3912 Automatic Retinal Oximetry

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Purpose

Hypoxia is believed to play a role in the pathogenesis of common ocular diseases such as diabetic retinopathy [1] and glaucoma [2].

A reliable method for human retinal oximetry is needed for basic research and, in the future, for clinical work. The traditional method of spectrophotometry calculates hemoglobin oxygen saturation from the color of the blood [3,4]. We seek to automate and improve the reproducibility and sensitivity of this method.

Methods

Fundus images were obtained with four different wavelengths of light simultaneously with the retinal oximeter shown schematically in figure 1.

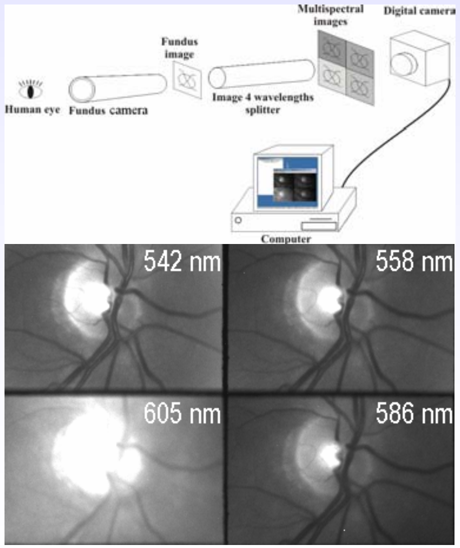

Figure 1. The retinal oximeter.
Above: Components. Below: A typical image.

Specialized software automatically locates the optic disc and selects points on vessels and adjacent fundus for calculation of optical density ratios (ODRs). ODRs have an approximately linear inverse relationship with hemoglobin saturation [4].

The automatic point selection method is designed to minimize the effect of specular reflection and noise. For comparison, measurement points were also selected manually.

Reproducibility was evaluated by measuring the same vessel on five consecutive images. Coefficient of variation was calculated as

$$\frac{\text{Standard dev. of ODR (5 measurements of the same vessel)}}{\text{Mean ODR (5 measurements of the same vessel)}}\left(1+\frac{1}{4n}\right)$$

where n = 5 measurements (images). One arteriole and one venule were measured in images from 11 eyes.

Sensitivity was evaluated by comparing automatic measurements on five healthy volunteers which inhaled either room air, 100% oxygen or 12% oxygen. Finger pulse oximetry was used as a reference for retinal arteriolar oxygen saturation.

Figure 2 shows a prototype of the retinal oximeter.

Figure 2. The retinal oximeter.

Results

Reproducibility:

Table 1. CV for automatic and manual point selection

	Arterioles		Venules	
	Manual	Automatic	Manual	Automatic
CV (mean, range)	48% (15-139%)	16% (8-26%)	19% (5-81%)	8% (3-16%)

Sensitivity and calibration:

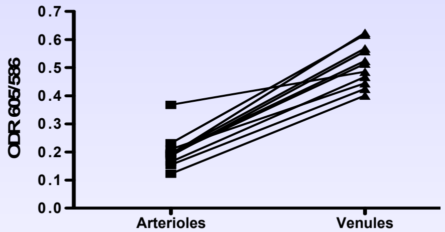

Figure 3. Arterioles and venules measured at 21% O_2. Each line represents one eye. Paired t-test: $p<0.0001$.

Linear regression for $\Delta SO_2 = k\Delta ODR$ using finger pulse oximetry values for SO_2 in arterioles yielded
k = -89 (-125 to -53) (mean and 95% c.i.).
$\Delta SO_2 = -89\Delta ODR$ was used to calibrate the results on figure 4.

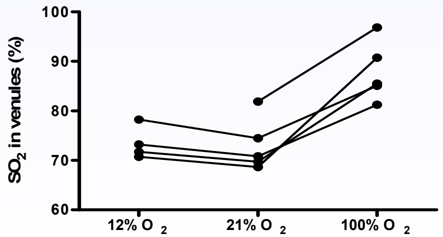

Figure 4. Venules measured at different O_2 concentration in inhaled air. Paired t-test: 21% vs. 100%: $p=0.0023$.

Oxymap:

The automatic software calculates hemoglobin oxygen saturation for every major vessel and can show the result either numerically or as a color coded map as shown in figure 5.

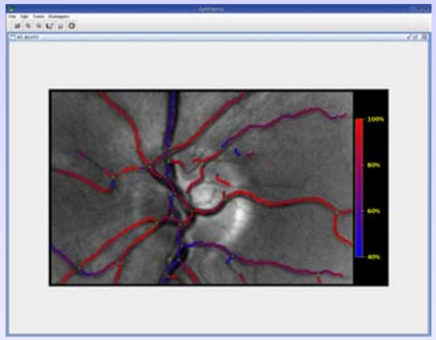

Figure 5. A color coded map of retinal vessel oxygenation.

Conclusions

The automatic analysis yields better reproducibility than the manual approach. The system can detect differences in retinal oxygen saturation when oxygen concentration in inhaled air is altered. A color coded map, made by the automatic software, displays retinal vessels' oxygenation in a convenient manner.

References

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Commercial relationship:

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