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SHORT COMMUNICATION

**Richard Maier · Peter Heilig · Robert Winker
Barbara Neudorfer · Robert Hoeranter · Hugo Ruediger**

Welder's maculopathy?

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Abstract *Objective*: The aim of this study was to verify or to disprove whether the term 'Welder's maculopathy' or 'Welding arc maculopathy' has to be considered being a justifiable occupational hazard and is to be annexed to the list of occupational diseases. *Methods*: Multifocal electroretinography (MERG) and thorough ophthalmologic examinations were performed in a group of 89 welders. The matched control group comprised 81 subjects who had never been exposed to welding. All participants of this study were examined by a specialist of occupational medicine prior to the MERG. *Results*: Multifocal electroretinography as well as ophthalmological tests did not reveal a significant morphological or functional differences between the welders and the control group. On an average, the welders' visual acuity appeared to be better than that of the control group. This phenomenon could be attributed to the so-called healthy worker effect. *Conclusion*: Welding arc maculopathy seems to be rather a sequel of occupational accidents and negligence of safety regulations. The results of this study indicate that the usual protective measures in professional welding appears to be sufficient in order to prevent an occupational risk of welding arc maculopathy.

R. Maier (✉) · R. Winker · H. Ruediger
Clinical Department of Occupational Medicine,
Medical University of Vienna, Waehringer Guertel 18-20,
1090 Vienna, Austria
E-mail: richardmaier@chello.at

P. Heilig
Department of Ophthalmology,
Medical University of Vienna, Vienna, Austria

B. Neudorfer
Eye Department, Hospital Barmherzige Brueder Linz,
Austria

R. Hoeranter
Eye Department, Hospital Barmherzige Schwestern Ried,
Austria

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Introduction

Severe phototoxic traumata caused either by natural or artificial light may lead to lesions at the level of the retinal pigment epithelium (RPE) with the secondary involvement of the other retinal elements (Uniat et al. 1986). One of the reasons for performing the present study was a communication of Stokkermans et al. (1998). Phototoxic macular (PM) degeneration occurring in 0.14% of ophthalmologic patients. As many as 15% of patients with phototoxic maculopathy reportedly were welders.

Phototoxic maculopathy has been documented thus far in casuistic reports only. Studies comprising representative patient numbers have not been published yet. Phototoxic maculopathies have been described in Welder's in spite of their alleged adherence to all safety regulations (Arend et al. 1996). Consequently these reports roused the question as to whether the current safety regulations are adequate or need to be improved.

Actinic mechanisms of damage appear to be the main factors responsible for phototoxic maculopathy. Such damage largely occurs in the wavelength range of 400–500 nm. Ultraviolet (UV) light (100–400 nm) is absorbed by the cornea and the lens while visible light and infrared light radiation (400–1400 nm) penetrate to the retina (Brittain 1988). The photochemical cascade of reactions may release free radicals, hyperoxide anions and hydrogen peroxide, which may react with the tissue and membranes to form aldehydes when these substances are not degraded promptly. Several mechanisms are existing to prevent a phototoxic injury, including molecular detoxification, antioxidants and lipofuscin deposits (Denk et al. 1997).

In case of a severe phototoxic trauma individuals develop a so-called photoelectric keratitis, also known as the ''Welder's eye'' some hours following exposure. It is associated with pain and foreign body sensation. In the early stage, these symptoms may mask PM. Subsequently some patients develop phototoxic maculopathy with metamorphopsias and relative central scotoma (Kozielec et al. 1997). Phototoxic maculopathy has been observed to be partially reversible in some cases while persisting poor visual acuity (0.3 to 0.6) was reported in others (Fich et al. 1993).

The multifocal electroretinography (MERG), a sensitive method to determine retinal damage was used in order to document objectively the sequelae of possible light—damage. Functional retinal deficits can be demonstrated by MERG in the absence of subjective complaints and in the absence of visible retinal changes.

Methods

We examined a group of 170 male subjects from a large metal manufacturing enterprise. The experimental group consisted of 89 welders who were working in this occupation for at least 5 years, the control group consisted of 81 age-matched non-welders. Both groups were examined from August 2003 to November 2003. The probands were selected on a random-sample basis. All probands were informed and gave their written consent prior to entering the study. The examination has been performed in accordance with the ethical standards of the Declaration of Helsinki.

Exposed individuals

We examined 89 professional welders who were using arc welding procedures for at least 5 years. Exposure time for all individuals was evaluated. Arc welding applies to a large and varied group of processes including manual metal arc welding, gas tungsten arc welding and gas metal arc welding. In arc welding processes, the joining of metals, or weld, is produced by the heat of an electric arc drawn between an electrode and the workpiece, or between two electrodes. Welding arcs produce an intense source of optical radiation. Ultraviolet, visible and infrared light are the main components of arc welding emission. Each type of welding procedure produces a different focal point of optical radiation. For metal arc welding infrared radiation, for gas tungsten arc welding and gas metal welding UV light is the dominant emission (Tenkate 1998, Okuno et al. 2002).

Other sources of possible phototoxic trauma, such as operating microscope lamps, high-altitude sun or other possible phototoxic sources, were excluded by the medical history.

Control group

The 81 members of the age-matched control group never had been exposed to welding arc light. The exclusion criteria were identical to those of the exposed group.

Medical examination

Clinical examination was performed and a detailed occupational history was obtained for all probands. At the beginning of the study a detailed medical history was documented by means of a questionnaire and personal interviews. The occupational history included the welding procedures, welding-working hours, working conditions and -adherence to the safety regulations.

Ophthalmological examination

The proband's corrected visual acuity (near and distant vision) was obtained. Objective refraction using an autorefractometer was performed; this was followed by subjective alignment for near and distant vision.

The subjects underwent orthoptic examination with a Cover test, test of binocular functions according to Bagolini and Lang I test, to study stereofunctions, test of motility, identifying the dominating eye and a convergence test. By means of orthoptic examinations manifest or latent forms of strabism and amblyopia could be excluded. Slit-lamp examination followed testing at Amsler's grid. For pupillary dilatation cyclopentolate (1%) and viscous neosynephrine (2.5%) was instilled in both the eyes of all patients. Multifocal electroretinography was followed by funduscopy. The MERG is an electrophysiological technique that is designed for evaluation of central retinal function. By presenting stimuli in a pseudorandom sequence, focal retinal responses can be obtained in a short period of time and each response is being relatively free of influences from other stimulated retinal areas. The MERG can reveal localized abnormalities by mapping the central retina in five concentric rings in which ERG amplitudes are reduced and the ERG latencies are delayed (Bearse and Sutter 1996). The Retiscan (Roland Consult) was used for stimulation and recording of the MERG. A total of 61 hexagonal stimuli zones (hexagons) were used for stimulation. The stimulation area was corresponding to a field of 30° of central retina. Stimulus technique was 'm-sequence' (pseudo-incidental sequence of black and white hexagons), which allowed detailed analysis of macular electrophysiologic function. Multiple retinal areas were stimulated simultaneously and independently of each other. Within the central 30°-area five groups of these hexagons were arranged surrounding the centre of the visual field. Sites of equal excentricity in these five groups were averaged and then evaluated according to amplitude and latency. The normal ranges for amplitudes and latencies were defined by calculation of the median and the 95% confidence intervals in each eye of 81 controls (Marmor et al. 2004). Electrodes : DTL (Dawson, Trick, and Litzkow electrode).

Statistical analysis

The statistical packet for social sciences' (SPSS) was used for data analysis. A Mann–Whitney test was used for statistical evaluation of non-normally distributed data.

Results

The mean age of welders was 40.7 years (SD 11.3 years) and that of the control group, 39.4 years (SD 12.8 years). The mean duration of welding work was 21.9 years (SD 10.8 years).

The results of slit-lamp examination, funduscopy and orthoptic examination were unremarkable. No retinal changes in funduscopic examination were observed in welders and controls. No statistical difference of electrophysiological data was found between the group of leading and partner eyes (Table 1).

In both groups, the recordings of the MERG revealed no abnormalities. No significant difference could be proven between the electrophysiological data of welders and controls concerning the amplitude P1 in nV/deg2 for the central rings 1 +2 (Table 2). In the recordings of rings three to five in the right eye welders had slightly larger amplitudes ($P > 0.01$). No significant difference for the left eye could be observed. The analysis of latencies to amplitude P1 in ms (Table 3) showed a value significantly smaller only for ring 1 on the right side in welders compared to controls. All other groups revealed no significant differences. The values observed for the first ring most probably have to be interpreted as incidental. Comparison of the amplitude N1 and the analysis of latency to amplitude N1 also showed no significant difference between the two groups.

Comparison of visual acuity revealed no significant difference between the two groups (Table 4). Ninety percent ($n = 73$) of controls and 60% ($n = 53$) of welders were using spectacles.

In welders no relationship between MERG results and duration of welding exposure could be documented (Fig. 1, Table 5).

Table 1 Sociodemographic data

	Welders	Controls
N	89	81
Age (SD)	40.7 (±1.3)	39.4 (±2.8)
Duration of welding work in years (SD)	21.9 (±0.8)	–
Staff membership (years)	18.4 (±8.8)	10.2 (±7.6)

SD standard deviation

The medical examination showed that three individuals in welders as well as in controls were suffering from hypertension, thus no other notable medical problems could be detected.

Discussion

The present study was designed in order to shed light on the question of welding arc maculopathy. It is essential to determine whether phototoxic maculopathy should be labelled as an occupational disease. In some casuistic reports (Magnavita 2002; Arend et al. 1996), causalities have been postulated between welding and phototoxic retinal damage.

In animal experiments, a significant functional damage of the retinal pigment epithelium could be induced by light exposure (Kawano et al. 2003). A retinal photochemical hazard appears critical without appropriate filters, permitting only short exposure time (Michael et al. 2004). After light exposure of the retina during cataract surgery amplitude decrease of electroretinogram and electro-oculogram (EOG) could be observed (Lessel et al. 1991), the EOG particularly reflecting the phototoxic damages at the level of the RPE.

The results of this study seem to prove that the retinae of the welders did not show psychophysically or electroretinographically recordable or clinical ophthalmologically recognisable sequelae of phototoxicity. No symptom could be related to occupational welding exposure. No statistically significant difference between welders and controls was found. Diffuse macular damage of cones secondary to welding has not shown in the population examined.

The MERG showed a significant difference ($P < 0.01$) in the electrodes of rings 3–5 in the right eye of welders. This finding however, difficult to interpret, does not indicate a phototoxic maculopathy, since the evaluation of the amplitude for the central rings 1 + 2 did not show significant differences between welders and controls. Rings 1 and 2 are corresponding to the foveal area while rings 3–5 are corresponding to the peripheral region of the posterior pole.

The fact that more subjects in the control group were wearing spectacles than welders appears to be related to a 'healthy worker effect'. Welding being a demanding occupation requires excellent visual acuity thus causing some selection influences. All subjects recruited obviously have made sufficient use of their protective equipment[1] during welding. This could explain why our results are in discordance to previous studies. The normal MERG and the the lack of clinical symptoms and signs of phototoxicity are verifying and supporting our conclusions. These facts once more are laying stress upon the importance of correct and regular application of welding shields and other sufficient protective equipment.

[1] Autodarkening protective welding helmets' were not included

Table 2 Amplitude of MERG of welders and controls (nV/deg^2)

Right eye	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Left eye	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Mean controls	89.8	44.8	28.6	18.6	16.0	($n=81$)	96.8	48.8	32.5	20.8	17.4
SD	36.1	19.1	12.1	8.5	7.9		34.4	15.8	10.7	7.2	6.8
Mean welders	97.9	49.5	32.7	21.5	18.7	($n=89$)	106.2	51.5	33.5	22.4	18.8
SD	27.9	12.4	7.2	5.2	4.9		28.6	11.3	7.9	6.1	4.9
Mann-Whitney *U*–Wilcoxon Test *P*	0.15	0.08	0.012	0.004	0.001		0.10	0.20	0.23	0.05	0.02

SD standard deviation

Table 3 Latency of MERG of welders and controls (ms)

Right eye	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5	Left eye	Ring 1	Ring 2	Ring 3	Ring 4	Ring 5
Mean controls	44.00	39.61	38.41	38.24	38.64	($n=81$)	43.94	39.83	38.51	38.65	39.87
SD	3.64	2.29	2.35	3.43	3.07		3.34	2.13	2.42	0.32	4.08
Mean welders	42.72	39.61	38.21	37.74	38.33	($n=89$)	43.33	39.08	38.41	38.20	38.26
SD	3.71	2.91	2.58	2.67	2.86		3.48	3.07	3.39	0.24	4.23
Mann-Whitney *U*–Wilcoxon Test *P*	0.003	0.12	0.53	0.16	0.09		0.16	0.02	0.36	0.57	0.25

SD standard deviation

Table 4 Visual acuity (VA) of welders and controls

Right eye	VA sc distant vision	VA cc distant vision	VA sc close vision	VA cc close vision	Left eye	VA sc distant vision	VA cc distant vision	VA sc close vision	VA cc close vision
Mean controls	1.1	1.1	1.0	1.0		1.1	1.1	1.0	1.0
SD	0.1	0.2	0.1	0.1		0.1	0.2	0.1	0.1
N	(30)	(52)	(18)	(62)		(30)	(52)	(18)	(62)
Mean welders	1.1	1.1	0.9	0.9		1.1	1.1	0.9	0.9
SD	0.1	0.1	0.1	0.1		0.2	0.2	0.1	0.1
N	(49)	(39)	(43)	(47)		(48)	(39)	(43)	(48)
Mann-Whitney *U*–Wilcoxon Test *P*	0.84	0.86	0.10	0.50		0.48	0.86	0.10	0.52

SD standard deviation*VA* visual acuity*sc* sine correctione*cc* cum correctione

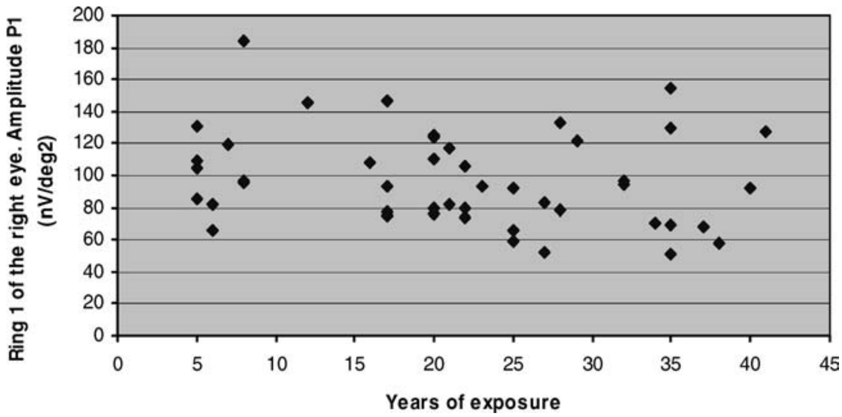

Fig. 1 (Table 5): Amplitude of MERG in ring 1 (nV/deg^2) of welders right eyes and duration of welding work. Normal range amplitude P1: 40–185 nV/deg^2

As a resumé the study presented here is suggesting the following conclusions for the prevention of welding arc maculopathy in occupational medicine:

1. The existing safety regulations in this study were sufficient and the existing protective equipment seemed to be adequate in order to prevent phototoxic damage of the retina.
2. Phototoxic retinal damage in welders may have been attributed to occupational light exposure probably when welders did not adhere to the recommended

safety regulations. In conclusion, welding arc maculopathy should be interpreted as a working accident and not as an occupational disease.

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