Principles of medical rehabilitation of survivors of acute radiation sickness induced by gamma&beta and gamma&neutron radiation

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Medical rehabilitation is one of most important components of medical care provided in case of any accident. It is essential for radiation accident not only for early radiation effects but also for late effects of radiation.

Many years of medical care providing in radiation accident victims have given the experience of five decades of the atomic industry existence, which experience has resulted to the significant success of the therapy at acute period (bone marrow form) of the acute radiation sickness (ARS). The application of complex massive antibiotic therapy, aseptic conditions, gross factors, thrombocyte mass transfusion etc. has provided the significant increase of the patient survival. However, at the follow up period the consequences of the survived acute radiation damage often cause the disability and necessity for repeated expensive therapies and strongly decrease the quality of life of the ARS survivors.

MATERIALS AND METHODS

Many years of dynamic observation of survivors of ARS of different severity grades provided by the clinical department of State Research Center of Russia – Institute of Biophysics include 92 patients of $\gamma\beta$ exposure and 21 ARS survivors of accidental $\gamma_n$ exposure. The distribution of patients versus ARS severity grades is given by Figures 1 and 2.

![ARS diagnosis structure for gamma&beta radiation victims](image1)

![ARS diagnosis structure for gamma&neutron radiation victims](image2)

Figure 1. ARS diagnosis structure for gamma&beta radiation victims

Figure 2. ARS diagnosis structure for gamma&neutron radiation victims

Age characteristics of patients are given in Table 1.
Table 1. Patient groups versus ARS severity grades, kind of radiation and ages at the moment of accident and at the moment of last clinical admittance

<table>
<thead>
<tr>
<th>ARS grade</th>
<th>Gamma &amp; beta exposure</th>
<th>Gamma &amp; neutron exposure</th>
<th>Number of patients</th>
<th>Average age at the moment of accident (years)</th>
<th>Average age at the moment of last observation (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>31</td>
<td>5</td>
<td>31.91 ± 2.49</td>
<td>50.5 ± 3.9</td>
<td>31.0 ± 4.46</td>
</tr>
<tr>
<td>2</td>
<td>46</td>
<td>6</td>
<td>35.13 ± 3.34</td>
<td>51.3 ± 3.6</td>
<td>30.83 ± 4.67</td>
</tr>
<tr>
<td>3</td>
<td>14</td>
<td>10</td>
<td>37.43 ± 7.52</td>
<td>52.4 ± 8.27</td>
<td>30.8 ± 3.48</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>25</td>
<td>38</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2. Rates of most severest late effects in observed ARS survivors

<table>
<thead>
<tr>
<th>Late radiation effect</th>
<th>Gamma&amp;beta exposure</th>
<th>Latent Period (min-max), years</th>
<th>Gamma&amp;neutron exposure</th>
<th>Latent Period (min-max), years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin LRI</td>
<td>36 (39 %)</td>
<td>3-13</td>
<td>10 (47.3 %)</td>
<td>21-36</td>
</tr>
<tr>
<td>Radiation cataract</td>
<td>14 (15.2 %)</td>
<td>3-39</td>
<td>13 (61.9 %)</td>
<td>10-35</td>
</tr>
<tr>
<td>Malignant neoplasm</td>
<td>6 (6.5 %)</td>
<td>4-38</td>
<td>5 (23.8 %)</td>
<td>17-32</td>
</tr>
<tr>
<td>Benign neoplasm</td>
<td>12 (13 %)</td>
<td>1-37</td>
<td>9 (42.8 %)</td>
<td>1-34</td>
</tr>
</tbody>
</table>

Observation materials were compiled into the database. Standard software applications of Microsoft Office-97 were applied to process these data.

RESULTS

Major medical problems of the follow up period after gamma&beta and gamma&neutron exposure are the consequences of local radiation injuries (LRI) including radiation skin burns and radiation cataracts, which are often accompanied by concurrent somatic diseases with early revealing and radical therapy of neoplasm [1-5].

Many years of the dynamic observation of patient group exposed to radiation resulted from the Chernobyl accident, which patients have survived ARS and severe beta burns of skin have demonstrated that the expressiveness of local radiation injuries is directly proportional to the severity of injury i.e. to the exposure dose (Figure 3).

![Figure 3 LRI outcomes versus skin damage severity grades at the follow up period](image)

The kind of damaging radiation determines some specific features of the LRI clinical course due to the peculiarities of the biological effects of neutrons. The larger input of neutrons to the exposure dose the more difference is observed for developing radiation injury if comparing to the injury induced by gamma radiation only.

Most expressed differences were predominantly observed for earlier development of all symptoms of the acute phase. These symptoms include more expressed and peculiar damage of the subcutaneous cellular tissue (larger...
depth and more expressed edema) and more expressed vascular component.

The persistence of the primary erythema and, essentially, the addition of tissue edema certify to the significant severity of damage, which are the prognostic signs of the danger of the development of early necrosis and serious aggravation of the patient status with development of endogenous intoxication signs. In case of such injuries occurred at early terms the problem on the convenience of plastic microsurgery or early amputation of the extremity or its segment has to be judged.

In the observed group of gamma&neutron exposure patients (21 patients) five patients have got amputations at late terms due to the persistent relapses of late radiation ulcers, their infection and severe pain syndrome.

In is necessary to indicate to the fact that all gamma&neutron accidents have happened before 1986 and the problem of the extremity amputations was solved at that time too. Probably, such large number of amputations (23.8%) was related to the insufficient development of microsurgery techniques at these early times.

Basic principles of the LRI therapy at the follow up period include the following:
1. Improvement of the reparative processes of damaged tissues;
2. Control of the concurrent infection if late radiation ulceration is present;
3. Surgery applied in case of the imperfect reparation of tissues.

Surgery treatment of severe and extremely severe acute LRIs at the follow up period is the one of major techniques of the combined therapy [6-8]. If ulcers and necrosis were revealed, it is necessary to start active surgery. To eliminate anatomical changes and defects of tissues the following types of surgeries have to be applied:

1. Necrectomy with skin grafting including:
   a) free non-splintered grafts;
   b) moved full-layered grafts with pedicle;
   c) cutaneous muscular grafts with vascular pedicle (microsurgical technique).

Transplantation of free non-splintered graft does not prevent the development of secondary radiation ulcers and chaps. The transplantation of full-layered graft with pedicle is directed to eliminate scar contractures and to repair the function of joint. Application of most modern techniques of plastic surgery (microsurgery) to treat the extremely severe LRIs is very perspective concerning the degree of saving of large segments of the body if compared to previously applied techniques. The coverage of the defect is provided by full-quality grafts after the wide early necrectomy, which has to improve the nutrition of the residual tissues and to decrease the probability of the trophic disturbance development due to the autonomous blood circulation [9].

2. Transplantation of skin grafts on the ulcer defect without preliminary dissection of the ulcer is indicated if LRI is localized in the face, hand fingers or if the bottom of the ulcer is comprised by major arteries, nervous trunks or ligaments. The best terms to do such surgery is the period of the complete cleaning of the ulcer from necrotic masses and occurrence of bright red juicy granulations. The surgery consists in the coverage of the ulcer defect by the transplanted full-layered skin graft with pedicle. The experience has shown that transplantation of free splintered skin grafts does not completely prevent the relapse of late radiation ulcers.

3. Amputation of the injured segment of the extremity should be done in case of the dry gangrene and wide necrosis of soft tissues with bone naked. The amputation level depends upon the site and volume of the destruction process and on the possibility to create most favorable conditions for full-quality stump taking into account the possibility for future prosthesis.

The other severe consequence of the survived skin LRI is the radiation fibrosis. The experience of the researcher group of Professor R. Peter is interesting, when they inform on the successful conservative therapy of the radiation fibrosis developed after gamma&beta exposure, which success has been reached by pentoxyphillin and polypheron administration [10,11].

The specific importance for improvement of the patients life quality, if these patients have survived LRI of moderate and severe grades is the daily care with life span application of different topical medications to improve the status of injured skin sites (different vitamin creams for softening, nutrition and moisturizing of skin) as well as the balneology therapy (hydrogen sulfur baths). The essential importance consists in the comfortable functional prosthesis in patients with extremity amputation. Analgetics have to be prescribed in case of phantom pains.

The development of radiation cataract induced by gamma&beta exposure is described by the inverse linear dependence of latent period duration versus radiation dose (Figure 4). The minimum exposure dose, when the radiation cataract development has been observed is 2 Gy. Besides, these cataracts were observed more frequently to be stable and they need surgery more rarely.
The basic feature of cataracts induced by gamma&neutron exposure is the relatively more rapid occurrence without dose dependence (within first 3.5 years after the accident) (Figure 5) and relatively rapid decrease of vision ability as well as the large number of complications accompanying the development of radiation cataract. Routine surgery for artificial lens transplantation repairs the vision and represents large importance for rehabilitation.

Peripheral blood changes at the follow up period are usually multi-directed, moderate and transient and they do not comprise the separate therapeutic problem. In such cases when these changes are relatively stable (leukopenia and neutropenia, essentially) they are usually corresponded to the concurrent diseases (chronic hepatitis, ulceration disease, hereditary neutropenia, etc.). The persistent moderate leukocytosis is usually related to the presence of the late radiation ulcers infected.

Generally accepted viewpoint consists in the oncogenic action of radiation of large doses. Even small excess (1-2%) from the natural oncological morbidity of the population, which excess is resulted from ionizing radiation exposure has to be compensated by timely diagnosis and effective therapy of the revealed diseases. Therefore, ARS survivors undergone to the annual oncological in-patient examination. List of neoplasms found in the observed patients is given in Tables 3 and 4.

The dissemination of skin neoplasms (basalioma and papilloma) should be addressed. Other observed tumors had different localization, so the in-patient oncological examination has to cover the possible maximum of organs and systems.

With the time course the concurrent somatic diseases becomes more and more important for the patient
disability; according to our observations, these concurrent somatic diseases does not have the relationship to the radiation dose and their structure is not different from that for non-exposed population of Russia. The structures of the in-patient morbidity for different kinds of radiation exposure (gamma&beta or gamma&neutron radiation) are similar. Cardiovascular system diseases, GIT diseases, bone-muscular system diseases and nervous system diseases and mental diseases dominate [12]. Probably, the mental disease occurrence relates to the psychological stress (social life disadaptation, radiophobia, expectation of the development of serious disease). Correspondingly, the system of out-patient surveillance has to take into account these data to substantiate prophylaxis measures in these patients.

CONCLUSION
Thus, the rehabilitation of ARS survivors of radiation accident has to be directed to the recovery of functions of organs and systems critical to ionizing radiation; the disturbance of these systems results to the decrease of health level and work ability. The prophylaxis and therapy of concurrent diseases have to be properly addressed too. The rehabilitation measure complex has to include:

1. general supportive therapy together with psychological correction, which have to mitigate the expressiveness of asthenic and vegetative signs and to change the social motivation of patients;
2. prophylaxis and therapy of late consequences of skin LRI;
3. surgical treatment of radiation cataracts;
4. early reveling and radical therapy of tumors;
5. therapy and prophylaxis of concurrent somatic diseases;
6. rational employment of patients and their return to active social role in family and society.
### Table 3 Neoplasms of ARS survivors of gamma&beta radiation.

<table>
<thead>
<tr>
<th>Accident</th>
<th>Number of accident victims</th>
<th>Total number of malignant neoplasms</th>
<th>Nosology forms</th>
<th>Latent period duration (years)</th>
<th>Total number of benign neoplasms</th>
<th>Nosology forms</th>
<th>Latent period duration (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td></td>
<td></td>
<td>Chronic myeloleukemia</td>
<td>4</td>
<td>12</td>
<td>Uterus myoma</td>
<td>1</td>
</tr>
<tr>
<td>1969</td>
<td></td>
<td></td>
<td>Hypernephroma</td>
<td>6</td>
<td></td>
<td>Kidney cyst</td>
<td>2</td>
</tr>
<tr>
<td>1956</td>
<td></td>
<td></td>
<td>Cancer of low lobe bronchi (left)</td>
<td>21</td>
<td></td>
<td>Skin basalioma</td>
<td>12-38</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Skin basalioma</td>
<td>12-38</td>
<td></td>
<td>Liver hemangioma</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Papillomas</td>
<td>3-37</td>
<td></td>
<td>Skin hemangioma</td>
<td>7</td>
</tr>
</tbody>
</table>

### Table 4 ARS patient neoplasm (gamma&neutron exposure)

<table>
<thead>
<tr>
<th>Accident</th>
<th>Number of accident victims</th>
<th>Total number of malignant neoplasms</th>
<th>Nosology forms</th>
<th>Latent period duration (years)</th>
<th>Total number of benign neoplasms</th>
<th>Nosology forms</th>
<th>Latent period duration (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Different Accidents In 1953-1978</td>
<td>21</td>
<td>5</td>
<td>Ependioma of the front lobe of the right hemisphere of brain</td>
<td>17</td>
<td>9</td>
<td>Multiple nevuses</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Skin basalioma</td>
<td>22-32</td>
<td>uterus fibromyoma</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tongue cancer</td>
<td>unknown</td>
<td>Skin papilloma</td>
<td>20-23</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lipomas</td>
<td>28, 28</td>
<td>Kidney cyst</td>
<td>30-34</td>
<td></td>
</tr>
</tbody>
</table>
REFERENCES


N.M.Nadejina, I.A.Galstian, A.A.Savitsky, J.N.Rtisheva, I.V.Uvatcheva, O.G.Kashirina. Late radiation effects of ARS in victims of different gamma&beta and gamma&neutron accidents. IRPA-11, (May 2000), Hiroshima, Japan.