Methodical approaches to estimate health risk under prolonged and chronic long term exposure to ionizing radiation

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Introduction

The many year investigation summing results of different groups of people employed (or lived) in different conditions of long term chronic repeated exposure to ionizing radiation sources are analyzed, which investigations were participated by author. The clinical data interpretation was comprised with exposure levels of external and internal exposure sources (A.K. Guskova, G.D. Baisogolov, N.D. Okladnikova, A.V. Akleev, M.M. Kosenko, I.I. Kiroushkin et al) as well as health effects in different groups of different dose levels and dose rates. Early effects are revealed including these of subclinical shifts of the status of most radiosensitive and critical body systems to manifested forms of chronic radiation sickness (CRD) and its different variants (classificated by G.D. Baisogolov, A.K. Guskova, 1969).

Materials of original studies of different occupational groups (atomic industry personnel, personnel of research reactors and industrial reactors and cyclotrons, medical x-ray technicians, etc.) were compared to literature references on radium project and health data in personnel of atomic power plants and other facilities of different countries.

Basing upon these comparisons the approximate dose thresholds were determined to induce clinical manifestations in hemopoiesis and adaptive system reactions (nervous system, cardiovascular system, endocrine system) specific to CRD. The termination of irradiation or sharp decrease of its rate to 5 cSv/year have resulted to regress of the indicated manifestations (or to its prophylaxis in case of exposure below the dose threshold), which was evaluated to be the major therapeutic prophylactic measure of the system of human protection against chronic exposure.

Some data are also provided (G.D. Baisogolov, V.N. Doshenko, N.A. Koshurnikova, V.F. Khokhriakov, N.D. Okladnikova) on late effects of chronic exposure (leukemias, solid cancers) and outcomes of chronic radiation sickness syndromes (A.K. Guskova, G.D. Baisogolov, V.N. Doshenko, T.V. Azizova, N.D. Okladnikova) for the observations within terms of up to 40 years.

Materials and Methods

The basis of present study consists in:

- materials of long term dynamic observations (1949-1999) in personnel of the first atomic industry facility of the former USSR (“Mayak” Productive Association), which observations were published in a number of clinical references (G.D. Baisogolov, A.K. Guskova, V.N. Doshenko, E.A. Emanova, V.K. Lemberg, N.D. Okladnikova, N.A. Koshurnikova);
- data of observation materials in people used the radiation sources for research, medicine and different branches of industry (A.K. Guskova, E.A. Denisova, V.A. Soldatova, N.I. Gorbarenko, V.V. Sokolov, I.A. Gribova, A.A. Losev, G.I. Kirsanova, A.V. Barabanova et al);
- information on exposure levels and health status of large groups of public lived in the radioactive fallout area of “Mayak” atomic facility for a long time (V.L. Shvedov, A.V. Akleev, V.I. Kiroushkin, M.M. Kosenko, V.N. Romanov, L.A. Ilyin, L.A. Buldakov).

The investigation methods include:

- complete dynamic observations done within the process of directed out-patient examinations in local medical facilities;
- field missions of teams of clinicians and laboratory technicians;
- medical examination at the employment (personnel) or at early terms of the period of the accumulation of major portion of dose (population of reas near by to the release source);
- selective in-patient examination of people exposed dynamically using specific techniques for the evaluation of critical organs and systems (biopsy and trepan biopsy, cytogenetic examinations of peripheral blood, pulmonary function examination, examinations of nervous system and blood circulation system, etc);
- epidemiology study of oncological effects in cohorts of most unfavorable radiation exposure conditions (1949-1958 period of “Mayak” personnel operation; living in upper stream of Techa river at the period of 1949-1952 when maximum radionuclide contamination was observed);
- correction and forming of databases both on the exposed persons and on their progeny (children, grandchildren);
- selective scientific generalizations on most actual problems including: CRD syndromes, cancer and leukemia epidemiology, radiation input to the totality of risk factors of some somatic nervous

diseases (ischemic heart disease, stroke, bronchi-pulmonary diseases) etc;

- correction and retrospective reconstruction of dose values done together with physics dosimetry specialists for different radiation factors and their spatial temporal distribution versus terms of clinical effect revealing.

Results and Discussion

1. One of regions of most complete and careful monitoring of radiation situation is the near by area of :Mayak" PA. According to system adopted in Russia the following zones are separated: industrial zone, sanitary protective zone and so-called zones of surveillance (outside the sanitary protective zone). The routine and accidental releases of the facility are taken into account including non-radiation (other) contaminants as well as the number of population and possible levels of the exposure.
2. The most complete data are related to the professional cohort employed at most unfavorable years (highest doses), which cohort has demonstrated the development of occupational diseases of different forms. Table 2 shows the number of personnel of different technological factories, average gamma doses and average internal exposure doses of Pu. Table 3 shows the substantiation of chronic radiation sickness diagnosis, its major manifestations and outcomes after the termination of the exposure. Table 4 compares the data of initial pre-employment medical examination versus the dynamics of manifestations at the CRD forming period and at follow up terms.
3. Figures 5 and 6 provide data of dynamic observation (35 years) of the leukocyte and thrombocyte counts (in % of initial level of 100%) in CRD patients of different cumulative doses (≤ 2 Gy, 2.01-4.00 Gy and >4 Gy) and maximum annual doses of 0.5-1.0 Gy, 1.01-1.5 Gy, 1.51-2.0 Gy and >2.0 Gy. The differences in depth, decrease & increase terms of indices are obvious.
4. Tables 7-9 illustrate the 20 year quantitative dynamics of the thrombocyte counts, total leukocyte counts and separate counts of granulocytes and lymphocytes in 659 persons undergone to chronic exposure of different cumulative dose ranges (30 cSv, 50-100 cSv and 50-150 cSv) and of different annual dose rates (from ≤ 5 cSv/year to 10-25 cSv/year). One can see that confident shifts of examined indices were not observed. This finding confirms that the threshold dose for the bone marrow syndrome development in case of CRD is above 2.0 Gy of cumulative dose with 0.25 Gy/year of dose rate.
5. Figures 10 and 11 based upon the comparison of two groups of similar cumulative doses accumulated within different periods of time for revealed CRD (major group) and people without CRD (control group) confirm the basic statement on the importance of the rate of the accumulation of cumulative dose (its high rate within short period of time) to reveal CRD symptoms. The comparison group (Figure 11) was predominated by people of large term of work (~ 20 years).
6. Table 12 provides data on maximum annual doses and maximum cumulative doses, when the regular development of CRD neurological syndromes have been observed. The increase of dose versus the increase of the severity of neurological manifestations is visible. Similar regularities are specific to the development of early manifestations of the cerebral blood circulation insufficiency (Figures 13 and 14). The regular relationship of the rate and character of brain strokes versus the radiation exposure was not found, although the CRD group was more aggravated by other risk factors too (Figure 15).
7. The number of people, their collective and average individual doses were assessed for different terms of the involvement into accidental situations. The cohorts of low average doses (<100 mGy) accumulated within different terms of contact with sources (Table 16) dominate. However, considering non-threshold most conservative hypothesis the collective doses and incidence rate of excess tumors if compared to the spontaneous rate were calculated. One can see that even for such (worst) assumption these excesses can be below 3.1% in the accidental zone of strict monitoring for the cohort of 273,000 of people.

Conclusion

The assessment of chronic exposure effects in human is very complex because of the following circumstances.

- The exposure intensity has been significantly changed and, usually, the periods of exposure were short and have been replaced by long periods of complete termination of the exposure or sharp decrease of the dose rate if the contact with radiation source persisted.
- To evaluate the process dynamics both at the period of accumulation of major part of cumulative dose and at the following periods it is necessary to arrange long term observation within many years. The influence of other competitive risk factors is obvious in such case. The observation group was selectively changing too. It makes the effect interpretation more complex, which effects are of polyetiological character.

The difficulties of the selection of the adequate control are also obvious.

- Threshold dose values and dose rates of chronic exposure when the forming of hematological and neurological syndromes of CRD has occurred were reached at the start-up period of the atomic

industry of the former USSR only. Their determination and verification applying different medical techniques correspond to the level of medical methodology of 50th . It makes their comparison to the contemporary diagnosis criteria more difficult and forces the investigator to apply concepts and terms adopted at that time to keep the sense of successor.

- The recovery processes were completely clear for radiation syndromes essentially, if the exposure rate has been decreased. However, the significant increase of the average age occurred within many years of observation together with other factor influences within these years have caused the significant distortion of the health of the examined population at follow up period. The complex problem occurred for the establishing of the radiation factor input on the background of influences referred above and specific for the general public of the country (region) of the correspondent age, sex, ethnic group and calendar period.
- It was shown that late effects of chronic exposure (leukemia, cancer) the statistically confident importance of their rate shifts can be only reached for the specific dose range though lower than that for direct effects determined by radiation (different CRD variants induced by homogeneous and heterogeneous radiation). This finding coincides with RERF data on A-bombing effects.
- The generalization of materials on chronic exposure effects should be accepted as one of most actual directions of clinical radiobiology for near future years due to the widening of contingents of such exposure type.

References

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