Radiation Emergency Medicine: Based on a general overview of disaster medicine

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Disaster Is a Common Product of Civilization: We have no choice but to deal with unforeseen disaster at any time

I believe that the purpose of today's training program is to clarify how the Japan Medical Association (JMA) should be involved in disaster management as a professional group of physicians. From that aspect, the Great East Japan Earthquake and Tsunami and the subsequent Fukushima Daiichi Nuclear Power Plant accident provided both opportunities and lessons for us. Today, I will discuss radiation emergency medicine in the context of this training program.

Being civilized means being urbanized. In the Indus Civilization that flourished in 2000 BC, about 40,000 people lived in its largest city, Mohenjo Daro. The population of London was about 50,000 in the 1500's, but increased to several million during the Industrial Revolution.

In Japan, the urbanization rate in the 1950s was 56%. At that time, natural disasters such as earthquakes or typhoons would result in the deaths of thousands of people. The current urbanization rate is over 80%, and some metropolises today are of proportions that were unimaginable during the 1950s. The population that a disaster can affect is, therefore, far greater now than that in the 1950s. When a city is exposed to a massive amount of energy—either externally in the form of a natural disaster or internally as an infectious disease—many lives become vulnerable. Further, cities require transportation systems, chemical facilities, and energy production facilities in order to function. Such facilities are risk factors for disasters themselves. In a city, these facilities may be sequentially affected, even in a natural disaster, and a simple disaster can turn into a compound disaster and the damage grows in scale.

A civilization always progresses. Thus, humans are destined to face a mega-disaster on a scale we have not previously experienced. Nuclear disaster is indeed one such potential event.

Emergency Medical Resources Required in Non-Metropolitan Areas in Times of Disaster Can Be Extensive

Urbanized areas have higher populations than non-urbanized areas. Naturally, the size of the population affected in a disaster is greater in urbanized areas. This may lead to the conclusion that a disaster occurring in a non-urbanized area with a small population would require fewer emergency medical resources. However, that assumption is false.

The rates of urbanization and aging are negatively correlated. The aging rate in urbanized areas is lower than that in non-urbanized areas. In my survey of ambulance transport data in Kitakyushu City, the number of transported cases increased exponentially with increasing age when the patients were in their late 50's or older. Considering these 2 facts, the following conclusions

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can be drawn. Urbanized areas require more emergency medical resources in the acute phase of disaster because of the higher population. On the other hand, the number of people affected by a disaster is smaller in non-urbanized areas because such areas are less populated. However, the higher aging rate in a non-urbanized area will likely increase the proportion of people requiring emergency medicine in the acute phase. We can anticipate the following relationship:

(Size of population that requires emergency medicine in times of disaster)
=(Population size)×(Aging rate)

Therefore, a disaster occurring in a non-urbanized area does not necessarily require fewer emergency medical resources. We should be sufficiently prepared at all times.

Disaster Can Affect the Most Vulnerable Part of Community Health Care

When the number and proportion of deaths resulting from the Great East Japan Earthquake are examined by town, it can be seen that for a small town receiving relatively few casualties, those casualties represented a high proportion of the town's population, and therefore the proportional damage was significant. The most pronounced example is the town of Otsuchi, Iwate Prefecture. Before the disaster, the population of Otsuchi was approximately 12,000 and the aging rate was 28.5%; the Prefectural Otsuchi Hospital (with 121 beds) was responsible for the community health care of the area. This hospital, however, was completely demolished by the tsunami. This meant that both emergency medicine and community health care were inaccessible during the acute phase of the disaster and for an extensive period of time afterwards. Earlier today, Dr. Kayden said that the idea that "we will recover from the damage in several weeks" is just a "common myth in disaster," and she is indeed correct. Dr. Arii earlier introduced the idea of conducting visual observation and rapid assessment of disaster areas on foot immediately after a disaster, and I believe these surveys would be extremely valuable in determining the extent of damage to community health care and quantifying the necessary aid.

The duty of establishing and maintaining community health care is, as stipulated in the Medical Affairs Act, the responsibility of the local municipality—and so is the restoration. However, when local municipalities responsible for these duties suffer extensive damage, they of course cannot execute their duties, and it is only natural that the central government will act on their behalf. In my eyes, however, the government has made very little progress in this regard since the Great East Japan Earthquake.

General Overview of Existing Disaster Medicine: "Local response systems for the acute phase of disaster medicine" are undeveloped

In order to conduct a general overview of disaster medicine, let us set 2 axes: One axis is the *response*, as in "whether the response comes from *inside* disaster areas or *outside*" and the other is the *time-phase*, as in "if the response is in the *acute* phase or *chronic* phase."

The Disaster Medical Assistance Team (DMAT) is the program responding to the needs in "the *acute* phase from *outside*," whereas the Japan Medical Association Team (JMAT) of the JMA is the program responding to the needs in "the *sub-acute to chronic* phase from *outside*." This means that there is no disaster medicine system that responds to "the *acute* phase from *inside*" (**Fig. 1**). Basic disaster management plans have incorporated disaster medicine responses in disaster areas as extensions of daily medical practice. However, the people of Japan learned that disaster medicine is very different from daily medicine, through their experience during major disasters such as the Hanshin-Awaji Earthquake. Disaster medicine, in any case, should start "immediately after a disaster" at "disaster areas," and medical institutions in disaster areas must get involved whether they would wish to or not. Therefore, a disaster medicine response system should be prepared to start during "the *acute* phase from *inside*." However, this "*acute* phase from *inside*" aspect of disaster medicine response has been hardly addressed.

The Kitakyushu Medical Association and the Fukuoka Prefecture Medical Association, along with the Yanagawa-Yamato Medical Association (Fukuoka Prefecture) that responded to their activities, have spent several years constructing a disaster medicine system to respond during "the *acute* phase from *inside*." We wish to provide the details of this system through the JMA in

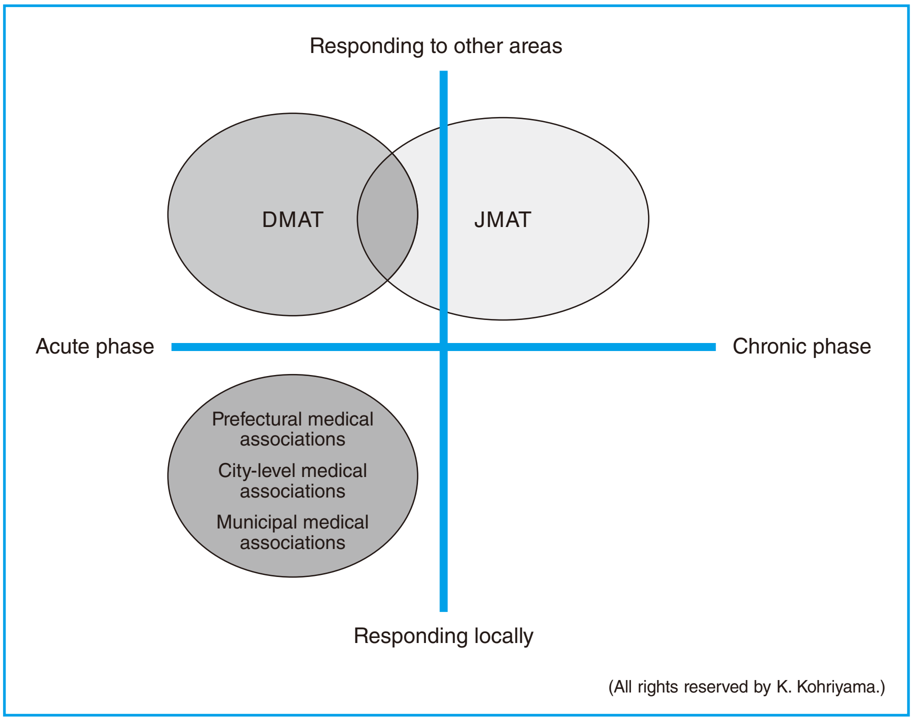

Fig. 1 Mapping of disaster medicine focusing on the assistance areas and the time phases

the future, and we hope that it will serve as a model for other medical associations to study.

The Risk of Nuclear Disasters

The Fukushima Daiichi Nuclear Power Plant accident, which is yet to be concluded in my personal view, is often described as an unforeseen and unexpected nuclear disaster because this accident followed a once-in-every-1,000-years natural disaster that has become known as the Great East Japan Earthquake. After such a major accident, how will the risk of a future nuclear disaster be considered in future? Will such accidents continue to be "unexpected"?

In 2004, the third unit of the Mihama Nuclear Power Plant (Fukui Prefecture; construction started in 1972) experienced an accident, in which the secondary pipe burst and spouted high-temperature vapor. There were workmen nearby, preparing for a regular maintenance check; 11 were injured and 5 lost their lives. The accident occurred at a secondary pipe, and there was no risk of radioactive materials leaking into the environment, but that is not the point. Because thickness tests of secondary pipes had been neglected for 27 years, the pipe that should have been replaced remained in use beyond its functional lifespan, and consequently burst. The rule of thumb for industrial accidents, *Heinrich's law*, states that "in a workplace, for every accident that causes a major injury, there are 29 accidents that cause minor injuries and 300 accidents that cause no injuries." The oversight at the Mihama Plant could easily happen at other plants—no, it may be happening already. The construction of many nuclear plants in Japan began almost 40 years ago, and accidents due to "oversights" could start to occur soon. Furthermore, there are situations that we now know to be risky that could not have been addressed when these nuclear reactors were being developed, because the advancement of science was insufficient at the time of construction. Such situations include stress corrosion cracking in pipes and neutron embrittlement of pressurized containers. These factors are bound to increase the risk of nuclear disasters.

Basic Knowledge of Radiation: Points are the distance travelled in air, permeability of living bodies, and DNA damage

With the Fukushima Daiichi Nuclear Power Plant accident in mind, I wish to organize the knowledge necessary to understand the health risks associated with radiation disasters.

When considering the health risks from radiation, attention should be paid to the distance that radiation can travel in air, permeability of living organisms, and the damaging effect to DNA.

"External exposure" occurs when a body is exposed to radiation from a radioactive material outside the body. When radioactive material is brought inside the body and the body is exposed to radiation from the inside, it is called "internal exposure."

Let us start with external exposure. Alpha- and β-rays can travel a few millimeters or centimeters in the air, respectively; hence, a living body will not be affected if a radioactive material is located 1 m or more from the body. Even at distances of several millimeters or centimeters from the body, clothing or skin will provide protection. Given these facts, we do not have to consider the effects of α-ray. As for β-ray, when a very strong radioactive material is attached to a body, DNA in the subcutaneous tissue a few millimeters under the skin—specifically the dermis—will be damaged (β-ray burn). The type of radiation that has systemic effects after external exposure is γ radiation (and neutron ray). Of the radioactive materials used in the Fukushima nuclear power plant, cesium and iodine emit γ-ray. Iodine has a short half-life, and the effects have not been manifested thus far. The "Radioactive material contamination map from the Fukushima Daiichi Nuclear Power Plant" that is widely available to the public addresses cesium contamination.

Next, I would like to discuss internal exposure. With internal exposure, the distance that the radiation can travel is irrelevant, because radioactive material is in direct contact with tissues. Additionally, there is no clothing or skin to provide protection. Therefore, cells are directly exposed to the effects of radiation. Because α-ray substantially damage DNA (to a degree approximately 20 times greater than β- or γ-ray), caution must be taken with radioactive materials that emit α-ray.

Of the radioactive materials used in the Fukushima nuclear power plant, plutonium emits α-ray. However, it is believed that there was very little plutonium contamination at this time, and even if there was, it would be an extremely small quantity.

Units of Radiation and Effects on Living Bodies: Bonfire's law

The units of radiation and the effects on living bodies are easy to understand when you imagine standing in front of a bonfire (**Fig. 2**). You feel very hot if you stand very close, but you feel warm and comfortable at an appropriate distance. When you stand far away, you cannot even tell that there is a bonfire. The amount of heat you receive changes with the *distance* from the bonfire.

"Becquerel" (Bq) is the unit in radiology that is analogous to the strength of the bonfire. This figure represents the strength of the bonfire itself, and therefore it does not change no matter what your distance from the bonfire.

The energy provided by radiation, which is analogous to the "perceived heat" of the bonfire, is measured using the unit "gray" (Gy). This figure increases as you stand closer to the bonfire, and decreases as you move away. Specifically, this figure "Gy" is inversely proportional to the square of the distance from the bonfire. This clearly illustrates that the effect of the bonfire is correlated to the *distance*.

The distance, however, is not the only factor that influences the effects of the bonfire. Let us imagine that there is an ice cream at a certain distance from the bonfire. It will not start to melt until several seconds after being placed in front of the bonfire, but it will melt completely after several minutes. The effects of the bonfire include both *distance* and *time* factors.

Next, let us imagine an ice cream, a cake with whipped cream, and a pumpkin being placed at the same distance from the bonfire for the same duration. The ice cream will melt, and the cake will melt partially; the pumpkin, however, may become hot but will never melt. In other words, if different objects are placed at the same distance from the bonfire for the same duration, the effect of the "bonfire" on the different objects

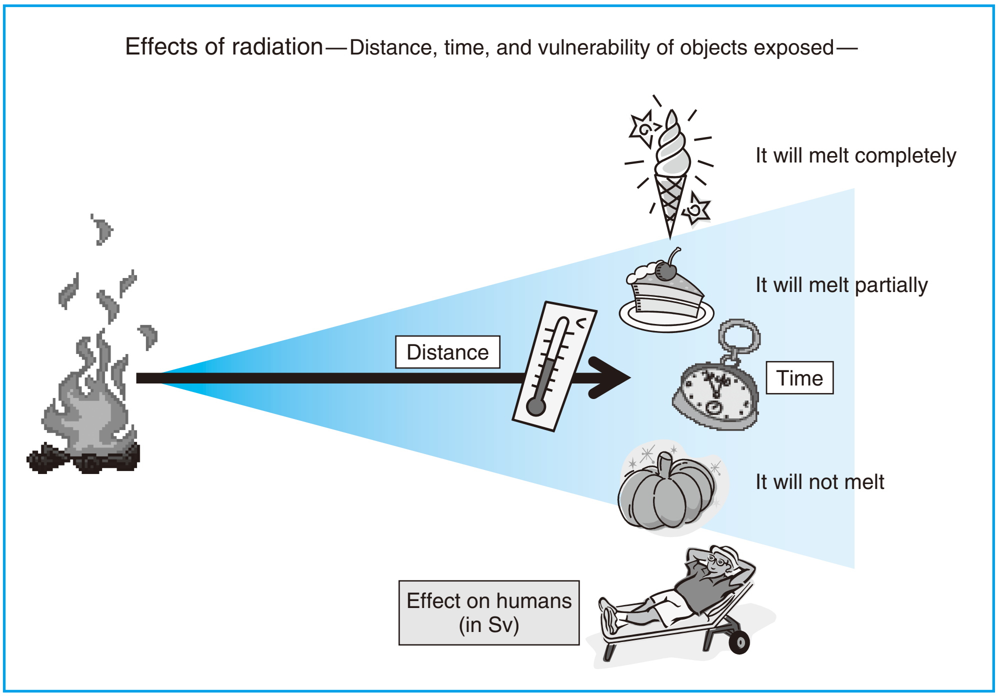

Fig. 2 "Bonfire's law" to understand the effects of radiation

is ultimately determined by each object's *distance*, *time*, and *vulnerability to heat*. The same applies to radiation.

The ultimate effect of radiation on a human body is measured using the unit "Sievert" (Sv), which incorporates distance, time, and all other factors. This figure illustrates the effect of radiation on a human body, regardless of whether the exposure was internal or external.

Effect of Radiation on Living Bodies: External exposure uses measured values, whereas internal exposure uses estimated values

The effect of radiation on living bodies is assessed by summing the levels of external exposure and internal exposure.

The level of external exposure can be measured by wearing a personal dosimeter. Most external exposure is due to γ-ray, so a personal dosimeter typically measures γ radiation. The assessment of external exposure is based on the total dose of γ-ray that a person is exposed to, starting from the time the personal dosimeter is first worn (i.e., "zero") until the measurement is recorded.

Internal exposure is estimated based on the future effects of radioactive materials that remain in a body. The manner by which the radioactive material found in a body will remain there for the next 50 years (or at 70 years of age for children) is estimated, the effect of the radioactive material on the DNA is calculated, and then the estimated effect is given in "Sv."

Ultimately, the figure shown in the unit of "Sv" is adjusted so that a given value will be equally damaging regardless of whether it is from internal exposure or external exposure. As confusing as it may be, 5 Sv of internal exposure is no more dangerous than 5 Sv of external exposure.

Radiation Dose Limit

There is a recommended radiation dose limit that is accepted internationally based on past basic research and epidemiology studies. The recommended radiation dose limit for the general public (excluding the dose that a person is naturally exposed to in the environment) is set at 1 mSv or less per year. Certain professionals

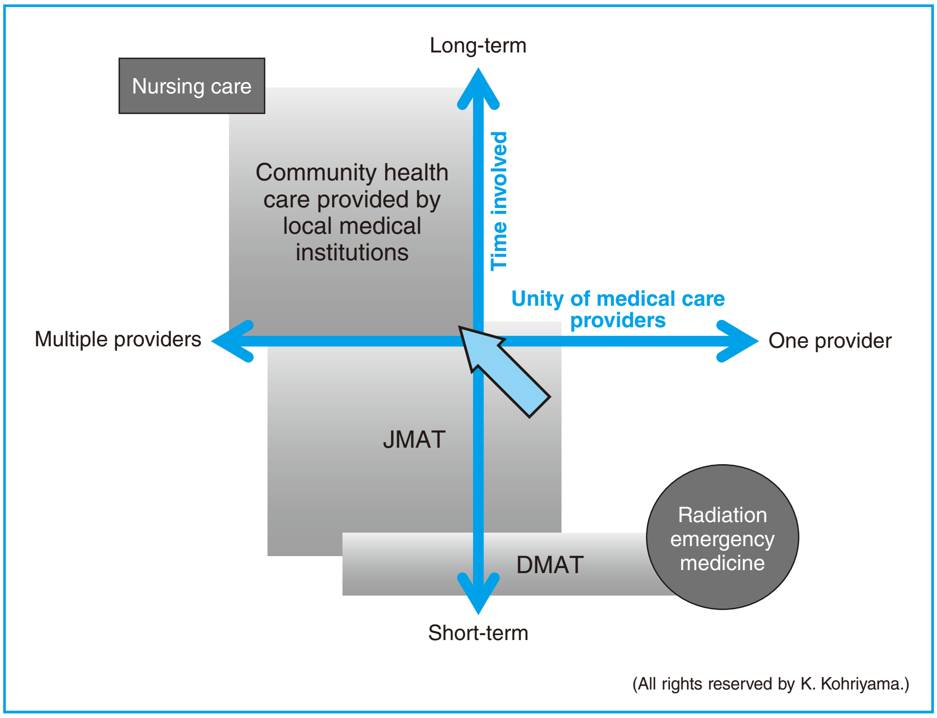

Fig. 3 Mapping of disaster medicine focusing on the time involved and the unity of medical care providers

such as physicians, radiologists, and those who work at nuclear power plants, are exposed to greater levels of radiation. For those people, the dose limit is set differently, at "100 mSv or less in 5 years and not to exceed 50 mSv for any given year." At this point, the risk of developing cancer for physicians or radiologists is not considered to be any higher than that for the general population.

Protecting Yourself From the Effects of Radioactive Materials

Let us think only in theories. I say "only in theories" because whether or not all these theories can be implemented depends on many factors, such as the radiation status of each region and health factors.

It is the γ-ray that is the primary problem in external exposure. Because γ-ray loses energy each time it passes through an object, its energy is considerably reduced inside a building. Therefore, an easy way to protect oneself from the effects of γ radiation is to minimize the time spent outdoors to minimize the direct exposure to γ-ray.

In order to reduce internal exposure, it is best to minimize the amount of radioactive material that enters through your mouth or nose. You can think of it like influenza prevention. Hand-washing and mouth-rinsing when you come home will help to wash away any radioactive material. In places where high doses of radiation are present, wearing a mask will be effective as well.

Conclusion

I would like to summarize my presentation from 2 standpoints, using the Great East Japan Earthquake as an example: the *time involved in disaster medicine*, and the *unity of health care providers* (**Fig. 3**).

Figure 3 shows the positions of disaster medicine, DMAT, and JMAT activities when using these standpoints as the axes. When a situation enters the upper left quadrant, it is considered that the "health care system in the disaster area is restored." I believe that the role of disaster medicine is to help push the health care systems of disaster areas, which in many cases exist in the lower right quadrant after a disaster, into the upper left quadrant. The more *time* it takes, the more the local health care providers closest to the local residents may need to respond to the anxiety toward radiation among them. Interpretations of the effects of radiation on health below a certain dose can vary considerably; it is in the field of trans-science. Therefore, physicians are often asked to provide scientific explanations as well as serve as spokespeople in response to residents' anxiety.

I would like to conclude by providing the outline of my presentation below.

1. Urbanization is in progress everywhere, and disaster medicine is a mission for all physicians.
2. Establishing a disaster medicine system requires a general overview of existing systems.
3. It is urgent to establish a rapid response system that can respond locally.
4. The risk of nuclear disaster will grow in the future.
5. Physicians should have a basic understanding of radiation medicine to be able to answer the questions of patients who are experiencing anxiety. Physicians should also serve as spokespeople for conveying patients' anxiety to the government.