

Medical Preparedness in Radiation Accidents: a Matter of Logistics and Communication not Treatment!

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Abstract

The currently reactor wreckage in Fukushima raised the following important questions: Is our knowledge of the possible dangers of ionizing radiation sufficient to warrant special action? What is the role of the medical community in technical radiation accidents from Windscale to Fukushima? What is the role of the medical community in terrorist radiation attacks? Are we prepared for those challenges? How can medical services communicate information in the media framework? What have we learned recently? And, what should be improved? In this review of the current literature on ionizing radiation, we try to answer these questions. Our conclusion is that medical services have to improve their communication skills and convince the public that the dangers of ionizing radiation can be quantitated within certain limits to support a qualified discussion about its risks and benefits.

Keywords: Mass casualty incidents; Radiation, ionizing; Emergency preparedness; Nuclear power plants; Radiation injuries; Radiation risk; Communication; Logistics

Introduction

The scope of this review is very well described by the definition of “disaster preparedness” provided by *Business-dictionary.com* as the “process of ensuring that an organization 1) has complied with the preventive measures; 2) is in a state of readiness to contain the effects of a forecasted disastrous event to minimize loss of life, injury, and damage to property; 3) can provide rescue, relief, rehabilitation, and other services in the aftermath of the disaster; and 4) has the capability and resources to continue to sustain its essential functions without being overwhelmed by the demand placed on them.”¹

In the context of a radiation accident like the currently experienced reactor

wreckage of Fukushima, we have to address the following important questions:

- Is our knowledge of the possible dangers of ionizing radiation sufficient to warrant special action?
- What is the role of the medical community in technical radiation accidents from Windscale to Fukushima?
- What is the role of the medical community in terrorist radiation attacks?
- Are we prepared for those challenges?
- How can medical services communicate information in the media framework?
- What have we learned recently?
- What should be improved? And,
- Is our knowledge of the possible dangers of ionizing radiation sufficient to warrant special action?

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For most of man's existence, ionizing radiation was an unrecognized natural phenomenon. Soon after its discovery and the capability of man-made ionizing radiation,²⁻⁵ it was recognized that its fruitful medical applications come with some severe adverse effects.⁶⁻⁸

The knowledge of radiobiological effects and their consequent health effects has rapidly grown since then and is now greater than that for most chemicals.^{9,10}

The basic mechanism by which ionizing radiation causes damage to living matter is well known and depends primarily on the energy deposition within the organism and its consequences.

Dose dependent deterministic effects are well defined for moderate to high doses (0.5 to 10 Sv) with an LD_{50/60} at 2.5 up to 5.1 Sv, depending on supportive treatment.¹¹ Stochastic effects, primarily the risk of inducing cancer, is also well defined for moderate doses but controversially discussed for very low and low doses (up to 0.1 Sv) and dose rates.¹² This can be explained by the simple fact that most of our knowledge stems from epidemiological studies based only on populations that have received high to low dose radiation, like atomic bomb survivors, patients treated by radiotherapy, occupational exposures in nuclear industries and residents of several atolls in the Pacific Ocean who were exposed to nuclear weapons testing fallout.¹³⁻¹⁹

The high prevalence (approx. 25%) of cancer in most societies is primarily due to other risks than ionizing radiation and makes it impossible to calculate the incremental impact of acute doses below 100 mSv, unless huge numbers of closely controlled persons are investigated.²⁰

Not without reason but lacking unequivocal evidence the stochastic risk for radiation doses below 100 mSv is extrapolated from higher doses according to a linear-no-threshold model.²¹ Much

of the confusion in the public discussions about radiation risk is caused by mixing up counted and just calculated numbers of casualties from radiation accidents.

Is our knowledge of the possible dangers of ionizing radiation sufficient to warrant special action?

To answer our first question, our current knowledge enables diagnosis and treatment of patients who were acutely exposed to moderate or high doses up to potentially fatal exposures. Despite considerable scientific efforts and a huge number of *in vitro* experiments to extend our knowledge to the risk of very low to low doses, one may speculate that this aim cannot be reached due to statistical demands.

What is the role of the medical community in technical radiation accidents from Windscale to Fukushima?

Analyzing historical radiation accidents (Table 1), only a few people were exposed to more than 1 Sv equivalent whole body dose and/or needed hospitalization. Usually these individuals were acutely exposed in the vicinity of the radioactive source and were diagnosed and treated by specialized medical personnel provided by the operator of the wrecked facility.

The majority of the possibly exposed people are too far away from the accident to get acutely exposed to even a moderate dose immediately after the accident.

Their health risk lies in a long-term exposure due to radioactive fall out and ingestion via the food chain. After the accident of Chernobyl in which huge amounts of activity were transferred into the atmosphere by the explosion of the reactor core, the doses due to the fall out were comparatively low even for those European countries with the highest mean dose during the first year—Poland: 932 μ Sv, Bulgaria: 760 μ Sv, Austria: 670 μ Sv, Greece: 590 μ Sv, Portu-

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Table 1: Events regarding nuclear energy from 1940 to 2011; 1INES: International Nuclear Event Scale, developed by the IAEQ and OECD; involved: means people exposed to more than 1 Sv effective whole body dose.

| 1940-49 | 1950-59 | 1960-69 | 1970-79 | 1980-89 | 1990-99 | 2000-09 | Since 2010 |
|--|--|---|---|--|--|---|--|
| Los Alamos, New Mexico, USA (INES 4) Involved: 1 | Chalk River, CAN (INES 5) Involved: 0 | Idaho Falls, Idaho, USA (INES 4) Involved: 3 | Windscale bzw. Sellafeld, GBR (INES 4) Involved: 35? | Saint-Laurent, FRA (INES 4) Involved: 0 | Sewersk, RUS (INES 2-4) Involved: 0 | Fleurus, BEL (INES 4) Involved: 1 | Fukushima, JPN (INES 7) Involved: 3? |
| Los Alamos, New Mexico, USA (INES 4) Involved: 8 | Idaho Falls, Idaho, USA (INES 4) Involved: 0 | Charlestown, Rhode Island, USA (INES 4) Involved: 1 | Leningrad, RUS (INES 4-5) Involved: 3 | Tschernobyl, RUS (INES 5) Involved: ? | Tökai-mura, JPN (INES 5) Involved: 66? | | |
| | Kyschtym, RUS (INES 6) Involved: 0 | Belojarsk, RUS (INES 4) Involved: 0? | Leningrad, RUS (INES 4-5) Involved: 0 | Buenos Aires, ARG (INES 4) Involved: 1 | | | |
| | Windscale bzw. Sellafeld, GBR (INES 5) Involved: 0 | Melekes, nahe Nischinii Nowgorod (Gorki), RUS (INES 3-4) Involved: 2? | Belojarsk, RUS (INES 5) Involved: 0? | Wladiwostok, RUS (INES 5) Involved: 39 | | | |
| | Los Alamos, New Mexico, USA (INES 4) Involved: 1 | Monroe, Michigan, USA (INES 4) Involved: 0 | Jaslovské Bohunice, CZE (INES 4) Involved: 0 | Gore, Oklahoma, USA (INES 2-4) Involved: 101 ? | | | |
| | Simi Valley, Kalifornien, USA (INES 5-6) Involved: 0 | Lucens, SUI (INES 4-5) Involved: 0 | Belojarsk, RUS (INES 3-4) Involved: 8? | Tschernobyl, RUS (INES 7) Involved: 134 | | | |
| | Knoxville, Tennessee, USA (INES 3-4) Involved: 0 | Rocky Flats, Colorado, USA (INES 4-5) Involved: 0 | Three Mile Island, Pennsylvania, USA (INES 5) Involved: 0 | | | | |

TAKE-HOME MESSAGE

- Analyzing historical radiation accidents showed that only a few people were exposed to more than 1 Sv equivalent whole body dose.
- Medical services will most likely not be challenged by a large number of severely irradiated patients or the need of large quantities of specific antidote or large-scale bone marrow transplantation.
- The premier task of medical services will be the communication of the quantity of individual risk and the appropriate behavior to avoid panic.
- Media play an essential role in spreading information and we have to find strategies to improve the quality of these informations before the next accident.
- The mean dose in a population is a poor indicator for the individual risk in a contaminated area, as regional contamination varies considerably due to the local meteorological situation.
- The contamination of air, sea, ground water and soil is an environmental disaster and an imminent danger for contamination of the food chain.

gal: 1.8 μSv and Spain: 4.2 μSv but higher than that in countries farther away from the accident like Canada (1.68 μSv).^{22,23}

Thus, for most European countries the additional exposure was within the variations in natural background radiation levels. Many refuse to accept these data as they feel that this can be misused to excuse such risks. This is definitely not our intention because the additional exposure, even if it is very small, is (in contrast to

naturally occurring environmental radiation) an avoidable risk that has to be justified. In addition, the mean dose in a population is a poor indicator for the individual risk in a contaminated area, as regional contamination varies considerably due to the local meteorological situation.²⁴ Nevertheless, if we believe in the current risk models for ionizing radiation (and there is little scientific alternative to them) we are talking about additional risks of the general population to develop cancer that do not exceed single digit percentages.

This includes the additional exposure via the food chain. During the first weeks after the Chernobyl accident especially milk and milk products got contaminated throughout Europe with ¹³¹I being the most important contributor.²⁵⁻²⁷ The mean concentration of ¹³¹I was indicated in these studies to be in a range from 43 Bq/L to 100 Bq/L in the first weeks of accident. The situation was different near Chernobyl. The intake of ¹³¹I contaminated milk was accused to be the main cause for dramatic increase of thyroid cancer in children.²⁸ Guiraud-Vitoux, *et al*,²⁹ by arguing that the medical use of ¹³¹I in the treatment of hyperthyroidism in young subjects did not show any incidence of increased cancer risk in this population, mentioned that other iodine isotopes (mainly short lived) and external radiation should also be considered.³⁰ The 30-year follow-up in a cohort of 5000 patients of differentiated thyroid cancer in Russia, Ukraine and Belarus in young people exposed to the Chernobyl radioactive fallout showed a 1% disease specific mortality.³¹

After the first weeks, the major contributor to total exposure was ¹³⁷Cs and will remain so over some decades for certain foods like mushrooms and red deer.

The contamination of air, sea, ground water and soil is an environmental disaster and an imminent danger for contamination of the food chain. Consumers are

exposed to minimal but due to the long half-life of some radionuclides cumulative doses through internal contamination. This exposure depends on consumed quantity and variety of food. Data are available for contaminated sea food in the Irish Sea after the Windscale accident³² and for the continuous cesium contamination of mushrooms and deer after the Chernobyl accident³³⁻³⁶ contribution. Depending on the quantity of consumed food, the calculation for the additional exposure of individuals again ranged from the very low to low doses.^{37,38}

Of course, intake of contaminated food is preventable but this relies on consistent measurements and import controls by the authorities.

The role of the medical services in such a scenario is limited as, with the exception of potassium iodide prophylaxis if the exposure to ¹³¹I fallout exceeds certain limits, no special treatment is possible or warranted for low dose exposure. The most important task will be providing medical information to avoid panic.

What is the role of the medical community in terrorist radiation attacks?

Whereas radiation accidents in technical and medical facilities are well documented and can be used as teaching material, until now no terrorist radiation attack has taken place. A lot has been written about “dirty bombs” and similar radiological threats,³⁹ but all this—fortunately—is based on theoretical assumptions. However, some technical radiation accidents may serve as role model for the effects of dispersing radioactive substances.

In 1987, 112 000 persons had to be monitored to identify 249 contaminated persons after an old radiotherapy source was stolen from an abandoned private radiotherapy institute in the city of Goiana, Brazil.^{40,41} Four people died; 129 (51.8%) of the 249 contaminated persons had in-

ternal contamination with the majority of whom were estimated to suffer small doses of less than 50 mSv. Even in the cohort of the Hiroshima atomic bomb survivors, the median dose was 0.15 Gy or less.^{42,43}

In contrast to the public belief and regardless of the different possible scenarios, medical services have to be prepared to be confronted with very large numbers of patients who were exposed to zero or small doses rather than to deal with the classical radiation sickness syndrome. Depending on the type of assault, possible injuries caused by the actual explosion or by the consequent panic may be the dominant problem.

Analyzing the needs for medical treatment of mass casualties of an incident involving deliberate release of radiation agents show a clear disparity between reasonable *vs.* possible health care capabilities.⁴⁴ It is often overlooked that most of the efforts in such situations are not needed to treat the few critically exposed but to prove that individual risk of most involved persons is sufficiently low. Nevertheless, the logistics for measuring large numbers of the population may not be the premier task of the medical services. The premier role of medical services in terrorist attacks depends on the type of scenario but will not change significantly if ionizing radiation is involved or not. Again, the most important task will be providing medical information to avoid panic.

Are we prepared for those challenges?

We have learned that the larger part of the medical community will not be challenged by the therapy of exposed people in the aftermath of a radiological accident but with the logistics to identify actually exposed people and to communicate short- and long-term risk to the general population. Let us go back to our initial definition.

Has the medical community complied with preventive measures?

Few will answer this with a fully qualified “yes.”⁴⁵ Most countries have some kinds of emergency plans, many have regular exercises, but even the recent experience with the Fukushima accident showed that the initial response of most of the not directly involved countries appeared to be chaotic and consequently induced unnecessary fear. Legal matters were unclear⁴⁶ and actions⁴⁷ appeared uncoordinated. It goes without saying that regular training would minimize those problems but the question arises if we should invest more into this area. Among all the other possible threats, large scale radiological accidents have a very low probability to occur and it may be speculated if the necessary efforts (including money) for adequate preparedness may be better channeled into other scenarios. Nevertheless, with one exception most of the preventive measures are not directly related to the medical services but to other authorities. This exception is, as already stated above, risk communication and we will come back to this later.

Are we in a state of readiness to handle the effects of an accident?

Most of the catastrophes including terrorism demonstrated that even if the local emergency relief units (police, fire department and medical service) have the best and professional armament they need time to react. The people affected are left to their own devices in the first minutes to hours depending on the magnitude of the catastrophe. In other words, the acute challenges of radiological accidents are not significantly different from those of other emergencies. The big difference to other scenarios like earthquakes, flooding, *etc.*, is that some radiological accidents pose a cumulative and long time risks to the population. What we have learned

from accidents like Chernobyl and recently Fukushima and what will also be true for some terrorist attacks is that the premier role of the medical services in areas remote from the actual accident is that of a provider of information. Somebody has to tell the large number of people not directly involved in the accident what to expect and what to do to correctly estimate and potentially minimize personal risk.^{48,49}

In contrast to other disaster scenarios, radiological accidents apart from the acute phase have a very long aftermath, thus the challenge for medical services remote from the actual disaster areas is not to act quick but lasting.

This leads us to the most important question of preparedness in radiological accidents:

Can we provide support in the aftermath of an accident and do we have the necessary resources?

The estimation of radiation risk is an interdisciplinary task involving several medical specialties and other professions (health physicists, nuclear physicists, meteorologists, ecologists, *etc.*) and this sometimes complicates the matter if close cooperation of those individuals cannot be achieved. Medical services rely on external expertise, measurements and predictions to estimate and consecutively communicate risks and feasible ways of avoidance.

How can medical services communicate information in the media framework?

We lack information to comment on the information politics inside Japan during the first weeks after the Fukushima accident but the evidence in Western media suggests that hysteria increased with distance to the site of the accident. Not only the yellow press exaggerates local risks and home stories about the “last defense

of 50 workers”⁵⁰ superseded useful information.

During the first weeks after the event, radioactive nuclides could be measured worldwide⁵¹ but the amount of activity outside Japan was so small that only sophisticated measurements could differentiate it from the natural radiation. Nevertheless, the population in some countries unnecessarily purchased and possibly swallowed potassium-iodine tablets. This irrational behavior was initialized by almost all Western media but showed significant differences between nations.

Why Europe, particularly Germany and Austria (9000 km from Japan) responded with media initiated panic, is part of the social and political attitude. “What might look like a dragon in Germany appears the French like an earthworm.”⁵²

Part of this can be explained by reviewing how nuclear technology was presented to the people. Nuclear technology handles an incredible source of energy (“nuclear energy”) and this was used in the 1940's to destroy life by constructing an atom bomb. As spin-off product, nuclear power plants were built—first of all to deliver material for bombs, but sold to the public as peaceful utilization of nuclear energy to provide electricity.

It is easily understandable that this discrepancy caused mixed feeling and makes risk communication of ionizing radiation a difficult task. The perception that ionizing radiation cannot be felt, seen, scent, heard or tasted caused most people to encounter ionizing radiation with awe and fear.

The ambiguous information politics about military and industrial radiation accidents in the past worsened this.

Possible risks have too often been trivialized in the past from the 1951 US Federal Civil Defense Administration cartoon telling that “duck and cover” protects you against the atomic mushroom⁵³ to the “Plutonium boy” cartoon shown to Japa-

nese kids in 1993 to prove that “Plutonium is safe to eat.”⁵⁴ To make things worse, we are currently experiencing an increasing awareness of radiation risks in diagnostic⁵⁵ and therapeutic⁵⁶ medicine. It is beyond the scope of this article to discuss the statistical limitations of most of these studies here but they are cited to show the need for profound risk communication. Risks of ionizing radiation have to be quantitated based on our best scientific knowledge and put into relation to the potential benefits of their application in medicine as well as in the industries.

Coming back to the recent experiences after the Fukushima accident, the major task of health services in Europe and the US was to communicate that the healthiest attitude to this event was to do nothing. In contrast to the public behavior, no member of the medical community advised to take potassium-iodine tablets.

The premier task of the medical services is to communicate that in most accidents very few people are exposed to an acute life-threatening dose. Even in the most recent event in Fukushima, no case of acute radiation sickness has been confirmed so far.⁵⁷

Contrary to all other catastrophes the adequate response to radiation accidents is not acute escape but raise long-term awareness.

Another very important aspect is to communicate the magnitude of the expected risk of long-term effects like leukemia and solid cancer. These have been linked to radiation exposure even in low-dose ranges, but are usually much lower than appreciated by many.²¹

Scientific evidence on radiation risk alone cannot dispel the public fear; the only way to achieve this is by adequate communication. Risk communication of the inherent risks in radiology and nuclear medicine could be a good starting point.

Irrational “radiophobia” is even seen in

some medical departments⁵⁸ and requires proper management. Media are not helpful and turn scientific concerns and evaluations into facts.⁵⁹ So far, there are just a few studies related to this issue and a final statement is that physicians in training have to be educated in communicating benefit and risk to patients adequately.⁶⁰

Eight weeks after the Fukushima wreckage, the media are not interested anymore and there are just a few embers left. Politicians push their interests by misemploying media for lobbying their own interests.

But what we have seen in this few weeks is that the population demands as much assurance as possible. They desire certainty from experts and “trial without error” or “uncertainty.”

Medical preparedness should cover issues related to health and effects as a consequence of disasters and their aftermath.

The media hype divides the population into two groups: those who panic and those who deny. Any rational information is either too little or too much for both groups. Consequently, other than pure medical issues have to be addressed. Communicating radiation risk in the aftermath of an accident has to address more than such cancer risk. It has to deal with psychosocial issues.

Is the medical society able to fulfill these desires?

Can evidence-based risk assessment and management be communicated to the public during radiation accidents? Possibly yes, if communication has started well before the accident.

What have we learned recently?

What should be improved?

Starting communication against the hype is always difficult. Medical services have to communicate risks of ionizing radiation independently of accidents. Ionizing radiation in medicine is a good starting point

to educate ordinary people and medical staff; to explain that we cannot exactly quantitate the risk of very low exposure, but all data indicate that it is somewhere between zero and minimal.⁶¹

Conclusion

Media play an essential role in spreading information and we have to find strategies to improve the quality of these informations before the next accident. The focus of medical preparedness for large-scale radiation accidents depends on the distance to the site of disaster. Medical services will most likely not be challenged by a large number of severely irradiated patients or the need of large quantities of specific antidote or large-scale bone marrow transplantation. They will be challenged by the quality of information about the actual accident provided by other authorities. Its premier task will be the communication of the quantity of individual risk and appropriate behavior.

By educating people about applications of ionizing radiation in medicine independent from those in the industrial application, we may be able to raise critical apprehension and fight hysteria.

Medical services have to improve their communication skills and convince the public that the dangers of ionizing radiation can be quantitated within certain limits to support a qualified discussion about its risks and benefits.

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