Operational Topic

Recommendations on effective management of children during a radiological or nuclear emergency.

Managing Children during a Radiological or Nuclear Emergency—Canadian Perspectives

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Abstract: *Children have a higher chance of being contaminated by radioactive materials during a radiological or nuclear (RN) emergency. They are more sensitive to radiation health effects and suffer more significant psychosocial impacts than adults during emergency response. This paper presents a summary of recommendations on effective management of children during an RN emergency. These recommendations intend to be additional considerations for existing RN response protocols and procedures implemented at local, state/provincial, or national level. Health Phys. 108(Supplement 2):S54–S59; 2015*

Key words: *operational topics; children; emergencies, radiological; radiation protection*

INTRODUCTION

On March 11, 2011, a significant earthquake and subsequent tsunami in northeastern Japan triggered a nuclear accident in the Fukushima Daiichi Nuclear Power Plant (IAEA 2011), another significant emergency event following the Chernobyl nuclear accident in 1986 (IAEA 2001) and the Goiânia radiological accident in 1987 (IAEA 1988). All these three radiological or nuclear (RN) accidents caused significant contamination in the environment and people. Emergency management and public health organizations in the affected countries and around the world have gained experience and learned lessons in managing the affected populations (IAEA 1998; WHO 2006, WHO 2013).

Some populations, such as children, pregnant women, and the elderly need special attention as they are more vulnerable to radiation effects or the emergency response process itself (Chen et al. 2009). Children have a higher chance of being contaminated by radioactive materials and are more sensitive to radiation health effects (Tracy 2010). Following the Chernobyl accident, over 6000 children developed thyroid cancer due to the exposure to radioactive iodine isotopes, mainly ^{131}I, through inhalation of contaminated air and ingestion of contaminated food and milk (UNSCEAR 2014). In addition, they suffered more significant psychosocial impacts than adults (WHO 2006). During the Goiânia accident, more than 100,000 people were screened for external or internal contamination with ^{137}Cs and about 200 were treated, of them many were children (IAEA 1998). Although no detailed report is yet available on the management of children during and following the Fukushima accident, the Fukushima Health Management Survey plans to monitor all children in the Fukushima Prefecture in the coming 30 years (FMU, 2014).

In Canada, a multi-partner project team has recently developed proposed recommendations on the effective management of children during an RN emergency. The full document entitled "Recommendations for The Effective Management of Children during A Radiological/ Nuclear Event" is available upon request. The target audience includes emergency management organizations, public health agencies, first responders/receivers, and schools/ child care centers. The recommendations are intended to be additional considerations for existing RN response protocols and procedures implemented at local, provincial, or national level. This paper presents a summary of these recommendations to share with colleagues in other countries.

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RECOMMENDATIONS

The recommendations were developed to address nuclear emergencies that occur at nuclear power plants and other nuclear facilities, such as the Chernobyl and Fukushima accidents (IAEA 2001, 2011); medical or industry-related radiological accidents, such as the Goiânia accident (IAEA 1988); malicious activities where radiation is emitted or radioactive materials are dispersed, such as a radiological dispersal device (RDD), a radiological emission device (RED), and deliberate food/water/environment contamination. The target population is children who may be impacted by radiation and/or other factors during and after a radiological or nuclear emergency. Recommendations are summarized in four groups of interventions: immediate on-site protective actions, monitoring and decontamination, medical management, and long-term follow-ups.

Recommendations on immediate on-site protective actions

Soon after the confirmation of the imminent threat from an RN event, immediate protective actions should be implemented to minimize radiation exposure to children and to reduce psychological impacts to all involved, especially the children and their parents. These include sheltering, potassium iodide thyroid blocking if radioactive iodine involved, evacuation, and emergency communication. Health Canada has published the Canadian Guidelines for Intervention during a Nuclear Emergency (Health Canada 2003), where the intervention levels for the application of various countermeasures following a nuclear emergency are recommended. The guidelines were developed to base intervention levels on radiation doses to the most sensitive group in the population, which was taken to be children. The U.S. Environmental Protection Agency has also developed the Protective Action Guides and Planning Guidance for Radiological Incidents (U.S. EPA 2013). However, during an RN emergency, countermeasures should not be delayed while waiting for complete radiation dose assessment. In any case, schools and child care centers will follow their normal protocols and await instructions from emergency management authorities and first responders on whether a particular countermeasure is to be implemented. If the emergency occurs outside of school hours, parents/guardians should follow the guidance of the first responders and emergency management authorities and take the suggested immediate actions to protect their children from being exposed to radiation or contaminated with radioactive materials.

Sheltering has been identified as an effective countermeasure during the immediate phase of an RN emergency. Most of the time, it refers to sheltering in place rather than in a designated sheltering center. During an RN emergency, the radioactive plume might pass over a school or a child care center. In this case, asking all children to go inside of the building (with windows and doors closed well, and ventilation shut down) will help reduce their exposure to direct external radiation and inhaled internal contamination. The lockdown procedures implemented at schools or child care centers are directly applicable for sheltering during an RN emergency. If a school or child care center is not in lockdown, children should be directed to the interior of the building, preferably to an area that has the least amount of windows and doors (e.g., gymnasium). Children may have been contaminated with radioactive particles before sheltering. In this case, their shoes and outer clothing needs to be removed before entering the building. During an emergency, parents may arrive at schools and child care centers to retrieve their children. If the school or child care center is not in lockdown, parents may be allowed to join their children if they are possibly not contaminated; otherwise parents should be asked to follow the lockdown procedure. A designated staff or officer should be stationed at the school perimeter to inform parents regarding the situation.

Stable iodine thyroid blocking may be administered with sheltering when radioactive iodine is released during an emergency, such as an accident in a nuclear power plant. The thyroid gland is the main destination of radioactive iodine taken into the body via inhalation or ingestion. Stable iodine, commonly in the form of potassium iodide, can be administered to saturate the thyroid gland shortly before or immediately after the exposure to block the uptake of radioactive iodine. However, potassium iodide can have side health effects and should be taken only if instructed to by the emergency management authority or a medical authority. Detailed instructions for iodine prophylaxis, including dosages for children of different ages, can be found in the recent publications of the World Health Organization (2011) and U.S. EPA (2013).

Evacuation is a common public health countermeasure following an emergency or natural disaster. Each school or child care center should have a designated evacuation center and ideally have an alternate evacuation center (in case the primary evacuation center is contaminated by the passing radioactive plume). It is recommended that schools and child care centers have designated transportation to the evacuation centers in their emergency plan. The locations of the evacuation centers should be communicated with parents/guardians upon the registration of their children. Following an emergency, the arrival point(s) should be communicated using all available communication channels (radio, websites, paper posting, social media etc.).

Parents may show up prior to commencement of evacuation but they should be encouraged to meet their children at the evacuation center. If they disregard the advice and insist on retrieving their children, teachers should update their attendance records prior to releasing the children. This is very important for tracking children during the emergency.

Effective communication is paramount during the immediate phase of an RN emergency. This includes notifying schools/child care centers and parents as early as the trusted information is available and communicating to parent/guardians the radiation risks to their children and countermeasures implemented using clear and non-technical language. There are a variety of communications means available to most municipalities; however, the strategies for using fast-spread communication means, such as social media, should be addressed in the emergency management plan. Note that only confirmed information from trusted sources should be released, and mixed messages and the use of technical jargon should be avoided. An incremental communication strategy may help mitigate the psychological impact on children and their parents and caregivers.

Following an RN emergency, parents will want to know if their children are safe. Communication means for parents to contact schools, child care centers, and evacuation centers should be made available. For older children, their parents may be able to connect with them using their own phones or social media. Note that overreaction of parents/guardians and teachers/caregivers to the news regarding the RN emergency will create emotional responses in children. Children can also be influenced significantly by the media. Repeated exposure to media coverage of an emergency has been shown to cause fear and anxiety in children, as they may believe the event is reoccurring. For this reason, children should be limited from media exposure during an emergency.

Recommendations on monitoring and decontamination

Following an RN emergency where radioactive materials are released to and dispersed in the environment, individuals, including children, in the path of the radioactive plume may be contaminated. They need to be monitored for and decontaminated from potential contamination, if necessary. Detailed information on monitoring and decontaminating people following an RN emergency can be referenced to the Population Monitoring in Radiation Emergencies published by U.S. Centers for Disease Control and Prevention (U.S. CDC 2014) and the Canadian Guide for Medical Management of Radiation Emergencies (Health Canada 2014). If the emergency occurs outside of school hours, parents/guardians should follow the directions of emergency management organizations and first responders to have their children monitored and decontaminated (note that decontamination may be done at home, e.g., taking a shower, if there is no injury involved). Otherwise, teachers and caregivers at the schools or child care centers will need to follow the instructions from the emergency management organizations and first responders and guide the children through the monitoring and decontamination process, which involves four major steps: registration and tracking, monitoring for potential contamination, decontamination (if necessary) and re-monitoring, and discharge for family reunification. Note that during an RN emergency, although symptoms from acute radiation injury are unlikely to develop at the scene of an event, children may get physically injured. Normal medical triage is used to assess injuries, and life threatening injuries take precedence over monitoring and decontamination.

Registration and tracking. Upon arrival for contamination monitoring and decontamination (if necessary), each child should be given a physical identifier, such as a unique number (or a combination of numbers and letters) marked on their skin (using a permanent marker). This identifier should be recorded together with other information, such as name, school name, home phone number, in his/her registration form. It is critical that children are tracked throughout the entire monitoring and decontamination process, including where they are transported in the event of an emergency, the results for contamination monitoring, record of decontamination (if necessary) and results of re-monitoring, when they are discharged to parents/guardians, and if a medical or radiological follow-up is recommended. Note that children should never be separated from their responsible adult when they go through monitoring and decontamination.

Monitoring for potential contamination. Children will take more time to respond to requests and understand the monitoring process due to fear or lack of understanding. First responders or other emergency management personnel may need to use different language when communicating with children, especially with the younger ones. Clear, brief, and specific instructions should be given. Children should be allowed to see other children being monitored. The process for monitoring children is not different than that for monitoring adults, usually using either hand-held detectors or portal monitors. However, when children are monitored, audible signals from monitoring equipment should be turned off or headphones used. This will help reduce the psychological effects to children and minimize the perception of singling out children who are contaminated. When a hand-held detector is used, the child should be scanned from

head to toe looking for the presence of radioactive contamination, with an emphasis on head, shoulder, hands, and feet. When a portal monitor is used, children are required (and encouraged for the younger ones) to walk through the portal one by one. A demonstration by an adult or an older child will help other children learn the process as many young children may be frightened by the monitoring process. If a child is very young, he/she may need to be monitored together with his/her caregiver.

Decontamination and re-monitoring. If monitoring results showed that a child is contaminated with radioactive material, he/she needs to be decontaminated as early as possible. Removing outer clothing may reduce external contamination by more than 80%. For decontaminating uncovered areas (skin, hair), dry decontamination (e.g., using a slightly damp cloth or towel) is favored over wet decontamination (e.g., taking a shower). However, wet decontamination may be necessary if the contamination persists following dry decontamination. During the decontamination process, the responsible adult (teacher or caregiver) may not directly assist, but must remain responsible for the children until they are released to the parents. Children are more susceptible to hypothermia than adults; they should be kept warm during the decontamination process. It is important to maintain privacy during the decontamination process; gender-specific areas should be used. If disrobing is required, children should keep their undergarments on.

Following decontamination, children should be re-monitored for remaining external contamination or potential internal contamination. If they have no external/internal contamination, they are ready to be discharged. If they are identified to have internal contamination, they should be referred to hospitals/physicians for further bioassay and necessary medical treatments.

Discharge for family reunification. Once the monitoring and decontamination have been completed, the child can be discharged to his/her parent(s)/guardian(s). Identity of parent(s)/guardian(s) should be confirmed at reunification. At this time, the registration and tracking form should be collected and reviewed. If important demographic information is missing from the form, such as contact information for follow-ups, an attempt to obtain such information can be made.

Recommendations on medical management

During an RN emergency, children may be physically injured and/or exposed/contaminated by radiation. As recommended in the above sections, life-saving takes precedence over treating radiation injuries or contaminations. This applies to medical actions both on-site and in hospital.

Medical and radiological triage. Children who are injured and/or contaminated during an RN event will require both medical triage and radiological triage. Casualties with life-threatening symptoms and/or additional trauma need to be treated on-site or in hospital without delay regardless of their contamination status. If they are contaminated with radioactive materials involved in the emergency, they can be decontaminated once they are stabilized. Life-saving actions are performed in the same manner whether or not radioactive contamination is present on the surface of the casualties or inside their bodies. Casualties who are in stable condition need to be monitored for potential radioactive contamination and decontaminated, if necessary. If re-monitoring following decontamination indicates internal radioactive contamination, bioassay (*in vivo* or *in vitro*) is needed to assess the intake level and inform necessary treatments.

Children not in the immediate vicinity of an RN event are unlikely to experience acute radiation syndrome (ARS). However, due to lack of knowledge, parents of children may present their concerns. They need to be reassured during the triage process. Some ARS-like symptoms, such as nausea or vomiting, can be caused by fear or other factors.

Assessment and treatment for internal contamination. The Canadian Guide for Medical Management of Radiation Emergencies recently published by Health Canada (Health Canada 2014) provides detailed information on how affected individuals are assessed and treated for internal radioactive contamination. This guide applies to assessing and treating children. Internal contamination may be assessed via *in vivo* bioassay (e.g., whole body counting, lung counting) or *in vitro* bioassay (e.g., urine or fecal bioassay, nasal swabs), depending on the routes of contamination (e.g., inhalation, ingestion), the physical and chemical properties of the radioactive materials, and other factors/considerations. Treatments of internal radioactive contamination depend on the nature of contamination and the radioactive materials involved, such as blocking the absorption of the radioactive materials by specific organs/tissues (e.g., using stable iodine to block the absorption of ^{131}I by the thyroid gland during a nuclear emergency), reducing the absorption of radioactive materials from the GI tract (e.g., using Prussian blue for treating ^{137}Cs contamination), and removing the radioactive materials from the body (e.g., using DTPA-Zn to decorporate ^{239}Pu contamination).

Children should be treated early as they are more sensitive to radiation health effects than adults. Medical treatment should be administered by a physician, and potential side health effects should

be considered. For example, decorporating agents can cause dehydration, electrolyte imbalance, or aspiration in children.

Assessment and treatment for acute radiation injuries. The Canadian Guide for Medical Management of Radiation Emergencies (Health Canada 2014) provides detailed information on medical management of acute radiation injuries. As mentioned above, children not in the immediate vicinity of an RN event are unlikely to experience acute radiation syndrome (ARS). However, if they have been in the vicinity for a relatively long time, they may (e.g., a strong radiation source is maliciously put in a school yard). If such radiation exposure is suspected, some examinations need to be done as early as possible, including a thorough physical examination, a complete blood test, chromosome analysis, and lymphocyte counts. Some symptoms, such as nausea and vomiting, bleeding, reddening of skin, and fever, may indicate the underlying radiation injury. It takes some time for ARS to develop, ranging from hours to weeks, depending on the radiation dose and dose rate a person receives, the dose distribution in the body, and individual susceptibility.

Treatment of acute radiation injuries will be patient-specific and depend only on the symptoms and not on a perceived or estimated radiation dose. It is imperative that all signs, symptoms, and results of the preliminary medical examinations and blood tests are accurately recorded. Several clinical syndromes may occur individually or in combination, including hematopoietic, cutaneous, gastrointestinal, and neurovascular syndromes. The collective signs and symptoms can be followed to determine the severity of the radiation injury, document the evolution of the ARS, and document the prognosis to enable a decision on treatments, such as supportive care, blood substitution, growth factor therapy, stem cell transplantation, and surgery.

Recommendations on long-term follow-ups

Once the immediate phase of an RN emergency passes, children affected by the emergency should be followed for a longer term for their health and well-being. During the emergency, food, drinking water, and the environment may be contaminated by the radioactive materials involved. Children should be protected from consuming contaminated food, and drinking water, as well as from contaminated environment. The Canadian Guidelines for Restriction of Radioactively Contaminated Food and Water Following a Nuclear Emergency, published by Health Canada should be followed (Health Canada 2000). If the levels of radioactive materials in food and drinking water are lower than the guideline levels, the food and water are safe for consumption.

Areas in the vicinity of an RN event may be initially considered unsafe for human occupation due to high levels of radioactive contamination. With the physical decay of the radioactive materials and weathering, these areas may be acceptable for re-occupation. If families decide to move back to these areas, radiation doses (both external and internal) of children should be monitored regularly until it becomes unnecessary.

Health surveillance and medical follow-up. Following the Fukushima nuclear accident in 2011, the Japanese government and the Fukushima Prefecture initiated a long-term health surveillance program, the Fukushima Health Management Survey (FMU 2014), to monitor the radiation-related and non-radiation related health effects in residents of Fukushima Prefecture in the coming 30 y. This type of monitoring and surveillance is very important for children as they are more sensitive to radiation effects and psychosocial impacts.

The greatest long-term concern for children (including children *in utero* at the time of exposure) is the eventual development of cancer. Accurate assessment of radiation dose received and committed (in case of internal contamination) by children can be used to predict the probability of radiation-induced cancer. Life-time risks for certain cancers can be considerably higher for children than for adults (UNSCEAR 2013). Of course, some other radiation-related health effects also need to be followed for a long period after the emergency event.

Psychological follow-up. Children are more likely to suffer long-term adverse psychological effects than adults. This has been observed following the Chernobyl nuclear accident (WHO 2006) and is anticipated for the Fukushima nuclear accident. The sudden trauma of evacuation, disruption of their social networks, being evacuees for a prolonged time, and the social stigma from having been an "irradiated child," lead to stress, anxiety, and even sickness. Parents, caregivers, teachers, and social workers need to be sensitive to the psychological and social difficulties children may suffer and provide them comfort and education. Providing long-term education, training, and follow-up programs to children to ensure their mental health is very important. Not only the affected children but also the others need to be included in the educational plan.

DISCUSSION

It is expected that the above interventions, if executed properly, can help result in the following outcomes related to the health and well-being of children who are directly and indirectly impacted by an RN emergency: a) reduced radiation health risks if the immediate protective countermeasures

were taken, early monitoring and decontamination were implemented, and necessary medical management was provided; and b) reduced psychological health risks if effective emergency communication, including radiation risk communication, was implemented and if long-term follow-ups to the children and their families were provided. Additional outcomes, including reduced psychological health effects to the parents of children and reduced social-economic impacts, would also be achieved if the children were well managed during an RN emergency event.

It is suggested that the above recommendations on managing children be incorporated in the overall management plan for an RN emergency and exercised regularly. It is critical to understand that during an RN emergency, people will want to help, people will behave according to what they understand and know about the situation, parents will want to connect and rejoin with their children, and teachers/caregivers will want to protect the children under their responsibility.

When emergency management organizations develop their RN emergency management plan, it is suggested that they involve schools and child care centers. The plan should include a risk communication strategy directed to children and their parents. When the emergency management plan is exercised, schools/child care centers, children and parents should be involved. The emergency management plan should also address required training for first responders and receivers in managing children during an RN emergency, resource scarcity during emergency response, and all weather conditions.

It is suggested that radiation science be built into the education program so that children can learn and understand the risks from being exposed to radiation. This also helps teachers and parents in understanding radiation risk.

General effective approaches in managing children during an emergency or disaster apply to RN emergencies. The recommendations provided in this short paper offer additional and RN specific considerations. The authors hope that emergency management organizations, first responders/receivers, and schools/child care centers find this paper a useful reference when they develop their emergency plans and/or training programs.

Acknowledgments—This project was funded by the CBRNE Research and Technology Initiative (Project ID: CRTI 09-0553TD), a Canadian federal government program managed by the Department of Defence.

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