Diagnostic Criteria for Assessment by General Practitioners of Patients Injured in Radiation Incidents and Cases of Radiological Terrorism

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ABSTRACT

The general practitioner is an important figure in the provision of medical care during radiation incidents and cases of radiological terrorism. Knowing the nature of the radiation injury is essential for correct diagnosis and treatment. Insufficient knowledge of most physicians, and of general practitioners in particular, on the clinical manifestation of radiation injuries is the reason such conditions remain unrecognized and improperly treated. We suggest some simple diagnostic criteria for assessment of the injured by general practitioners, based on the results of our own studies and on the recommendations of prominent international organizations. (*Disaster Med Public Health Preparedness*. 2018;12:507-512)

Key Words: general practitioners, radiation incidents, diagnostic criteria, medical care provision

Since the discovery of ionizing radiation in 1895, our knowledge of its harmful effects is growing constantly. Despite significant developments in radiation protection practices, incidents with sources of ionizing radiation do happen. Their wide application in medicine, agriculture, industry, and science makes it possible for these sources to be lost, stolen, or left unattended, with a real possibility of injuring persons in contact. There has been a growing number of incidents in recent years, and the possibility of radiological terrorism seems most alarming.[1-6] The multiplication effect—fear of terrorism and fear of radiation—makes the probability of committing acts of radiological terrorism very high.[7-10] The most probable scenario considered is the spread of radioactive material (dirty bomb) in the central part of a large city.[6,11-15] The act of radiological terrorism itself can be defined as one that has been caused deliberately and conscientiously. Essentially, this means that we must use the experience gathered from preceding accidents for the purpose of providing medical care. Population health effects and medical care provision activities can both be defined based on such previous experience.[6,10,12,16-18]

Exhaustive document analysis of preceding radiation incidents shows that, frequently, the first physician examination of the survivors is performed by general practitioners.[19,20] The main reason radiation injuries remain unrecognized is insufficient knowledge on the consequences of radiation exposure and their clinical manifestations. This leads to improper and, in some cases, outright erroneous treatment of victims in the early hours after the incident. Thus the health condition of the survivors deteriorates further, and the opportunities for later effective treatment are limited.[7,11,17,18,21-23]

We believe that for these reasons, general practitioners are in need of clear and precise diagnostic tools applicable in the field as well as criteria for long-term follow-up of the survivors. Long-term medical aid is needed for several specific reasons: to provide information about the gravity of health effects, to diagnose early the radiation-induced health effects, to forecast the necessity for further medical and psychological aid, and to provide answers to people who express fear or anxiety.[24,25]

RESEARCH OBJECTIVES

The aim of the study is assisting general practitioners involved in the provision of medical care during radiation incidents and cases of radiological terrorism through the adoption of simple and clear criteria for long-term follow-up. Such criteria can only be adopted following the analysis of the general practitioners' competence in the field and their preparedness to be entrusted with additional responsibilities. It is important to note that, in Bulgaria, the general practitioner fulfills the role of a family physician, and thus naturally represents the point of first contact for a patient with the national health system.

MATERIALS AND METHODS

We performed a thorough document analysis of data from preceding radiation accidents, existing emergency plans, emergency drills, and recommendations of prominent national and international organizations concerning the participation of general practitioners in emergency medicine.

We utilized a cross-sectional study design, gathering information about the knowledge, skills, preparedness, and systemic education of general practitioners to take part in the provision of medical care to the population during radiation incidents and cases of radiological terrorism. We formed a representative sample of general practitioners in the city of Sofia. We created a simple random sample from the register of general practitioners in Sofia using a random numbers generator. The 400 general practitioners included in the study formed a 45% relative share out of 890 total shares with a SE of 2.5% and a 95% CI (40.1%-49.9%).

We utilized the following statistical techniques to process the data:

- Mean and standard deviation—as a measure of dispersion—and confidence interval—for interval assessment—for descriptive analysis;
- Pearson χ^2 test, Exact test, and Cramér's V contingency coefficient test for studying interdependencies of descriptive data and for assessing the results already established with the χ^2 dependency test;
- The Z test for comparing relative shares.

DISCUSSION OF RESULTS

Experience from past radiation accidents shows that the general practitioner tasks and responsibilities should be clearly defined. However, our own study demonstrated that relevant guidelines are non-existent. None of our respondents had at their disposal such guidelines. To our question: "Can you define a radiation injury?" only 3% answered positively. Practically all general practitioners felt the need for simplified diagnostic criteria for assessment of the injured—96.3% of all respondents. Data are presented in Figure 1.

In order to establish correct diagnosis and treatment behavior, it is imperative to know the nature of radiation impairment. The traditional approach to provision of medical care with respect to diagnostics, treatment, and prognosis is to base them on the dose received. In light of the complex interaction of ionizing radiation with a biological substance, the dose itself is not sufficient to forecast the degree of impairment of the organism as a whole, or to forecast future clinical developments. Despite a number of undisputable advantages, the unified standardized procedure for diagnosis and treatment of the injured, based on Medical Treatment Protocols for Radiation Accident Victims, which was offered by Fliedner et al. and approved by the European association for bone marrow transplantation, is largely inapplicable for general practitioners.[26-29] Its complex examinations and tests require qualified personnel and high-quality medical technology.

Diagnosing radiation injury from the point of view of general practitioners is relatively complicated, as it has no strictly specific symptoms.[30,31] General practitioners should think of possible radiation injury in patients with nausea and vomiting, especially if accompanied by erythema, fatigue, diarrhea, or other symptoms that cannot be linked to gastrointestinal infections, food poisoning, and/or allergy; in those with skin lesions, where chemical or thermal impairment, insect bite, preceding dermal disease, or an allergic reaction have already been excluded but desquamation, epilation, and erythema dating 2-4 weeks may be observed; and in patients with epilation, hemorrhages (like petechial and nose or gum bleeding), and anamnestic data for nausea and vomiting for 2-4 weeks. According to the International Agency for Atomic Energy, this diagnostic competence is one of the key issues in medical response.[24,31-33] Our results demonstrated that, taking into account the maximum error of representation, it can be safely said that between 26.02% and 35.27% of general practitioners know that this type of impairment produces no specific symptoms (Figure 2).

General practitioners should be aware that exposure to high doses of radiation leads to adverse outcomes, whereas their manifestation and duration are dose dependent. Low doses do not manifest with visible effects. The assessment of the degree of radiation impairment and the respective physician's

FIGURE 1

Percentage Distribution of Answers to the Question: "Do You Feel the Need for Diagnostic Criteria for the Assessment of Injured After Radiation Exposure?"

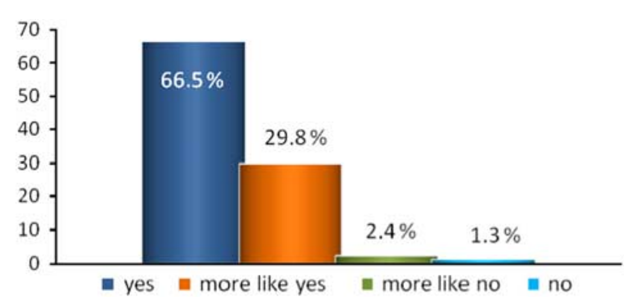
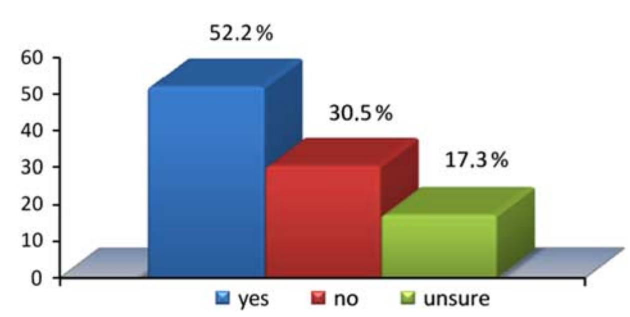


FIGURE 2

Percentage Distribution of Answers to the Question: "Do You Think That Radiation Exposure Manifests With Specific Symptoms?"



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behavior is based on clinical and paraclinical signs.[25,26,31,32,34-40] To the question evaluating the general practitioners' competence in laboratory tests and biologic dosimetry—"Are you acquainted with the relevant laboratory tests and biologic dosimetry in radiation injuries?"—we received unequivocally positive answers from only 11% of our respondents (Figure 3).

We feel that concerning the hematopoietic system, it is sufficient to register only the changes in lymphocyte counts. Their dose-dependent reduction in absolute number in the first 24 hours and the easily preformed automatic count makes them a suitable marker to forecast the degree of the acute radiation syndrome. It should be noted that conventional trauma goes hand in hand with lymphopenia, which makes this marker less suitable in combined trauma. General practitioners must also be aware that the initial leukocytosis is of redistributive nature. Regardless of the radiation exposure dose, during the first 24-48 hours, no erythrocyte, thrombocyte, leukocyte, or neutrophil count decrease in peripheral blood is observed except at high doses.[12,24,25,32,41] If such a decrease is found, the possibility of another underlying condition, like preceding disease or trauma should be investigated. In Table 1 we present the lymphocyte count changes in the initial days following whole body exposure.[12,15,30-32]

If possible, additional lab probes may be obtained in the initial diagnostic stages (although there is no consensus on some of them) as follows, to serve as the basis for development and confirmation of the diagnosis: differential blood count; changes in serum amylase; reduced concentration of serum citrulline as a biomarker of radiation-induced impairment of gut mucosa; increased values of C-reactive protein (CRP); increased concentration of FMS-like tyrosine kinase 3 (FLT-3) ligand, which can be used to assess the severity of radiation impairment. Using blood samples for the cytogenetic study of chromosomal aberrations in peripheral blood

FIGURE 3

Percentage Distribution of Answers to the Question: "Are You Acquainted With the Relevant Laboratory Tests and Biologic Dosimetry in Radiation Injuries?"

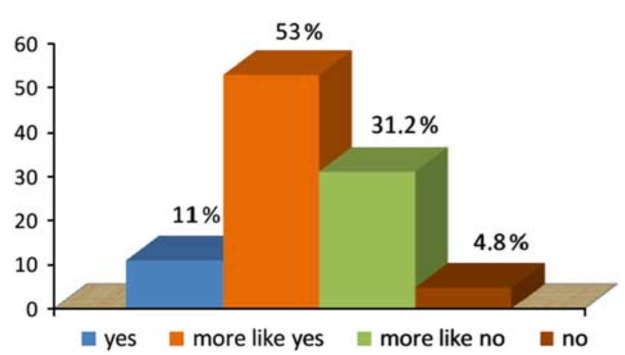

TABLE 1

Changes in the Number of Lymphocytes

Degree	Dose (Gy)	Number of Lymphocytes (g/L)[a]
Light	1-2	0.8-1.5
Medium	2-4	0.5-0.8
Severe	4-6	0.3-0.5
Extremely severe	6-8	0.1-0.3
Lethal	Over 8	Under 0.1

[a]Expressed as 10^9 cells/L.

TABLE 2

Time of Onset and Intensity of Vomiting

Degree	Dose (Gy)	Time of Onset of Vomiting	Intensity of Vomiting
Light	1-2	After 2-3 hours	Once or twice
Medium	2-4	After 1-2 hours	Several times
Severe	4-6	Under 1 hour	Many times
Extremely severe	6-8	After 30 minutes	Uncontrollable

lymphocytes is known as the "gold standard" of biological dosimetry.[24,25,42] The sample preparation is time-consuming and requires highly qualified personnel, including for interpreting results.

Regarding symptoms from the neurovascular system, the ones that are most suitable and of the greatest diagnostic value would be the onset and frequency of nausea and vomiting. These are due to neuro-humoral factors, which are also paramount for their treatment.[15,24,25,27,28,30,32,36] Only 32.7% of our respondents know that vomiting symptoms may serve to assess the gravity of exposure. In Table 2 we present the time of onset and intensity of vomiting in relation to exposure. The appearance of strong pain and bloody diarrhea, as well as having arterial blood pressure (RR) < 90/60, is a poor prognostic sign.[27,31,32,43,44] The remaining symptoms like headache, anorexia, and fatigue are more pronounced with higher doses and dose intensity, but these reactions bear a more individual character, making them less suitable for prognosis. Bodily temperature raise (subfebrile or over 38°C in severe cases) is an additional marker of intoxication, complementing other signs.

Regarding dermal signs, general practitioners should be aware that dose-dependent symptoms are similar to those found in thermal burns, but their time of onset is delayed by several days, and sometimes by more than a week. Reaction from the skin and adjunct tissues develops gradually. The pain increases and is very resistant to treatment. In Table 3 we present symptoms according to dose ranges.[12,24,31,32,37,45-47]

Symptoms resulting from vascular damage in tissues do not become apparent immediately after exposure. The higher the

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TABLE 3

Dose-Dependent Skin Symptoms

Degree	Dose (Gy)	Objective Symptoms	Subjective Symptoms
Light	8-12	Minimal, transient erythema	Itching
Medium	12-20	Mild erythema, swelling, bloating	Light pain
Severe	20-25	Pronounced erythema, swelling, bloating, ulcers	Mild persisting pain
Extremely severe	Over 25	Severe erythema, swelling, hemorrhagic bloating, deep ulcers, necrosis	Severe persisting pain

dose intensity, the earlier the onset is. Any observed hyperemia of the oral and nasal mucosa, sialadenitis, and primary skin erythema are indications of impairment above the average degree. Following local exposure, progressively increasing swelling of the wrists, forearms, knees, and feet may be observed during the first 24 hours. These symptoms point to an exposure of over 15-20 Gy. Total blood count shows mild leukocytosis and increased erythrocyte sedimentation speed.[31,32,37,38,46]

According to the assessed degree of radiation injury, the behavior of general practitioners should be as follows:

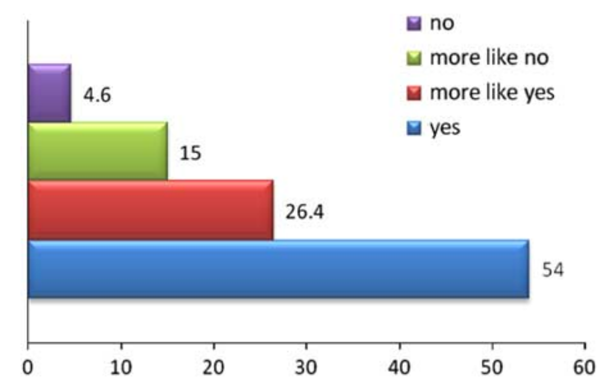
- light—outpatient observation;
- mid to severe—referral to specialized treatment;
- severe and extremely severe—referral to highly specialized treatment.

An important issue for discussion is whether a follow-up of all injured in radiation accidents is necessary.[6] The first problem here is the anticipated risk level. If the risk level was assessed as being lower than the spontaneous frequency of the disease, no follow-up is necessary. In high-risk cases, the onset of follow-up should be relevant to the latency period—2-3 years for leukemia, 3-4 years for bone tumors, 4-5 years for thyroid tumors, and over 10 years for solid tumors. Currently, screening programs are available for breast cancer, genital cancer, and colon cancer. There are no reliable screening tests for radiation-induced leukemia, gastric, and lung cancer. Sufficiently reliable screening methods for thyroid cancer are palpation and echography.

Despite the lack of a definitive answer to whether a follow-up of all victims is necessary, we still believe that defining criteria for post-accident follow-up will increase the probability of early detection of cancer, and thus increase survivability. This belief is shared by the majority of respondents in our study—80.4% of them think they need such criteria (Figure 4).

FIGURE 4

Percentage Distribution of Answers to the Question: "Do You Feel the Need for Specific Criteria for Long-Term Follow-Up of Injured After Radiation Incidents?"



The generally accepted criteria for long-term follow-up of radiation injured are:[6,15,24,25,27,48-60]

- Adults with whole body exposure effective dose of over 200 mSv. Most current research demonstrates the presence of dose thresholds for radiation-induced tumors: 200 mSv for bone marrow, 100 mSv for the thyroid in children, and 500 mSv for all other organs and tissues;
- Children below 18 years with a whole-body effective dose of over 100 mSv. On the basis of analysis of thyroid cancer in children, the UN Nuclear Regulatory Commission considers the possibility of radiation-induced thyroid tumors in children with doses over 100 mSv[20];
- Infants with prenatal exposure of over 50 mSv for the period between 8 and 15 gestational weeks and over 100 mSv for the rest of pregnancy;
- All injured with acute radiation syndrome.

Any deviations found during the follow-up should necessitate consultation with a specialist. Children are in need of specialized thyroid laboratory studies. The results of all examinations and tests should be sent annually to specialized radiobiology centers.

CONCLUSIONS

We reached the following conclusions:

1. General practitioners have their role and place in the provision of medical care in radiation incidents and cases of radiological terrorism.

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2. Our collected and analyzed data make us believe that general practitioners should have at their disposal simplified and clear diagnostic criteria for assessment of the injured.
3. The adoption of criteria for long-term follow-up of the injured will ensure the early detection of radiation-induced cancer and thus improve the patients' survivability.

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