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Development and statistical assessment of a radiation safety literacy measurement tool

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► ***Original article***

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ABSTRACT

Background: The public's understanding of radiation and protection of radiation harm is not high. Therefore, it is meaningful to know the radiation safety literacy level in terms of health care. This study developed a measurement tool that can help to identify the actual condition of radiation safety literacy and conducted the statistical assessment of the developed tool. ***Materials and Methods:*** We developed a radiation safety literacy measurement tool in four steps: preliminary term extraction, content validity, face validity, and response scale composition using expert groups such as radiologist, professor of radiological science, angiography nurse, and professor of Korean language. And we developed a questionnaire and conducted a survey on samples of n = 280 (male: 124, female: 156). For statistical assessment, descriptive analysis, Cronbach's coefficient, and correlation analysis were performed, and receiver operating characteristic (ROC) curve was obtained. ***Results:*** As a result of developing measurement tool of four steps, radiation safety literacy measurement tool consisting of a total of 46 items were developed. The result of the survey showed high reliability with the internal consistency reliability coefficient of 0.963. The correlation coefficient of the developed measurement tool with the rapid estimate of adult literacy in medicine was found to be valid with 0.448 ($p<0.05$). ***Conclusion:*** The radiation safety literacy measurement tool developed in this study can be used as a useful tool for the process of patient evaluation for appropriate communication between the healthcare provider and the patient regarding radiation.

Keywords: *Radiation safety, health literacy, reliability, validity, receiver operating characteristic curve.*

INTRODUCTION

Every human being wants to live long and healthy. There are many factors that affect health, and recent studies have shown that health information literacy is also one of factors. Health information literacy is defined as the ability to use and understand health-related information [1]. In Korea, it is given different names such as “medical information comprehension ability,” “medical information literacy,” “health information utilization ability,” “health literacy,” “ability to understand health information,” and “health literacy” [2]. “Ability to understand health information" includes the ability of individuals to understand explanations from medical staff when using medical care, reading or filling out health questionnaires and consent forms, understanding health education materials, and solving descriptions of basic medication and methods [3]. To sum up the above, the health information literacy can be defined as “the ability to acquire basic health information and a series of processes to understand it, and the degree to which services necessary for health care can be used.”

Health information literacy consists of rapid estimate of adult literacy in medicine and

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functional literacy. The rapid estimate of adult literacy in medicine (REALM) refers to an understanding of the 66 common terms used in medical institutions related to disease or body. Functional health information literacy refers to the ability to read and understand health-related data, such as medication manuals, appointments, and examination-related instructions, and to take appropriate health actions [4]. Previous studies on the relations and effects of the health information literacy on health in Korea include 'a study on the development of a Korean health information literacy evaluation tool' [5], and 'a study on the development of Health Literacy Scale for Korean Teens (KHLS-Teen)' [6].

Overseas studies include 'a research on the relationship between health promotion behavior and health information literacy of Taiwanese teenagers' [7] and 'a study on the development and validity of health information literacy prediction model for Europeans' [8]. As identified in these previous studies, low health information literacy becomes a negative factor in proper health-related activities, and furthermore, a barrier of effective communication in doctor-patient relations, resulting in deterioration in the quality of medical services. In this respect, health information literacy is closely related to health promotion.

Recently, with the Fukushima nuclear disaster, interest in radiation safety has been increasing in our lives. Radiation is small particle radiation or electromagnetic wave that causes ionization or excitation. It is important to avoid exposure as much as possible since human exposure to radiation can cause biological damage such as cancer. Like this, despite the importance of radiation related to health, the public's understanding of radiation is not sufficient. As a result, researches on the role of radiologists to improve the health information literacy of patients in relation to radiation therapy have been conducted recently [9]. In addition, researches on measuring radiation-related knowledge of the general public are being conducted [10, 11].

These studies are all related to safety from radiation, which is very meaningful for health. However, few studies have been conducted to measure literacy level associated with radiation safety so far. In other words, as most of the literacy measurement tools previously studied in relation to health measure general literacy in the health and medical field, it is not enough to measure the literacy of the radiation field, which has become a hot issue in recent years.

If healthcare providers are informed of the level of literacy associated with the radiation safety of the patient during the course of treatment, they can maximize the effectiveness of the treatment by providing more appropriate terminology or instructions to the patient. In this respect, the development of a tool to measure radiation safety-related literacy is very necessary and significant. Based on previous studies that the degree of health information literacy is closely related to health promotion activities, it is considered that radiation safety literacy is also closely related to health. However, since there is no measurement tool for this purpose, this study intends to develop a tool for the measurement of radiation safety literacy (MRSL) and to identify actual condition through survey.

In addition, we will evaluate the statistical aspects by analyzing the reliability of the developed measurement tool and checking the validity using correlation coefficient with REALM. We will also examine whether developed measurement tool is a meaningful tool for setting the criteria for literacy level determination using the receiver operating characteristic (ROC) curve. The results of the radiation safety literacy assessments based on the tools developed in this study can be useful for evaluating patients for the appropriate communication between healthcare providers and patients and for evaluating the radiation safety literacy for the public.

MATERIALS AND METHODS

Development procedure of radiation safety literacy measurement tool

The tool development procedure for radiation safety literacy measurement was performed by applying a four-step procedure for

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the development of general literacy measurement tools [12]. First, the researchers of this study selected terms that had high frequency of occurrence more than 10 times in the books such as radiation-related safety education materials, radioiodine therapy guide, radiation terminology dictionary [13], radiation and life [14], and nuclear energy and radiation [15] as preliminary terms. Second, the content validity of the items extracted in step 1 was evaluated using experts consisting of 1 radiologist working in the dep. of radiology, 2 professors of dep. of radiological science majoring in radiation therapy and 1 angiography nurse. The criteria for the selection of experts were for those who could explain and have enough knowledge about radiation to assist in the development of radiation literacy measurement tools during evaluation process of the content validity. Third, another expert group was composed of 2 radiologists, which included one from a department of radiation oncology and another from a department of nuclear medicine, and 1 professor of radiology majoring in magnetic resonance imaging to examine the difficulty level of each item by verifying face validity of the items extracted in step 2. Fourth, a survey must be conducted for statistical assessment of the final terms selected according to the above three steps. At this time, the result of the response is greatly affected by how the response scale is constructed. Therefore, a desirable scale of survey responses was constructed by the consultation of a professor of the Korean Language department. Previous studies measuring medical information comprehension presented only 'yes' or 'no' to check the respondents' understanding of the meaning of the proposed term. However, although this dichotomous response type is expected to have active responds, it not only increases the response burden of respondents but also respondents who know to some extent may respond "no." A response of "so so" may reduce the burden of respondents but may lead to passive response. Therefore, in order to solve these problems, the response category of this study is composed of 4 scale response types (1 point: I don't know–4 points: I know well) on the advice of the professor of the Korean Language department.

Data collection

The questionnaire presented in table 1 was made and used for data gathering for the statistical assessment of developed radiation safety literacy measurement tool. The survey was conducted from October 1 to October 29, 2018 for students of J university and samples of n=280 were collected by convenience sampling to allow them to respond according to the self-administered method. Demographic information of the sample is shown in table 2. The survey was conducted on students who only voluntarily expressed their willingness to participate after explaining the purpose and contents of the study fully before obtaining the response. Respondents were provided with a coffee coupon. Data input and analysis for statistical assessment was done using IBM SPSS 25.

Table 1. Questionnaire for data gathering (part).

How much do you know about the following health care and radiation related terms?

① I don't know	② I do not know well
③ I know a little	④ I know well

REALM				
term	①	②	③	④
fat				
flu				
pill				
dose				

MRSL				
term	①	②	③	④
nuclear power generation				
proton therapy				
radiation				
radiation activity				

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Table 2. Demographics of sample.

characteristic	summary value
age mean (SD)	20.89(3.98)
male/female (%)	124(44.3)/156(55.7)
Major (%)	radiological science(34.2) nursing(18.0) accounting(12.5) textile(13.6) engineering(14.0) sports couching(7.7)

RESULTS

The result of measurement tool development

A total of 79 terms were selected through the extraction of preliminary terms, the first stage for the development of a radiological safety literacy measurement tool. However, among these, terminology such as linear accelerator and brachytherapy and general terms such as radiation and radon were mixed. One of the main purposes of this study is to measure the radiation safety related literacy of the general public. Therefore, 26 terms including deterministic effect, stochastic effect, thoron, spent nuclear fuel, and radioactive attenuation, which are judged to be too professional or low validated were excluded on the advice of a group of four experts. In addition, some terms have been modified to more general terms, such as 'ultrasound examination ' for 'ultrasound scan ' and 'shielding material ' for 'shielding block'.

Terms such as X-rays, computed tomography, and Sievert were written X-ray, CT, and Sv in parentheses in English, respectively. In addition, term of 'electromagnetic waves' was revised into 'electric waves' more commonly used in our lives. For the 53 terms selected through the content validity evaluation, which is the second step, the face validity evaluation for the difficulty evaluation was performed as the third step.

As a result, unusual terms such as 'containment' and 'decontamination' and relatively easy terms such as 'energy' were excluded and 'internal exposure' and 'external exposure' were simply modified to ‘radiation exposure’. Finally, a total of 46 terms were selected as shown in table 3.

Table 3. Final extracted radiation safety related terms.

Item number	Term	Item number	Term
1	nuclear power generation	24	radioisotope
2	proton therapy	25	beta rays
3	radiation	26	gamma ray
4	radiation activity	27	alpha ray
5	Radioactive material	28	radiation therapy
6	electromagnetic wave	29	radon
7	X-ray	30	uranium
8	Computed tomography	31	radiation exposure
9	Magnetic resonance imaging	32	protection of radiation harm
10	Ultrasound examination	33	shielding material
11	cosmic radiation	34	irradiated food
12	natural radiation	35	Sievert
13	radioactive iodine	36	Radioactive contamination
14	radioactive waste	37	Department of Nuclear Medicine
15	Chernobyl nuclear accident	38	Department of Radiation Oncology
16	Fukushima nuclear accident	39	Department of Radiology
17	atomic bomb	40	angiography
18	positron emission tomography	41	half-life
19	high level / low level(radioactivity)	42	Radioactive decay
20	radiation sensitivity	43	ultraviolet rays
21	nondestructive inspection	44	infrared rays
22	International Atomic Energy Agency	45	visible rays
23	cancer	46	Genetic modification

Descriptive statistics of 46 MRSL items

According to the survey using n=280 sample for the radiation safety literacy measurement developed in section 3.1, the mean and standard deviation of the response scores for 46 items are shown in table 4. The least understood term was

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'protection of radiation harm' of 1.80 points, followed by 'radioactive iodine' (1.83 points) and 'Sievert' (1.87 points). On the other hand, the most understandable terms were 'cancer' (3.35 points) and 'X-ray' (3.28 points), which are commonly encountered in everyday life. Meanwhile, the score of n = 280 for the sum of 46 MSRL items was 116.71 ± 27.38 and the score for the sum of 66 REAL items was 211.92 ± 30.44.

Table 4. Mean and standard deviation of 46 MRSL items.

Item number	Mean ± SD	Item number	Mean ± SD
1	2.91±0.8130	24	2.37± (1.055
2	2.04±0.856	25	2.41±1.027
3	3.15±0.717	26	2.47±1.035
4	3.14±0.714	27	2.46± 1.024
5	2.96±0.830	28	3.03±1.485
6	3.18±1.939	29	2.12± 1.028
7	3.28±0.660	30	2.39±0.976
8	2.92±0.879	31	2.80± 0.961
9	2.89±0.957	32	1.80±0.890
10	3.12±0.789	33	1.94±1.039
11	2.09±0.951	34	1.85±0.932
12	2.16±0.963	35	1.87±1.053
13	1.83±0.819	36	2.84±1.095
14	2.48± 0.951	37	2.14±0.996
15	2.50±1.112	38	2.10±0.997
16	3.12± 0.795	39	2.71±0.974
17	3.08±0.774	40	2.20±1.063
18	2.11±0.980	41	2.33±1.099
19	1.90±0.934	42	2.26±1.046
20	2.13±1.018	43	3.18±0.699
21	1.93± 0.955	44	3.14±0.762
22	2.24±0.998	45	2.97± 0.876
23	3.35±0.688	46	2.96± 0.887

DISCUSSION

Health literacy is the level of the individual ability to obtain, process, and understand the basic health information and services necessary to make right health decisions. In other words, health literacy means the ability to obtain, read, understand, and utilize health information so that an individual can make correct judgments regarding his or her medical use. The most widely used and representative test tools for measuring literacy in the health care sector are Rapid Estimate of Adult literacy (REALM) and Test of Functional Health Literacy in Adult (TOFHLA) [16].

Since then, various variant tools of REALM and TOFHLA have been developed and used. Some examples include Rapid Estimate of Adult Literacy in Medicine, Revised (REALM-R), Rapid Estimate of Adult Literacy in Medicine—Short Form, and Short Assessment of Health Literacy for Spanish Adults (SAHLSA-50) [17].

However, these health literacy measurement tools are all for measuring general health-related literacy. Meanwhile, after 2011 Fukushima nuclear disaster, radiation safety has emerged as an important issue related to health for neighboring countries in East Asia, including Japan. High literacy level related to radiation safety increase the ability to acquire relevant information, resulting in acquiring high-quality medical services. In other words, the higher the radiation safety literacy, the safer it is from radiation. For this reason, it is necessary to identify the actual condition of radiation safety literacy and to carry out related research to protect our health from radiation. Accordingly, many researches related to radiation safety have been conducted recently. Recent studies related to radiation safety include ‘a study suggesting the need to provide appropriate educational materials to parents to assist in decision making during computed tomography for children’[18, 19], ‘a study of a pediatric emergency department showing that the lower the health literacy of the guardian, the lower the degree of radiographic examination’ [20], and ‘a study of the relationship between radiation concern and health literacy among residents living in evacuation area and non-evacuation area after the Fukushima nuclear accident’ [21]. However, there are few measurement tools that can measure the radiation safety literacy of the public in the previous studies related to radiation safety. Therefore, this study developed 46 MRSL in accordance with the four-step procedure outlined in figure 1. However, it is difficult to discuss the relative superiority of MRSL as there is no appropriate previous study to compare with the developed measurement tool, MRSL. In this regard, this study will discuss the adequacy of the developed radiation safety literacy measurement tool through the various statistical aspects of MRSL – reliability, validity, and the discussion on whether a measurement tool developed using receiver operating characteristic (ROC) curve is meaningful for setting criteria for literacy level determination.

First, reliability analysis was conducted to find out how consistent the measurement tool developed through this study showed. The reliability of this study was determined using Cronbach's "α" coefficient since the response of the study was the multiple-choice scale (1 point: I don't know ~ 4 points: I know well) compared to response of dichotomous, which use KR-20 confidence coefficient. The Cronbach's coefficient, an internal consistency measure for all 46 items, was very high at $\alpha=0.963$, indicating that the reliability of the radiation safety literacy measurement tool of table 3 is considered to be very high. Meanwhile, when the specific items were removed, only two items of the 6th (electronic wave) and 28th (radiation therapy) had Cronbach's "α" coefficient greater than 0.963. However, the overall reliability coefficient value did not increase significantly to 0.966 and 0.964 respectively when these items were removed. Consequently, these two items were not removed from the radiation safety literacy measurement tool. As the Cronbach's "α" coefficient for the rapid estimate of adult literacy in medicine (REALM) of 66 items presented in the previous study was 0.977, the reliability coefficient of MRSL was as high as the previous studies.

Next, in order to evaluate the criterion validation of the radiation safety literacy measurement tool developed in this study, the correlation coefficient with REALM, which was proved in previous studies, was examined. To this end, the sum of 66 items (66 to 264 points) for measuring REALM and the sum of 46 items (44 to 176 points) developed in this study to measure radiation safety literacy (MRSL) were obtained. Pearson's correlation coefficient was found to be 0.448, showing statistically significant ($p<0.01$) at the significant level of 1%. Therefore, the measurement tool developed to measure radiation safety literacy in this study was evaluated to be statistically valid. As another method to assess the validity, response distribution of the radiation safety literacy measurement tool developed in this study (figure 2) was examined whether it follows the normal distribution. The result of the Kolmogorov-Smirnov normality test showed that it was suitable for the normal distribution at the significant level of 5% with $p=0.051$.

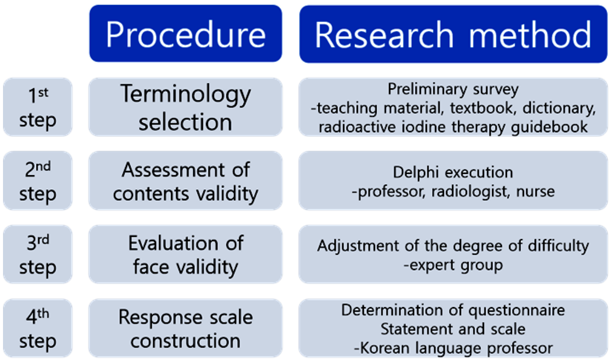

Figure 1. Flowchart of radiation safety literacy measurement tool development.

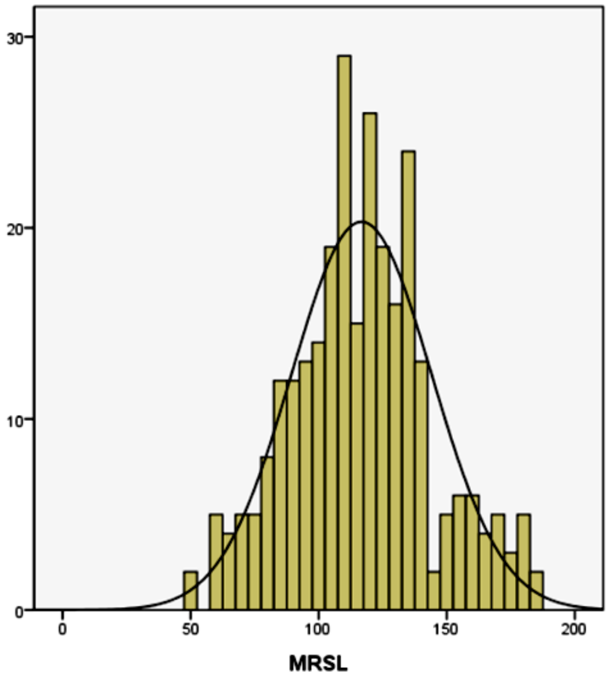

Figure 2. Response distribution of MRSL score.

Finally, the ROC curve shown in figure 3 is used to help determine whether the respondent's literacy level is high or low based on the MRSL [22]. In this curve, the horizontal

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axis represents 1-specificity and the vertical axis represents sensitivity. As the point is upward and on the left on the graph, the sensitivity is greater, which means more accurate determination. In table 5, sensitivity refers to the probability (A/(A+C)) that accurately detects low MRSL in person with low radiation safety literacy level, and specificity means the probability (D/(B+D)) to determine that a person with a high radiation safety literacy has high level of MRSL. In figure 3, the area below the MRSL curve is 0.709, with a significant probability of $p<0.01$, indicating that the judgment method using MRSL is a statistically valuable [23].

Table 5. Result for assessment of literacy level.

MRSL	REALM	
	low	high
low	A	B
high	C	D

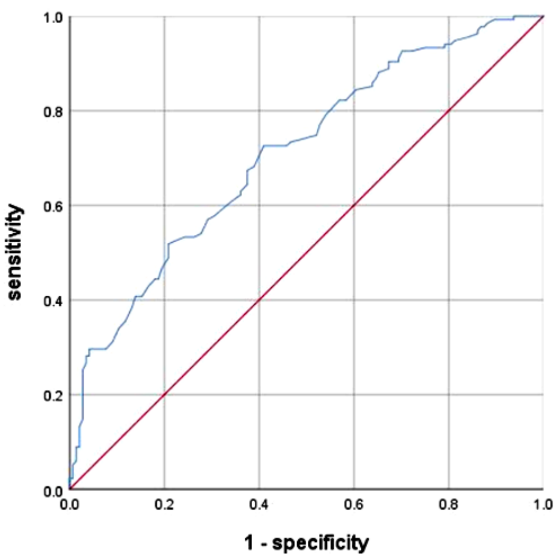

Figure 3. ROC for decision criterion making.

CONCLUSION

The MRSL tool consisting of 46 terms developed in this study has been proven its reliability and validation in statistical terms. In addition, from the test on the ROC curve, the radiation safety literacy level evaluation using MRSL was found to be a statistically valuable judgment method. Therefore, it is believed that the radiation safety literacy measurement tool developed in this study can be very useful for conducting future researches in East Asia affected by the Fukushima nuclear disaster. Furthermore, the results of the radiation safety literacy assessment measured based on MRSL can be used for appropriate communication between health care providers and patients, or for developing and providing educational materials by level for the public.

Conflicts of interest: *Declared none.*

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