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Risk Communication Strategies: Lessons Learned from Previous Disasters with a Focus on the Fukushima Radiation Accident

Erik R. Svendsen[1] · Ichiro Yamaguchi[2] · Toshihide Tsuda[3] · Jean Remy Davee Guimaraes[4] · Martin Tondel[5]

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Abstract
Purpose of the Review It has been difficult to both mitigate the health consequences and effectively provide health risk information to the public affected by the Fukushima radiological disaster. Often, there are contrasting public health ethics within these activities which complicate risk communication. Although no risk communication strategy is perfect in such disasters, the ethical principles of risk communication provide good practical guidance.
Findings These discussions will be made in the context of similar lessons learned after radiation exposures in Goiania, Brazil, in 1987; the Chernobyl nuclear power plant accident, Ukraine, in 1986; and the attack at the World Trade Center, New York, USA, in 2001. Neither of the two strategies is perfect nor fatally flawed.
Summary Yet, this discussion and lessons from prior events should assist decision makers with navigating difficult risk communication strategies in similar environmental health disasters.

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✉ Erik R. Svendsen
esvendse@tulane.edu

Ichiro Yamaguchi
drhyama@niph.go.jp

Toshihide Tsuda
tsudatos@md.okayama-u.ac.jp

Jean Remy Davee Guimaraes
jeanrdg@biof.ufrj.br

Martin Tondel
martin.tondel@medsci.uu.se

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Introduction

Risk communication can be summarized into four different pieces: (1) what do we know about the exposures, (2) what medical consequences are expected from those exposures, (3) what should be done to mitigate those public health risks from those exposures, and (4) what message and method should be communicated to the public about these health risks and plans to mitigate them? [1]. We often tend to limit our risk communication focus to emergent health consequences for mankind alone rather than the broader and persistent environmental and ecological health risks. However, such additional risks can contribute to public indignation and sometimes need to be addressed within environmental disaster risk communication [2•].

1 Medical University of South Carolina, 135 Cannon Street, Suite 303, MSC 835, Charleston, SC 29425, USA

2 Department of Environmental Health, National Institute of Public Health, 2-3-6, Minami, Wako City, Saitama 351-0197, Japan

3 Okayama University, 3-1-1 Tsushima-naka, Okayama City 700-8530, Japan

4 Inst. de Biofisica Carlos Chagas Filho, Lab. de Tracadores, Bloco G, CCS, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ 21941-902, Brazil

5 Occupational and Environmental Medicine, Department of Medical Sciences, Uppsala University, Ullerakersvagen 40, SE-751 85 Uppsala, Sweden

The job of the risk communicators is easiest when the assessment of both the exposure and risk are well known, and the resulting mitigation efforts are developed within public health preparedness plans a priori [3]. However, that is certainly not the case regarding the exposures and health consequences which have followed the Fukushima radiological disaster. There still remains great uncertainty in the exposures which occurred and continue to occur within the affected communities [4]. Furthermore, there are vast uncertainties about the health effects from radiation exposure, especially at low doses [5]. The resulting uncertainty in both of these first two risk communication steps have led to the many divergent mitigation efforts being used by varying levels of government within Japan [6•]. Consequently, based on a summary of our personal experiences and the scientific literature regarding radiation risk communication in Japan after the Fukushima disaster, there are many, and often conflicting, risk communication messages being distributed across Japan [7–13]. These may contribute to inappropriate risk-taking or risk-adverse behaviors, such as consumption of potentially contaminated food without adequate awareness of risk or inappropriately limiting outdoor activities or evacuation without adequate social support, and/or the resulting adverse influences on health.

Recently, a paper, a related commentary and editorial, seven letters to the editor, and a response from the authors [14••, 15••, 16••, 17••, 18••, 19••, 20••, 21••, 22••, 23••] were published in the journal *Epidemiology* which presented population-level evidence of and comments on an association between radioactive iodine exposure from the Fukushima disaster and the development of pediatric thyroid cancer. These highlighted an ongoing debate within the environmental epidemiology community—Is the increase in pediatric thyroid cancer in the regions impacted by the Fukushima radiation disaster real? And if so, is it associated with prior exposure to radioactive iodine? This ongoing debate is an example of a larger dialog regarding strategies to communicate radiation health risks to the Japanese public impacted by ionizing radiation from the Fukushima radiation disaster. The International Society for Environmental Epidemiology has published an open letter to the leaders of Japan supporting continued public health screenings for pediatric thyroid cancer in radiation-exposed regions of Japan and has opened a scientific blog to foster this debate further (http://www.isee-europe.com/blog). The debate has risen to the broader scientific audience [24••], unfortunately often resulting in an unbalanced view of the scientific evidence. Scientific uncertainties [25] and varying risk perceptions, even within the scientific community [26], may have clouded the approaches to risk communication across the affected Japanese communities and influenced both the ongoing public health interventions and research activities. These recent experiences indicate that it is difficult to provide a unanimous message on exposure and health risks to the public, especially at an early stage after an emergency event. People's preparedness to handle conflicting information could be different in various populations and influenced by several factors.

Risk communication about ionizing radiation is as complex as this risk agent is itself, since the latter includes light or heavy particles like beta and alpha, as well as photons, with radical differences in their ranges and mechanisms of interaction with matter, but all with ionization as the common end result. In addition, ionizing radiation carries powerful symbolic dimensions that risk communication strategies often fail to recognize but are important in the mind of the many lay citizens. Ionizing radiation is invisible, being detected only by specialized instruments and recorded in units (such as Becquerel, Gray and Sieverts), which can confuse the public. It does not make it easier when older units (like Curie, rad and rem) are still in use. The expectations of radiation experts trained in physics can be unrealistic because often they have not been trained for communicating the health risk in a manner that can be understood by the affected population. These concerns were highlighted during the development of the radiation risk communication guidelines in response to the Japanese nuclear disaster [27].

Ionizing radiation can be stopped by a sheet of paper, if in the form of alfa particles, or penetrate hard rock, when present as gamma rays. Due to potential genotoxicity, it can affect both you and/or your offspring. It becomes even more frightening for the public when there is a lifelong risk of developing cancer. People seek information on how to reduce their health risks from radiation exposures, which is easier for them to grasp than to understand the probability of developing disease after exposure to ionizing radiation. What kind of risk information is acceptable or not depends on the situation and could be partially explained by the regulatory-focus theory [28] and feelings regarding social justice. Even if the information is understandable, residents do not want to be educated about radiation health risks unless the attitude of the risk communicator is fair and the information is relevant to their daily life.

The world of science fiction has done the public a vast disservice by woefully misrepresenting ionizing radiation in pop culture. Therefore, even greater transparency in risk communication will not necessarily be efficient, while the slightest opacity or secrecy around the issues of ionizing radiation safety will aggravate an already difficult dialog [3, 29, 30]. Risk communication of radiation exposures needs to have a multidisciplinary approach—including physicists, physicians, and risk communicators and risk managers. The situation in Japan is also unique because of their prior experiences of the aftermaths of two atomic bombs, dropped on the populations of Hiroshima and Nagasaki.

The purpose of this paper is to contrast two juxtaposed risk communication strategies being used and recommended by ionizing radiation public health experts—one university researcher and one federal research scientist. The strategies are neither right nor wrong but have sufficient public health ethics to support their use. Herein, we will introduce the further context of this debate from prior case studies, the conflicting science which risk decisions are predicated on, the contrasting strategies for communicating risk, and a discussion of the relevance of these strategies to the broader risk communication debate which is permeating contemporary scholarship. These discussions will be made in the context of three disaster case studies, radiation exposures in both Chernobyl, Ukraine, in 1986 and Goiania, Brazil, in 1987, and the attack at the World Trade Center in New York, USA, in 2001.

Case Studies

World Trade Center Collapse After the 9/11 attacks on the World Trade Center in New York City, there were several government agencies which downplayed the health risks from the dust exposures resulting from the disaster. The US EPA even stated that there will be no long-term health effects from exposure to the 9/11 dust because the concentrations of the toxins in the dust were too low [1]. Those statements were correct for the hazardous substances which they were most concerned about in the dust, such as asbestos and lead. But, they failed to recognize the significant exposures to alkaline dusts and were unaware of their long-term toxicity simply because such science was yet unknown. Consequently, their risk communication was wrong because they based their statements on overly optimistic interpretations of the existing science. Some may argue that this same mistake has occurred at multiple levels within the risk communication efforts regarding the Fukushima radiation disaster.

Chernobyl But when the risks are high, there may be a concern that the public may not reasonably respond to such elevated risks. Rather than making rational choices based on their elevated risks, people may make rash choices or become overwhelmed by their emotions rather than using rational thinking. In such circumstances, a more paternalistic view of risk communication may be preferentially valued. Such was the concern when the Soviets intentionally lied to the people of the many evacuated cities and towns when they evacuated them urgently, telling them that they would return soon. The people complied, and many thousands were evacuated very quickly and in an orderly fashion. But, the public was not fully informed of the risks which they faced at the time of the evacuations. Undoubtedly, this rapid evacuation saved the lives of many who were exposed to very high levels of radiation [31] because many likely would not have responded very well to the full information about their health risks to radiation.

Although the radiation contamination in Fukushima is less than that in Chernobyl, there has still been a rampant concern for public panic across all levels of Japanese government and agencies. Many government representatives have chosen to use this Chernobyl model of risk communication, which assumed that the governments were in the best position to make the risk decisions for their populace, and they imposed the risk decisions upon the population in rescue, relief, and resettlement efforts. However, that is not the only model for risk communication in the midst of an ionizing radiation disaster [32, 33].

Goiania Although the risk communication during the Chernobyl evacuations was highly successful at protecting public health, that paternalistic approach is not universally applicable. The Goiania accident, also, is a case study of ineffective ionizing radiation risk communication which further jeopardized public health.

The following is based on a first-hand account of the Goiania event (Guimaraes, personal communication). More comprehensive descriptions of the Goiania event are presented elsewhere [34–37]. In September 1987, one and a half years after the Chernobyl accident, the Goiania radiological accident occurred in Brazil, with four casualties, many amputations, and several hundred persons irradiated and/or contaminated. The following are examples of risk communication challenges within the Goiania event.

Mixed Messages The evacuation of contaminated houses was justified to the press by the provincial government as a response to a gas leak. This was because an international motorcycle race was occurring in Goiania then, and local officials feared that the radiation story would lead to the cancelation of this prestigious event. In Portuguese, pump and bomb are named by the same word, *bomba*, and in the medical jargon, a ^{137}Cs source is called a "cesium pump." Therefore, there was confusion about the source being a pump or a bomb. Then, the federal Brazilian Nuclear Energy Commission assumed the coordination of the radiation event. Risk communication was possibly the worst challenge, and the previous history of government secrecy and isolation resulted in untrained risk communicators addressing an untrusting audience. National and local authorities made very poor use of radio and television. One of the risk communication obsessions was to explain the difference between irradiation and contamination, which was surely relevant because the accident involved both. Indeed, the source was made of granulated $^{137}CsCl$ and the fascination caused by these crystals that glowed in the dark explains why the source fragments were dispersed among family and friends. However, the Goiania population insisted in amalgamating both terms and processes, coining the term "radiado." Hence, irradiated, contaminated, or both, you were "radiated." In practice, this meant that such people were both stigmatized and ostracized. The inhabitants of the affected district were severely discriminated against by the rest of the city, the latter by the rest of the province, and these collectively by the rest of the country. A few months after the event, patients from Goiania were still refused by hospitals of nearby cities; cars with Goiania license plates were occasionally stoned or blocked at interprovincial road checkpoints. In the first weeks after the event, crops or manufactured products from the state of Goiás were refused or sold only after heavy discounts. The Goiania event did yield new dose-response data [38–42] as well as the development of internal ^{137}Cs decontamination methods [35, 43–46]. Despite large and successful efforts in the monitoring and cleaning-up of Goiania contaminated sites, risk communication efforts were only modestly successful.

Conflicting Science—the Threshold Hypothesis There is currently a strong debate in the scientific community regarding the linear-no-threshold hypothesis [5, 47–50], recognized for many decades as the hypothesis with the greatest scientific evidence and adopted within countless policies worldwide over the past several decades. Some scientists in Japan have adopted the opposing "100-mSv threshold" hypothesis within their risk communication strategies, which has been greatly emphasized in Japan since the radiation disaster [51]. The threshold hypothesis was emphasized by varying levels of Japanese governments and many professional Japanese scientific societies, such as the Japan Radiological Society, Japan Pediatric Society, President of the Science Council of Japan, Japan Epidemiologic Society, and the Japanese National Institute of Radiological Science (NIRS). However, this threshold theory is in direct opposition to the internationally recognized official position that is fully supported by the research on the Hiroshima and Nagasaki nuclear bomb survivors, which is the linear-no-threshold theory of ionizing radiation-induced carcinogenesis [50]. In some cases, the ethical principle of non-maleficence seemed to support discourse of a 100-mSv threshold predicated on the necessity for risky medical interventions in populations who stayed in radiation-affected areas. Although such inconsistency within the scientific community is motivated to support vulnerable residents from both perspectives, it brings confusion to the public.

In recognition of the heterogeneity within the radiation risk communication efforts within Japan, on October 5–8, 2015, there was a workshop on best practices for radiation risk communication within the media and public relations [52]. During one workshop presentation, it was noted that with adequate exposure mitigation efforts, residents were able to confront the radiation risk influencing their daily life [53]. However, it was reported that the majority of parents in the exposed regions wanted to know all of the radiation health effects and they felt insufficiently informed, even in the districts next to Fukushima Prefecture. This difference would indicate the importance of the risk communication setting.

The Current Japanese Situation The Fukushima Health Survey uses many medical tests to screen for adverse health outcomes from radiation exposure, including thyroid ultrasound examinations to screen for pediatric thyroid cancer [54]. This survey is repeatedly screening ~360,000 residents aged 0 to 18 years at the time of the nuclear accident [55]. The preliminary screening to assess baseline health level had been performed within the first 3 years after the accident, followed by screening for detecting radiation effects from 2014 onward [56]. From this survey, concerns have been raised by local residents, such as the purpose of the survey and the interpretation of the initial results and follow-up surveys.

It is inevitable during the recovery phase of a nuclear disaster for public health activities in local communities to result in difficult ethical issues, such as how to communicate radiation risks and empower residents for their own risk decisions, how to carry out scientific research that solves problems, how to share the burden of risks fairly, and how to find a solution to the settlement of compensation issues. Public health activities in Fukushima are revealing that consideration of ethical issues regarding complex situations is a key factor to strengthening public trust.

Based on our own experiences and observations of the involved community in Fukushima, we have observed that many parents within the exposed Japanese regions have been distrustful of governments' roles in radiation protection and risk communication. Therefore, additional risk communication is necessary. But how should it be done? The following are two paradigms and strategies being proposed within the scientific community.

Strategies

We suggest that risk communicators within Japan strongly consider the flaws in the risk communication models from Goiania and Chernobyl along with the very clear risk communication mistakes from the World Trade Center disaster and earlier efforts in Fukushima. We strongly encourage risk communicators in Japan to fully consider the scientific uncertainties in both the public exposures to radiation and their resulting health effects prior to developing any additional mitigation plans and risk communication strategies. Any potential new risk communication strategy should leverage the lessons learned from these previous disasters and place the risk messages within the appropriate context of the Japanese culture. There is no perfect risk communication plan. But, there certainly could be improved risk communication strategies. Herein, we present two.

Strategy 1—a Public Health Approach: Abridged Disclosure, Emphasizing Full Physical and Emotional Support Not Only the Comprehensive Radiation Health Effects The difficulty of risk communication reflects social tension in affected regions. Some residents prefer a *health promotion* (promotion of healthy lifestyles and risk decisions) focus and other residents prefer a *health prevention* (prevention of adverse health outcomes) focus due to their personal situation, as explained by regulatory-focused public health theory [57, 58]. In such a situation, the support for one side might unintentionally harm the other even though both sides require strong emotional support. Especially for public announcements, public health agencies should pay attention to both sides considering that such agencies are expected to protect human health from hazardous environmental substances, which they were unable to do in Fukushima.

Therefore, the National Institute of Public Health in Japan (NIPH) carried out seminars for nursery school teachers in Fukushima with many relevant organizations in attendance [6•]. This approach did not fully disclose all health risks; rather, the health risk information which was considered to be harmful to either the health promotion or health prevention subclasses of the public were not discussed. Rather than confuse the public within the mire of the scientific debate on the threshold theory, this strategy only discussed the few irrefutable risks relevant to the entire public. This strategy is cognizant of the potential psychological burden within exposed populations if they feel overburdened by too much health risk information [6•]. This concern is predicated on the fact that collaborative efforts with stakeholders and supportive attitudes to support residents are needed. Empowerment is needed, especially for residents who are confused. This strategy leans on the precautionary principle through the lens of non-maleficence, not imposing new health risks on the population while trying to solve others [6•].

Evidence for Strategy 1 The public health approach used by the Japanese NIPH in Fukushima revealed that consideration of ethical issues regarding complex situations is a key factor to strengthen public trust [6•]. After the Fukushima nuclear disaster, the basic strategies of risk communication were issued from other governmental organizations, such as the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and food safety commission in Japan, and these are consistent with the global principles of risk communication. The NIPH strategies are also consistent with many global principles of risk communication [6•] in terms of the ethical considerations.

Ethical issues regarding the thyroid mass screenings were presented at seminars from 2012 to 2014 for nursery teachers ($n = 359$) organized by the Fukushima prefectural government and under the assistance of the federal government. The results are reported herein (Ichiro Yamaguchi, personal communication). To assist their own decisions on complex radiation issues, loss of life expectancy was explained at six local radiation seminars in Fukushima prefecture for mothers ($n = 51$) and nursery teachers ($n = 17$) held in February 2015. Participatory and questionnaire surveys were performed. Although the explanation of the adverse effects of the thyroid-screening test would not be easy for nursery teachers to understand, they recognized the honest attitudes of the facilitators and eventually understood their explanations. At local radiation seminars, about 40 % responded that they felt worried about radiation health risks. About 90 % responded that they understood the contents of the seminar, and 80 % responded that these seminars were appropriate. Before the seminar, 15 % of attendees who responded did not drink tap water due to concerns about radiation (despite the fact that the concentration of radioactive cesium in the water is at a few mBq/l); the percentage decreased to 3 % of attendees after the seminar ($p = 0.03$).

Strategy 2—Full Disclosure, with Knowledge Focus Researchers continue to clarify the causal relationship between radiation and its health effects quantitatively [59–61]. As previously mentioned, the findings have been published in numerous research papers and organizational reports. Based on the quantitative evidence, another risk communication strategy is that *all* potential radiation risks should be communicated with residents, governmental officers, and stakeholders as precisely as possible in clearly understandable terms. The Centers for Disease Control and Prevention in the USA leans more toward this approach within their risk communication recommendations [62•]. This strategy leans more strongly on the full disclosure of risks and benefit ethics than on the precautionary principle. These strategies have been adopted by many public health agencies worldwide.

Evidence for Strategy 2 After the nuclear accident in March 2011, most people in Japan believed expressions like "no cancer due to radiation occurs under 100 mSv of exposure" or "excess cancer cannot be found under 100 mSv of radiation" because some agencies in the Japanese government and Fukushima Prefecture officials continued to repeat such statements [63, 64]. In April 2011, the National Institute of Radiological Sciences placed a figure "quick help on radiation health effects" on its website. In the figure, a red line was drawn at 0.1 Gy, stating "no excess cancer is observed." It was taken away in 2012 but remained on many other websites, including those of local governments. In August 2014, the Japanese Government released a public service announcement entitled "Accurate Knowledge on Radiation" in five major nationwide and two local Fukushima newspapers with an opinion that excess cancer risk would not be observed with radiation under 100 mSv. Academic research has documented misrepresentation of the radiation risks within the media and inadequate risk communication from the Fukushima disaster [9, 65–68]. The 100-mSv threshold theory, however, is unproven both empirically and theoretically (Linear Non-Threshold). Since an association between fetal exposure to ionizing radiation in utero and the subsequent risk of cancer in childhood was first reported [69], numerous other studies have indicated that the relationship under 100 mSv of radiation is not only an in utero [70] exposure concern but also a concern for children and adults exposed after birth [71–74]. Radiation health effects have been clarified for various sources of radiation, such as atomic bomb survivors [75–77], nuclear facilities (including nuclear power plants, both during regular operations and after accidents) [73, 78–82], natural radiation (including radon exposure), occupational exposures in aircrafts [83–87], and medical diagnostic radiation [74, 88–90]. Results of these numerous studies can be obtained easily. Therefore, risk communication efforts based on the 100-mSv threshold hypothesis were misleading. Furthermore, contents of the WHO report [91], which indicated that there is an expected excess risk of thyroid, blood, breast, and other solid cancers in Fukushima was not readily available in Japan.

The 100-mSv threshold claim has already begun to differ from reality, yet it is still used by Japanese and local government agencies. This may be to prevent "fear" or "panic" in the Fukushima residents ahead of telling the public the full truth about the risks. Misdirected risk-communication, such as the 100-mSv threshold theory, resulted in distrust. Furthermore, it completely deprived constructive discussions and performance of feasible radiation protection measures in Fukushima. Minimization of health hazards and economic losses cannot be achieved without public trust. Therefore, full disclosure of the real health effects is paramount.

Discussion

Risk Communication

True risk communication is an interactive exchange of information, not a one-way process. Best practices, therefore, includes consideration of risk perceptions in the public. It is essential to have the ability to explain a risk on at the population level versus the individual level, e.g., relative versus absolute risk for those exposed. But, ionizing radiation is a very difficult concept to explain to such diverse audiences. Furthermore, there are many levels of government engaged in ionizing radiation risk communication, from local to national, and many potential agencies within each level of government, such as public health and environmental regulatory bodies. Inappropriate or ineffective risk communication could cause more harm to the public's health. Therefore, there are often contrasting goals and ethics which influence the strategies for risk communication in ionizing radiation-affected populations and different tactics by different levels and agencies within governments. Environmental epidemiology should avoid harm to the individuals and communities studied. Some of these ethics principles could, therefore, also be applied for risk communication, i.e., beneficence (doing good), accessible language (including strength and limitations), respect for autonomy (the individual's right to self-determination), community engagement, full disclosure of risks and benefits, and prompt communication of results [92•] http://www.iseepi.org/About/documents/ethics_guidelines_adopted_april_25_2012_001.pdf. But, understanding social context is crucial.

Risk communication has to be seen in a cultural perspective. In Western societies authorities often have trust in the public's own capability of making their own educated risk choices. Hence, full transparency in information dissemination is seldom a problem. The challenge is whether the risk communicators have fully understood the underlying factors affecting risk perception and whether those could be handled properly. Poor risk communication can result from not listening to the fear of the public, from their point of view, and not giving fully honest answers. Ensuring that people are safe does not automatically make them feel safe and secure. Some people want to have detailed information on their individual exposures and risks. Others just want to have the simple answer to the question "Is it dangerous for me, yes or no?" The challenge is, therefore, to give each individual as much information that they need for managing their fear and give them tools for making their risk decisions in daily life. Available information that gives the needed answers is more important than comprehensive assurances from the perspectives of the government. Therefore, information on exposure and risks should be as accurate as possible under the given circumstances of the disaster. Honesty about uncertainties most often creates trust. These are the principles which fundamentally govern risk communication within Western societies.

Ethical Guidelines

The International Society for Environmental Epidemiology (ISEE) Ethics and Philosophy Committee has taken an active role in supporting ethical conduct and formulating ethics guidelines. The second revision to the Ethics Guidelines for Environmental Epidemiologists was adopted by the Governing Council of the ISEE in 2012 [93]. A core value for environmental epidemiology is to avoid harm to the individuals and communities studied. These ethics principles, therefore, include the concepts of (a) beneficence (doing good), (b) accessible language (including strength and limitations), (c) the precautionary principle, (d) non-maleficence (doing no harm), (e) respect for autonomy (the individual's right to self-determination), (f) community engagement in the research process, (g) full disclosure of risks and benefits, and (h) prompt communication of results. Other essential ethical guidelines include informed consent, confidentiality, and data security. The research protocols should be approved by research ethics boards. Full disclosure of financial or other conflicting relationships ensures transparency but also enables the interpretation of results. A communication and action plan is needed to fulfill the obligation of transparency. It includes (a) reporting of research findings, (b) communications with the media, (c) transparency regarding assumptions and uncertainties, (d) communications and action plan, (e) avoidance of misrepresentations and improper inferences, and (f) psychological impact of research results. These principles are a framework, rather than a set of rules or an ultimate solution, as we confront ethical tensions. However, some concepts of applied ethics established in Western societies might be perceived differently in other cultures. Humility and cultural sensitivity are, therefore, warranted in the application of these guidelines. As these two risk communication strategies illustrate, sometimes, ethical principles may be juxtaposed. Perhaps full disclosure may be harmful, or the precautionary principle may violate autonomy. Such circumstances require objective debate and respect for opposing opinions regarding ideal risk communication strategies. Many other radiation risk communication resources are available which may help guide such debates (Table 1).

Public Health Screening

At the initial phase of the Fukushima nuclear disaster, the messages on radiation risk were announced by politicians with little technical consideration of risk communication. For example, the issue on standards for the use of school buildings and schoolyards that had attracted the strong attention in Japan was explained by the International Commission on Radiological Protection [94•, 95•]. "This 20 mSv/year was really a guidance value for formulating specific criteria of school buildings and schoolyards. But certainly, the MEXT explanations at the time might have been comprehended as if establishing the 20-mSv/year as a reference value for the use of school buildings and schoolyards. It is difficult to say that such an explanation could allay the strong sense of anxiety and unease toward radiation, and it was not appropriate from the point of view of risk communication either. Furthermore, there is still room for debate as to whether it was appropriate to apply the upper limit of the value, that is, used under 'existing exposure situations,' to school buildings and schoolyards that were used by children, who are generally considered to be more susceptible to the influence of radiation than adults." Even an important standard of the screening level for whole-body decontamination was modified without a certain scientific reason. A credible risk communication cannot be assessed by the authorities alone without involving the

Table 1 Key radiation risk communication resources

On public health communication		
WHO	Communication for behavioral impact	2012
WHO	Outbreak communication guidelines	2005
WHO	Outbreak communication planning guide	2008
WHO	Participant handbook communication training program for WHO staff	
US Department of Health and Human Services	Communicating in a crisis	2002
On radiation		
WHO	Establishing a dialog on risks from electromagnetic fields	2002
US Nuclear Regulatory Commission	Guidance on developing effective radiological risk communication messages	2011
US Nuclear Regulatory Commission	Effective risk communication	2004
US Federal Emergency Management Agency	Planning guidance for response to a nuclear detonation	2010
US Environmental		
• Protection Agency	Communicating radiation risks	2008
UK Agriculture and Food Countermeasures Working Group	Communications workshop summary report	2009
Swedish Radiation Protection Authority	Questions and answers concerning Chernobyl (in Swedish)	1999
Swedish Radiation Protection Authority	After Chernobyl, information about the consequences in Sweden (in Swedish)	
IAEA	Communication with the public in a nuclear or radiological emergency	2012
IAEA	Report on enhancing transparency and communication effectiveness in the event of a nuclear or radiological emergency	2012

stakeholder's opinion whether a dialog is in progress. In the case of the press releases of the mother milk survey of the Ministry of Health, Labor, and Welfare, the team discussed in advance with the specialist on risk communication and had enough time for question and answers with the media. Implementation in a public health intervention was discussed previously. Future risk communication will engage public health officials in the process and lean more on the expertise of trained risk communicators rather than uninformed elected officials.

Risk Communication Ethics

Ethical issues regarding the thyroid mass screenings has become more recognized. The letter from ISEE to Japan's leadership emphasized the significance of a long-term epidemiological study. Although several differences exist in regard to nature and level of exposure, the follow-up of atomic bomb survivors by the Radiation Effects Research Foundation has provided us with unprecedented knowledge for risk assessment and of fundamental importance for radiological protection. A similar prospective study including inhabitants in Fukushima prefecture and an unexposed population could probably be equally important in regard to health effects of protracted low-dose radiation since it has potentially high statistical power due to the large sample size.

The basic ethical principle for risk communication is to give the public the information of their own individual risks. Government agencies should provide risk information. Listening to the story about risk is not an easy thing in general. It depends on the psychological phase of the disaster, as explained by regulatory-focus theory [28]. What kinds of considerations are needed to tell about the risk information when the risk would be relatively small (nevertheless risk information should be announced to save their rights for avoiding risk) and local residents are reaching "a promotion-focus on hopes" mode after the severe disaster? Thyroid ultrasound examination might be harmful to certain residents due to overdiagnosis and high sensitivity on cyst detection although those cysts would not be harmful at all. Screening is not only a matter of avoiding false positive cancer but also to ensure avoiding false negative, i.e., missing cases of malignant disease. Inherent in a screening program is, therefore, to use a technique with high sensitivity to detect disease. The screening for thyroid cancer would probably not have been launched without the obvious increased incidence of childhood thyroid cancer in Belarus and Ukraine following the Chernobyl accident. There was a rational for the screening program, in order to detect and treat early cases; but subsequently, it became a problem for the authorities to explain the unexpected relatively high number of cases. A screening program is expensive and could be easier to start than to terminate. So, ethical questions also arise whether it can be justified to stop screening and to identify the line between health check-up and research. The Fukushima Health Survey was a program launched for health surveillance, to comfort the population, not primarily designed as a research initiative to give answers on the important issue of quantifying the risk of thyroid cancer in children and adolescents. This has now become a problem. What kinds of considerations are needed to tell about risk information on thyroid ultrasound examination when almost all will have a normal finding? A certain problem, therefore, arises when starting a screening program for an extremely rare, basically non-lethal disease but with large consequences for the individual, leaving the operated child with lifelong thyroid hormone supplementation. The other basic ethical principle is to respect the autonomy of participants who are being engaged in a scientific research. How should we respect autonomy of children regarding thyroid ultrasound examination? These are complex ethical considerations which have permeated the Fukushima risk communication debate. The participation rate is now dropping for the Fukushima Health Survey especially in the assigned control areas making it even more difficult for evaluation of the effects of radiation.

Context

Large-scale releases of radioactive substances into the environment offer a possibility to study this relationship, e.g., the nuclear power plant accidents in Chernobyl, Ukraine, 1986 and in Fukushima, Japan, 2011. Some aspects of human health after exposure to low doses of ionizing radiation are poorly understood. It is unethical to perform medical research on humans with methods intentionally inflicting harm. It is also difficult because a large number of exposed people are needed to achieve statistically significant results if risks are small. Environmental disasters, such as those in Chernobyl and Fukushima, provide a laboratory for observing health effects over a range of doses and over a long period of time. These types of large-scale nuclear accidents are fortunately rare but might also happen in the future. Knowledge of low-dose radiation health effects can be of great value in preventing harm in the event of new accidents. Such studies can also provide information on cost effectiveness of medical screening and help the development of intervention strategies for the purpose of minimizing harm to human health. Now, when concerns have risen on whether the increased incidence of thyroid cancer is a screening effect, or to what extent the exposure to radiation is a contributing risk factor, is it ethical *not* to continue with a research project, e.g., case-control study, of thyroid cancer within the screened cohort?

In the case of an accident, the initial focus for the public health community should always be in helping those affected. At the same time, it is often possible to advance scientific knowledge even in the midst of assisting communities in chaos. In Fukushima, there was a double disaster. The tsunami directly killed people and then there was a radioactive release from the nuclear power plant. The ionizing radiation had little immediate health effects on the public but might affect the people's health in the future. The Fukushima nuclear power plant accident is also a challenge to the authorities in mitigating health consequences and providing information for people concerned about their health.

Conflicting Risks But, does the benefit of reducing radiation risks by sustained evacuation cause additional health risks from prolonged absence from one's familial homeland? Unlike Goiania and Chernobyl, many of the displaced families in Fukushima have left homes and land which have been in their family for hundreds of years. Not only have these people lost their homes but their family heritage, also. Furthermore, the evacuees have been placed into very small evacuation shelters which were never designed for long-term habitation. What are the adverse health consequences from those living conditions, from lack of work, social disruption? Any risk mitigation and resulting risk communication messages should be placed within the context of competing risks, social, mental health, and economical and medical risks for individuals and the local society. Testing scenarios and developing strategies before a potential disaster might be helpful in reducing the humanitarian costs of the mitigation process itself. The precautionary principle should not just apply to the radiation health risks alone but to the entirety of the risk management process. Table 1 has many risk communication resources which may be helpful within this context.

Conclusions

Japan is at the cross-roads in their continued recovery from the Fukushima radiological disaster. Some evacuees are returning to their homes within the formerly evacuated zones. Other towns and villages may be reopened soon. What are the health risks associated with these decisions and how should they be communicated? An ethical question is also the autonomy for the people returning, if well informed and prepared to take whatever risk, should not that be respected as an expression of their free will? There are many unanswered questions. The environmental epidemiology guidelines should be used to design risk communication strategies which provide the greatest public health benefits. Given the many different conflicting ethics and varying perspectives on these complex issues, perhaps an interesting approach could be to create focus groups with researchers, government authorities, and local stakeholders in local workshops, e.g., in Japan, Sweden, the USA, and Brazil, discussing an identical fictional radioactive release scenario under their national risk communication strategies and then comparing the results between the four centers.

The dose-response curve on radiation and cancer is an interesting and very important discussion, with scientific, philosophical, and political implications. It is a scientific challenge to interpret epidemiological studies in the low-dose field where there might not be scientific consensus. In risk communication, it is important to differentiate between relative and absolute risks, on population level and on individual level, respectively. For successful risk communication, it is also essential to understand the public risk perception regarding ionizing radiation and the psychological dimension on the messages given and actions taken. Risk communication strategies in ionizing radiation affected communities are therefore complex, necessitating dialog across case-studies and leveraging the maximal ethical principles.

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Compliance with Ethical Standards

Ethical Guidelines The International Society for Environmental Epidemiology (ISEE) Ethics and Philosophy Committee has taken an active role in supporting ethical conduct and formulating ethics guidelines. The second revision to the Ethics Guidelines for Environmental Epidemiologists was adopted by the Governing Council of the ISEE in 2012 [93].

Conflict of Interest Erik R. Svendsen, Ichiro Yamaguchi, Toshihide Tsuda, Jean Remy Davee Guimaraes, Martin Tondel declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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