EARLY HAEMATOLOGICAL DETECTION OF THE EFFECTS OF LOW DOSES OF IONIZING RADIATION IN PROFESSIONALLY OR MEDICINALLY EXPOSED PERSONS

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Abstract

For early detection of the effects of low doses of ionizing radiation in professionally or medically exposed persons, we elaborated the method called by us X-ray resistance of the erythrocytes. We found the haemoglobin level of blood plasma elevated following professional exposure as well as after diagnostic X-ray procedures, therapeutic X-irradiation and internally applied therapic doses of radioactive isotopes. We attributed this elevation to increased erythrocyte membrane permeability and proved it by *in vitro* irradiation of the blood of persons exposed *in vivo* to low X-ray doses. The decreased X-ray resistance of erythrocytes was found to be dose-dependent. Our method is apt to demonstrate the immediate effects of very low doses on the human blood. Thus, it may be found valuable in radiation health control.

Early detection of eventual effects of low-level ionizing radiation in professionally, medicinally or accidentally exposed persons is a problem of outstanding importance in radiation health control. The changes induced by these effects might be functional or structural, or possibly both, and may be detected by various techniques of chiefly biochemical, cytogenetical, cytological and haematological character. The alterations demonstrated by these methods are the so-called biological indicators of radiation damage.

The great majority of the haematological tests are based upon quantitative and qualitative changes of the leukocytes. We, on our part, supposed that the erythrocytes exposed to ionizing radiation in the peripheral blood may also undergo certain changes. Owing to the large mass of erythrocytes these changes should be detected by relative ease.

We studied the membrane permeability changes of the erythrocytes, which could be easily followed by examining the actual plasma haemoglobin concentration. Successive determinations, e.g. before and after exposure, may supply quantitative data concerning the changes of erythrocyte membrane permeability, i.e. radioresistance of the erythrocytes.

Materials and Methods

The examinations were carried out in the following groups:

I. in vivo exposure

1. Seventy persons, professionally exposed to chronic doses of ionizing radiation far below the maximum permissible level, working either in the X-ray machine industry, or in the X-ray department of some medical institution for several years. The examinations were performed in course of routine health control.

2. Fifty persons, treated with therapeutic X-ray doses for various diseases, once or repeatedly.

3. Ten persons treated with therapeutic doses of I-131 isotope for malignant goiter, once or repeatedly.

4/a. Hundred persons, in whom diagnostic X-ray examination of the stomach was performed;

4/b. Thirty-two persons, in whom irrigoscopy was performed.

5. Unexposed, healthy control group.

II. in vitro exposure

Ten ml human blood samples were irradiated in Petri dishes with 25, 50 and 100 R doses, resp., (measured in air) by a therapeutic X-ray machine.

In each case heparinized blood was utilized. In Group 2, the samples were drawn immediately after exposure; in Group 3. both before and 3 to 4 days after I-131 administration; in Groups 4 a. and b. before and after X-ray examination. Plasma haemoglobin determination was performed photometrically.

The in vitro irradiated blood samples derived from the unexposed control group. In vitro irradiation was performed also in the Groups 3. and 4 b.

The results were evaluated by statistical analysis (Student's "t" test) wherever a satisfactory number of data rendered such an analysis possible (See Table I.).

Summarized results of radioresistance in exposed groups

Type of exposure	No.of persons	Elevation of plasma Hb mg %	P
Professional external	70	2.41	< 0.001
Therapeutic X-ray	50	3.09	< 0.001
I-131-therapy, internal	10	0.71 - 1.06	-
Diagnostic gastric X-ray	100	1.16	< 0.01
Irrigoscopy	32	statistically insignificant	

In Groups 1. and 2. the results were compared with those of the unexposed controls, whereas in Groups 3. and 4. the difference between plasma haemoglobin level before and after exposure has been calculated.

Results

Group I/1: in professionally exposed persons a mean plasma Hb concentration of 3.02 ± 0.39 mg% was found, against the value 0.608 ± 0.01 mg%, measured in unexposed controls. The difference is highly significant ($p < 0.001$).

Group I/2: in therapeutically X-irradiated patients the mean plasma Hb concentration was 3.7 ± 0.68 mg%. The difference against the unexposed control group is highly significant ($p < 0.001$); whereas there is no significant difference when compared with the results of the professionally exposed persons.

Group I/3: slight elevation of the plasma Hb level was found on day 4. after I-131 (mean: + 0.71 mg%). The elevation was somewhat more marked in those cases where the therapeutic doses of I-131 were applied repeatedly (mean: + 1.06 mg%). The difference became more pronounced when irradiating the blood samples *in vitro* with 50 and 100 R X-ray doses (25 R: no effect). Particularly high was the elevation following *in vitro* 100 R X-irradiation, in cases of repeated isotope administration.

Group I/4 a.: the mean difference between plasma Hb values in samples taken before and after gastric X-ray examination was +1.16± ± 0.036 mg%, highly significant ($p<0.01$). The difference was also highly significant between the mean results of X-ray examinations when reducing the intensity of electric current from 4 mA to 1-2 mA by the use of an amplifier and TV set (mean: +1.35 ± 0.14 mg% against +0.69 ± 0.083 mg%).

In those cases where the plasma Hb determination was repeated 3 days after the gastric examination, we found values almost on the level of the basic (pre-exam.) ones. Thus, the decrease of erythrocyte radioresistance, induced by gastric fluoroscopy, seems to be reversible[1].

Group I/4 b.: irrigoscopy exerted no demonstrable effect on erythrocyte membrane permeability. Similarly, no differences were found after *in vitro* X-irradiation as to the samples from the unexposed control group.

Groups I/5 and II.: the plasma Hb values of the control group were already cited in comparison with the groups of exposed individuals. The plasma Hb elevation, induced by *in vitro* 25, 50 and 100 R X-irradiation, resp., are represented by Fig. 1.

Discussion

The level of plasma Hb in the peripheral blood is fairly constant; apart from the haemolytic diseases only severe physical stress is known to induce its significant elevation. Its increase is generally attributed to partial haemolysis, induced by increased erythrocyte membrane permeability, that may be caused also by high doses of *in vivo* or *in vitro* irradiation[2,3,4,5,6]. The results of our examinations seemed rather surprising, since these were obtained in the majority of cases after exposure to low-level doses.

When analysing plasma Hb elevation found in the various groups, exposed under a variety of circumstances, it seems rather obvious that the changes were developing during exposure to ionizing radiation exerting a direct effect on the erythrocytes in the circulation. Particularly convincing seems the comparison of the effects of the two diagnostic procedures (Groups I/4 a. and b.). During gastric X-ray examination large vessels (e.g. abdominal aorta, v.cava, v.portae) and organs of considerable blood content are included in the observation field that are passed several times by

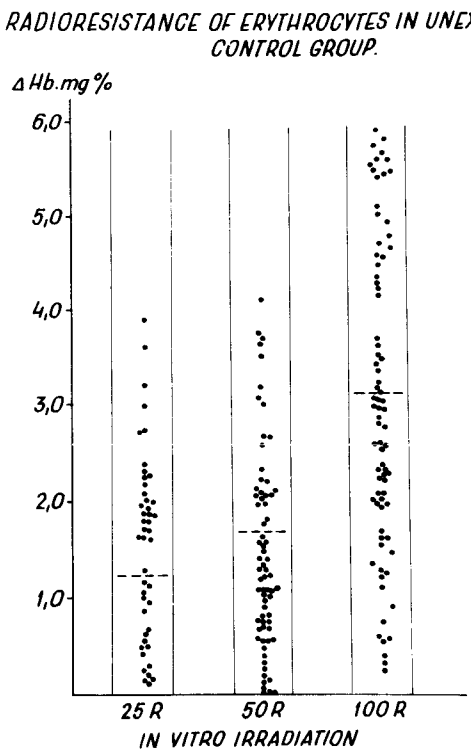

Fig. 1

the blood stream during the time of exposure. Here a significant rise in plasma Hb values was found. In course of irrigoscopy, however, only the a.iliaca and eventually a small section of the abdominal aorta may be exposed. Here the plasma Hb values remained unaltered.

We attribute also the elevation of plasma Hb concentration, induced by low-level chronic, or acute, in vivo and in vitro exposure to ionizing radiation from external or internal sources, to the increase of erythrocyte membrane permeability, in other words, to the decrease of erythrocyte radioresistance. This alteration may be due to changes of intracellular enzymatic activity[7], or to red cell lipid autooxidation. According to Dormandy[8], the susceptibility of erythrocytes, even to atmospheric oxygen, can be considerably increased in this respect by their preliminary exposure to ionizing radiation, producing free radicals, particularly in the blood, the organ of highest water and oxygen content.

Until now, we failed to establish any correlation between the dose of radiation, from external or internal source, or the duration of exposure in professionally involved persons and plasma Hb elevation. The dose-dependence, which was clearly manifested in the in vitro irradiated blood samples, justifies the hope that the method elaborated by us may be further developed, and will become a useful biological indicator, in a true quantitative sense, of radiation effect due to low-level ionizing radiation. Presently, the method is already apt to demonstrate the immediate as well as the chronic effects of very low doses on the human blood. Thus, it may be found valuable in radiation health control.

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