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The impact of indoor air pollution on the lung cancer – literature review

Wpływ zanieczyszczeń powietrza wewnątrz mieszkań na występowanie raka płuca – przegląd literatury

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ABSTRACT:

Introduction and purpose:
Lung cancer is the most diagnosed type of cancer as well as the leading cause of death around the world. The most important risk factor for lung cancer is tobacco smoking, which is associated with 80–90% of lung cancers. However, there are a lot of other lung cancer risk factors, which include: second-hand smoke exposure, environmental exposures, occupational exposures, genetic predisposition, and previous lung disease. In this study, we would like to present the actual state of knowledge about the influence of radon as well as other indoor air pollutants on the prevalence of lung cancer.

State of knowledge:
We analyzed nineteen studies in terms of the impact of indoor air pollution on morbidity and mortality caused by lung cancer. The authors of the included studies agree that both radon and other household air pollution (HAP) increase risk of the lung cancer. HAPs are formed during the combustion of solid fuels (i.e. charcoal, wood). Indoor air pollution can cause in the lungs chronic inflammation, cells damage and their proliferation, depletion of antioxidants, impairment of defense mechanisms, and production of reactive oxygen species as well as genetic mutations. Radon, on the other hand, emits alpha radiation, which can affect the respiratory epithelium and produce various cytotoxic and genotoxic effects, which promote carcinogenesis. The risk of lung cancer rises by approximately 6-16% per 100 Bq/m3 increase in long-time average residential radon concentration.

Conclusions:
Radon and other indoor air pollutants are crucial lung cancer risk factors. It is essential to reduce HAPs production, especially in rural areas, where many people still use coal, wood, or straw for household heating and cooking. Moreover, there are regions where is a need to improve ventilation as well as to switch to clean fuel sources, such as gas and electricity. The above-mentioned activities will contribute to reducing the concentration of radon and other HAPs in buildings and decreasing the risk of lung cancer.

Keywords: lung cancer, indoor air pollution, household air pollution, radon

ABSTRAKT

Wprowadzenie i cel:
Rak płuca jest najczęściej diagnozowanym nowotworem na świecie oraz główną przyczyną śmiertelności z powodu nowotworów. Najważniejszym czynnikiem ryzyka raka płuca jest palenie tytoniu, które jest związane z 80–90% przypadków zachorowań. Istnieje jednak wiele innych czynników ryzyka raka płuca, do których należą: narażenie na bierne palenie, czynniki środowiskowe, narażenie na czynniki zawodowe, predyspozycje genetyczne oraz przebyte choroby płuc. W niniejszej pracy pragniemy przedstawić aktualny stan wiedzy na temat wpływu radonu oraz innych zanieczyszczeń powietrza w pomieszczeniach na występowanie raka płuca.

Wyniki:
Przeanalizowaliśmy dziewiętnaście badań pod kątem wpływu zanieczyszczenia powietrza w pomieszczeniach na zachorowalność i śmiertelność z powodu raka płuca. Autorzy włączonych badań są zgodni co do tego, że zarówno radon, jak i inne domowe zanieczyszczenia powietrza (HAP) zwiększają ryzyko zachorowania na raka płuca. Domowe zanieczyszczenia powstają podczas spalania paliw stałych (tj. węgla drzewnego, drewna). Zanieczyszczenia powietrza w pomieszczeniach mogą powodować w płucach przewlekłe stany zapalne, uszkodzenia komórek i ich proliferację, wyczerpanie antyoksydantów, upośledzenie mechanizmów obronnych,

produkcję reaktywnych form tlenu, a także mutacje genetyczne. Z kolei radon emituje promieniowanie alfa, które może oddziaływać na nabłonek dróg oddechowych i wywoływać efekty: cytotoksyczny i genotoksyczny, które sprzyjają karcynogenezie. Ryzyko raka płuc wzrasta o około 6-16% na każde 100 Bq/m3 wzrostu długoterminowego, średniego stężenia radonu w budynkach mieszkalnych.

Wnioski:
Radon i inne zanieczyszczenia powietrza w pomieszczeniach są kluczowymi czynnikami ryzyka raka płuc. Niezwykle istotne jest ograniczenie produkcji HAP, zwłaszcza na terenach wiejskich, gdzie nadal wiele osób wykorzystuje węgiel, drewno lub słomę do gotowania i ogrzewania gospodarstw domowych. Ponadto istnieją regiony, w których istnieje potrzeba poprawy wentylacji w mieszkaniach, a także przejścia na czyste źródła paliw, takie jak gaz i energia elektryczna. Powyższe działania przyczynią się do zmniejszenia stężenia radonu i innych HAP w budynkach oraz zmniejszenia ryzyka zachorowania na raka płuc.

Słowa klucze: rak płuca, zanieczyszczenie powietrza w pomieszczeniach, radon

Introduction:

Lung cancer is the most common diagnosed type of cancer as well as the leading cause of death around the world. There are two main histological types of lung cancer: small-cell lung carcinoma (SCLC, approximately 15% of all lung cancer diagnoses) and non-small-cell lung cancer (NSCLC, approximately 85% of all lung cancer diagnoses). The NSCLC includes: adenocarcinoma, squamous cell carcinoma and large-cell carcinoma [1]. Tobacco smoking is the most important risk factor of the lung cancer, associated with 80–90% of lung cancers [2]. However there are a lot of other lung cancer risk factors, which include: second-hand smoke exposure, environmental exposures (radon, indoor and outdoor air pollution), occupational exposures, diet that includes a lot of red meat, consumption of alcohol, genetic predisposition, previous lung disease and arsenic exposure [3].

Household air pollutants are formed during incomplete combustion of solid fuels (i.e. charcoal, wood, straw). The increased production of many toxic inorganic and organic compounds, such as carbon monoxide, polycyclic aromatic hydrocarbons, aldehydes and free radicals is the effect of using these fuels for heating apartments, lighting or cooking [4]. Lack or inadequate ventilation of living spaces (caused for example by the low number of windows) results in a high concentration of these particles in a small space in which people often stay. The smaller particulate matter (PM) is more important than the larger PM because it lasts longer in the air and more easily penetrates the lungs causing inflammation [5]. Significant accumulation of PM as well as long time of exposure to these particles inside apartments, increase the lung cancer incidence and mortality.

An extremely important, often mentioned as a separate risk factor for lung cancer is radon. It is a colorless, odorless, and tasteless naturally occurring radioactive noble gas. Radon arises in the radioactive decay chain of uranium-238. This gas is the main source of natural radiation for human beings and widely exists in the daily environment (homes, schools and workplaces). The main sources of indoor radon include: soil around the foundation, building materials, fuels and domestic water [1]. According to the U.S. Environmental Protection Agency (EPA), radon has been classified as the second leading cause of lung cancer, after cigarette smoking and the first risk factor for never-smokers [1,6]. Buildings constructed in places where the rocks in the Earth's crust contain high uranium concentrations have a greater likelihood of experiencing high indoor radon concentrations, if they are not well insulated from the subsoil [6]. The concentration of the radon in buildings depends not only on housing factors (such as the type of housing, decoration materials, floor and age of housing), but also on environmental conditions (like: temperature, humidity and atmospheric pressure), time factors (including: season or day versus night) and the ventilation capacity of indoor and outdoor air [1].

In this review we would like to focus on the indoor air pollutants which are crucial lung cancer risk factors.

The aim of the study:

The aim of the study is to present the actual state of knowledge about the influence of indoor air pollutants on the prevalence of lung cancer.

State of knowledge:

The latest available literature on the PubMed database was reviewed. The analysis concerned publications written as full-text in English from 2012 to 2023. The data were collected from the PubMed database using the following keywords: "lung cancer, household air pollution, indoor air pollution, radon". Nineteen studies were analyzed in terms of the impact of indoor air pollution on morbidity and mortality caused by lung cancer. These studies concerned mainly the population of developing regions – particularly China where many people in rural areas still use coal for household heating and cooking [7]. The authors of the systematic review compared the impact of biomass fuel and coal use on lung cancer in China, Taiwan, Japan, India, Mexico, Morocco, USA, Canada and seven European countries. They reported a greater risk of the lung cancer development among China than other countries populations, where energy source is often smoky coal [8]. The pooled effect estimates that the risk of lung cancer among users of solid fuels is 70% higher than non-users [8].

Insoluble particles formed during combustion, entering the lungs can cause chronic inflammation, cells damage and their proliferation, depletion of antioxidants, impairment of defense mechanisms, production of reactive oxygen species as well as genetic mutations [4]. A higher risk of developing lung cancer was seen among people using smoky coal compared to smokeless coal and wood in Xuanwei. This was assessed based on the length of indoor stay, amount of consumed coal, type of ventilation, active and passive smoking [7].

An experimental study conducted in China in 2016 showed that mutations in the epidermal growth factor receptor (EGFR) gene are associated with exposure to PM 2.5 emitted during the burning of coal used by residents of the Xuanwei region on a daily basis, where lung cancer incidence is high among non-smoking women [9]. The PM 2.5 obtained for the study significantly reduced the viability of the cultured cells (human lung adenoma) [9]. Cells containing wild-type EGFR were more sensitive to PM2.5 than those with mutated EGFR. The response to EGFR-TKI (EGFR-tyrosine kinase inhibitors) depends on the type of coal used for burning and the concentration as well as time of exposure to polycyclic aromatic hydrocarbons (PAHs) [9]. PAHs getting into the body are metabolized to epoxides, phenols, dihydrodiols, dihydrodiol phenols, quinine and tetrols. These compounds can bind to DNA and then cause mutations in protooncogenes (ras) also in suppressor genes (TP53) which results in formation of tumors [4]. Moreover, TP63 polymorphism might be a genetic susceptibility factor for lung adenocarcinoma in Chinese non-smoking females, however further research is required to determine if there is an interaction between cooking oil fume exposure and the TP63 gene polymorphism [10].

Among people exposed to indoor air pollution, the presence of the glutathione S-transferase M1 (GSTM-1)-null genotype increases the risk of developing lung cancer, as it reduces the ability of PAHs detoxification, in relation to people with GSTM-1 positive genotype [7]. Another Chinese study showed that fumes generated during frying in oil cause changes in DNA and contribute to oxidative stress in the lung epithelial cells in non-smoking women who have developed adenocarcinoma [10]. Exposure to oil smoke contributes to an increased risk of lung cancer [2,11]. Frying in stir oil is more associated with an increased incidence of lung cancer compared to deep frying. This may be caused by higher oil fumes production during stir frying compared to deep frying [2]. Changing cooking habits, such as cooking food more often than frying it in oil, could reduce exposure to oil smoke.

An inverse correlation was found between the risk of lung cancer and good ventilation in the kitchen and bedroom. The risk of cancer was lower in non-smoking women living in multi-story homes (about 67% lower risk of developing lung cancer compared to women living in single story houses) and with many frequently opened windows and an isolated kitchen in the apartment [5,11]. Improved furnace ventilation resulted in a 2-6-fold decrease in internal benzo[a]pyrene (BaP) and PM10 levels, which contributed to a reduction in the incidence and mortality from lung cancer among both men and women in Xuanwei [7]. However the Nepalese study reported that there is no statistically significant relationship between ventilation during cooking, separate kitchen in the apartment, smoke level during cooking and the incidence of lung cancer [12].

Numerous studies emphasize that household air pollution increases the risk of lung cancer mainly among women who are much more likely to stay in closed rooms with poor ventilation and prepare meals [2,5,8,12,13]. The disability-adjusted life year (DALY's) attributable to household air

pollution due to lung cancer increased by 27% between 2000 and 2017 [13]. Authors found 3-fold increase in cancer risk among women who regularly cook more often than two times a day, compared to those did not cook regularly [5]. Long-term exposure to smoky coal fumes reduced the life expectancy of women by 6 years and men by 3 compared to people using smokeless coal in the Xuanwei region [14]. There was only one study in which the Xuanwei men had a greater risk of developing lung cancer compared to women exposed to indoor air pollution; however it concerned coal mine workers [15].

Exposure to indoor air pollution increases the risk of developing lung cancer more often in people with tuberculosis, COPD, pneumothorax, and a history of bronchitis (the study found no association with asthma). This risk applies to both smokers and non-smokers [16]. Harmful compounds released during combustion reaching the lungs increase the production of inflammatory factors, causing an enhancement in the incidence of lung diseases [4,5,16]. Long-term exposure to PAHs from biomass in non-smokers increases the risk of lung cancer. Nevertheless increased exposure to PAHs does not contribute to an increased risk of lung cancer in smokers [12].

Radon:

The role of radon in the development of lung cancer is related to the emission of alpha particles [6,17,18]. These alpha particles can affect the respiratory epithelium and produce various cytotoxic and genotoxic effects, which promote carcinogenesis. Iterative exposure to radon can cause the overproduction of reactive oxygen species (ROS) in the lungs and oxidative stress, leading to pulmonary inflammation. Furthermore, radon can intensify tumor immunogenicity by increasing genomic instability and cluster mutations in the tumor cells [17]. Radon exposure is strongly associated with increased lung cancer [1,6,17,18,19]. SCLC had the strongest association with residential radon followed by adenocarcinoma. The risks of SCLC and adenocarcinoma increased with increasing residential radon levels per 100 Bq/m3 by 19% and 13% respectively [6].

Reviewed studies emphasize that residential radon concentrations vary widely among the different countries and even within individual countries. For example a significantly positive association of residential radon exposure with lung cancer risk was observed in the studies conducted in Europe but not in the studies conducted in North-America [19]. High residential radon levels (>100 Bq/m3) can cause significantly harmful effects for the lungs, while radon levels <100 Bq/m3 should be considered less toxic to the lungs [17]. The risk of lung cancer rises by approximately 6-16% per 100 Bq/m3 increase in long-time average residential radon concentration [17,18,19]. According to *Zhang ZL. Et.al.* it is necessary from 5 to 25 years of residential radon exposure for lung cancer to develop.

Conclusions:

Radon and other indoor air pollutants are crucial lung cancer risk factors. Our study shows that there is essential to reduce HAPs production especially in rural areas, where many people still is use coal, wood or straw for household heating and cooking. There should be an exchange of these solid fuels to clean fuel sources, such as gas and electricity. Moreover there are regions where is need to improve ventilation (by increasing the number of windows in apartments and opening them more often, improving the ventilation of furnaces or isolating the kitchen from other rooms). Additionally it should be recommended to use more healthy cooking methods (like boiling, steaming, braising or baking) to reduce the risk of lung cancer caused by cooking oil fume.

It also seems extremely important to popularize devices for measuring radon concentration in buildings, especially in regions where the concentration is high. Radon sump systems which increase under-floor ventilation, improving ventilation, preventing radon from passing from the basement into living spaces, and sealing floors and walls could be helpful in reduction of the concentration of radon in apartment. The above-mentioned activities will contribute to reducing the concentration of radon and other HAPs in buildings and to decreasing the risk of lung cancer.

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