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Radiation Emergency Medical Preparedness in Japan: A Survey of Nuclear Emergency Core Hospitals

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Abstract

Objective: Based on experiences following the Great East Japan Earthquake and nuclear power plant accident in 2011, Nuclear Emergency Core Hospitals (NECHs) were designated as centers for radiation disaster management in Japan. This study aimed to investigate their current status and identify areas for improvement.

Methods: This cross-sectional study was conducted in October 2018. Demographic data were collected by a questionnaire with free text responses about attitudes toward NECHs. Considerations regarding risk communications during a radiation disaster were analyzed using qualitative text mining analysis.

Results: A total of 36 hospitals participated in this study. Only 31% of NECHs anticipated a radiation disaster. The importance of business continuity plans and risk communications was shown. Text analysis identified 7 important categories for health care workers during a radiation disaster, including media response, communications to hospital staff, risk communications, radiation effects on children, planning for a radiation disaster in the region, rumors, and the role in the region.

Conclusion: The radiation disaster medical system and NECHs in Japan were surveyed. The importance of risk communications, planning for a radiation disaster in each region, and the role in the region are identified as issues that need to be addressed.

Many people fear radiation disasters, including health care providers,[1] and establishing a radiation disaster medical system is a difficult task. Based on experiences following the Great East Japan Earthquake and nuclear power plant accident in 2011, the medical response system for radiation disasters in Japan was revised.[2] Following guidelines related to the Act on Special Measures Concerning Nuclear Emergency Preparedness, Nuclear Emergency Core Hospitals (NECHs) were designated as centers for radiation disaster management in Japan.[3] Designated NECHs must meet the following 3 requirements. First, NECHs need to accept and treat patients suffering from radiation exposure regardless of their contamination status. Second, in the event of a nuclear accident, NECHs need to form radiation disaster medical teams, including physicians, nurses, and radiologists with professional knowledge of radiation medicine. Third, NECHs need hospital staff (physicians, nurses, radiation technician, pharmacists, administrative staff) with specific knowledge of radiation medicine. As of August 1, 2020, there are 50 NECHs certified in prefectures in Japan in which nuclear power plants are located or are nearby. Other NECHs are also designated in prefectures in which nuclear power plants are located or are in neighboring prefectures. This is significant, because once a nuclear power plant

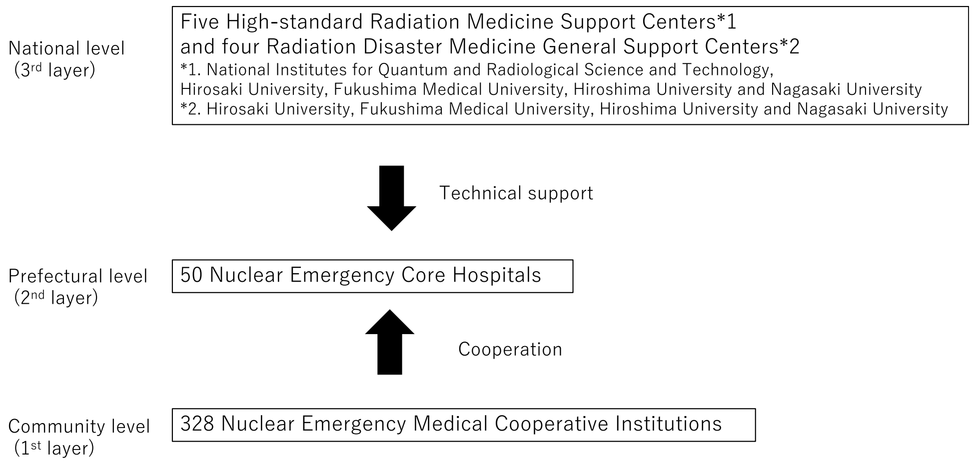

Figure 1. Three layers of the radiation disaster medical system in Japan.

accident occurs, a wide area will be affected. Therefore, response by a network of NECHs is suitable. The radiation disaster medical system in Japan consists of 3 layers (Figure 1), and the NECHs are in the second layer. The first layer consists of Nuclear Emergency Medical Cooperative Institutions, which are hospitals and health organizations responding to a radiation disaster locally. The third layer is a group of 5 High-standard Radiation Medicine Support Centers and 4 Radiation Disaster Medicine General Support Centers. The role of High-standard Radiation Medicine Support Centers is to serve as referral hospitals for radiation disaster patients and to provide training and education in radiation disaster medicine. The role of Radiation Disaster Medicine General Support Centers is to coordinate the radiation disaster medical team's deployment and establish the network for radiation disaster medicine. The 5 High-standard Radiation Medicine Support Centers and 4 Radiation Disaster Medicine General Support Centers provide expert support for radiation disaster medicine, accepting patients who cannot be treated at NECHs, and coordinate the dispatch of medical teams. In 2018, the Ministry of Health, Welfare and Labor requested that all disaster center hospitals, the core of the disaster response in the local areas, create business continuity plans.[4] Earthquakes are considered an assumption of risk assessment for disaster center hospitals in Japan, and radiation disasters such as nuclear power plant accidents have not been considered. Therefore, it is important for NECHs to create business continuity plans as part of the radiation disaster program.

Historically, the medical response system for radiation disasters in Japan was established after the Tokaimura nuclear accident in 1999.[5] Three workers were exposed to high levels of radiation in a small plant preparing fuel for an experimental reactor, and 2 died despite extended treatment in the intensive care unit. Hospitals in Fukushima Prefecture were faced with difficulties at the time of the Great East Japan Earthquake and nuclear power plant accident on March 11, 2011. Eleven people injured by the hydrogen explosion of Unit 3, Fukushima Daiichi Nuclear Power Plant station were accepted by designated hospitals on March 14, 2011. During the first 2 weeks after the accident, more than 60 people died during transportation from the evacuation zone in Fukushima.[6] Since the evacuation zone expanded every day due to the deteriorating situation at the Fukushima Daiichi Nuclear Power Plant, patients in hospitals and nursing facilities within the evacuation zone were forced to stay without sufficient supplies or logistic support. Most hospitals outside the stricken area had no capacity to accept the patients at that time. These patients were especially vulnerable, including the elderly, mentally ill, or bedridden. When they were rescued, most were in critical condition and died during transportation to receiving facilities. Additionally, many hospitals had difficulty maintaining operations because social functions were widely affected by fear of radiation effects among staff.[7]

Preparedness for radiation disasters is important, and, therefore, efforts such as ensuring the availability of decontamination facilities, stockpiling of countermeasures or measuring devices, human resources, and training, are mandatory. Risk communications for first responders in case of a radiation disaster have already been established.[8] Hachiya et al. reported that a basic knowledge of radiation for first responders was important to deal with the difficulties of the radiation disaster in Fukushima.[7] Although the importance of radiation disaster medicine and risk communications among health care workers is widely acknowledged, these have not yet been adequately established.[9,10]

Several studies have been conducted to investigate hospital preparedness for chemical, biological, or radio/nuclear incidents. Mortelans et al. conducted a survey of 93 hospitals in the Netherlands and reported that even after the Fukushima disaster in 2011, most hospitals in the Netherlands were not well-prepared.[11,12] Other studies also showed that most hospitals did not have adequate facilities, stockpiles of supplies, or training.[13,14] The present study aimed to investigate the current status of NECHs in Japan and identify areas for improvement.

Materials and Methods

Study Design and Participants

This cross-sectional study was conducted in October 2018. A questionnaire was electronically sent to contact personnel at the NECHs. At the time of the survey, there were 43 designated NECHs in Japan. Senior physicians at the NECHs in charge of radiation disaster response and their administrative staff responded to the questionnaire after discussion with other designated staff involved in dealing with nuclear/radiation disasters. Ethical approval for this study was obtained from the Kyushu University Graduate School and Faculty of Medicine Ethics Committee.

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Table 1. Characteristics of nuclear emergency core hospitals

		Mean/number	SD or %
Number of beds			241.2
			Range 230–1275
Number of employees	Total	1557.5	819.0
			Range 338–3523
Tertiary hospital	Yes	24	67%
Estimated disasters by risk assessment			
	Earthquake	35	97%
	Tsunami	11	31%
	Typhoon	15	42%
	Landslide	4	11%
	Nuclear disaster	11	31%
Previous mass casualty incident (>5 injuries) experience	Yes	15	42%
Previous disaster with activation of emergency operation center in the hospital	Yes	22	61%
Disaster management department exists	Yes	12	33%
Dedicated facilities for radiation/nuclear disaster (including decontamination)	Yes	17	47%
Nuclear disaster facility is facilitating independently from the main hospital building	Yes	10	28%
Developing a standard operation procedure using the facility above	Yes	14	39%
Distance from the closest nuclear power plant	(km)	54.9	23
			Range 11–120
Provides regular training for radiation/nuclear disasters	Yes	27	75%
Establishing hospital network in the prefecture	Yes	21	58%
Patients with high dose radiation exposure similar to the Tokaimura incident, Japan, 1999 can be treated	Yes	8	22%
Countermeasures stockpile			
1. Ca-DTPA	Yes	6	17%
2. Zn-DTPA	Yes	5	14%
3. Prussian blue	Yes	7	19%
4. Potassium iodide	Yes	21	58%
Is it possible to treat patients who inhaled or ingested plutonium accidentally?	Yes	10	28%
Hospital business continuity plan in case radiation/nuclear disaster exists?	Yes	1	3%
Acknowledging the importance of business continuity plan for radiation/nuclear disaster	Yes	29	81%
Acknowledging difficulties in creating business continuity plan	Yes	31	86%
Acknowledging difficulties in assessing the damage caused by radiation/nuclear disaster	Yes	25	69%
Preparing for other types of radiation disasters such as dirty bomb, etc.	Yes	11	31%
Acknowledging importance of planning risk communication for radiation disaster	Yes	36	100%
Acknowledging the importance of risk communication for the hospital	Yes	36	100%
Establishing standard operation procedure for risk communication in case of radiation/nuclear disaster	Yes	2	6%
Contact person for media in case of radiation/nuclear disaster	Yes	15	41.7%

Questionnaire Items

Tujiguhi et al. conducted a survey of NECHs and Nuclear Emergency Medical Cooperative Institutions in 2017.[3] They identified the need for education and an overall lack of human resources and specific instruments. Based on that questionnaire and study results, we created a new questionnaire to focus on NECH structure and function, such as level of preparation, significant issues, and difficulties. There are several existing studies focusing on hospital preparedness for radiation/nuclear disasters. Marzaleh et al. conducted a systematic review of hospital preparedness for radiation/nuclear disasters, and extracted 32 key components. Based on expert opinions, they summarized the results as 3 "S" subjects—Staff, Stuff, and Structure.[15,16] Based on these findings, the questionnaire for this study was created. Kotota et al. conducted an online survey of health care workers at hospitals in the United States and asked about the degree of preparedness for chemical, biological, or radio/nuclear disasters and determined that there are critical gaps in hospital capacity.[17] In summary, based on these findings, questionnaire items in the present study included (1) basic characteristics of the hospital, (2) capacity for disaster response, (3) capacity for radiation/nuclear disaster response, and (4) hospital staff attitudes toward a nuclear emergency core hospital. Specifically, in the questionnaire, the expression "mass casualty" was used. In Japan, a mass casualty incident is defined as an event with more than 5 injured persons who are transferred to medical facilities in a single event. NECHs have

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Table 2. Attitudes regarding designation as a nuclear emergency core hospital and considerations for risk communications during a radiation disaster

		Number	Percent
Attitudes toward designation as a nuclear emergency core hospital			
Designation as nuclear emergency core hospital is honorable.	Yes	13	36%
Human resource development can be achieved by radiation disaster medicine training.	Yes	22	61%
Strengthening the hospital system can be achieved.	Yes	21	58%
Social trust and repetition in the local community can be achieved.	Yes	6	17%
Financial support can strengthen the hospital system.	Yes	18	50%
Preparation for a radiation disaster can be useful for daily clinical work.	Yes	2	6%
Preparation as nuclear disaster base hospital could be helpful for real disaster response.	Yes	4	11%
Designation as nuclear disaster base hospital is a financially or resource-wisely burden.	Yes	12	33%
Human resource development for nuclear disaster core hospital is a financially or resource-wisely burden.	Yes	14	39%
System maintenance is a financially or resource-wisely burden.	Yes	16	44%
Obtaining understanding among hospital staff is difficult.	Yes	12	33%
Obtaining understanding in the local community is difficult.	Yes	3	8%
The local government is not sufficiently cooperative.	Yes	2	6%
The mission of a nuclear disaster base hospital was not fully understood by general hospital staff.	Yes	7	19%
Incentive is needed for designation as a nuclear disaster base hospital.	Yes	23	64%
There is disagreement among hospital staff regarding the designation as a nuclear base disaster hospital.	Yes	4	11%
There is criticism from people outside the hospital regarding designation as a nuclear disaster base hospital.	Yes	0	0%
Considerations for risk communications during a radiation disaster			
Risk communication is important in disaster response.	Yes	34	94%
Press response is important during a disaster.	Yes	25	69%
Experience and knowledge regarding risk communication are lacking.	Yes	23	64%
Information regarding risk communication is lacking.	Yes	23	64%
Hospital staffs fear a radiation disaster.	Yes	18	50%
Hospital staffs have distrust regarding radiation disasters.	Yes	14	39%
Standard Operation Procedure for risk communication during a radiation disaster is needed.	Yes	17	47%
Training in risk communication during a radiation disaster is needed.	Yes	17	47%

discrete facilities designated for decontamination and treatment of patients involved in radiation/nuclear disasters. These facilities are independent buildings or units located at a hospital site.

Data Collection and Analysis

Demographic data were collected in the questionnaire and the results evaluated. Demographic parameters are reported as means with standard deviations, and quantitative parameters were calculated as percentages. Free-text descriptions concerning attitudes toward NECHs and considerations for risk communications during a radiation disaster were analyzed using KH Coder for qualitative text mining analysis. KH Coder was developed in R by Dr Higuchi at Ritsumeikan University in Japan[18] and uses the "ChaSen" language-morphology-analysis system as the backend program. KH Coder produces a list of words ordered according to their frequencies and interrelationships. High-frequency occurring words in the same text unit were extracted, and a hierarchical cluster constructed, using the Jaccard distance.[19] For co-occurrence network analysis, 2 words were connected by a line, based on the Fruchterman and Reingold layout algorithm.[20]

Results

Of 43 NECHs designated by 2018, 36 (83%) participated in this study. The characteristics of the NECHs are shown in Table 1. Of these, 67% are categorized as tertiary emergency hospitals, and 47% own separate facilities for radiation medicine that serve as the initial treatment area for triage, decontamination, and radiation measurement. However, only 31% of the hospitals have conducted a concrete risk assessment for a radiation disaster, and less than 40% have prepared standard operating procedures or manuals for the management of patients during a radiation disaster. Although the importance of business continuity plans and risk communications is recognized, specific plans or appropriate human resources have not been prepared. NECHs were categorized by the distance to the closest nuclear power plant and differences were evaluated based on this distance (see Supplementary Table S1). There were no differences found, implying that the sense of urgency does not vary with distance from the nuclear power plant.

Table 2 shows respondents' attitudes toward NECHs and considerations for risk communications during a radiation disaster. Hospital staff and the local community understand the importance of designation as an NECH. However, similar to the results shown in Table 1, specific plans for risk communications have not been prepared.

Figure 2 shows the result of KH coder text mining analysis of free text comments. Frequent terms included "nuclear," "disaster," "response," and "communication." Figure 3 summarizes the free text descriptions of attitudes toward the NECH and considerations for risk communications during a radiation disaster categorized into 7 groups based on hierarchical cluster analysis. The 7 categories include media response, communications to hospital staff, risk

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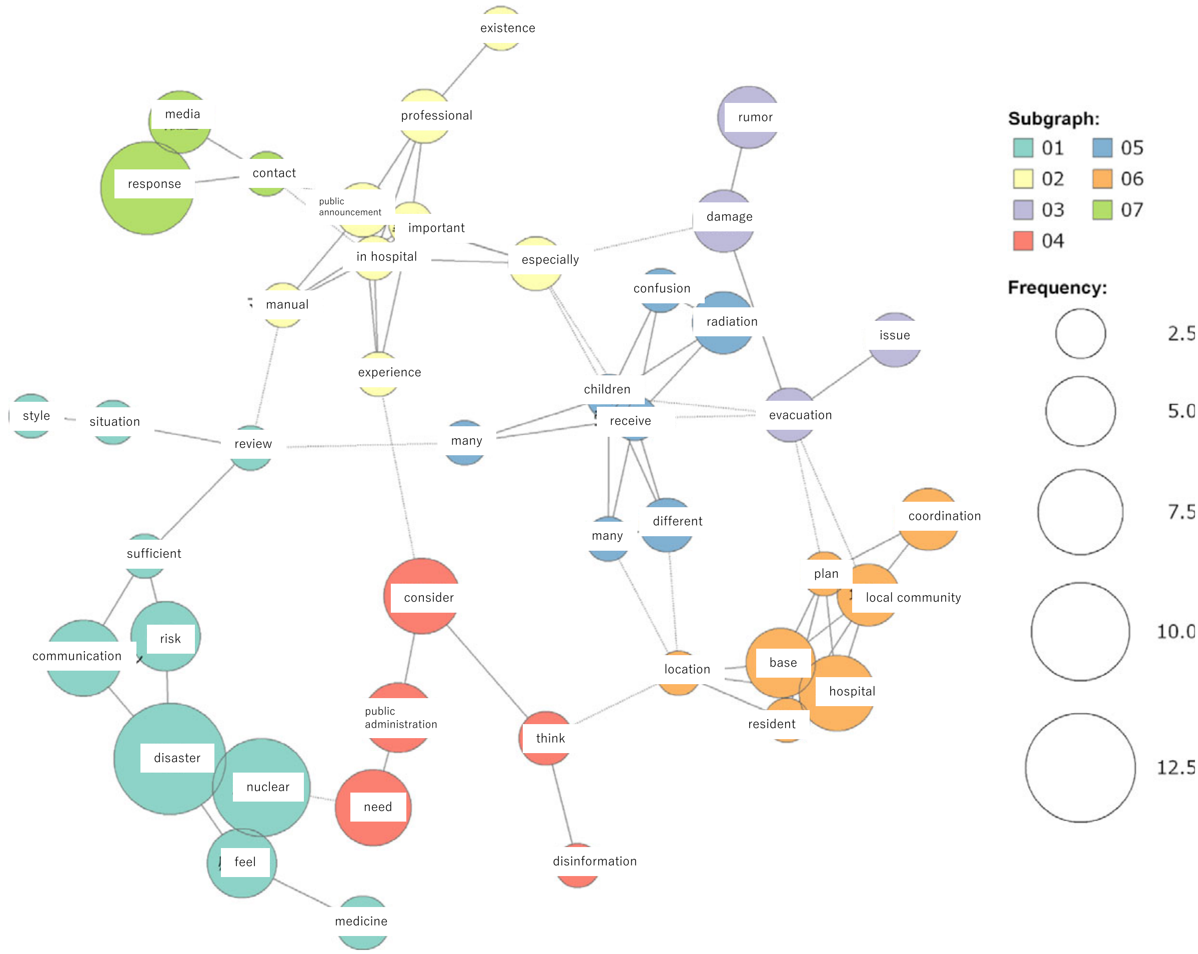

Figure 2. Results of KH Coder analysis of free text responses by co-occurrence network of words.

communications, radiation effects on children, planning for radiation disasters in the region, rumors, and the role of the NECH in the region.

Discussion

In this study, the current status of the radiation disaster medical system and NECHs in Japan was evaluated. The number of NECH designated hospitals is increasing, and organizational manuals, standard operating procedures, human resources, and risk communications were identified as issues needing resolution. Although the NECH network is designated to function in radiation disasters, only 31% of the NECHs have formally anticipated the risk of a radiation disaster, suggesting that improvement overall and technical support are needed to complete the risk assessment process and strengthen the overall NECH network capacity on a national level. KH Coder, a Japanese language specific quantitative content analysis system, was used to analyze free text fields in the responses.[18] Quantitative context analysis provides objective analysis of nuances regarding issues raised by respondents regarding the NECHs, which might not be evident based on analysis of discrete items in a questionnaire. The importance of risk communications, planning for a radiation disaster in each region, and the role of the NECH in the region was raised as issues in this study, which should be addressed by providing additional training and technical support.

Japan is the only country to have experienced a simultaneous triple disaster (earthquake, tsunami, and nuclear power plant incident). The damage was devastating, and to respond effectively to such a combination of events, a single hospital is not sufficient. A functioning coordinated hospital network was needed in the aftermath of the Great East Japan Earthquake.[2] This is one of the lessons learned, and we suggest that a hospital network will provide hospital preparedness for a future radiation/nuclear disaster. Nuclear power plants are operating in 31 countries in the world, and organizing an appropriate radiation disaster medical response is not straightforward. Several studies have been done in the United States,[13,17] Canada, European countries,[12] and Iran[15,16] regarding hospital preparedness for radiation disasters. Only Japan has established a hospital network to respond to radiation disasters.[2] Although there is a difference in health care systems, geography, and population density, the NECH network may serve as a model for other countries.

In Table 1, only 28% of NECHs have the capacity to effectively respond to a plutonium incident. In 2016, accidental leakage of plutonium occurred in a laboratory in Tokaimura, Japan. One worker inhaled a small amount of plutonium and was transferred to the National Institutes for Quantum and Radiological Science and Technology for care. This may be the reason why a response capability to plutonium was partially confirmed in the questionnaire. Additional preparedness for this type of incident needs to be further considered by NECHs.

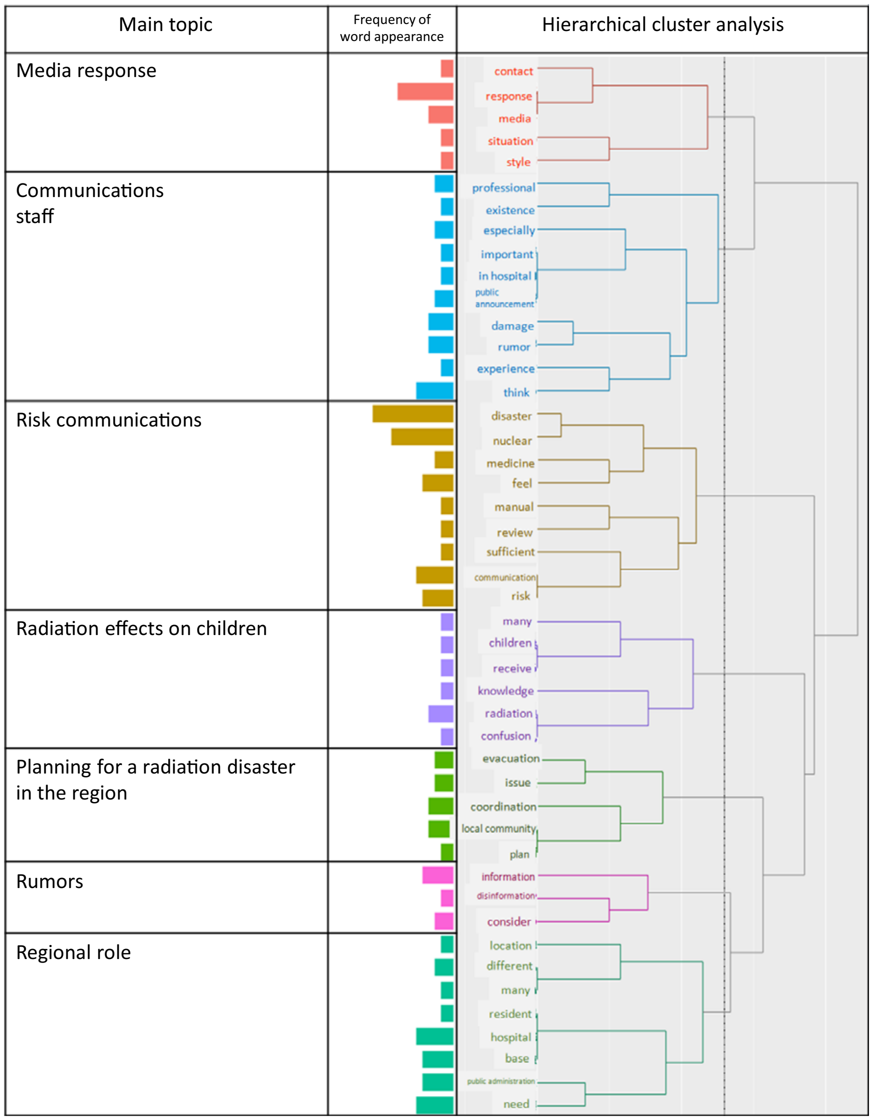

Figure 3. Results of the hierarchical cluster analysis.

Considering the amount of radiation disseminated after the Great East Japan Earthquake and nuclear power plant accident in 2011, many studies have shown that the direct effect of radiation on health after that disaster was limited. However, radiation disasters cause serious psychological effects on people and society, and people have great fear of nuclear power plant accidents.[21] Effective risk communications among health care workers may help ameliorate this fear. However, systems for risk communications during crises or disasters are not well established in Japan.[9] In this study, the importance of including training and optimal utilization of human resources as part of a hazard-preparedness program is recognized.

There are several limitations to this study. First, the survey was conducted in October 2018, and at that time, the number of NECHs was 43. There are 50 NECHs designated as of August 2020. Therefore, the results cannot fully evaluate the current status of the radiation disaster medical system in Japan. Second, in this survey, the details of equipment such as decontamination facilities, stockpiles of personal protective equipment, radiation measuring devices, such as Geiger counters or NaI scintillation counters, or whole-body radiation counters, were not investigated. Third, this survey is focused on NECHs, the second layer of the radiation disaster medical system in Japan. Further comprehensive surveys including the Nuclear Emergency Medical Cooperative Institutions, High-standard Radiation Medicine Support Centers, and Radiation Disaster Medicine General Support Centers should be conducted in the future. Fourth, respondents to the questionnaire were senior physicians and their administrative staff. Although senior physicians and administrative staff are in charge of the NECH mission, responses from these leadership groups may not be representative of all employees at NECHs. Thus, the answers may be personal opinions rather than general perceptions of the NECHs. Fifth, since the sample size was small, multivariate analysis could not be conducted.

Conclusion

In this study, the current status of NECHs in Japan was studied, and areas needing improvement identified. The importance of risk communications, planning for a radiation disaster in each region, and the role of the NECH in the region were identified as specific issues that need to be addressed.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2021.348

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