CONTRAST SENSITIVITY OF HEMODIALYSIS PATIENTS

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Abstract—The contrast sensitivity of patients undergoing hemodialysis therapy for chronic renal failure was measured and compared to that of a control group. Both contrast sensitivity and visual acuity of the patients were reduced. Ocular and fundoscopic exams revealed differences between the patients and controls, but these differences could not fully account for the visual deficits. The visual deficits could be expected to cause reduced visibility under everyday conditions for the patients.

Key words: Dialysis Contrast sensitivity Visual acuity Intraocular pressure Blood urea nitrogen Creatinine

INTRODUCTION

Some hemodialysis patients complain of disturbances in vision after a dialysis session [1]. Although patients tested before and after dialysis do exhibit some changes in refractive state, these changes were rather small. In an attempt to further investigate the visual function of hemodialysis patients, we gathered data on contrast sensitivity, visual acuity, and ocular status for a group of 14 volunteers being treated at the Satellite Dialysis Unit of the Northwestern University Medical School. These data were compared to those of a control group of normal individuals drawn from the staff of the Dialysis Unit.

We were particularly interested in contrast sensitivity because VER studies [2] have shown that responses to patterned stimuli are better correlated with clinical status than responses to diffuse flashes, and that responses to low contrast stimuli are more closely related to clinical state than are those to high contrast stimuli. Contrast sensitivity testing gives psychophysical data on responses to patterned stimuli at threshold contrast, and allows for independent testing of several spatial frequencies.

METHODS

Patient Characteristics

Individual data on our patients are given in Table 1. Their renal dysfunctions were
Table 1. Characteristics of patients

<table>
<thead>
<tr>
<th>PT</th>
<th>Age</th>
<th>Dialysis (years)</th>
<th>Primary disease</th>
<th>MAR (minutes)</th>
<th>Contrast sensitivity (peak)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE</td>
<td>30</td>
<td>2.5</td>
<td>Alport’s Syndrome</td>
<td>0.81</td>
<td>0.69</td>
</tr>
<tr>
<td>MH</td>
<td>36</td>
<td>4.5</td>
<td>S.L.E.</td>
<td>0.75</td>
<td>1.19</td>
</tr>
<tr>
<td>RH</td>
<td>27</td>
<td>8.8</td>
<td>Glomerulonephritis</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>GL</td>
<td>20</td>
<td>0.4</td>
<td>S.L.E.</td>
<td>0.81</td>
<td>0.81</td>
</tr>
<tr>
<td>ML</td>
<td>55</td>
<td>2.2</td>
<td>S.L.E.</td>
<td>1.25</td>
<td>1.19</td>
</tr>
<tr>
<td>DM</td>
<td>67</td>
<td>1.4</td>
<td>Hypertension</td>
<td>1.00</td>
<td>0.94</td>
</tr>
<tr>
<td>MM</td>
<td>49</td>
<td>4.6</td>
<td>Polycystic kidney</td>
<td>0.91</td>
<td>0.75</td>
</tr>
<tr>
<td>GP</td>
<td>20</td>
<td>2.8</td>
<td>S.L.E.</td>
<td>1.25</td>
<td>2.00</td>
</tr>
<tr>
<td>MP</td>
<td>64</td>
<td>3.0</td>
<td>Polycystic kidney</td>
<td>1.32</td>
<td>3.50</td>
</tr>
<tr>
<td>ER</td>
<td>50</td>
<td>3.8</td>
<td>Glomerulonephritis</td>
<td>0.75</td>
<td>1.00</td>
</tr>
<tr>
<td>MS</td>
<td>67</td>
<td>5.0</td>
<td>Pyelonephritis</td>
<td>1.19</td>
<td>1.19</td>
</tr>
<tr>
<td>HS</td>
<td>30</td>
<td>1.7</td>
<td>Pyelonephritis</td>
<td>0.78</td>
<td>0.78</td>
</tr>
<tr>
<td>GW</td>
<td>37</td>
<td>10.0</td>
<td>Glomerulonephritis</td>
<td>0.91</td>
<td>0.78</td>
</tr>
<tr>
<td>CW</td>
<td>47</td>
<td>7.7</td>
<td>Hypertension</td>
<td>0.87</td>
<td>1.80</td>
</tr>
</tbody>
</table>

*PT (column 1) stands for Patient.
*S.L.E. is systemic lupus erythematosus.
MAR, the minimum angle resolvable, is expressed in minutes of arc.
Contrast Sensitivity, the reciprocal of the contrast at threshold, is the peak value of the contrast sensitivity function. For our control subjects, the mean peak contrast sensitivity was 116 (standard deviation = 68.6).

of diverse origins, with a distribution of etiologies not markedly different from a recent study of over 1000 dialysis patients [3]. Their mean age was 43, compared with a national estimated average of 50. At the time of testing, they had been on dialysis therapy for an average of 4.2 years.

The mean age of our control group was 28. The age difference between patients and controls must be considered when interpreting the experimental results.

**Ophthalmic Examinations**

Intraocular pressure (IOP) was determined with a Perkins hand-held tonometer. Dialysis patients were examined immediately after a dialysis session; in some cases, additional measurements of IOP were made just prior to the session. Pupil diameter was measured by visual match to a millimeter scale while the subject looked at a surface whose luminance was 10 cd./m².

**Fundoscopic examination.** Each subject’s fundi were examined by direct ophthalmoscopy with dilated pupils; in addition, permanent records were made using a portable fundus camera. For dialysis patients these examinations were performed immediately after a dialysis session.

**Psychophysical Testing**

**Visual acuity.** All subjects were refracted for the distance at which the testing was done (3 m). Best corrected, monocular visual acuities were measured using a Snellen chart whose luminance was 75 cd./m².

**Contrast sensitivity.** Using an Optronix Corporation Vision Tester (Series 200), we measured each subject’s contrast sensitivity function (CSF) for the eye with the higher acuity. We concentrated attention on this eye because we expected that visibility in everyday situations would depend on the visual function of the better eye. To obtain a CSF, we determine the minimum contrast that just permits sinusoidal gratings to be seen. For each grating the subject’s sensitivity is taken to be the reciprocal of the threshold contrast. With a
tracking method [4], contrast thresholds were determined for gratings of 0.5, 1, 2, 4, 8, and 16 cycles/degree (c/d) of visual angle. Dialysis patients were tested immediately before and immediately after a dialysis session; control subjects were tested only once.

Test stimuli were vertical gratings presented on a 12 inch video monitor visual angle = 5.8°). Viewing was from a distance of 3 m. Seen against a large, white background, the monitor had a luminance of 88 cd./m². No fixation point was provided; the natural pupil was used. Prior to data collection, subjects practiced with gratings of 1 and 8 c/d.

Using the patients’ medical records, we ascertained the levels of clinically relevant blood chemistries (blood urea nitrogen, creatinine, sodium, potassium, and calcium) from tests made as close as possible to the day of the visual tests. We then computed pair-wise correlations between these blood chemistry levels and the patients’ performance measures on the visual tests.

RESULTS

Ophthalmic Examinations

There was no significant difference between the IOP of the patients and controls (11.2 and 11.7 mm Hg., respectively). The three patients tested both before and after dialysis sessions showed small, non-systematic variations (mean = 10.1 mm Hg before, 11.5 mm Hg after) such as have been reported before [1]. The mean pupillary diameter of the control subjects was 3.8 mm; omitting the single patient who had undergone an iridectomy, mean pupillary diameter of dialysis patients was 3.3 mm. This difference, though not statistically significant \( (p > .25) \) is approximately the magnitude expected from the relation between age and pupillary diameter [5].

Fundoscopic examinations. Virtually every patient showed changes characteristic of hypertensive retinopathy. Six patients showed some degree of vessel tortuosity; eleven patients showed some vessel attenuation and six showed arteriovenous crossing changes, usually nicking. The fundus changes observed in various patients did not bear any obvious or simple relation to their acuities.

Psychophysical Testing

Visual acuity. In order to compare the acuities across individuals quantitatively, we converted from standard Snellen notation to the Minimum Angle of Resolution (MAR), expressing the smallest critical details that can be seen in terms of minutes of arc. The mean MAR of the dialysis patients, using the better eye, was 0.91 minarc (standard deviation = .23); that of the control subjects was 0.74 minarc (standard deviation = 0.04). The difference between the two groups was statistically significant \( (t = 2.78, df = 27, p < .01) \). However, it is clear that the dialysis group was quite heterogeneous, with a standard deviation more than 5 times that of the control group. The range of MAR for dialysis patients was 0.69 to 1.32 minutes of arc; the corresponding range for the control subjects was only 0.65 to 0.78 minutes of arc. In passing it is worth noting that only two of our control subjects had even a single line difference between the acuities of their two eyes, but that half the dialysis patients had one or more line difference between their eyes.

Contrast sensitivity. Figure 1 (A) shows the mean CSF of control subjects and of dialysis patients measured immediately before dialysis therapy. Expressed as log contrast thresholds, these data were entered into an analysis of variance. The overall difference between the control group’s contrast sensitivity and that of the dialysis patients was statistically significant \( (F = 10.19, df = 1, 27, p < .01) \). In addition, the interaction between group and spatial frequency was statistically significant \( (F = 2.64, df = 5,135, p < .05) \),
Fig. 1. Contrast sensitivity functions. The ordinate is the reciprocal of the contrast needed for detection of a vertical sinusoidal grating of the spatial frequency stated on the abscissa. Each vertical bar represents one Standard Error of the Mean. A.) Mean contrast sensitivities for dialysis patients measured immediately before dialysis, and for control subjects. B.) Mean contrast sensitivities for dialysis patients measured immediately before and immediately after a dialysis session.

showing that the difference between groups varies significantly from one spatial frequency was statistically significant ($F = 2.64$, $df = 5,135$, $p < .05$), showing that the difference between groups varies significantly from one spatial frequency to another. We used t-tests to identify those spatial frequencies at which the difference between the patients' sensitivity and that of the controls was statistically reliable. The patients had significantly lower sensitivity ($p < .05$) at all frequencies except 0.5 and 2 c/d. The difference between groups approached significance at 2 c/d ($p < .06$) but not at 0.5 c/d ($p > .50$). The general picture emerges, then, that from about 1 c/d up, dialysis patients had less sensitivity than controls.

Figure 1 (B) shows CSFs of dialysis patients measured immediately before and immediately after dialysis therapy. An analysis of variance performed on these data indicated that there were no systematic differences between the pre- and post-dialysis functions. To test the hypothesis that the effect of dialysis on one patient's CSF was nullified by an equal and opposite change in the CSF of other patients, we computed Pearson product moment correlations between a patient's sensitivity before and after dialysis. Test-retest correlations were significant ($p < .05$) for 1 through 8 c/d. It is therefore unlikely that changes in one patient's CSF cancelled those in another's.

There were no statistically reliable correlations between the psychophysical performance measures and the clinical blood chemistry levels of our patients ($p > .05$). In particular, we found no evidence for a connection between a patient's health as assessed by blood urea nitrogen or creatinine and that patient's contrast sensitivity or visual acuity.
DISCUSSION

The dialysis patients in our study had reduced acuity and contrast sensitivity relative to the controls. The patients showed deficits for all spatial frequencies except the lowest (0.5 c/d). This parallels the result [2] that VERs to higher spatial frequency stimuli show clearer abnormalities than those to low spatial frequencies.

We found no reliable difference between CSFs measured before and after a dialysis session. This inefficacy of a single dialysis session parallels the finding [6] that a single dialysis session had no effect on the VER. Only by following the changes in evoked response latency over a period of several months of dialysis treatment did Hamel and associates [7] find a change in the VER.

The contrast sensitivity losses of our patients cannot be fully explained by their ocular status. They do have slightly smaller pupils than the controls. But this pupillary difference would result in an average reduction in retinal illuminance of just 30%, and this is not likely to significantly affect performance on the tests we used. In addition, the mean IOP of our renal patients was not significantly different from that of our controls. Although it has been reported that the response of IOP to dialysis is highly variable [8], the three patients we tested before and after dialysis showed no major changes in IOP. Many of our patients showed evidence of hypertensive retinopathy, but these changes seemed unrelated to their contrast sensitivities. Finally, although contrast sensitivity for higher spatial frequencies does decline with age, our patients showed larger losses, and losses at lower spatial frequencies than could be explained by age alone [9]. Presumably the differences are due to some unknown combination of factors that may include neural as well as non-neural mechanisms.

Of course, in assessing the psychophysical data, we must consider the possibility that the generally poorer health of the dialysis patients, together with the psychological stresses of renal disease and dialysis therapy, could have decreased concentration and motivation, leading to poorer test results even in the absence of specific sensory deficits. We do think, however, that the high test-retest reliabilities achieved with some spatial frequencies suggest that the dialysis patients were not inattentive as a general rule.

We feel it is probable that the patients in our study experience a reduction in the visibility of everyday scenes under some conditions. We base this conclusion upon the facts that they have reduced contrast sensitivity even at the peak of their CSFs, and that this reduction occurs in the better eye [10].

REFERENCES


Reviewer’s Comments—This is a concise, easily read and understood report on certain visual aberrations in hemodialysis patients. Suspect visual problems in these patients—particularly relating to contrast sensitivity and visual acuity—were nicely evaluated scientifically and appropriate clinical correlations were proved or disproved as appropriate. This is a rare “should be published as is” report. In fact, the only two points I might request is to: 1) comment on the quite low ocular pressure (10–11 mm Hg which approaches episcleral venous pressure), and, 2) elaborate on the statement on top of page 5 that fundus changes bear no “obvious or simple relation to their acuities.”