

Fig. 1. Prototype of the Tuebingen Mobile Campimeter seen from the patient's side: a) screen, b) stimulus light pen, c) dimming device, d) mains voltage supply, e) chin support, f) thin rim glass holder, g) rechargeable batteries (inside the handle).

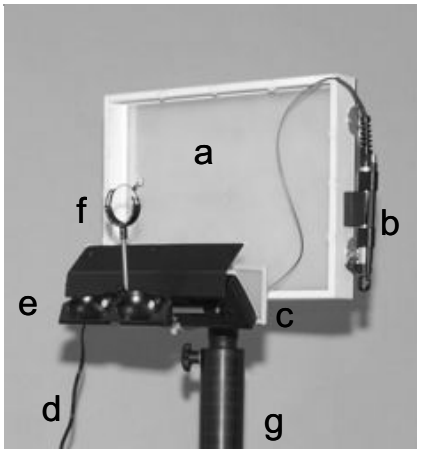


Fig. 2 Grids: a) 30-NO-grid of Octopus 101, 192 stimulus points, b) TMC grid projected onto 30-NO-grid (big grey dots), c) TMC grid, 84 stimulus points

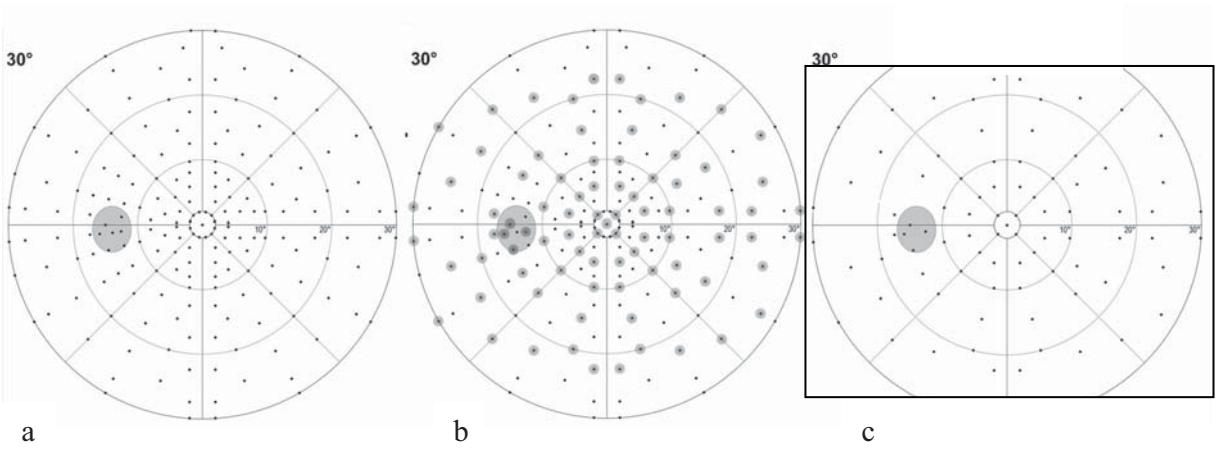
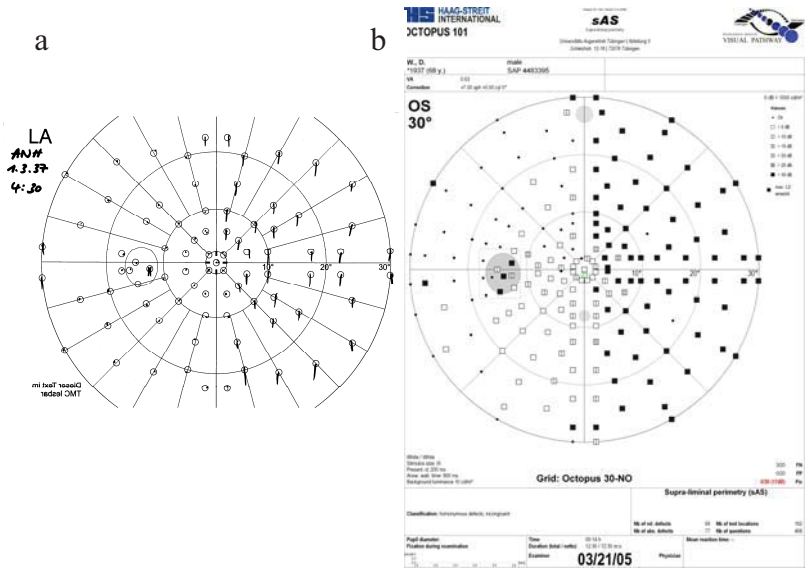


Fig. 3. Example of a scotoma with VFD respecting the vertical meridian, left eye examined
a) Results of examination with the TMC, examination time 4.5 min, open circle: stimulus perceived, circle with strike: stimulus not perceived
b) Results of the examination at the Octopus 101, examination time 12.5 min, dot: stimulus perceived, open squares: relative defect (5 steps), filled black square: absolute defect



REFERENCES

Anicho UM & Yager D (2001): The design of a simple, low cost perimetry instrument for visual field screening in developing regions of the world. In: Henson DB & Wall M (eds). Perimetry Update 2000/2001. The Hague, The Netherlands: Kugler Publications 293-298.

Aulhorn E & Durst W (1997): Automatisierte Perimetrie in der augenärztlichen Praxis. Sonderdruck aus "Programmgesteuerte Perimetrie".

Aulhorn E & Karmeyer H (1977): Frequency distribution in early glaucomatous visual field defects. Docum Ophthal Proc Series **14**: 17-83.

Bass SJ, Cooper J, Feldman J, & Horn D (2004): A new automated confrontation testing device vs. finger counting in the detection of field loss in glaucoma. Investigative Ophthalmology & Visual Science **45**, E-Abstract 4507. 2004.

Beck RW, Bergstrom TJ, & Lichter PR (1985): A clinical comparison of visual field testing with a new automated perimeter, the Humphrey Field Analyzer, and the Goldmann perimeter. Ophthalmology **92**: 77-82.

Bräuning J, Schüller S, & Fink W (1997): Digitale Video-Fixationskontrolle in einem "Head Mounted Campimetric System" (HMCS). Ophthalmologe **94** (Suppl. 1): 32.

Bruckmann A, Willmann H, Paetzold J, Vonthein R, Krapp E, & Schiefer U (2006): Comparison of Advanced Visual Field Defects (VFDs), Assessed With the Tuebingen Mobile Campimeter (TMC) and With Conventional, Slightly Supraliminal Standard Automated White–on–White Perimetry (SAP). Investigative Ophthalmology & Visual Science **47**, E-Abstract 796

Damato BE (1985): Oculokinetic perimetry: a simple visual field test for use in the community. Br J Ophthalmol **69**: 927-931.

Damato BE, Mutlukan E, & Jay JL (1993): A multi-fixation campimeter for the detection of glaucoma. In: Henson DB & Wall M (eds). Perimetry Update 1992/1993. The Hague, The Netherlands: Kugler Publications 299-303.

Gloor B (1993): Perimetrie mit besonderer Berücksichtigung der automatischen Perimetrie. Stuttgart: Enke.

Goldmann H (1945): Ein selbstregistrierendes Projektionskugelperimeter. Ophthalmologica **109**: 71-79.

Heijl A & Krakau CET (1975): An automatic static perimeter, design and pilot study. Acta Ophthalmologica **53**: 293-310.

Hollander DA, Volpe NJ, Moster ML, Liu GT, Balcer LJ, Judy KD, & Galetta SL (2000): Use of a portable head mounted perimetry system to assess bedside visual fields. Br J Ophthalmol **84**: 1185-1190.

Johnson LN & Baloh FG (1991): The accuracy of confrontation visual field test in comparison with automated perimetry. J Natl Med Assoc **83**: 895-898.

Lee MS, Balcer LJ, Volpe NJ, Liu GT, Ying GS, & Galetta SL (2003): Laser pointer visual field screening. J Neuroophthalmol **23**: 260-263.

Mandahl A (1994): Red square test for visual field screening. A sensitive and simple bedside test. Acta Ophthalmol **72**: 683-687.

Mutlukan E, Keating D, & Damato BE (1993): A touch-screen multi-stimulus video campimeter. In: Mills RP (ed). Perimetry Update 1992/93. Proceedings of the Xth International Perimetric Society Meeting. Amsterdam New York: Kugler 589-595.

Mutlukan E & Spaeth GL (2001): A portable visual field screener using a back-projection method with a laser pointer in the diagnosis of glaucomatous field loss. In: Wall M & Mills RP (eds). Perimetry Update 2000/2001. The Hague/The Netherlands: Kugler Publications 277-281.

Norden LC (1989): Reliability in perimetry. Journal of the American Optometric Association **60**: 880-890.

Schiefer U, Paetzold J, & Dannheim F (2005): Konventionelle Perimetrie - Teil 1 Einführung - Grundbegriffe [Conventional techniques of visual field examination. Part I: Introduction - basics]. Ophthalmologe **102**: 627-646.

Schiefer U & Wilhelm H (1995): Gesichtsfeld-Kompendium. Klin Monatsbl Augenheilkd **206**: 206-238.

Shahinfar S, Johnson LN, & Madsen RW (1995): Confrontation visual field loss as a function of decibel sensitivity loss on automated static perimetry. Implications on the accuracy of confrontation visual field testing. Ophthalmology **102**: 872-877.

Straub W, Kroll P, & Küchle HJ (1995): Augenärztliche Untersuchungsmethoden. Stuttgart: Enke.

Stürmer J (1985): What do glaucomatous visual fields really look like in fine-grid computerized profile perimetry? Dev Ophthal **12**: 1-47.

Trobe JD, Acosta PC, Krischer JP, & Trick GL (1981): Confrontation visual field techniques in the detection of anterior visual pathway lesions. Ann Neurol **10**: 28-34.

Vistec Technologies (2005): Perivist FeV und perivist compact. Vistec.

Deutschsprachige Zusammenfassung

Ziel dieser Studie war, die Gesichtsfeld-Untersuchungsergebnisse von zwei verschiedenen Perimetern an Patienten mit fortgeschrittenen Gesichtsfeldausfällen zu vergleichen. Dazu wurde ein Standardgerät, das Octopus 101 (Haag-Streit) und das zu testende, in der Augenklinik neu entwickelte tragbare Gerät, das Tübingen Mobilcampimeter (TMC) verwendet.

Methoden: 31 Patienten im Alter zwischen 18 und 75 Jahren mit fortgeschrittenen Gesichtsfeldausfällen (fortgeschrittene Bogenskotome, konzentrische Einengung, Gesichtsfelddefekte, die die Mittellinie respektieren) und 6 gesunde Probanden wurden in die Studie eingeschlossen. Die erste Untersuchung fand immer am Referenzinstrument Octopus 101 statt: 30° NO Raster mit 192 Stimuli, 10 cd/m² Hintergrundleuchtdichte, Stimulusgröße Goldmann III = 26’ und 320 cd/m² maximaler Stimulusleuchtdichte. Die zweite Untersuchung am TMC erfolgte innerhalb der nächsten drei Stunden und verblindet hinsichtlich der Referenzdiagnose mit 84 präsentierten Stimuli als Teil des Octopus 101 Rasters, Hintergrundleuchtdichte zwischen 8 und 20 cd/m², Stimulusgröße 34’ und Stimulusleuchtdichte 320 bis 370 cd/m².

Die Genauigkeit (Anteil der an beiden Geräten konkordant wahrgenommenen und konkordant nicht wahrgenommenen Gesichtsfeldorte), die Sensitivität und die Spezifität wurden pro Person ausgezählt und ihre Mediane über die durchschnittlichen Logits berechnet. Ebenso in ein 95%-Konfidenzintervall (KI) geschätzt wurde das geometrische Mittel des Verhältnisses der Untersuchungszeiten.

Ergebnisse: Da alle Gesichtsfelder mit dem TMC den gleichen Defektklassen zugeordnet wurden, betragen die Untergrenzen von KI für die Genauigkeit 91 %, die Sensitivität 89 % und die Spezifität 54 % der Personen. Bezüglich der gesamten Stichprobe war der Anteil der am TMC aber nicht am Octopus 101 wahrgenommenen Punkte von allen diskordant wahrgenommenen Punkten 35 % (KI: 30 % bis 40 %). Im Hinblick auf die einzelnen

Gesichtsfelddefekte war die mediane punktweise Genauigkeit am größten bei den gesunden Probanden (97,9 %; KI: 97 bis 98.5 %), und am geringsten bei Patienten mit Bogenskotomen (80,6 %; KI: 77,3 % bis 83,5 %). Die mediane punktweise Sensitivität war am höchsten bei Patienten mit konzentrischer Einengung (94.5 %; KI: 82,9 bis 98,4 %), am niedrigsten bei gesunden Probanden (59,1 %; KI: 26,3 bis 85,3 %). Die mediane punktweise Spezifität lag am höchsten bei gesunden Probanden (98,1 %; KI: 96,6 bis 98,9 %), am niedrigsten bei Patienten mit konzentrischer Einengung (77,4 %; KI: 62,1 bis 87,7 %).

Die durchschnittliche Untersuchungszeit lag bei 4,6 min am TMC und bei 9,8 min am Octopus 101.

Zusammenfassung: Die Ergebnisse zeigen, dass das TMC ein geeignetes Gerät ist, um Gesichtsfeldausfälle sicher aufzudecken und zu dokumentieren.

Nicht zur Publikation eingereichte Tabelle:

Vergleich der Eigenschaften des Tübinger Mobil-Kampimeters mit denen anderer tragbarer Gesichtsfelduntersuchungsgeräte.

(VFA = Visual Field Analyzer, VFD = Visual Field Defect)

Visual field screeners/ qualities	**Bruckmann/ Schiefer TMC**	**Mutlukan Portable visual field screener** Mutlukan E & Spaeth GL (2001)	**Hollander Portable head mounted perimetry system** Hollander DA et al. (2000)	**Lee Laser pointer visual field screening** Lee MS et al (2003)	**Anicho Slide based static perimeter** Anicho UM & Yager D (2001)	**Damato Multi-fixation campimeter /OKP** Damato BE, Mutlukan E, & Jay JL (1993)
Design of the instrument	Portable campimeter, back projection technique	Campimeter, back projection technique	2 full colour 0.7x0.7 inch liquid crystal systems	Tangent screen	Slide-based, back projection technique	Handheld chart
Strategy	Static, supra-threshold, single intensity	Static, supra-threshold, single intensity	Kasha visual field system, binocular view, supra-threshold, single intensity	Static, supra-threshold, single intensity	Static, supra-threshold, single intensity	Oculo-kinetic, supra-threshold, single intensity
Screen	Semi-transparent plexiglass screen	11x17 inch semi-transparent	Portable automated perimeter with headset	1m tangent screen	55x55cm, uniform translucent adapting tangent screen	White screen
Eccentricity/ Grid	30°, concentric (Octopus grid)	30° , rectangular (Humphrey grid)	24° , rectangular, 6°spacing	30° , concentric along the meridians	30°, rectangular, 6°square matrix, decentred 3° from midlines	12.5-15° , spiral
Number of test points	84	40/42 (not stated clearly)	52	49	56	26 fixation numbers
Blind spot	Repeatedly tested	---	Repeatedly tested 12-20x	Repeatedly tested	> 7 catch trials	Used to help understand exam. procedure
Test stimulus	stimulus size 34', stimulus luminance 320-370 cd/m²	3.5 mW Standard laser pointer, 0.2-0.3s single flash flicker mode	Moving stimulus: crawling beetle, luminance 1.3-500asb	laser pointer <5mW wave-length 633-680nm, 1.75 mm diameter (0.1°)	Approx. Goldmann size III, (0.43°) on a slide, 200ms target duration	1.5mm and 3.0mm black test stimulus, 26 numbers in light blue

Visual field screeners/ qualities	**Bruckmann/ Schiefer TMC**	**Mutlukan Portable visual field screener** Mutlukan E & Spaeth GL (2001)	**Hollander Portable head mounted perimetry system** Hollander DA et al. (2000)	**Lee Laser pointer visual field screening** Lee MS et al (2003)	**Anicho Slide based static perimeter** Anicho UM & Yager D (2001)	**Damato Multi-fixation campimeter /OKP** Damato BE, Mutlukan E, & Jay JL (1993)
Central fixation	4 central spots	Central spot	check 1 in 10	Central button	Maltese cross point	No, eye moves
Sequencing	Random	?	Random	Random	Random	following numbers
Illumination	8-20 cd/m², dark room	100 lux illuminated room	Room light dimmed	---	10cd/m² dark room	daylight
Examination duration	2.17 min - 5.67 min /eye	Approx 1 min/eye	4.8min-5.8min /both eyes	---	---	---
Documentation	Pencil attached to the laser pointer/ second pencil on folio	Pencil attached to the laser pointer	computerized	Extra sheet?	Extra sheet?	Extra sheet?
Patients	31 eyes of 31 patients, 6 healthy	84 right eyes, 75 left eyes of 90 patients	37 neurosurgery patients	150 eyes of 84 patients	---	222 eyes of 126 patients
Visual field defect pattern/ diagnosis	VFDs respecting the vertical meridian, arcuate scotomas, concentric constriction, healthy	Glaucoma or suspicion	(Neurosurgery patients) Normal fields, hemianopic character	Glaucoma, Suspicion, AION, hydroxyl-chloroquine screening, stroke, optic neuritis	Glaucoma	Glaucoma
Comparison to standard instrument	Octopus 101	Humphrey VFA SITA fast	Confrontation test	Confrontation visual field screening, Humphrey VFA FastPac or SITA Standard protocol	---	Dicon 3000 autoperimeter, TAP, Friedmann VFA, Henson VFA

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