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Examination History and Abnormal Thyroid and Breast Lesions According to Residential Distance from Nuclear Power Plants

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ABSTRACT

Background: Ascertainment bias are common in epidemiologic studies to assess the association between thyroid cancer risk and living near nuclear power plants because many thyroid cancers are diagnosed by chance through health examination. We surveyed the ultra sonography (USG) examination history and conducted thyroid and breast USG in residents living near nuclear power plants.

Materials and Methods: The study population comprised 2,421 residents living near nuclear power plants in Korea. Information on demographic characteristics, including diagnostic examination history, was collected by interview using questionnaires. USG examination was conducted to evaluate the presence of thyroid nodules and breast lesion. Study participants were divided into 3 groups according to the distance of their respective villages from a nuclear power plant. The proportions of USG examination history and prevalence of thyroid nodules and breast lesions were compared between groups.

Results and Discussion: Examination histories of thyroid USG were 23.1%, 13.7%, and 10.5% in men and 31.3%, 26.7%, 18.3% in women in the short, intermediate, and long distance groups, respectively. There were significant inverse associations between thyroid USG history and the distance from nuclear power plants (P for trend = 0.001 for men and 0.017 for women). However, there was no association between the distance of villages from nuclear power plants and prevalence of thyroid nodules.

Conclusion: Our results suggest that there may be an ascertainment bias in population-based studies examining the harmful effects of NPPs examination and researchers should pay attention to ascertainment bias resulted from differential health examination. Correction for ascertainment bias, active follow-up and examination for all study population to remove differential health examination is needed.

Keywords: Nuclear power plants, Thyroid cancer, Ascertainment bias

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Introduction

The thyroid is highly sensitive to radiation exposure [1]. In a study of atomic bomb survivors in Japan, exposure to ionizing radiation was associated with thyroid cancer among women and children [2]. The nuclear power plant (NPP) accident in Chernobyl resulted in an excess morbidity from thyroid cancer among children and adolescents living near NPP facilities [3, 4]. In addition to concerns about accidents at NPP facilities, there is public concern about whether living near NPPs is associated with thyroid cancer [5, 6].

Although several population-based studies have assessed the association between thyroid cancer risk and residence distance near NPPs, the results have been inconsistent due to low dose radiation, varying study designs, measurement error, and confounding factors, among others. Furthermore, because many thyroid cancers are diagnosed by chance through health examination, ascertainment bias or detection bias are common in epidemiologic studies.

Recently, a cohort study reported cancer risk in adult residents living near NPPs in Korea, prompting criticism [6-8]. Ascertainment bias could not be entirely excluded during follow-up. Thyroid cancer has been the most common cancer in Korea since 2009, and cases have increased rapidly by 22.3% per year [9]. This thyroid cancer epidemic has largely resulted from health check-up and over-diagnosis, such as thyroid ultrasound examination, and it is important to consider the possibility of screening effect in observational epidemiologic studies [10].

We surveyed the thyroid ultrasonography (USG) examination history in residents living near NPPs to assess whether the examination rate varied according to the distance of residences from NPPs. We also conducted thyroid USG to assess whether the prevalence of thyroid nodules varied in patients according to the distance of their residence from NPPs.

Materials and Methods

1. Study population and data collection

In Korea, 25NPPs are being operated commercially in 4 areas (Busan, Gyeongju, Yonggwang, and Ulchin). The study population was selected from residents who live near the Wolsong NPPs in Gyeongju. Since 1983, five power plants have been operational in Gyeongju. Of the 17,066 residents aged 20 yr or older who lived within 20 km of NPP facilities, 2,421 were voluntarily recruited for this study in 2013.

We divided participants into 3 groups according to the distance of the village hall from the NPPs: short (within 5 km), intermediate (6-10 km), and long distance (11-20 km). Sample sizes were allocated; sampling fractions were 20%, 15%, and 10% for short, intermediate, and long distance groups, respectively. We informed villagers about our study through village foremen and enrolled the volunteer participants within the allocated sample size. And then well-trained interviewer visited house of each participants.

Information on demographic characteristics, life style, dietary habits, and health examination history was collected through interviews using questionnaires. Participants were asked to answer the question “Have you ever had a thyroid USG examination?” Participants were asked to respond “Yes”, “No”, or “I do not know”. Participants were asked the same question about history of abdominal USG, breast USG, carotid artery USG, cardiac USG, abdominal computer tomography (CT), chest CT, brain CT, and brain magnetic resonance imaging (MRI).

After excluding missing data, the final study sample was 2,414. Written informed consents were obtained from all participants, and this study was approved by the Ethics Committee of the Institute of Medicine at the Seoul National University.

2. USG examination of thyroid and breast

After 2 months from questionnaire survey, enrolled participants were asked to assemble to have a health check. Of the 2,414 study participants, 1,976 had received a thyroid USG to check for thyroid nodules, and 1,275 women received a breast USG from three expert radiologists. The radiologists assessed the thyroid nodules as yes or no according to presence of nodule more than 1 mm and classified breast USG results according to the Breast Imaging Reporting and Data System (BI-RADS). In the BI-RADS system, C1 is negative, C2 is benign, C3 indicates probably benign, C4 is suspicious abnormality, C5 is highly suggestive of malignancy, and C6 indicates proven malignancy.

3. Statistical analysis

Analysis of variance and chi-square tests were conducted to identify differences between groups with regard to the means and proportions of baseline characteristics such as age, sex, cigarette smoking history, alcohol drinking history, household income, education status, regular exercise and self-rated health status. The proportions of participants who received thyroid USG, abdominal USG, breast USG, carotid artery USG, cardiac USG, abdominal CT, chest CT, brain CT, and brain MRI are expressed as percentages and 95% confidence intervals. To assess the association between examination history and distance of residence from NPP facilities in men and women, the *P* values for the trend test were calculated by treating the numerical value of the categorical variable as a score in multiple logistic regression models. To assess the association between presence of thyroid nodules and distance of residence from NPP facilities, we used multiple logistic regression models. Potential confounders considered were age, cigarette smoking history, household income per month, years of education, regular exercise and self-rated health status. Prevalence was estimated as *examination rate of USG × positive rate of USG*. We considered statistical significance at a *P* value less than 0.05. All analyses were conducted using SAS 9.3 (SAS Institute, Cary, NC).

Results

The short, intermediate, and long distance groups comprised 788, 1,313, and 313 study participants, respectively (Table 1). The distribution of smoking history, monthly household income, education status, regular exercise, and perceived health status differed among distance groups. The short distance group had relatively higher income, higher education, and better self-rated health status compared with the intermediate and long distance groups. The smoking proportion was low and regular exercise proportion was high in the short distance group.

History of thyroid USG was 31.3%, 26.7%, and 18.3% among women in the short, intermediate, and long distance groups, respectively (Table 2). Examination history of breast USG were 41.7%, 26.5%, 30.1% among women in short, intermediate, and long distance groups, respectively. After adjusting for age, smoking history, alcohol drinking history, regular exercise, household income, education level, and self-rated health status, a significant inverse association between USG history and distance from NPPs remained (*P* for trend = 0.015 for thyroid and *P* for trend < 0.001 for breast). Except for thyroid and breast, CT, and MRI examination history, there was no trend in proportions according to distance group in the other USG groups.

History of thyroid USG was 23.1%, 13.7%, and 10.5% among men in the short, intermediate, and long distance groups, respectively (Table 2). After adjusting for potential

Table 1. Baseline Characteristics of Study Population

Variables	Distance of villages from NPPs			*P*-value
	Short (≤5 km) (N = 788)	Intermediate (6-10 km) (N = 1,313)	Long (11-20 km) (N = 313)	
Age, mean (SD)	60.7 (14.2)	64.6 (10.5)	62.9 (9.78)	< 0.001
Sex, n (%)				0.132
Men	265 (33.6)	476 (36.3)	125 (39.9)	
Women	523 (66.4)	837 (63.7)	188 (60.1)	
Smoking status, n (%)				0.003
Never	585 (74.2)	886 (67.5)	204 (65.2)	
Past	99 (12.6)	234 (17.8)	53 (16.9)	
Current	104 (13.2)	193 (14.7)	56 (17.9)	
Alcohol drinking, n (%)				0.516
Never	390 (49.5)	628 (47.8)	138 (44.1)	
Past	40 (5.1)	78 (5.9)	17 (5.4)	
Current	358 (45.4)	607 (46.2)	158 (50.5)	
Household income per month, n (%)				< 0.001
-$ 999	264 (33.5)	609 (46.4)	135 (43.1)	
$ 1,000-1,999	198 (25.1)	385 (29.3)	89 (28.4)	
$ 2,000-	326 (41.4)	319 (24.3)	89 (28.4)	
Educated years, n (%)				< 0.001
-5 years	203 (25.8)	363 (27.7)	77 (24.6)	
6-12 years	343 (43.5)	681 (51.9)	171 (54.6)	
13 years-	242 (30.7)	269 (20.5)	65 (20.8)	
Regular exercise, n (%)				< 0.001
No	590 (74.9)	972 (74.0)	266 (85.0)	
Yes	198 (25.1)	341 (26.0)	47 (15.0)	
Self-rated health status, n (%)				0.002
Healthy	291 (37.0)	397 (30.3)	108 (34.5)	
Intermediate	284 (36.1)	456 (34.8)	103 (32.9)	
Not healthy	212 (26.9)	459 (34.9)	102 (32.6)	

SD, standard deviation.

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confounders, there was still a significant reverse association between history of thyroid USG and distance from NPPs (P for trend = 0.001). However, there was no trend of proportions according to distance group in the other USGs except for thyroid, CT, and MRI examination history.

The prevalence of thyroid nodules among men in the short, intermediate, and long distance groups was 10.2%, 11.7%, and 17.0%, respectively (Table 3).[1] The prevalence of thyroid nodules among women in the short, intermediate, and long distance groups was 18.6%, 17.8%, and 17.6%, respectively. However, there was no association between the distance of villages from NPPs and the presence of thyroid nodules. The prevalence of benign breast masses was higher in the short distance group, although this finding was not statistically significant.

We estimated the expected prevalence of thyroid nodules in the community by multiplying the proportion of those in the study population with a history of thyroid USG by the

Table 2. Examination History According to Distance of Villages from NPPs in Women and Men

Examination history	Men, % (95% CI)				Women, % (95% CI)			
	Short (≤5 km) (N=265)	Intermediate (6-10 km) (N=476)	Long (11-20 km) (N=125)	P for trend	Short (≤5 km) (N=523)	Intermediate (6-10 km) (N=837)	Long (11-20 km) (N=188)	P for trend
Thyroid USG	23.1 (18.3-27.9)	13.7 (10.8-16.6)	10.5 (5.4-15.6)	0.001	31.3 (27.8-34.8)	26.7 (24.0-29.4)	18.3 (13.2-23.5)	0.015
Abdominal USG	43.9 (38.3-49.5)	41.1 (36.9-45.3)	36.8 (28.7-44.9)	0.279	38.7 (35.0-42.4)	36.1 (33.2-39.0)	35.0 (28.6-41.4)	0.732
Breast USG					41.7 (38.0-45.4)	26.5 (23.8-29.2)	30.1 (24.0-36.2)	<0.001
Carotid USG	8.7 (5.5-11.9)	4.9 (3.1-6.7)	8.1 (3.5-12.7)	0.501	6.2 (4.4-8.0)	4.3 (3.1-5.5)	4.3 (1.6-7.0)	0.229
Cardiac USG	20.1 (15.6-24.7)	22.7 (19.2-26.3)	19.2 (12.6-25.8)	0.842	18.1 (15.2-21.0)	17.8 (15.5-20.1)	14.0 (9.4-18.6)	0.139
Abdominal CT	28.4 (23.3-33.5)	20.8 (17.4-24.2)	24.2 (17.0-31.4)	0.109	16.8 (14.0-19.6)	14.4 (12.3-16.5)	17.1 (12.1-22.1)	0.317
Chest CT	28.0 (22.9-33.1)	21.3 (17.8-24.8)	21.0 (14.2-27.8)	0.054	16.2 (13.4-19.0)	13.1 (11.1-15.2)	14.4 (9.7-19.1)	0.102
Brain CT	19.4 (14.9-23.9)	14.3 (11.3-17.3)	16.1 (9.9-22.3)	0.245	13.7 (11.1-16.3)	13.2 (11.1-15.3)	11.8 (7.5-16.1)	0.242
Brain MRI	23.5 (18.7-28.3)	20.6 (17.2-24.0)	20.3 (13.6-27.0)	0.273	24.1 (20.9-27.3)	22.3 (19.8-24.8)	22.6 (17.0-28.2)	0.059

USG, ultrasonography; CT, Computer tomography; MRI, Magnetic resonance imaging.

Table 3. Prevalence of Thyroid Nodule and Breast Lesion According to Distance of Villages from NPPs

	Distance to NPPs			P for trend
	Short (≤5 km)	Intermediate (6-10 km)	Long (11-20 km)	
Men				
Thyroid nodule (+), n (%)	22 (10.2)	46 (11.7)	16 (17.0)	0.173
Thyroid nodule (-), n (%)	193 (89.8)	348 (88.3)	78 (83.0)	
OR (95% CI)*	1	1.16 (0.68-1.99)	1.80 (0.90-3.61)	
OR (95% CI)†	1	1.02 (0.58-1.76)	1.81 (0.88-3.71)	
Women				
Thyroid nodule (+), n (%)	82 (18.6)	122 (17.8)	26 (17.6)	0.166
Thyroid nodule (-), n (%)	359 (81.4)	565 (82.2)	122 (82.4)	
OR (95% CI)*	1	0.95 (0.69-1.29)	0.93 (0.57-1.52)	
OR (95% CI)†	1	0.75 (0.54-1.03)	0.80 (0.49-1.31)	
BI-RADS classification of breast mass				
C1, n (%)	381 (85.8)	643 (94.0)	138 (95.2)	
C2-C3, n (%)	59 (13.3)	40 (5.9)	7 (4.8)	
C4, n (%)	4 (0.90)	1 (0.20)	0 (0.0)	
OR (95% CI)†,‡	1	0.63 (0.39-1.01)	0.49 (0.21-1.14)	
OR (95% CI)†,§	1	0.11 (0.01-1.17)	0.34 (0.04-3.04)	
OR (95% CI)†,ǁ	1	0.59 (0.37-0.93)	0.45 (0.19-1.03)	

OR, odds ratio; CI, confidence interval; BI-RADS, Breast Imaging Reporting and Data System.
*Crude odds ratio and 95% CI.
†Adjusted for age, cigarette smoking, monthly household income, years of education, regular exercise and self-rated health status.
‡C2-C3 vs. C1.
§C4 vs. C1: The OR was estimated using the Firth method.
ǁC2-C4 vs. C1.

[1] C1 is negative, C2 is benign, C3 indicates probably benign, C4 is suspicious abnormality, C5 is highly suggestive of malignancy, and C6 indicates proven malignancy.

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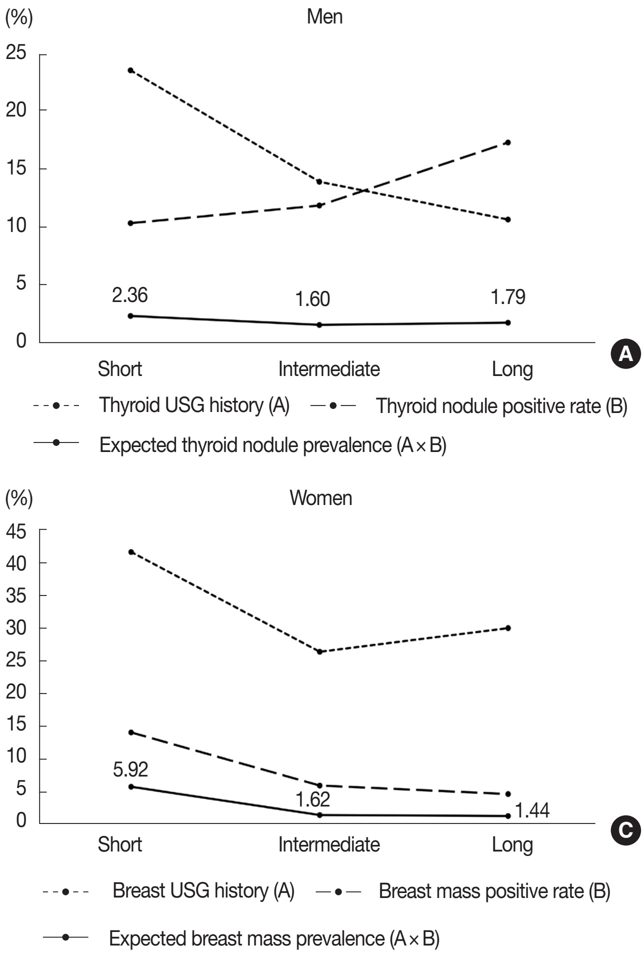

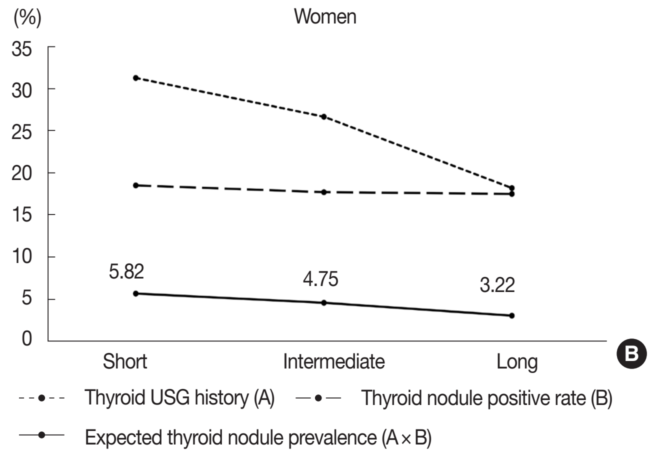

Fig. 1. Possibility of ascertainment bias according to distance of villages from NPPs. (A) Expected thyroid nodule prevalence of men in the community. (B) Expected thyroid nodule prevalence of women in the community. (C) Expected breast mass prevalence of women in the community.

positive proportion of thyroid nodule detection in the study population (Figure 1).[2)] The prevalence of thyroid nodules and breast masses observed in the community was higher in the short distance group than in the intermediate or long distance groups.

Discussion

There were differences in thyroid and breast USG history according to the distance of villages from the NPPs. However, there was no association between the distance from NPPs and prevalence of thyroid nodules.

Many studies of the effects of high-dose radiation exposure on thyroid cancer were conducted in relation to the Chernobyl accident, atomic bombing areas, and the Fukushima NPP accident. A case-control study conducted in Belarus and Russia reported that the estimated linear coefficient of the excess relative risk of thyroid cancer per gray was 4.5 (95% CI = 1.2-7.8) [11]. A cohort study in Ukraine estimated the excess relative risk of thyroid cancer per gray at 5.2 (95% CI = 1.7-27) [12].

However, there were doubts about whether the Chernobyl NPP accident resulted in an increase in thyroid cancer because of artifacts through active case finding, previous underreporting before the accident, unexpected geographic distribution between thyroid cancer and cesium contamination, short latency period, and decrease of thyroid cancer after initial increase [13]. These doubts were mainly related to ascertainment bias, which arises when the intensity of case-finding activities changes.

Because of the harmful effects and epidemiologic discrepancies of radiation, the public has concerns about the safety

[2)] Legend: The expected prevalences of thyroid nodules in the community were estimated by multiplying the proportion of those in the study population with a history of thyroid USG (A) by the positive proportion of thyroid nodule detection in the study population (B). The expected prevalence of thyroid nodules and breast masses observed in the community was higher in the short distance group than in the intermediate or long distance groups.

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of low-dose radiation exposure originating from NPPs. In recent decades, epidemiologic studies have been conducted to assess the association between living near NPPs and risk of thyroid cancer. A Korean prospective cohort study of 11,367 adults living within a 5 km radius of NPPs and 24,809 adults living far away from NPPs showed that women living within a 5 km radius of a NPP had a 1.9 times higher risk of developing thyroid cancer compared to the living far away from NPPs [6]. However, in a retrospective cohort study in the UK, living near a NPP was not associated with risk of thyroid cancer. Each standardized incidence ratio (95% CI) of 3 areas near NPPs in the UK was 0.00 (0.00-6.88), 0.86 (0.58-1.23), and 1.04 (0.79-1.34) [14]. In a retrospective cohort study in Canada, there was no increased risk of thyroid cancer associated with living near an NPP. The standardized incidence ratio (95% CI) in the Canadian study was 0.69 (0.50-0.95) in women and 0.92 (0.52-1.50) in men [15]. A recent meta-analysis reported that despite heterogeneity among studies, there was no association between increased risk of thyroid cancer and living near a NPP regardless of region, gender, exposure definition, reference population, and study quality [16].

These discrepancies in results from epidemiologic studies might be caused by low-dose radiation, genetic susceptibility, dietary iodine intake, study designs, bias, definition of exposure, confounding factors, and statistical power [17]. According to a National Research Council report, the radiating dose from normally operating NPPs is estimated to be less than 0.01 $mSv \cdot yr^{-1}$, and this dose is low compared with natural background radiation exposure levels despite variation from plant to plant [17]. Additionally, thyroid cancer is affected by ethnic background such as genetic susceptibility to BRAF and RET mutation and iodine intake; therefore, results between studies could be inconsistent [18-20]. Study design is also an important factor that could lead to inconsistencies. Study designs commonly used in radiation research were ecologic, case-control, and cohort study. Results are vulnerable to ecological fallacy, temporal bias, information bias, and selection bias depending on the study design. The cohort study design provides the strongest evidence among observational studies. Although the previously mentioned Korean study was a prospective cohort study and it reported a significant association between thyroid cancer and living near NPPs, the conclusion about whether living near NPPs was associated with an increased risk of thyroid cancer was inconclusive because of low-radiation dose, different results between men and women, and possibility of detection bias [6, 7].

The residential area of our study population overlapped with the previous Korean cohort study. In Korea, health service accessibility for thyroid USG is relatively good, and the cost for thyroid USG is 30-50 US dollars [10]. A nationwide cancer screening survey conducted in 2009 reported that 8.4% of men and 16.4% of women underwent thyroid USG [21]. The examination proportion of thyroid USG in our study population living near NPPs was 16.5% in men and 27.2% in women. Although we compared the crude rate instead of the age-standardized rate, the USG screening rate of our study population living near NPPs was higher than the nationwide rate because our study population had higher USG screening rates in all age strata.

Since 1999, national screening services for gastric, hepatic, colon, breast, and cervical cancer have been provided free of charge or at low cost in Korea. Additionally, most hospitals have promoted their health examination program, including thyroid USG in their programs [22]. Two-thirds of thyroid cancer cases were detected by such health examination programs.[3)] The following socioeconomic characteristics of those receiving thyroid USG might be associated with having a thyroid USG: income and educated level. In a study based on the Korean National Health and Nutrition Examination Survey, high household income (OR: 3.30 for highest household income vs. lowest household income) and high educational level (OR: 2.74 for 10-12 yr vs. <7 yr) were associated with thyroid cancer [23]. These results supported our findings that in our population, residents living within a 5 km radius of an NPP had higher household income and educational level compared with residents living farther away from NPPs.

Our study had considerable limitations. One limitation is that our study population was not a representative sample because we recruited volunteer participants. This convenient sampling might result in selection bias. Second, there was the possibility of information bias. For example, recall bias could occur if participants in the short distance group had a tendency to recall previous USG examinations more than participants in the long distance group. Third, because we obtained information on USG examination history through questionnaire interviewing, there might be mea-

3) National Cancer Information Center. Korea cancer registry statistics.2012 http://www.cancer.go.kr/mbs/cancer/jsp/album/gallery.jsp?addCancerTitle=&spage=1&boardId=31817&boardSeq=8471320&mcategoryId=&id=cancer_050207000000.

surement error due to memory decay.

Our results suggest that there may be an ascertainment bias in population-based studies examining the harmful effects of NPPs examination and researchers should pay attention to ascertainment bias resulted from differential health examination. Correction for ascertainment bias, active follow-up and examination for all study population to remove differential health examination is needed.

Conclusion

There were differences in self-reported thyroid and breast ultrasonography history according to the distance of villages from the nuclear power plants. However, when we conducted thyroid and breast ultrasonography, there was no association between the distance from nuclear power plants and prevalence of thyroid nodules. Our results suggest that there may be an ascertainment bias in studies examining the health effects of nuclear power plants and that active follow-up and examination are needed to assess thyroid cancer in study populations.

References

1. Brent GA, Braverman LE, Zoeller RT. Thyroid health and the environment. Thyroid 2007;17:807-809.
2. Richardson DB. Exposure to ionizing radiation in adulthood and thyroid cancer incidence. Epidemiology 2009;20:181-187.
3. Brenner AV, et al. 131I dose response for incident thyroid cancers in Ukraine related to the Chornobyl accident. Environ. Health Perspect. 2011;119:933-939.
4. Zablotska LB, et al. Thyroid cancer risk in Belarus among children and adolescents exposed to radioiodine after the Chornobyl accident. Br. J. Cancer. 2011;104:181-187.
5. Wang SI, Yaung CL, Lee LT, Chiou SJ. Cancer incidence in the vicinity of nuclear power plants in Taiwan: a population-based study. Environ. Sci. Pollut. Res. Int. 2016;23(1):571-580.
6. Ahn YO, et al. Cancer risk in adult residents near nuclear power plants in Korea - a cohort study of 1992-2010. J. Korean Med. Sci. 2012;27:999-1008.
7. Kim JM, Kim MH, Ju YS, Hwang SS, Ha M, Paek D. Re: cancer risk in adult residents near nuclear power plants in Korea: a cohort study of 1992-2010. J. Korean Med. Sci. 2014;29:1436-1437.
8. Lee WJ. Cancer risk among population near nuclear power plants in Korea. J. Korean Med. Sci. 2015;30:666-667.
9. Oh CM, Won YJ, Jung KW, Kong HJ, Lee JK, Lee DH, Lee KH. Cancer statistics in Korea: incidence, mortality, survival, and prevalence in 2013. Cancer Res. Treat. 2016;48(2):436-45.
10. Ahn HS, Kim HJ, Welch HG. Korea's thyroid-cancer "epidemic"-screening and overdiagnosis. N. Engl. J. Med. 2014;371:1765-1767.
11. Cardis E, et al. Risk of thyroid cancer after exposure to 131I in childhood. J. Natl. Cancer Inst. 2005;97:724-732.
12. Tronko MD, et al. A cohort study of thyroid cancer and other thyroid diseases after the chornobyl accident: thyroid cancer in Ukraine detected during first screening. J. Natl. Cancer Inst. 2006;98:897-903.
13. Bleuer JP, Averkin YI, Okeanov AE, Abelin T. The epidemiological situation of thyroid cancer in Belarus. Stem Cells. 1997;15 Suppl. 2:251-254.
14. Bunch KJ, Vincent TJ, Black RJ, Pearce MS, McNally RJ, McKinney PA, Parker L, Craft AW, Murphy MF. Updated investigations of cancer excesses in individuals born or resident in the vicinity of Sellafield and Dounreay. Br. J. Cancer. 2014;111:1814-1823.
15. Wanigaratne S, Holowaty E, Jiang H, Norwood TA, Pietrusiak MA, Brown P. Estimating cancer risk in relation to tritium exposure from routine operation of a nuclear-generating station in Pickering, Ontario. Chron. Dis. Inj. Can. 2013;33:247-256.
16. Kim J, Bang Y, Lee WJ. Living near nuclear power plants and thyroid cancer risk: A systematic review and meta-analysis. Environ. Int. 2016;87:42-48.
17. National Research Council. Analysis of cancer risks in populations near nuclear facilities: phase I. National Research Council; 2012;148-174.
18. Xing M. BRAF mutation in thyroid cancer. Endocr. Relat. Cancer. 2005;12:245-262.
19. Kondo T, Ezzat S, Asa SL. Pathogenetic mechanisms in thyroid follicular-cell neoplasia. Nat. Rev. Cancer. 2006;6:292-306.
20. Dal Maso L, Bosetti C, La Vecchia C, Franceschi S. Risk factors for thyroid cancer: an epidemiological review focused on nutritional factors. Cancer Causes & Control. 2009;20:75-86.
21. Han MA, Choi KS, Lee HY, Kim Y, Jun JK, Park EC. Current status of thyroid cancer screening in Korea: results from a nationwide interview survey. Asian Pac. J. Cancer Prev. 2011;12:1657-1663.
22. Chung JH. Unfounded reports on thyroid cancer. J. Korean Med. Sci. 2014;29:1033-1034.
23. Choi SW, Ryu SY, Han MA, Park J. The association between the socioeconomic status and thyroid cancer prevalence; based on the Korean national health and nutrition examination survey 2010-2011. J. Korean Med. Sci. 2013;28:1734-1740.

https://doi.org/10.14407/jrpr.2016.41.4.402