Cataracts and avionic radiations

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SUMMARY Nine cases of hertzian radiation cataracts are reported among personnel working in operational aviation environments, where they were irradiated repeatedly at subliminal non-thermal field intensities. The resultant ocular pathology evolved insidiously and slowly over a period of years in a similar way to other forms of radiational injury. By the time of consultation examination, all had progressed to a relatively late state, exhibiting not only capsular cataract but also vesiculation and opacification of the proximal subcapsular lens substance.

In addition to the ocular dangers of chronic exposure to nonionising radiation reference is made to the nonthermal effect or the radiation effect *per se*, as this could relate to general health—for example, as a possible previously unsuspected aetiological or contributory factor in many other disease processes.

Recently, high ambiances of stray nonionising radiation, vernacularly known as 'electronic smog', have been reported as a pervading air pollutant of importance (Bowers and Frey, 1972). Practically everyone in the general population is continuously or intermittently exposed—for example, from telecommunication networks—to field intensities greater than background levels of naturally occurring hertzian radiations (Tunney, 1973). The proceedings of the First International Symposium on the Biological Effects and Health Hazards of Microwave Radiation (Czerski, 1974) contain papers incriminating chronic exposure to hertzian radiation as an aetiological or contributory factor in neurophysiological, hormonal, haematopoietic, immunological, and cardiovascular dysfunction, teratogenesis, mutagenesis, and cataractogenesis.

The full significance of these findings has not yet become apparent to the medical community. With that aside, we will limit ourselves here to some ophthalmic aspects of this subject. First, we would call attention to a brilliantly prescient manuscript about cataractogenesis published more than 50 years ago (Duke-Elder, 1926). Sir Stewart showed that cumulative exposure to radiant energy, including long-term irradiation by sunlight, was the primary or sensitising aetiological factor for most types of cataract acquired during life. The data he presented indicated that rays originating anywhere throughout

the electromagnetic radiation spectrum, from the longest wavelengths generated by electrical oscillations to the shortest wavelengths of ionising radiation, had the property of initiating cataract formation.

Here our attention will be limited to the wavelengths occupying the middle region of the non-ionising portion of the spectrum, that is hertzian radiation, including microwaves and radiowaves. The lens opacities they produce are commonly referred to as microwave cataracts but more properly should be termed hertzian radiation cataracts.

Generally, the ubiquitous nature of electronic smog when coupled to the delayed appearance and slow evolution of signs and symptoms of hertzian radiation sickness present a formidable obstacle for the epidemiologist and militate against any immediate quantitative analysis in studying the hazards of electronic smog. Nevertheless, we can define qualitatively what are believed to be both a special population group at risk and an objective sign of injury by hertzian radiation.

The selected special population group at risk worked in operational aviation, where hertzian radiation has widespread applications in communication, navigation, and radar. For each individual in the cluster being reported, continuing good health was a requirement of the job, and all were obliged periodically to pass medical examinations which included a search for ocular disorders such as cataract and disturbed visual function.

In the absence of history or findings suggestive of prior intraocular inflammatory disease capsular cataract, the sign used as our end point, is an unusual form of cataract in contrast to the ordinarily encountered forms of cataract occurring entirely within the lens substance itself. That microwave radiation may produce capsular cataract was (1) first reported in 1964 in 3 relatively young individuals who tested prototype microwave radiating devices (Zaret, 1964); (2) subsequently confirmed independently in a very young radar technician (Bouchat and Marsol, 1967); and (3) more recently reported in a middle-aged housewife who had used a consumer-type microwave oven for a period of 5 years (Zaret, 1974a).

One of us (M.M.Z.) was consulted about all the cases reported here and confirmed by slit-lamp biomicroscopy that far-advanced capsular cataract was present in at least 1 eye of each subject. Thus, these 9 patients had all worked for a long time in operational aviation environments containing stray hertzian radiation and all developed capsular cataract.

Case reports

Radar technicians. Three patients had been radar technicians who served as in-flight crew aboard EC121 (electronic intelligence) type aircraft. Case 1 was 35 years old when originally diagnosed as having cataracts. Case 2 was 48, and Case 3 was 35.

Air traffic controllers. Five patients had been air traffic controllers. Disturbance of visual function, which occasionally antedates the appearance of lens opacification, is described for 1 of the men. Case 4 was 50 years old when originally diagnosed as having cataracts. Case 5 was 39, case 6 was 52, and case 7 was 39. Case 8 was 48 years old when originally diagnosed as having incipient cataracts in 1970. However, his visual complaints began 3 years earlier, in 1967, with an episode of sudden obscuration of vision while actively controlling some 15 to 18 aircraft. The visual disturbance lasted for several hours. During the following 6 weeks 3 separate ophthalmological examinations, an extensive physical examination, and a neurological evaluation were performed, all without revealing any cause for the visual disturbance.

The patient continued to work as an air traffic controller between 1967 and 1972 despite similar sporadic recurrences of visual problems while at work. Each episode was followed by ophthalmic examinations, by which time visual acuity had improved and was then correctable to 20/20 for distance and Jaeger No. 1 print for near vision. On this basis he was continuously certified as being

able to perform his duties as an air traffic controller despite the fact that potentially dangerous operational situations occurred on many occasions because of intermittently faulty vision. For example, while actively controlling 12 to 15 aircraft in 1971, without realising he could not see them on the radar-scope, the patient lost the position and flight pattern of 2 military jet aircraft in his sector. Fortunately an associate controller noticed that the patient was having difficulty, recognised the danger, and intervened immediately.

Still other examples occurred in 1972 when on each of 2 successive shifts the patient wrongly identified 2 aircraft on the radarscope and in each instance unwittingly directed them into potential mid-air crash patterns. After these near-miss episodes the patient sought a change of job, and he was finally disqualified from working as an air traffic controller because of his difficulty with visual perception. At that time his visual acuity was correctable to 20/20 in the right eye and 20/30 in the left (where an incipient cataract had been known to be forming since 1970 but was not considered by the examiners to be disabling).

Airline pilot. Case 9 was a commercial airman having been certified in 1965 at age 30 and flying since then as a flight engineer, co-pilot, and pilot. In 1971, at age 37, the patient first noticed that his vision became fuzzy owing to glare when light was shining directly into his eyes. However, it was not until late in 1972 that he was found to have an early stage of cataracts, but, as he was still able to see 20/20 with each eye under the contrived dark-room conditions of the visual acuity test, he was approved for flying. He also passed this examination in May 1973. He was not disqualified from flying until September 1973, when he failed the examination because vision then was reduced to 20/40 in his right eye; nevertheless, his left eye was still capable of 20/20 despite the stage of cataractous change clearly evident in Fig. 1. This remarkable photograph, taken with a Kowa retinal camera used as an ophthalmoscope at a distance of 0.5 m and focused on the posterior surface of the crystalline lens, shows many minute areas of opacification of the posterior capsule. Although the patient's visual acuity was normal under the contrived illumination conditions for ordinary visual testing, severe obscuration of vision owing to glare occurred whenever the eye was illuminated from directly in front.

Pathology

The left lens of case 2 became available for histological study after cataract extraction in May

Fig. 1 Photograph of left eye of airline pilot (case 9), with sharp focus on posterior surface of crystalline lens, where extensive capsular opacification is readily observed. Although visual acuity was recorded at 20/20 under contrived illumination conditions for usual testing, severe obscuration of vision due to glare occurred whenever the eye was illuminated from directly in front

1976. Fig. 2 shows the anterior surface of the lens lying behind the iris. Note vacuolation and degeneration of the subcapsular epithelium, including pyknotic nuclei and irregular intercellular spacing. At the external surface of the anterior capsule there is a small remnant of iridial tissue, representing a proteopexic adhesion similar to that described in cataract after exposure to nonionising radiant energy (Zaret *et al.*, 1976).

Fig. 3 is a section at the posterior surface of the same lens. Note the capsule, where there are several discrete vacuolated areas of degenerated lens fibres abnormally adherent to its internal surface. These loci are separated by clear areas where the internal edge of the capsule is free of abnormal adhesions. These histological findings appear to provide an explanation for the honeycomb appearance of the posterior capsule as observed clinically by slit-lamp biomicroscopy.

Discussion

Many features about this cluster of cataract cases should be of concern to all physicians, not only those with special training in ophthalmology, epidemiology, and preventive, aerospace, and occupational medicine, but also others who use

hertzian radiation as diathermy in either consulting room or operating theatre. However, before looking in that direction, the corollary of air safety should be considered.

Simply stated, the techniques of eye examination at present in use to certify operational aviation personnel are inadequate. They fail to identify the early stages of either capsular cataract or visual impairment. Better methods, including some simple new procedures such as testing for entopic glare function and detailed inspection of the lens capsule, should be incorporated immediately into the routine physical examination. Furthermore, in addition to lens opacification, macular and paramacular retinal lesions resembling the residua of subclinical inflammatory reactions have been reported in microwave workers (Aurell and Tengroth, 1973). Case 8 may represent an example of this type of retinal pathology at an early subclinical stage where the visual disturbances are still transient and, therefore,

Fig. 2 A microphotograph ($\times 440$) of the anterior surface of the left lens of EC 121 aircraft radarman (case 2). Note aberrations in lens epithelial cells and remnant of posterior synechia indicating firm proteopexic adherence of iris to anterior lens capsule

Fig. 3 A microphotograph ($\times 440$) of the posterior surface of the same lens (case 2). Note particularly the highly refractile internal edge of the capsule as the site where scattered areas of degenerated lens fibres are seen to be adherent. This correlates with the slit-lamp sign of honeycomb capsulopathy, the earliest clinically recognisable stage of hertzian radiation cataractogenesis

subside by the time the ophthalmic examination is performed.

A few words about acquired capsular cataract may help us to understand some aspects of injury from nonionising radiation. During the nineteenth century capsular cataract was found to occur primarily among workmen in occupations with chronic or repeated environmental exposure to the radiant energy emitted from molten masses of glass or metal. It practically disappeared as a clinical entity during the first half of the twentieth century after it was established as a compensatable occupational disease (Legge, 1907), and employers instituted protective measures—goggles which reduce the transmission of infrared radiant energy.

Capsular cataract was known originally as one form of 'heat cataract' because most earlier investigators accepted the assumption it was caused

by raised intraocular temperature: they did not recognise there could exist a nonthermal radiant energy effect *per se* at infrared band frequencies. The same 'thermal' bias was accepted initially to explain microwave cataractogenesis. However, with the development of a classification of a microwave cataract into acute, subacute, and chronic types (Zaret in Czerski, 1974b) it became apparent that, although acute microwave cataract had a thermal component presenting as a burn of the lens substance, chronic microwave cataract did not. Chronic microwave cataract develops slowly over a period measured in years and follows repeated irradiation at nonthermal intensities; it presents clinically as a gradual degradation of the lens capsule, without any evidence of burn, and resembles a delayed, purely radiational effect. Recently experiments have confirmed that chronic or repeated exposure to hertzian radiation at low field intensities produces changes principally in the lens fibres proximal to the posterior capsule (Williams *et al.*, 1975). Moreover, low field intensity or nonthermal irradiations have been shown to affect adversely hertzian radiation workers (Sadzikova in Czerski, 1974) the immunological response (Stodolnik-Baranska in Czerski, 1974), chromosomes (Heller and Teixeira-Pinto, 1959), and even the molecular structure of DNA and RNA (Frazer, 1976).

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