An Analysis of Arguments on the Radiation Risk of Thyroid Cancers in the Fukushima Nuclear Accident: Application of the Toulmin Model

Yasui, Shojiro
Ministry of Health, Labour and Welfare, Tokyo, Japan

In response to the Fukushima nuclear accident in 2011, the Fukushima prefectural government has begun a thyroid cancer screening program. The data showed higher rates of thyroid cancer than had previously been observed in Japan. The findings induced massive controversy regarding whether the high incidence rate was due to radiation exposure. The experience revealed that a gladiatorial arena is suitable for the model of risk communication, which concerned how to secure the underlying conditions of democratic debate. This paper aims to demonstrate how argument analysis by Toulmin's model could help resolve issues regarding radiation risks and show that sound scientific argument needs to accompany sufficient data and warranted claims. The paper revealed that the analysis can provide useful information to foster rational debate and that fostering an affective disposition of critical thinking in the authors is necessary. Further studies to facilitate a rational debate on health risks is warranted.

1. INTRODUCTION

During the Fukushima nuclear accident in 2011, anxiety concerning the health effects of radiation exposure rose drastically (Kitada, 2013) (Shinoda, et al., 2014) (Nakayachi, et al., 2015) . Particularly for parents of children and adolescents, the risk of thyroid cancer became a primary concern. After the Chernobyl accident, a notable increase in thyroid cancer incidents in children and adolescents was observed within the group who experienced high thyroid gland exposure to radioactive iodine (UNSCEAR, 2011). It was estimated that the cumulative effective dose of radiation to the thyroid gland of children in the Fukushima accident was significantly lower than that of the Chernobyl accident (UNSCEAR, 2013). However, to relieve parental concerns, the Fukushima Prefectural Government began a thyroid cancer screening program called the Fukushima Health Management Survey for children and adolescents living in areas near the affected plant (Yasumura, et al., 2012). Contrary to that goal, the screening program increased parental anxiety.

The data from the survey of the program showed 30-fold higher thyroid cancer rates than had previously been observed in the national cancer registries in Japan (Tsuda, et al., 2016a). The findings induced substantial controversy between some experts and activist groups who insisted that the high incidence rate was due to radiation exposure and governmental experts on radiation health effects who argued that detected cases might have been prevalent, subclinical cases, or "overdiagnosis" of cancers by screening, rather than radiation-induced cancers (Suzuki, 2016). A controversy ensued involving international organizations.

Experts developed the debate from both sides in the international academic journal "Epidemiology." However, even one year after the debate in the journal, there remained some discourses in which both parties were convinced that their opinions were correct and that the other party's argument was not "scientific." An UNSCEAR expert, Makoto Akashi said;

"Professor Tsuda of Okayama University has published a paper to argue that the effects of radioactive substances released from the Fukushima Daiichi Nuclear Power Plant induced the increase of thyroid cancers in children in Fukushima. This paper was written based on the scientifically deficient study, so its scientific quality is unacceptable. However, since this paper was judged to be "a paper that has a great social impact," it was deliberately evaluated…. It is essential to rightly criticize "a paper whose method is scientifically

inappropriate despite its large social impact". Simply rejecting it means that UNSCEAR has overlooked a paper that has a social impact, and if UNSCEAR does not explicitly criticize it, UNSCEAR will lead to a misconception that "this paper is evaluated as sufficient to adopt from a scientific point of view." (Hattori, 2018)

On the other hand, an expert from the other party claimed that UNSCEAR's evaluation is hindering "science." "….the UNSCEAR 2016 White Paper distorted the debate that took place in the academic journal "Epidemiology." In particular, UNSCEAR completely ignores Tsuda's response to the letters to the editor, which criticizes the electronic version of the Tsuda paper... UNSCEAR is hindering science." (Yamauchi, 2018)

It is not clear what "scientific" argument refers to; however, the conclusion in the field of epidemiology differs from that of other natural sciences. In areas such as physics, chemistry, and biology, experimental results can directly show conclusions. For example, substance A and substance B reacted in chemical reaction C; then it generated substance D. However, in epidemiological studies, epidemiological findings cannot directly indicate conclusions. Suppose the group exposed to harmful substance A had a higher prevalence of disease B than the unexposed group; such an observation does not directly suggest that substance A is responsible for disease B. Substance C may cause the disease if the group was exposed to not only substance A but also substance C, or the difference in age distribution between the exposed and unexposed groups may give rise to the result. By eliminating the effects of these confounding factors (factors that affect both exposure and endpoints) one by one, the study may conclude that substance A is the likely cause of disease B.

Thus, epidemiological studies are a kind of argument based on data and warranted claims and are well suited to argument analysis using informal logic. However, risk communication researchers have used a simple model without paying attention to how the message sender argued, although risk communication mainly takes care of the public health risks that epidemiological studies cover. Scholars of the social amplification of risk framework (SARF) employed the "sender-message-receiver model" to model risk communication (Kasperson & Kasperson, 1996). In this model, the main issue that must be resolved concerns the process of "information transfer." Namely, media reports do not adequately transmit information from governments and experts to the general public (Frewer, 2003) (Smith & McCloskey, 1998). This model is based on the historical conception of power advocated by Max Weber in which power refers to the ability to compel compliance with "rules and commands independent from the subjugated group's convictions." (P.185 in (Renn, 1992))

On the other hand, scholars in the field of policy analysis proposed the model of policymaking as a gladiatorial or sporting arena in which several competing powerholders battle for advantage and public support (Renn, 1992). Murdock et al. developed this model and proposed the arena model of risk communication (Murdock, et al., 2003). The arena model consists of six major sets of players, i.e., government and state agencies, opposition parties, campaigning groups, corporations, scientific and expert communities, and the media. The players continually compete for position and advantage in terms of commanding public communications and attention.

In the arena model, the main problem concerns how to secure the underlying conditions of democratic debate. Jürgen Habermas has most forcefully advocated the idea of open, rational debate as to the touchstone of the democratic process in his model of the public sphere. Rational debate should forge a communicative bridge between civil society's concerns and the government's operations (Habermas, 1989).

The Fukushima accident experience revealed that authorized information from international organizations and governmental experts' statements are no longer protected and unchallenged. It means that the model of risk communication as a gladiatorial arena, in which several competing powerholders battle for public support (Murdock, et al., 2003), obviously fits the situation of risk communication on radiation health risks.

Since risk communication aims to persuade the general public, it is a kind of rhetoric advocated by Aristotle. Aristotle defines rhetoric as complying with credibility/trust (ethos), emotions/values (pathos), and logic (logos). In risk communication, trust in experts (ethos) is an essential element, and the general public shows an emotional reaction (pathos) from media reports with photos of specific cases. However, the most crucial part should be the

logic that evaluates epidemiological research results. Initially, the health effects of harmful factors are physical phenomena, so they should not involve ethos and pathos (excluding physiological disorders). Thus, analyzing the mainstream and anti-mainstream argument as informal logic is a meaningful attempt consistent with the "scientific" argument claimed by both parties.

This paper aims to reveal how the argument analysis could help resolve the issues of radiation health risks and shows that good scientific argument needs to accompany sufficient data investigation and warranted claims. For this purpose, the paper demonstrates a structural analysis of the argument using the Toulmin model and discusses how the model can provide useful information to foster a rational debate among the parties involved.

2. LITERATURE REVIEW

2.1 Fukushima Health Management Survey

The accident of the Fukushima Daiichi Nuclear Power Plant in 2011 released a massive amount of radioactive substances into the surrounding environment. The equivalent doses and health risks on children in Fukushima were evaluated in the report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in 2013.

UNSCEAR was established by the General Assembly of the United Nations in 1955. Its mandate in the United Nations system is to assess and report levels and effects of exposure to ionizing radiation. Throughout the world, governments and organizations rely on the Committee's estimates as the scientific basis for evaluating radiation risk and establishing protective measures.

As for the radiation dose exposed, UNSCEAR estimated that "settlement-average absorbed doses to the thyroid of up to about 80 mGy for 1-year-old infants who were evacuated", and "for infants who remained in the non-evacuated areas, district-average doses were up to about 50 mGy." As for the health risks by the exposure, UNSCEAR stated that "most of the absorbed doses to the thyroid were in a range for which an excess incidence of thyroid cancer has not been observed in epidemiological studies." UNSCEAR also stated that "the occurrence of a large number of radiation-induced thyroid cancers as were observed after the Chernobyl accident can be discounted because doses were substantially lower." (p. 78, para 175 in (UNSCEAR, 2013)).

The Fukushima Health Management Survey was launched to monitor residents' long-term health, promote their future well-being, and confirm whether long-term low-dose radiation exposure has health effects. It includes a basic survey to estimate levels of external radiation exposure among all 2.05 million residents and detailed surveys that comprise a thyroid ultrasound examination for all Fukushima children aged 18 years or younger, a comprehensive health check for all residents from the evacuation zones, and an assessment of mental health and lifestyles of all residents from the evacuation zones (Yasumura, et al., 2012). Furthermore, for establishing control groups to compare with the observed groups in the Fukushima Survey, a survey, using similar equipment and screening criteria, of approximately 4,000 children and adolescents was also administered in the prefectures of Aomori, Yamanashi, and Nagasaki, which were mostly unaffected by the accident (Taniguchi, et al., 2013).

2.2. Argument on the Increase of Thyroid Cancers among Children in Fukushima

In 2016, a paper published by Tsuda et al. argued that "we could infer that the incidence of thyroid cancer in Fukushima rose more rapidly than expected based on the cumulative attributable thyroid cancer risk over 15 years", and "the radiation burden to the thyroid in Fukushima Prefecture might have been considerably higher than estimated." (Tsuda, et al., 2016a) The authors reported a 30-fold excess in Fukushima Prefecture without precise records of radiation exposure in residents in Fukushima;

> "Although precise measurements of both external and internal radiation exposure in Fukushima were not obtained, in external comparison, we observed an approximately 30-fold increase in the number of thyroid cancer cases among children and adolescents using the area/district of residence to provide a surrogate for exposure information." (Tsuda, et al., 2016a)

In the "external comparison," Tsuda et al. calculated the incidence rate of 9 districts in Fukushima prefecture from the Fukushima

health survey's baseline rate. The incidence rate is the frequency with which a disease or other incident occurs over a specified period. Tsuda et al. estimated incidence rate ratios (IRR) calculated by the incidence rate in nine districts in Fukushima divided by the reference incidence rate. The reference rate was derived from the data from 2001 to 2008, as reported by the Japanese National Cancer Center. The authors argued to justify that the study employed areas and districts as a surrogate for exposure estimation;

> "We employed areas and districts as a surrogate for exposure estimation, which could have introduced nondifferential exposure misclassification that can bias the effect estimates toward the null…. There is little potential for spatial confounding both in Japan and within Fukushima Prefecture because the subjects in this study are all residents 18 years old and younger, as noted below. Furthermore, before the accident, no evidence existed that natural radiation was higher in Fukushima Prefecture than in the rest of Japan." (Tsuda, et al., 2016a)

Furthermore, the authors argued that a bias created by a screening effect was insufficient to explain their results, because the magnitude of the incidence rate ratio was too large;

> "One concern is that the approximately 30-fold increase observed in the number of thyroid cancer cases in external comparison might be the result of a screening effect. This concern is based on the potential presence of silent thyroid cancer among children and adolescents in the unscreened regions of Japan. However, the magnitude of the IRRs was too large to be explained only by this bias." (Tsuda, et al., 2016a)

2.3. Refutations from experts

The findings of Tsuda et al. (2016a) induced much controversy among experts who argued that detected cases might have been prevalent, subclinical cases, or "overdiagnosis" of cancers, rather than radiation-induced cancers. A controversy unfolded involving international organizations. Initially, the debate was done using the format of letters to the editor in the Journal "Epidemiology," which published the paper in question. Jorgensen argued the paper's conclusion was based on "the flawed inferential logic, known as ecologic fallacy" because of lack of individual dose data; (Jorgensen, 2016)

> "The flawed inferential logic, known as ecologic fallacy, threatens all studies that draw risk inferences based on community incidence rates without individual dose data, yet that is but one of problems with ecologic studies….", "the Tsuda article goes beyond failing to acknowledge that it is ecologic. It actually hides its design by using "the residential address of the subjects in March 2011…as a surrogate for individual [dose]," and then reports measures of association with odds ratios and relative rates—risk metrics typically employed in case–control and cohort studies, respectively. These two alternative study designs are much more reliable because they are based on individual dose data and, therefore, not prone to be influenced by factors that vary between communities." (Jorgensen, 2016)

Takamura argued that the incidence rate of the nonexposure group employed in the paper does not represent the real prevalence because "the prevalence of thyroid cancer detected by advanced ultrasound techniques in other areas of Japan does not differ meaningfully from that in Fukushima Prefecture"; (Takamura, 2016)

> "We recently conducted thyroid ultrasound screening, using the same procedures as the Fukushima Health Management Survey, in 4,365 children aged 3–18 years from three Japanese prefectures, and confirmed one patient with papillary thyroid cancer (prevalence, 230 per million). Furthermore, we recently reviewed findings of thyroid ultrasound screening conducted in Japan. In one survey, 9,988 students underwent thyroid screening and four students (including one foreign student) were subsequently diagnosed with thyroid cancer (prevalence, 300 per million). In another study at Okayama University that examined 2,307 students, three patients with thyroid cancer were found (prevalence, 1,300 per million), while at

> Keio High School, of 2,868 female students examined, one was found to have thyroid cancer (prevalence, 350 per million). These results show that the prevalence of thyroid cancer detected by advanced ultrasound techniques in other areas of Japan does not differ meaningfully from that in Fukushima Prefecture." (Takamura, 2016)

Wakeford et al. argued that screening programs could dramatically increase the incidence rate in proportion to the participation rate of the screening, based on the experience in South Korea. They also argued that no dose-response relationship was observed (Wakeford, et al., 2016).

> " Thyroid disease screening with ultrasound can have a dramatic effect on the detection of thyroid nodules. A 15-fold increase in the incidence of thyroid cancer occurred in South Korea after the introduction of a national cancer screening program in 1999, with the incidence rate in regions increasing in direct proportion to the percentage of screened people. Consequently, it is inappropriate to compare the data from the Fukushima screening program with cancer registry data from the rest of Japan where there is, in general, no such large-scale screening." (Wakeford, et al., 2016)
>
> " There is no statistically discernible difference in thyroid cancer prevalence between the low, intermediate, and high contamination areas of Fukushima Prefecture. The prevalence ratio for the highest to lowest contamination areas was 1.08 (95% confidence interval [CI]: 0.60, 1.96), and the highest prevalence was seen in the area with an intermediate level of contamination (prevalence ratio = 1.21 [95% CI: 0.80, 1.82])." (Wakeford, et al., 2016)

2.4. Response from the authors

Tsuda et al. filed a response to the journal upon the refutations from various experts. For the prevalence of the unexposed population, the authors argued that data from Belarus after the Chernobyl accident were appropriate. The authors partially refuted the data from the unexposed population at Okayama University and failed to refute the argument regarding the data from three prefectures that employed the same procedures as the Fukushima survey, as well as data from Keio High School (Tsuda, et al., 2016b).

> "(D)irect estimation from ultrasound screening data among 47,203 examinees in the unexposed or relatively low contaminated areas in Belarus would be more appropriate, where no cancer cases were detected (95% confidence interval: 0–78 per million examinees),16–19 as shown in eTable 1 of our article". (Tsuda, et al., 2016b)
>
> "Takamura presented another example of inappropriate comparison with the all-school screening program started at Okayama University, Japan in 2012. Although the Okayama study did detect three thyroid cancer cases by palpation among 2,307 freshmen (ages 18 or older) in 2012, no other cases were detected among the total of 36,927 students enrolled between 2012 and 2015". (Tsuda, et al., 2016b)

Furthermore, the authors presented new arguments that screening effects cannot explain the new cancer incidents found in the second round (Tsuda, et al., 2016b).

> "In addition, a likely underestimated but clear increase (eight cases: IRR = 12 with 3 years as a latent duration) of thyroid cancer incidence was observed in the second round screening among cases who were screened and cancer free in the first round. This result cannot be explained by the screening effect because most occult thyroid cancer cases would have been harvested in the first round screening". (Tsuda, et al., 2016b)

For evidence of the screening effects in South Korea, Tsuda et al. argued that South Korea's data were not applicable because of different diagnostic criteria and ages of patients (Tsuda, et al., 2016b).

> "Furthermore, although disregarded by some of the letters, comparability, for example by age and diagnostic criteria, should be considered when using the

findings from South Korea. Screening in South Korea was conducted among adults with different diagnostic criteria from Fukushima, where one quarter of surgical patients had tumors less than 5.0 mm in diameter, whereas no cancers in this size range were detected in Fukushima". (Tsuda, et al., 2016b)

2.5. Summary of the Argument by UNSCEAR

UNSCEAR summarized the debate over the issue and concluded that "the Committee does not consider that the study by Tsuda et al. presents a serious challenge to the findings of the 2013 report" (p. 25, para 112 in, (UNSCEAR, 2016)) based on the following:

> "111. One paper (Tsuda, et al., 2016a) and a subsequently published response to criticisms (Tsuda, et al., 2016b) claimed to demonstrate that there had been a radiation-induced increase in thyroid cancer incidence: the authors reported a 50-fold (95% CI: 25, 90) excess in Fukushima Prefecture. However, the study design and methods were too susceptible to bias (Jorgensen, 2016) to warrant this interpretation. Tsuda et al. (Tsuda, et al., 2016b) did not adequately account for the impact of the sensitive ultrasound screening of the thyroid upon the observed rate of thyroid cancer. Their conclusions were based on a comparison of the rate of thyroid cancer among those people screened by FHMS with the rates found elsewhere in Japan where few children had undergone thyroid screening. Studies of other populations screened in childhood, particularly those who underwent ultrasound screening in three unexposed Japanese prefectures (Hayashida, et al., 2013; Hayashida, et al., 2015), as well as other screening studies of young people in Japan (Takamura, 2016), found baseline rates of thyroid cancer in the absence of radiation exposure that were similar to the FHMS rates. Similarly, the Republic of Korea experienced an apparent large increase in thyroid cancer rates once they instituted universal screening (Ahn, et al., 2014)." (p. 25, para 111 in (UNSCEAR, 2016))

3. ANALYSIS

3.1. Brief background of the Toulmin model

The Toulmin model of argumentation is the methodology for structural analysis of informal logic often used in the field of speech communication (Toulmin, 1958). This paper employed the model to provide objective analytical grounds for argumentation. The model comprises data, claim, warrant, rebuttal, and backing. The definitions of the terminology of the model are widely presented and varied in detail. The author employed the following methodology. Claim: Assertion one wishes to prove. Data: Factual information that supports the claim and appeals as a foundation for the claim. Warrant: A bridge between the data and the claim shows that the step to the claim from the data is an appropriate and legitimate one. Rebuttal: A statement that addresses potential objections to the claim. Backing: Factual information without which the warrant itself would possess neither authority nor currency. The original example of the model by Toulmin is shown in Figure 1. (Toulmin, 1958)

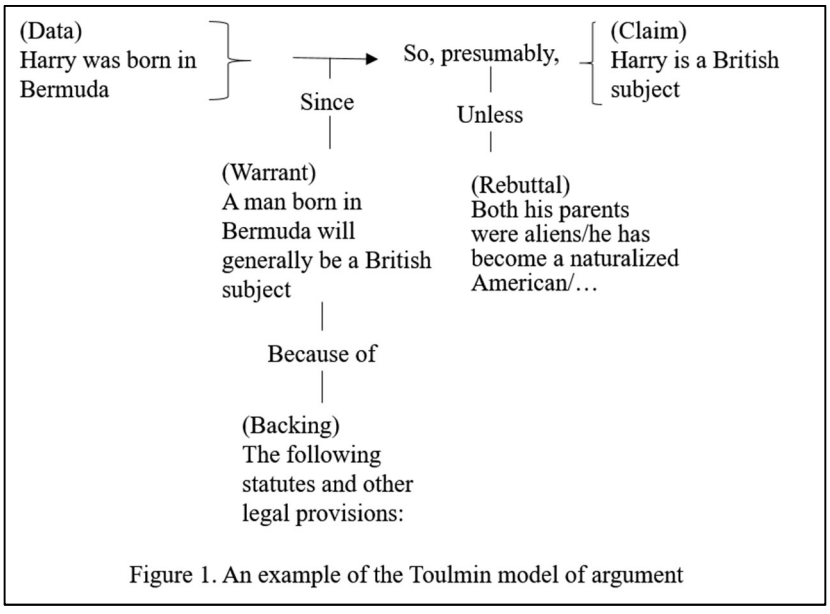

Figure 1. An example of the Toulmin model of argument

3.2 Analysis of Argument over Thyroid Cancer

Tsuda et al. asserted a claim that "there had been a radiation-induced increase in thyroid cancer incidence." The data were presented as "in external comparison, we observed an approximately 30-fold increase in the number of thyroid cancer cases among children and adolescents". The external comparison was the comparison between the incidence rate of 9 districts in Fukushima and the average rate in the cancer registration before the accident. Thus, the claim needs a warrant (warrant 1) as "the residential address of the subjects in March 2011…as a surrogate for individual [dose]". The backing of the warrant was "before the accident, no evidence existed that natural radiation was higher in Fukushima Prefecture than in the rest of Japan." Furthermore, Tsuda et al. added another warrant (warrant 2) as "the magnitude of the IRRs was too large to be explained only by this [screening effect] bias." The structure of the argument could be analyzed, as shown in Figure 2.

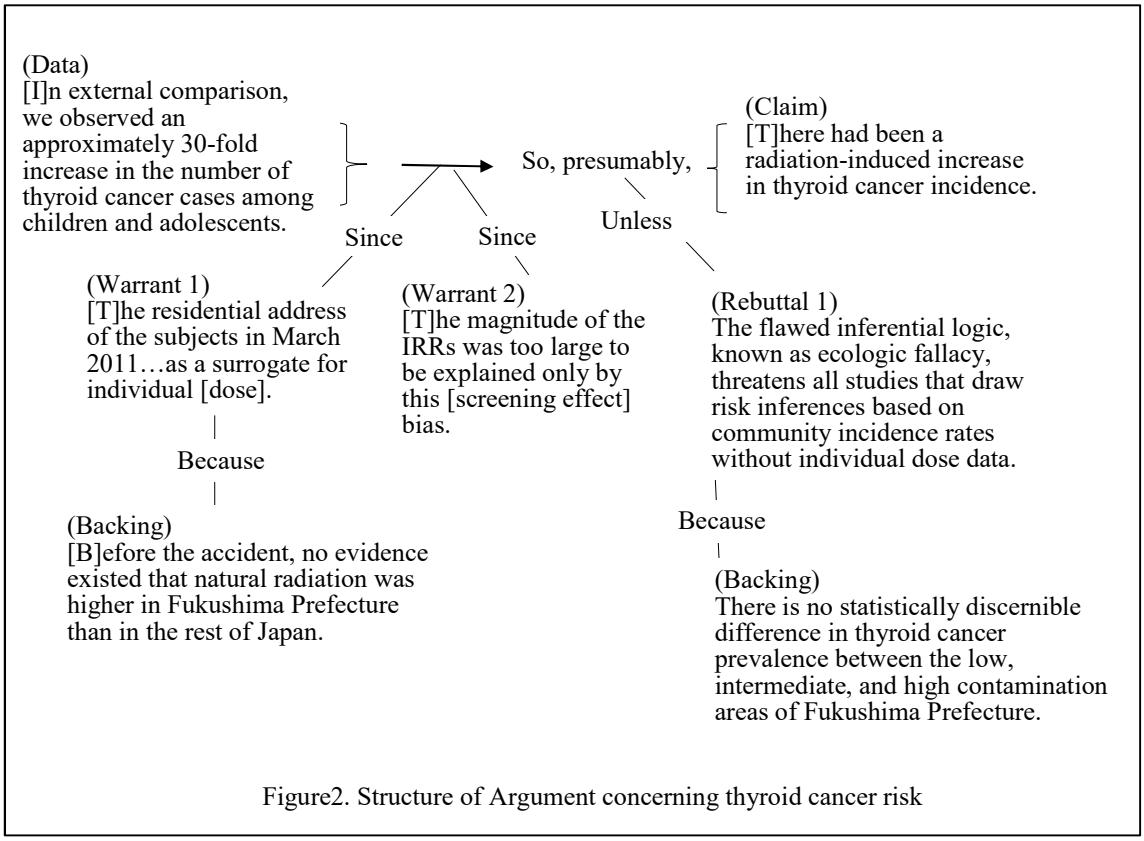

Figure2. Structure of Argument concerning thyroid cancer risk

The rebuttal presented by Jorgensen was "the flawed inferential logic, known as an ecologic fallacy, threatens all studies that draw risk inferences based on community incidence rates without individual dose data." For a better understanding of the rebuttal, an epidemiological study usually identifies the individual exposure (radiation dose) and their endpoint (a thyroid cancer), and then compares the incidence rate of the endpoint observed in an "exposure group" and that in a "nonexposure group." Because the individual endpoint was assumed to be caused by individual exposure, however, the individual dose exposed to children in Fukushima was unknown. Even in the same regional district, the ambient radiation dose rate varied geographically and temporally. This means that the ambient dose might not represent the radiation exposure.

Furthermore, Wakeford et al. presented the backing for the rebuttal as "there is no statistically discernible difference in thyroid cancer prevalence between the low, intermediate, and high contamination areas of Fukushima Prefecture." This backing contradicts and weakens the warrant (warrant 1).

In summary, without individual dose data, even if a difference in the ambient dose between the reference area and Fukushima was observed, other differences may have been the causes. In this case, the data did not to support the claim which asserted causal relationships between ambient dose and the increase in thyroid cancer. Thus, to support the claim, further warrant needed to hold to show that nothing other than

radiation effects is possible to induce 30-fold thyroid cancer increase. Warrant 2 is a typical example of the warrant. Generally, this logic was called "Ad ignorantiam," in which a lack of contrary evidence is used to prove that a proposition is true. (Ziegelmueller & Kay, 1997) .

3.3. Analysis of UNSCEAR's summary and conclusion

UNSCEAR concluded that "the Committee does not consider that the study by Tsuda et al. presents a serious challenge to the findings of the 2013 report " (p. 25, para 112 in, (UNSCEAR, 2016)). To justify the conclusion, UNSCEAR presented as a rebuttal that "the study did not adequately account for the impact of the sensitive ultrasound screening of the thyroid upon the observed rate of thyroid cancer (rebuttal 2)". UNSCEAR also presented as the backing of the rebuttal that "studies of other populations screened in childhood, particularly those who underwent ultrasound screening in three unexposed Japanese prefectures, as well as

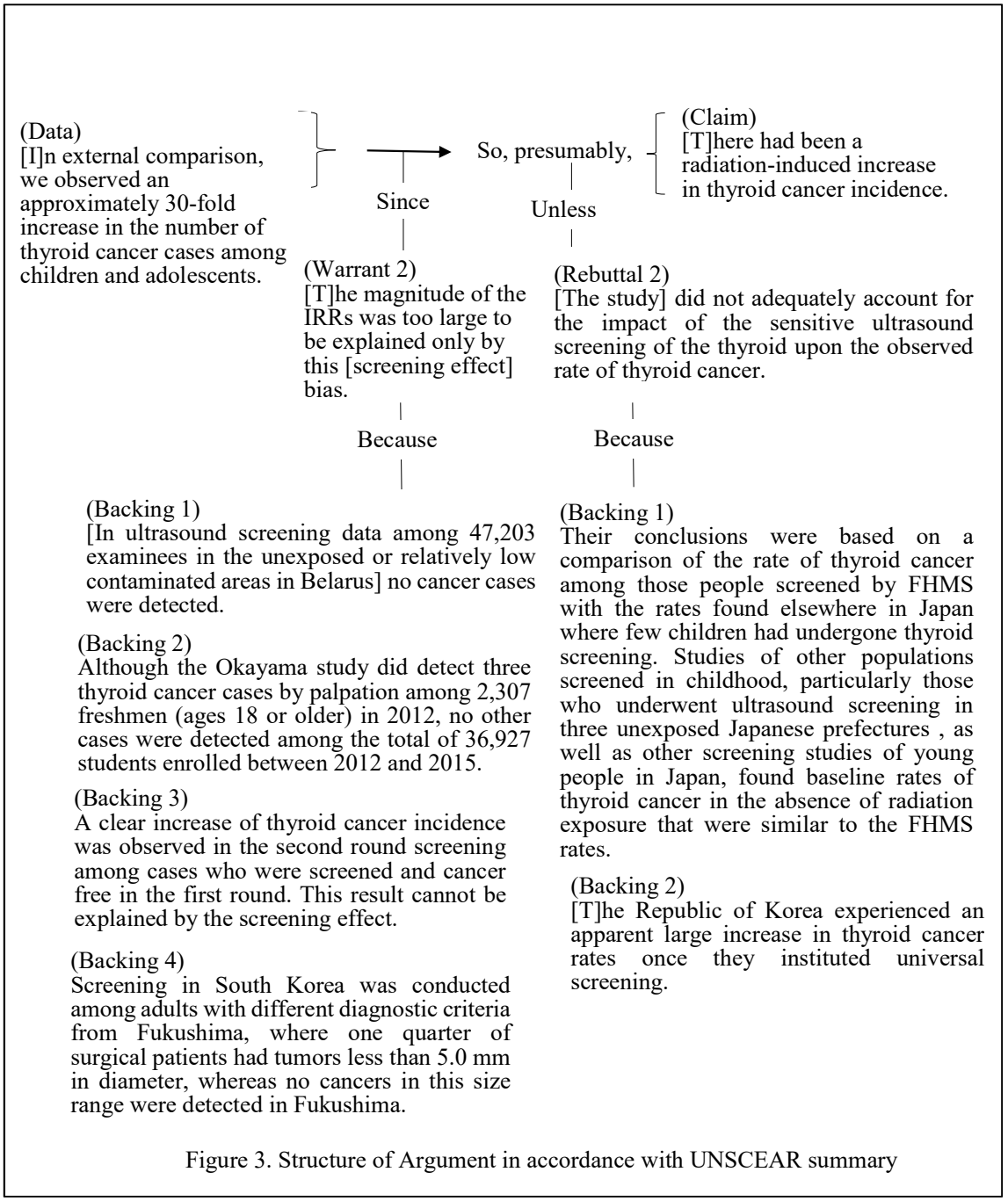

Figure 3. Structure of Argument in accordance with UNSCEAR summary

other screening studies of young people in Japan, found baseline rates of thyroid cancer in the absence of radiation exposure that was similar to the FHMS rates (backing 1)". The other backing was presented that the "Republic of Korea experienced an apparent large increase in thyroid cancer rates once they instituted universal screening (backing 2)". The structure of the argument could be analyzed, as shown in Figure 3.

To respond to the rebuttal, Tsuda et al. provided four backings to strengthen the warrant that "the magnitude of the IRRs was too large to be explained only by this [screening effect] bias (warrant 2)." For the argument on unexposed populations, three backings were presented as "in ultrasound screening data among 47,203 examinees in the unexposed or relatively low contaminated areas in Belarus, no cancer cases were detected" (backing 1), "although the Okayama study did detect three thyroid cancer cases by palpation among 2,307 freshmen (ages 18 or older) in 2012, no other cases were detected among the total of 36,927 students enrolled between 2012 and 2015" (backing 2) and "a clear increase of thyroid cancer incidence was observed in the second round screening among cases who were screened and cancer free in the first round. This result cannot be explained by the screening effect." (backing 3)

For the argument on South Korea's data, a backing was presented as "screening in South Korea was conducted among adults with different diagnostic criteria from Fukushima, where one-quarter of surgical patients had tumors less than 5.0 mm in diameter. In contrast, no cancers in this size range were detected in Fukushima." (backing 4)

3.4. Argument on Prevalence of the Unexposed Group

The study of Takamura and Hayashida quoted in UNSCEAR's response (Rebuttal 2's backing 1) showed that the prevalence of students' thyroid cancer screening was 230, 300, 1300 and 350 per million. (Takamura, 2016) (Hayashida et al., 2015) On the other hand, the incidence rate in 9 districts in Fukushima was between 236 and 605 per million (Tsuda, et al., 2016a). Thus, baseline rates of thyroid cancer in the absence of radiation exposure were similar to the Fukushima health survey rate.

In particular, the study of three Japanese prefectures (Aomori, Yamanashi and Nagasaki) was initially intended to be used as a control group for the Fukushima health survey; therefore, the period of implementation, age distribution, and procedure of screening were similar to those of the survey. Thus, it is highly reliable for comparison. (Taniguchi, et al., 2013) The prevalence in that study was 230 per million, and the rate of other studies was consistent with it.

Tsuda et al. (2016b) failed to refute these data, except at Okayama University (backing 2). For the data of Okayama University, the prevalence calculated from their asserted data (4 out of 36927) was 80 per million, which is 6.7 times higher than the rate used as a reference in the paper, which weakens their conclusions. Tsuda et al., however, did not provide any discussion of this result.

Based on these data, it is reasonable to estimate that the baseline rate is on the order of hundreds, and it is almost the same as the level observed in the Fukushima health survey. Thus, the effect of screening can explain the 30-fold excess in the incidence rate, and the warrant "the difference is so large that the screening effect cannot explain it" is hard to hold. The lacking of the warrant significantly weaken the argument of Tsuda et al.

Tsuda et al. (2016b) cited the Chernobyl data as counterevidence (backing 1), but it did not strengthen the argument. Their warrant is "the difference is so big that it cannot be explained by the screening effect," so if the young Japanese population's prevalence data could explain the reason for the 30-fold difference, other data does help to establish the warrant. Besides, the Chernobyl data did not weaken the credibility of the data in Japan. The reliability of the Japanese data is higher than that of the Chernobyl data because the data of the three prefectures in Japan have the similar medical skills, performance of the equipment used, screening criteria and the age distribution of target population.

Backing 3 asserted that screening effects cannot explain the new detection of cancers in the second screening (eight cases: incident rate ratio = 12 with 3 years as a latent duration). The backing, however, assumed the reference incident rate from the National Cancer Registry. Namely, the controversial incident rate was used as the premise during the argument over what value was the true incident rate. The logic of the backing circulates and does not reinforced the warrant 2.

3.5. Argument on screening data in South Korea

As for the screening effects in South Korea,

Tsuda et al. (2016b) refuted "screening in South Korea was conducted among adults with different diagnostic criteria from Fukushima, where one quarter of surgical patients had tumors less than 5.0 mm in diameter." (backing 4)
The difference in the target age is not a valid rebuttal. The cancer detection rate depends on the performance of the equipment used and the medical practitioner's skill, and the cancer detection rates would not differ between adults and children for cancers of the same size. On the other hand, cancer diagnosis (biopsy), including smaller nodules, can be reasonably estimated to increase cancer detection rate. Tsuda et al. might argue that if the screening effect in South Korea induced a 15-fold increase of detection, screening effects should be discounted by 25%, 11-fold at most, and was not enough to explain a 30-fold increase.

However, this counterargument ignores the fact that South Korea's detection rate increased "in direct proportion to the percentage of screened people," as pointed out by Wakeford et al. (2016). The participation rate in South Korea screening is only approximately 10% to 25% (Ahn, et al., 2014), while that of Fukushima is 74% to 88%, which is several times higher than that of South Korea. Therefore, extrapolating the Fukushima participation rate to the South Korea data gives the same level of screening effects as the Fukushima survey. Therefore, the experience of South Korea can be additional evidence to deny to hold warrant 2 and significantly weakens the argument.

4. DISCUSSION

4.1. Lessons learned from the perspective of an epidemiological study

The geographical analysis of prevalence is a useful method for some cases such as preventing infectious diseases. Suppose an infectious disease concentrically spreads from a well; the well may be the source of infection. The analysis method is useful and has no other practical way for non-quantitative exposure, such as exposure to a virus. However, in cases of quantitative exposure such as radiation exposure, geographical distribution of prevalence is not suitable and accurate to assess the exposure.

Even in the same regional district, the ambient radiation dose rate varied geographically and temporally. The radiation dose exposure depends on when and where children were located. Actually, immediately after the outbreak of the accident, the government of Japan ordered residents within 20 km from the affected plant to evacuate. They left their residential areas for various destinations including those outside of Fukushima prefecture through various routes and timings. (Investigation Committee on the Accident at the Fukushima Nuclear Power Stations, 2012) Thus, it is unreliable to assume that the address in 11 districts in Fukushima before the accident can represent their radiation dose exposure in the early stages of the accident. No matter how researchers analyze unreliable data, it cannot improve the reliability of the conclusions drawn.

4.2. Effectiveness of Informal Logic Model

The current paper's analysis shows that the informal logic model is useful for the analysis of argumentation. A simple fact check cannot handle the complex argument using many pieces of evidence. Evidence does not constitute argumentation by itself; rather, structural components construct argumentation. Argument analysis needs to clarify whether each component of the argument is well established or not, in other words, strong or weak, whereas the analysis does not judge which argument is correct or incorrect.

The analysis of the argument using the informal logic model can help a third party to judge the result of the debate by clarifying the strong and weak points. The analysis can also foster a rational debate by identifying the point to be argued further. Sharing the points of discussion can encourage both parties to research questions lacking evidence and to deepen their analysis for resolving the issue. Argumentation analysis is particularly essential when data and definitive evidence are insufficient or lacking because, with definitive evidence, the conclusions are definite and no debate occurs.

4.3. Lessons learned from Argumentation pedagogy

A number of epidemiological papers have attempted to draw intentional conclusions from inadequate epidemiological evidence. Two characteristics were observed in such studies. The first was that the author had strong beliefs in a specific direction and lacked a critical thinking disposition. The second was that the epidemiological data were incomplete or biased.

When the two overlapped, the paper had high potential to conclude inadequate epidemiological analysis in a manner consistent with the authors' beliefs.

Many studies emphasized the necessity of critical thinking as a prerequisite for establishing a rational debate (e.g., (Colbert, 1987). Full employment of critical thinking needs to include not only critical thinking skills but also its affective disposition to make use of these skills (Ennis, 1987) (Facione, 1990). Facione (1990) summarizes the list of affective dispositions to be good critical thinkers based on a consensus of experts. The list includes dispositions such as "honesty in facing one's own biases, prejudices, stereotypes, egocentric or sociocentric tendencies" and "willingness to reconsider and revise views where honest reflection suggests that change is warranted." (Facione, 1990)

To realize a rational debate on health risks, criticizing the study from an epidemiological perspective is not sufficient, and fostering an affective disposition of critical thinking in the authors is necessary.

It is beyond this paper's scope to discuss what kind of efforts are effective to cultivate critical thinking dispositions for researchers in natural sciences. At present, to avoid bias in research results, research papers of natural sciences (especially medical science) are obliged to specify conflicts of interest. However, there is no education to foster critical thinking dispositions in higher education in the natural sciences in Japan. There is no doubt need for further study of argument pedagogy to enhance the dispositions in natural science researchers.

5. CONCLUSION

Few studies have analyzed arguments on health risks. A couple of reasons may explain this lack of research. Sufficient knowledge on informal logic and training in argumentation skill is prerequisite to unearth the week points of arguments that seem sound prima facie and to explain them. Furthermore, researchers need to have expertise in the field of natural sciences for analyzing the arguments on health risks. Hence, an interdisciplinary approach is indispensable for conducting such research. These difficulties do not lessen the need to analyze arguments on health risk. To generate productive dialogues and rational debate on the issue, further studies are warranted.

REFERENCES

Ahn, H. S., Kim, H. J. & Welch, G., 2014. Korea's Thyroid-Cancer "Epidemic" — Screening and Overdiagnosis. The New England Journal of Medicine, 371(19), pp. 1765-1767.

Colbert, K. R., 1987. The effects of CEDA and NDT debate training on critical thinking ability.. The Jounal of American Forensic Association, Volume 23, pp. 124-201.

Ennis, R. H., 1987. A taxonomy of critical thinking dispositions and abilities. In: J. B. Baron & R. J. Sternberg, eds. Teaching Thinking Skills: Theory and Practice. New York: W.H. Freeman and Company, pp. 9-26.

Facione, P. A., 1990. Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction.. Newark: American Philosophical Association. (ERIC Doc, NO. ED315423).

Frewer, L. J., 2003. Trust, transparency, and social context: implications for social amplification of risk. In: N. Pidgeon, R. E. Kasperson & P. Slovic, eds. The social amplification of risk. Cambridge: Cambridge University Press, pp. 123-137.

Habermas, J., 1989. The Structural Transformation of the Public Sphere: An inquiry into a Category of Bourgeois Society. Cambridge: Polity Press.

Hattori, M., 2018. Reason why UNSCEAR's reports are trusted world wide - Interview with Makoto Akashi on the reports on the Fukushima Accident- (Japanese). [Online]
Available at: https://synodos.jp/fukushima_report/21606

Hayashida, N. et al., 2013. Thyroid Ultrasound Findings in Children from Three Japanese Prefectures: Aomori, Yamanashi and Nagasaki. PLOS ONE, 8(12), p. e83220.

Hayashida, N. et al., 2015. Thyroid ultrasound findings in a follow-up survey of children from three Japanese prefectures: Aomori, Yamanashi, and Nagasaki. SCIENTIFIC REPORTS, 5(9046).

Investigation Committee on the Accident at the Fukushima Nuclear Power Stations, 2012. Final report of Investigation Committee on the Accident at the Fukushima Nuclear Power Stations. [Online]
Available at: http://www.cas.go.jp/jp/seisaku/icanps/eng/final-report.html

Jorgensen, T. J., 2016. Re: Thyroid Cancer Among Young People in Fukushima. Epidemiology, 27(3), p. e17.

Kasperson, R. E. & Kasperson, J. X., 1996. The social amplification and attenuation of risk. Annals of the American Academy of Political and Social Science, Volume 545, pp. 95-105.

Kitada, A., 2013. Public Opinion on Nuclear Power Generation Measured in Continious Polls Changes after Fukushima Daiichi Nuclear Power Plant Accident over the Past 30 Years. Trans. At. Energy Soc. Jpn., Volume 12, pp. 177-196.

Murdock, G., Petts, J. & Horlick-Jones, T., 2003. After amplification: rethingking the role of the media in

risk communication. In: N. Pidgeon, R. E. Kasperson & P. Slovic, eds. The Social Amplification of Risk. Cambridge: Cambridge University Press, pp. 156-178.

Nakayachi, K., Yokohama, H. M. & Oki, S., 2015. Public anxiety after the 2011 Tohoku earthquake: Fluctuations in hazard perception after catastrophe. Journal of Risk Research, Volume 18, pp. 156-169.

Renn, O., 1992. The social arena concept of risk dabates. In: S. Krimsky & D. Golding, eds. Social Theories of Risk. Westport, CT: Praeger, pp. 179-196.

Shinoda, Y., Tsuida, S. & Kimura, H., 2014. Periodical Public Opinion Survey on Nuclear Energy (Inhabitants Living in the Tokyo Metroporitan Area). Trans. At. Enercy Soc. Jpn, Volume 12, pp. 94-112.

Smith, D. & McCloskey, J., 1998. Risk communication and the social amplification of public sector risks. Public Money and Management, Volume 18, pp. 41-45.

Suzuki, S., 2016. Childhood and Adolescent Thyroid Cancer in Fukushima after the Fukushima Daiichi Nuclear Power Plant Accident: 5 Years On. Clinical Oncology, 28(4), pp. 263-271.

Takamura, N., 2016. Re Thyroid Cancer Among Young People in Fukushima. Epidemiology, 27(3), p. e18.

Taniguchi, N. et al., 2013. Ultrasonographic thyroid nodular findings in Japanese children. J Med Ultrason, 40(3), pp. 219-224.

Toulmin, S. E., 1958. The Use of Argument. Cambridge: Cambridge University Press.

Tsuda, T., Tokinobu, A., Yamamoto, E. & Suzuki, E., 2016a. Thyroid cancer detection by ultrasound among residents ages 18 years and younger in Fukushima, Japan: 2011 to 2014. Epidemiology, 27(3), pp. 316-322.

Tsuda, T., Tokinobu, A., Yamamoto, E. & Suzuki, E., 2016b. Response to the Commentary by Professor Davis and the Seven Letters. -A well-known fact should be disseminated to remedy the problems. Epidemiology, 27(3), pp. e21-23.

UNSCEAR, 2011. Sources and Effects of Ionizing Radiation. Volume II: Effects. Scientific Annexes C, D and E. UNSCEAR 2008 Report, New York: United Nations Scientific Committee on the Effects of Atomic Radiation.

UNSCEAR, 2013. UNSCEAR 2013 Report Volume I Report to the General Assenbly Scientific Annex A, New York: United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations.

UNSCEAR, 2016. DEVELOPMENTS SINCE THE 2013 UNSCEAR REPORT ON THE LEVELS AND EFFECTS OF RADIATION EXPOSURE DUE TO THE NUCLEAR ACCIDENT FOLLOWING THE GREAT EAST-JAPANEARTHQUAKE AND TSUNAMI-A 2016 white paper, New York, USA: United Nations Scientific Committee on the Effects of Atomic Radiation.

Wakeford, R. et al., 2016. Re Thyroid Cancer Among Young People in Fukushima. Epidemiology, 27(3), pp. e20-e21.

Yamauchi, T., 2018. What UNCSEAR 2016 white paper dose not mention on thyroid cancers among children- Accusation to an unscientific framework ―(Japanese). Kagaku, 88(9), pp. 906-914.

Yasumura, S. et al., 2012. Study Protocol for the Fukushima Health Management Survey. Journal of Epidemiology, 22(5), pp. 375-383.

Ziegelmueller, G. W. & Kay, J., 1997. Argumentation: Inquiry & Advocacy, Third Edition. s.l.:Allyn & Bacon.