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Rapid Detection of Changes in the Optic Disc: Stereochronoscopy

III. Retinal Venous Pulse as an Interfering Factor

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Abstract. In the evaluation of stereochronoscopic pairs of fundus pictures (Sc) venous pulse is an interfering factor. Visual observation and photography show that when a magnification of 15× is used, as in our case, venous pulse is seen only at the emerging part of the big veins and in their immediate neighborhood, whereas veins of 100 µm diameter or less show no pulsation. Over relatively short time intervals (some minutes) the temporal course of venous pulse in terms of vessel width is a more or less periodic phenomenon; for longer periods (months) a study is underway. In the majority of cases the filling state of pulsating veins seems to reach a minimum shortly after the R peak of the ECG. An investigation as to whether the interference of venous pulse can be reduced by coupling the camera flash to the R peak has been begun. However, for the time being, it appears that the best method is to pass over the pulsating vessel parts, and to observe Sc effects only in the small vessels, when Sc evaluation is applied. Statistics show that venous pulse is significantly more frequent in suspected and early glaucoma subjects (T > 21 mm appl.) than in healthy subjects. We feel that with the methods proposed all conditions pertaining to an extensive follow-up of ocular hypertension and early glaucoma cases are now established.

Zusammenfassung. Bei der Auswertung stereochronoskopischer Bildpaare des Fundus (Sc) tritt der Venenpuls als Störfaktor auf. Visuelle Beobachtung und Photographie zeigen, daß Venenpuls mit der von uns benutzten Vergrößerung von 15× nur am oder nahe dem Austrittsgebiet der großen Venen der Papille festzustellen ist, während bei Gefäßen von 100 µm Durchmesser und weniger keine Pulsation zu sehen ist. Über kurze Zeiten (einige Minuten) ist der Verlauf des Venenpulses, gemessen als Gefäßdurchmesser, ein mehr oder weniger periodischer Vorgang; für größere Zeitabstände (Monate) wird die Frage untersucht. Der Füllungszustand der betreffenden Venen scheint in der Mehrzahl der Fälle kurz nach der R-Zacke des EKG ein Minimum zu erreichen. Wir untersuchen z.Z., ob sich der störende Einfluß des Venen-

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pulses durch Kopplung des Kamera-Blitzes an die R-Zacke vermindern läßt. Vorderhand scheint es am sichersten, die fraglichen Gefäßteile bei der Sc-Auswertung außer acht zu lassen, und die Sc-Phänomene an den kleinen Gefäßen zu untersuchen. Eine Statistik an Fällen von vermutetem oder sicherem beginnenden Glaukom mit Augendrucken über 21 mm appl. zeigt, daß Venenpuls hier mit einer statistisch gesicherten größeren Häufigkeit auftritt. Wir sind der Ansicht, daß mit der vorgeschlagenen Methodik nun alle Bedingungen gegeben sind, um große Serien von Fällen mit ocular hypertension und beginnendem Glaukom zu untersuchen.

Introduction

In our first paper (I) on stereochronoscopy (Sc) we have explained the differences between stereo pictures of this kind and conventional ones (Goldmann and Lotmar, 1977). Conditions to be met in taking fundus pictures were specified, ensuring that every depth effect perceived in pairs of different date has to be interpreted as a temporal change of fundus configuration (especially of the disc). In another paper (II) (Goldmann and Lotmar, 1978) we showed, though only for a restricted material, that discs with a physiological excavation do not change their surface configuration when the intraocular pressure is varied by less that 10 mm appl., and that normal discs in a normal fundus do not change within a period of at least three years. In contrast, choked discs change already within a few days, and certain glaucoma discs in some months.

In a third communication (III) (Lotmar et al., 1978) we explained that in drawing conclusions about temporal changes it is in principle even possible to make use of fundus pictures taken without regard to the conditions mentioned, if one takes into account the characteristic property of Sc that during common rotation of any stereo pair formed by such pictures the position of zero stereo effect (Null-Lage) for different domains of the picture is reached, in general, at different azimuths of rotation. If, therefore, a Sc pair exhibits stereo effects that can be nulled at one and the same azimuth all over the picture, it is probable that the effects are due to (unintentional) conventional stereo technique arising by neglect of Sc conditions. This probability rapidly approaches near certainty when more than two temporally differing pictures are available and all the pairs can equally be nulled over the whole area at one azimuth, in general different for every pair. In this case the conclusion is that no temporal change has taken place in fundus configuration. Using these criteria we found that the configurations of normal discs of adults did not change over a period of eight years in at least 95% of 60 eyes investigated.

However, this result was arrived at only after an interfering phenomenon had been taken into account, namely, retinal venous pulse. In our earliest experience with Sc of the disc we already came upon depth effects even in pictures that had been taken only minutes apart or less. These effects were usually seen only at the big central veins and corresponded closely to pulsations observed visually. Our attempts to circumvent this interfering factor are the subject of the present paper.

The Problem

The following questions arise:
1. Which veins pulsate and where?
2. Is the course of spontaneous venous pulse a more or less regular (quasi-periodic) phenomenon in one and the same subject, like the electrocardiogram? If not, do at least certain phases repeat?
3. Is venous pulse observed more frequently when intraocular pressure is above normal, and if so, what is its frequency?

A strategy to minimize the influence of venous pulse in the Sc technique evidently depends on these points.

Experiments

a) Localization. In our experience visual inspection shows that pulsation is restricted to the emerging part of the big veins and its neighborhood. These observations were fully confirmed by photography. On 12 pictures of cases with strong pulsation near the disc center we measured the diameter of the pulsating veins at the border of the disc. The method of measurement with a 10× desk projector is described in detail by Bracher et al. (1979). The results are shown in Fig. 1. We conclude that the following rule may safely be formulated: In adults, no pulsation is to be found in veins $\leqq 100\,\mu m$; pulsation in big veins is restricted to the neighborhood of their emerging part. This opinion was also fully supported by the evaluation of more than 300 pairs of Sc pictures from our material accumulated over 3 years.

b) Temporal Course of Venous Pulse. From visual observation one gains the impression that retinal venous pulse is a fairly regular (periodic) phenomenon. If this is true it might be possible to eliminate, or at least reduce, the interfering effects of venous pulse in Sc pairs by taking all consecutive pictures of one and the same subject at the same pulse phase.

This can be done by coupling the trigger of the camera flash to one of the peaks of the ECG, preferably the R peak. When a device for time delay is included, the flash can be synchronized at will with any phase of the venous pulse (see Bynke and Krakau, 1961). We have built such

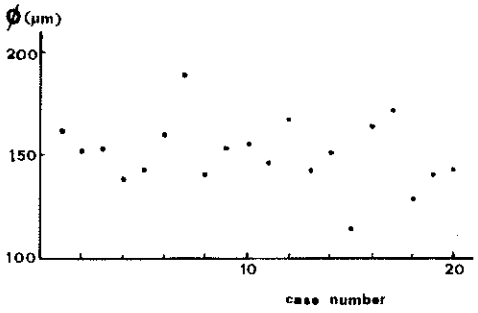

Fig. 1. Diameter of veins observed to pulsate near their emerging part, as measured at the border of the disc (20 cases). Absolute values were calculated by adopting Gullstrand's value of $f = 22.3$ mm for the focal length of the adult eye throughout $M = 151.5 \pm 16.12\,\mu m$; $M - 3\sigma = 103.14\,\mu m$ ($P < 0.001$)

a device which has now been in use for nearly a year. The patients are connected to the electrocardiograph by electrodes on both upper arms and the right forearm. When the starting switch is activated, the next R peak triggers the flash with a time delay that has been preselected on a scale running from 0.3 to 1.0 s. An interval shorter than 0.3 s could not be achieved with our fundus camera (a relatively old model) since 0.2 s is the time required for the swivelling mirror to come down. Synchronization of the flash with the R peak, for example, can however be realized by preselecting a time delay equal to the heart pulse period minus 0.3 s.

From the beginning we adopted the hypothesis that the most favorable phase for taking pictures, virtually alike when repeated, might be at the point where the filling state of the veins is at or near its minimum and additionally at its minimum rate of change. Accordingly we set the time delay at 0.1–0.2 s before a R peak of the ECG.

With this device, 32 glaucomatous eyes, observed visually to exhibit venous pulse, were photographed, most of them 3 times in a session with intervals of about 20 s as a mean, a few 5 times. This yielded a total of 122 picture pairs which should have shown no depth effects at the emerging parts of the big veins, had venous pulse been a strictly periodic phenomenon. In fact we found that 73 pairs (60%) did indeed show no difference, 29 pairs (24%) showed a slight difference, and 20 pairs (16%) a considerable one. Evaluation was made with the Sc scanning apparatus described in III, improved however by addition of cross-slides on both rotating supports. This facilitated and stabilized centering of the film slides. Overall magnification of the fundus was 15×. We again noticed the well-known phenomenon that much more detail is seen on the negatives than on corresponding paper copies.

The results cited make it clear that the proposed strategy is by no means a panacea against the interference of venous pulse in the Sc method of disc observation. However, since it considerably reduces the frequency of such interference, we decided to retain it in all cases of observed venous pulse.

Until now we have had little occasion to examine the repetitive characteristics of venous pulse over intervals of months. This will be further investigated.

In order to obtain some information about the temporal course of venous pulse we took sequences of pictures 0.1 s apart in phase through the available range of 0.3–1.0 s on several cases of observed strong pulsation. On all the film negatives vessel width was measured with the 10× desk projector at the site(s) of maximal pulsation. In some cases two different sites could be used. In this way a time course for the pulsation is obtained in terms of vessel width. Figure 2 shows two examples of the results thus obtained. It should be kept in mind that the individual points of the curves do not come from one and the same pulse wave, but from different waves some 20 s apart. Because of possible lack of repetition (see above) the somewhat erratic course of the curves is therefore not surprising.

However, from a small series of such curves we gained the impression that in the majority of cases, about 70–80%, there exists a minimum shortly after a R peak, thus justifying our strategy of picture taking.

From our material it became evident that not all cases of visually observed venous pulse show up as Sc effects. When pulsation is symmetrical about the vessel axis, no depth effect is produced. The same applies when pulsation is a matter of varying contrast rather than shape of the vessel concerned.

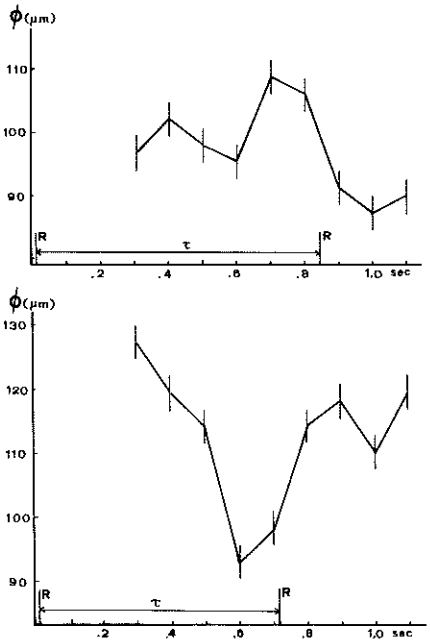

Fig. 2. Two examples of the temporal course of venous pulse in terms of vessel width as measured on the film negatives. R is the instant of the ECG peak, τ is the mean pulse period. Most cases are of the upper curve type

c) Frequency of Occurrence of venous pulse in healthy adults could be roughly assessed with the material presented in our third communication. Indeed, 12 of the 60 eyes (20%) investigated by the Sc method were suspected to exhibit this phenomenon. For all of them this diagnosis could be verified a posteriori by direct observation.

To arrive at a corresponding figure for cases of ocular hypertension we formed a group of 64 eyes, all with $T > 21$ mm appl. (mean value 28 mm) but otherwise chosen at random out of our material. However, we included only those cases that had been photographed before the synchronizing device became operative. This enabled venous pulse to be sought for by applying the Sc method on every triplet of pictures taken at a session. Since in the present context only those cases of venous pulse that are detected by, and therefore interfere with, Sc are of interest, the latter is precisely the method appropriate. Of the 64 eyes we found 23 showing venous pulse, i.e., 36%. This is considerably more than the figure for healthy eyes and underlines the importance of dealing with this problem. Since $\chi^2 = 4.07$ the difference is significant ($P < 0.05$).

Two results pertaining to issues treated in paper II may be mentioned here:

1. A case of glaucoma chron. simplex was observed in which tension dropped from 44 mm appl. to 17 mm in the course of 24 h as a consequence of Timolol 0.25% therapy. In contrast to our findings when tension was lowered with Diamox, namely, that there was no effect on disc configuration, the present case resulted in a considerable change as documented by Fig. 3. Note however that the pressure difference was much higher in the latter case.

2. The case R.A. shown in Fig. 4 of paper II has been seen again after an interval of two years. Visual field and tension o.s. were found to be unchan-

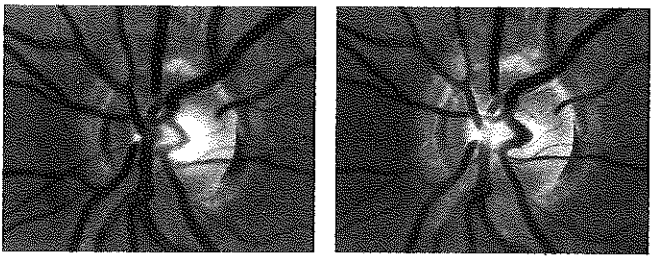

Fig. 3. Pictures of patient H.P. (glaucoma chron. simplex) taken 24 h apart; tension dropped from 44 to 17 mm appl. A configuration change is obvious, appearing as a cupping of the whole disc. Venous pulse at the emerging parts of both vena temp. sup. and inf. is superimposed

ged, and so was disc configuration, whereas for a period of 13 months before, changes of both had been found. This seems to confirm the power of the Sc method.

Conclusions

On the basis of our experience we suggest the application of the Sc technique in the following manner to investigate fundus changes:

1. The camera is centered on the cornea and the disc is centered on the frame (within tolerances as specified in I). A set of at least three pictures of every case should be taken at each session. Assume two sets A and B taken at different times t_1 and t_2, each set consisting of three pictures. When Sc scanning of triplet A reveals no differences, and the same is found for triplet B too, then any differences (depth effects) observed between a picture from A and one from B are caused by long-term changes of the disc between t_1 and t_2.

Should depth effects be found within set A and/or set B (usually due to short-term venous pulse)[1], then use only observations on relatively small vessels, that is, below 100 μm diameter, to decide whether a configuration change has occurred.

Coupling of the camera flash to a preselected phase of the patient's pulse is no guarantee for the exclusion of any visible venous pulse in Sc pairs, although it markedly reduces the percentage of such cases.

2. When only sets of non-centered pictures are available, follow the same procedure as sub (1) in case the sets are not homogeneous, i.e., consider only small vessels or other fine details and pass over the big veins near the disc center. Presence of Sc effects, and therefore, temporal change, is proven when nulling of stereo effects perceived in different parts of the picture occurs under different azimuths.

[1] Visible arterial pulsation in the fundus in cases of pulsus celer, as surmised in II and reported meanwhile by Kommerell (1978), also belongs to the category of short-term phenomena showing up already in a single set of pictures

It will be evident that the conditions of case (1) secure a more sensitive proof of changes within the disc.

With the methods described the premises for the investigation of extended series of ocular hypertension and incipient glaucoma cases are given. Our present knowledge suggests that in general changes of the disc configuration precede any changes of the visual field. However, only much more experience, and coordinated assessment of the visual field by the most sensitive and reproducible methods as offered by automatic perimetry (see Spahr et al., 1978) will reveal the exact relationships.

It is of course to be expected that sundry fundus diseases will cause configuration changes as well.

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