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Living near nuclear power plants and thyroid cancer risk: A systematic review and meta-analysis

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ABSTRACT

There has been public concern regarding the safety of residing near nuclear power plants, and the extent of risk for thyroid cancer among adults living near nuclear power plants has not been fully explored. In the present study, a systematic review and meta-analysis of epidemiologic studies was conducted to investigate the association between living near nuclear power plants and the risk of thyroid cancer. A comprehensive literature search was performed on studies published up to March 2015 on the association between nuclear power plants and thyroid cancer risk. The summary standardized incidence ratio (SIR), standardized mortality ratio (SMR), and 95% confidence intervals (CIs) were calculated using a random-effect model of meta-analysis. Sensitivity analyses were performed by study quality. Thirteen studies were included in the meta-analysis, covering 36 nuclear power stations in 10 countries. Overall, summary estimates showed no significant increased thyroid cancer incidence or mortality among residents living near nuclear power plants (summary SIR = 0.98; 95% CI 0.87–1.11, summary SMR = 0.80; 95% CI 0.62–1.04). The pooled estimates did not reveal different patterns of risk by gender, exposure definition, or reference population. However, sensitivity analysis by exposure definition showed that living less than 20 km from nuclear power plants was associated with a significant increase in the risk of thyroid cancer in well-designed studies (summary OR = 1.75; 95% CI 1.17–2.64). Our study does not support an association between living near nuclear power plants and risk of thyroid cancer but does support a need for well-designed future studies.

1. Introduction

Thyroid cancer is the most common type of endocrine cancer, and it has been rapidly increasing over the past several decades in most of the world (Pellegriti et al., 2013). Incidence has more than doubled since the early 1970s. An estimated 230,000 new cases of thyroid cancer were diagnosed among women and 70,000 among men in 2012 globally (Ferlay et al., 2012). This increase is likely due to overdiagnosis of small papillary carcinoma (La Vecchia et al., 2015) but may also be due to changing risk factors (Franceschi and Vaccarella, 2015). Ionizing radiation from either environmental or medical exposure is one of the major risk factors for thyroid cancer because the thyroid gland is highly sensitive to the carcinogenic effects of radiation (Ron et al., 1995).

Nuclear power plants (NPP) are a potential source of radioactive material in the environment. Many previous investigations have assessed the safety of living near NPP (National Research Council, 2012). However, the human health effects of low-level ionizing radiation exposure on residents living near NPP remain inconclusive. While the cancer risk among children living near NPP has been a primary focus of the past two decades (Baker and Hoel, 2007), the extent of the risk of thyroid cancer among adults living near NPP has not yet been fully explored.

Some studies have suggested an increased risk of thyroid cancer incidence or mortality (Levin et al., 2013; Ahn et al., 2012), and others have reported decreased risk of thyroid cancer among adults living near NPP (Boice et al., 2009; Bollaerts et al., 2014; Wanigaratne et al., 2013). However, the majority of these individual studies have several limitations, such as the lack of exposure data for individuals and small numbers of cases. Our knowledge about the degree of risk for thyroid cancer among residents living near NPP remains uncertain.

Therefore, we undertook a systematic review and meta-analysis of existing literature in order to assess the association between living near NPP and risk of thyroid cancer.

2. Material and methods

2.1. Search strategy

We conducted a comprehensive literature search of several electronic databases. Medline and EMBASE were selected as the target

Abbreviations: NPP, nuclear power plants; SIR, standardized incidence ratio; SMR, standardized mortality ratio.

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databases for our search. Relevant articles were identified using search strategy with subject heading, or with a combined text word and Medical Subject Headings (MeSH). Our search terms for radiation exposure from NPP were included: "nuclear facility", "nuclear sites", "nuclear industry", "nuclear power plants", "nuclear installations", "radiation exposure", "ionizing radiation", "environmental exposure". These were combined with search terms for thyroid cancer which included "thyroid neoplasm", "thyroid cancer", "thyroid carcinoma". Search terms were grouped according to the Boolean operators OR and AND. The search was conducted through March 2015 and restricted to human studies. We additionally retrieved studies manually by searching the bibliographies of review articles and original research articles.

2.2. Study selection

Our inclusion criteria were as follows: 1) studies about NPP under normal operations, 2) quantitative effect estimate provided, such as standardized incidence ratio (SIR), standardized mortality ratio (SMR), relative risk (RR), and odds ratio (OR), and 3) original articles. We only included studies about NPP in their routine operation to evaluate the possible impact on residents living near facilities; therefore, studies about cancer risk after accidents, fallout, or occupational exposure were excluded. However, the Hanford and Three Mile Island accidents were included because their levels of radionuclides releases were considered similar to normal operation.

Fig. 1 shows the selection process. We identified 2931 articles from the search strategies described above. After screening for titles that contained radiation exposure and risk of cancers, 45 articles were considered potentially eligible and a detailed review of the full text was conducted. Studies that reported results from the Chernobyl or Fukushima accidents, fallout, any accident from unusual operation, or nuclear weapons testing sites were excluded ($n = 19$). If there was more than one article with the same or overlapping population, preference was given to the article providing more comprehensive, updated information. Three articles were duplicates from previous studies of overlapping populations. If the article type was a review, letter, or comments, the study was excluded ($n = 3$). We further excluded studies that did not provide quantitative effect estimates about thyroid cancer ($n = 7$). Through this selection process, a total of 13 articles met our criteria. The articles often reported more than one estimate by region, gender, or endpoint of incidence or mortality. We treated the data from each region, gender, and endpoint as a separate study for our meta-analysis. Therefore, the number of individual estimates from 13 articles retained in the meta-analysis was 14 for incidence, 6 for mortality, 14 for region, and 8 for gender.

2.3. Exposure definition

The studies included in our meta-analysis used distance or geographic location to the NPP as a surrogate for radiation dose exposure. The exposure zone was defined variously in each study: less than 5 km, 9 km, 10 km, 16 km, 20 km, 30 km, 32 km, or living near the NPP. We classified different exposure zones into two categories: 20 km or less (i.e., less than 5 km, 9 km, 10 km, 16 km, 20 km) or living near (i.e., 30 km, 32 km, or living near the NPP). Comparison areas also differed by study. Some studies used distance from the nuclear sites such as 30 km or 50–100 km radius for a comparison area; others chose the area of adjacent counties or whole countries.

2.4. Quality assessment

To define study quality, we developed quality criteria based on a modified MOOSE guideline (Stroup et al., 2000). Each individual study was scored (-1, 0, 1) on each of the following dimensions of the study design: a) selection of cases and controls, b) comparability, c) assessment of exposure and outcome, and d) data analysis and measurement. For instance, a cohort design received a score of 1, while a 0 score was assigned to a case–control study and a score of -1 to an ecological or a surveillance study. A high proportion of missing information, or subjects lost to follow-up, was scored as -1 on the dimension of selection of cases and controls. If a study reported information about other potentially confounding factors, then the comparability section would receive a score of 1. The actual scoring process was displayed in the Supplementary Table 1.

Two researchers with expertise in the area of environmental epidemiology reviewed each article independently. Reviewers independently assigned an overall rating to each study. Any discrepancies were discussed and resolved through consensus. The final quantitative score was then transformed into a qualitative category for each study. Based on the qualitative assessment score, the studies were categorized as

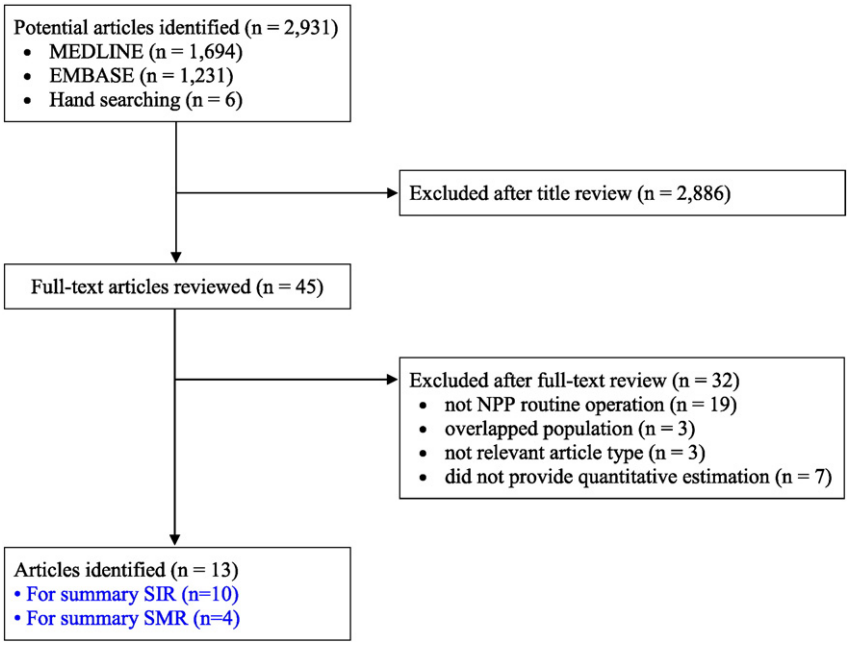

Fig. 1. Flow diagram of systematic literature search on thyroid cancer risk and living near nuclear power plants.