Spatial Alignment of Microperimeters

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Abstract

Purpose: In microperimetry, the locations of visual stimuli are reported on a retinal image. The term microperimetry came to represent retinal perimetry even though perimetry with as small or smaller targets can be performed in standard perimetry. The reason that this terminology was established is the assumption that retinal perimetry provides more accurate placement of targets, in relation to fundus features. This was indeed the case in early scanning laser ophthalmoscopes (SLO) where the imaging laser was also used to create the perimetric stimuli and therefore target position was known exactly. Most microperimeters today use different systems for stimulus presentation and retinal imaging. Reported locations on the retinal image will be incorrect when not spatially aligned. We report generic psychophysical methods for confirming spatial alignment of microperimeters.

Methods: Two techniques were developed and evaluated using normally-sighted observers and Nidek MP-1 instruments. (1) The physiological blind spot was identified using small stimuli. The center of the optic disk identified by locating the apparent edge of the disk in the retinal image was compared to the center of the blind spot. (2) Angioscotomata of at least two major retinal vessels with orthogonal orientations were mapped. The locations of those angioscotomata were compared to the locations of the vessels in the retinal image. In addition to these techniques, we compared the locations of the fovea of 16 normally-sighted observers to published SLO-derived normal population data based on optic disk location. The effect of head tilt on computed foveal location was examined.

Results: Repeatable spatial alignment errors of 0.5° or more could be found using both techniques. Measurement errors associated with different operators, subjects and images were less than about 0.2°. Differences between our small population sample and previous studies were explained by spatial misalignment. Even small tilts of the head produced apparent changes in foveal location.

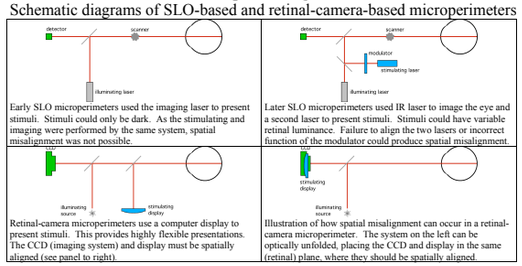
Discussion: These techniques for assessment of spatial alignment could be applied to any microperimeter. Only microperimeters that image the retina and present stimuli using the same system, as found in some SLOs, are not at risk of spatial misalignment. Mislocalization of the foveal location due to spatial misalignment and head tilt may affect studies of macular lesions such as AMD.

Microperimetry

- Microperimetry is retinal feature based perimetry (it does not require or imply very small stimuli).
- The perimetry results are presented relative to a retinal image
- The presumption is that perimetry results are located correctly on that image
- We have found that this may not be the case
- If the perimetry results are incorrectly placed, this is **spatial misalignment**
- Here we present a generic method to test for spatial misalignment
- The method uses psychophysical procedures and requires only a willing subject
- Next, we describe how a microperimeter could be spatially misaligned, then the two psychophysical procedures.

What is spatial alignment?

Schematic diagrams of SLO-based and retinal-camera-based microperimeters



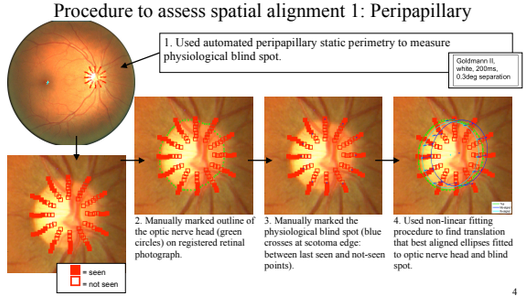
Early SLO microperimeters used the imaging laser to present stimuli. Stimuli could only be dark. As the stimulating and imaging were performed by the same system, spatial misalignment was not possible.

Later SLO microperimeters used IR laser to image the eye and a second laser to present stimuli. Stimuli could have variable retinal luminance. Failure to align the two lasers or incorrect function of the modulator could produce spatial misalignment.

Retinal-camera microperimeters use a computer display to present stimuli. This provides highly flexible presentations. The CCD (imaging system) and display must be spatially aligned (see panel to right).

Illustration of how spatial misalignment can occur in a retinal-camera microperimeter. The system on the left can be optically unfolded, placing the CCD and display in the same (retinal) plane, where they should be spatially aligned.

Procedure to assess spatial alignment 1: Peripapillary



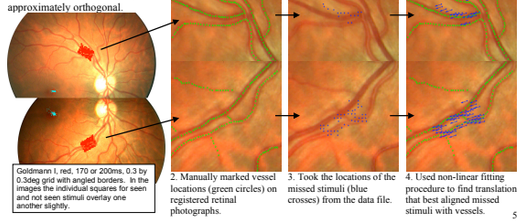
2. Manually marked outline of the optic nerve head (green circles) on registered retinal photograph.

3. Manually marked the physiological blind spot (blue crosses at scotoma edge: between last seen and not-seen points).

4. Used non-linear fitting procedure to find translation that best aligned ellipses fitted to optic nerve head and blind spot.

Procedure to assess spatial alignment 2: Angioscotomata

1. Used automated static perimetry to measure angioscotomata of upper and lower arcades vessels that were approximately orthogonal.



Goldmann I, red, 170 or 200ms, 0.3 by 0.3deg grid with angled borders. In the images the individual squares for seen and not seen stimuli overlay one another slightly.

2. Manually marked vessel locations (green circles) on registered retinal photographs.

3. Took the locations of the missed stimuli (blue crosses) from the data file.

4. Used non-linear fitting procedure to find translation that best aligned missed stimuli with vessels.

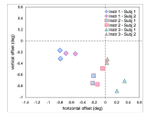
Measurements of spatial alignment

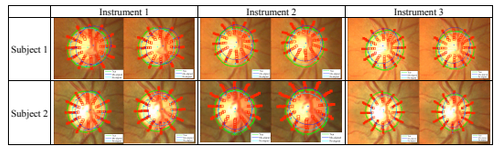
- Peripapillary and angioscotoma procedures were conducted with three retinal-camera-based microperimeters on two subjects (RW and FV-D).
- To reduce possible effects of image distortion, fixation was placed so that all "scotoma" regions were within the central 15° (e.g. panels 4 and 5).
- The three microperimeters were Nidek MP-1 instruments, which have real-time retinal feature (eye movement) tracking.
- Control experiments investigated effects of eye (left or right, which could affect peripapillary procedure) and location of "scotoma" region in image.

Results: Peripapillary

All three microperimeters had some spatial misalignment, of 0.5 to 1.0°.

- Two separate measurements with right eye of each subject on each instrument are shown on right
- Fitted ellipses and translations are shown below. Note effect of apparent incorrect responses at the bottom right.

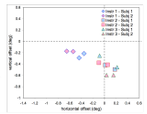


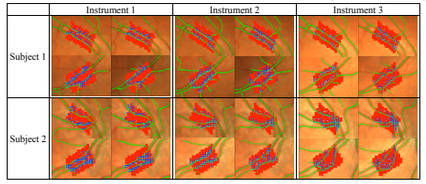


Results: Angioscotoma

All three microperimeters had some spatial misalignment, of 0.4 to 0.6°.

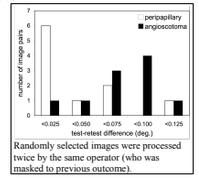
- Two separate measurements with right eye of each subject on each instrument are shown on right
- Translations are shown below.



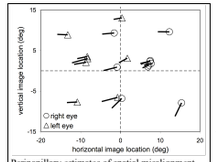


Control Experiments

- Variability due to manual marking of vessels and optic nerve head was ≤2pixels (≤0.125°).



Randomly selected images were processed twice by the same operator (who was masked to previous outcome).

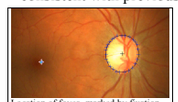


Peripapillary estimates of spatial misalignment (bar = 3 x vector) shown in relation to the center of the optic nerve head (open symbols).

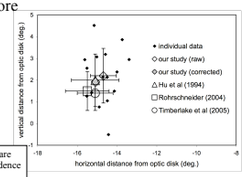
- Measured spatial misalignment varied with location in image of test region, but not between eyes.

Impact on measures of foveal location

- Determined the location of the fovea relative to the optic nerve head.
- Right eyes of 15 normally-sighted subjects on Instrument 1.
- Compared our (small) population to three SLO-based studies.[1-3]
- Spatial alignment correction made it more consistent with previous studies.



Location of fovea, marked by fixation examination (light blue dots), was found relative to the center of the optic nerve head (ellipse fitted to manual markings of edge: dark blue crosses).



Error bars are 95% confidence limits.

Discussion

- Two psychophysical methods for evaluating the spatial alignment of microperimeters were demonstrated.
- Small differences in the results between the two techniques have not been resolved.
- It is not clear whether our simple translation fit is sufficient to provide a correction factor.
- Eccentricity and (relative) location of the preferred retinal locus (PRL) assumes spatial alignment, since the optic nerve head is used as a reference.
- We noted, but do not illustrate here, that even small head tilts affect the determination of the location of the fovea relative to the optic nerve head.
- Manufacturers should provide a method of spatially aligning (calibrating) microperimeters in the field.

Acknowledgements

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2. Rohrschneider K. (2004). Determination of the location of the fovea on the fundus. *IOVS*. 45, 3257-3258.
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