CRCPD E-18-2

Reducing the Risk From Radon:
Information and Interventions

A Guide for Health Care Providers

RadonLeaders.org

Acknowledgements

The Conference of Radiation Control Program Directors, Inc. (CRCPD) is a nonprofit, non-governmental professional organization that promotes consistency in addressing and resolving radiation protection issues, encourages high standards of quality in radiation protection programs, and provides leadership in radiation safety and education. CRCPD would like to acknowledge and thank the following people who contributed significantly to development of this document:

R. William Field, Ph.D., Professor of Public Health at the University of Iowa, who authored the draft guidance and met on numerous occasions with stakeholders from the medical, academic, health physics, and other user communities.

All the numerous peer reviewers and stakeholders who provided input on the guide. Their comments and edits assured that the guide met the needs of health care professionals in their understanding of the risks from radon and communication of information on radon and radon reduction to their patients and other members of the public.

Purpose and Structure of This Guide

Health care providers play a key role in reducing their patients' exposure to unecessary radiation. With the rate of medical imaging and related radiation exposure increasing, it is even more crucial to reduce radiation exposure from other sources, including radon. Because radon is a leading environmental cause of cancer mortality in the United States,[1] it is imperative that patients be informed about the health risks of protracted radon exposure and the simple steps they can take to reduce their exposure.

This document serves as a reference guide on radon and contains the following sections:

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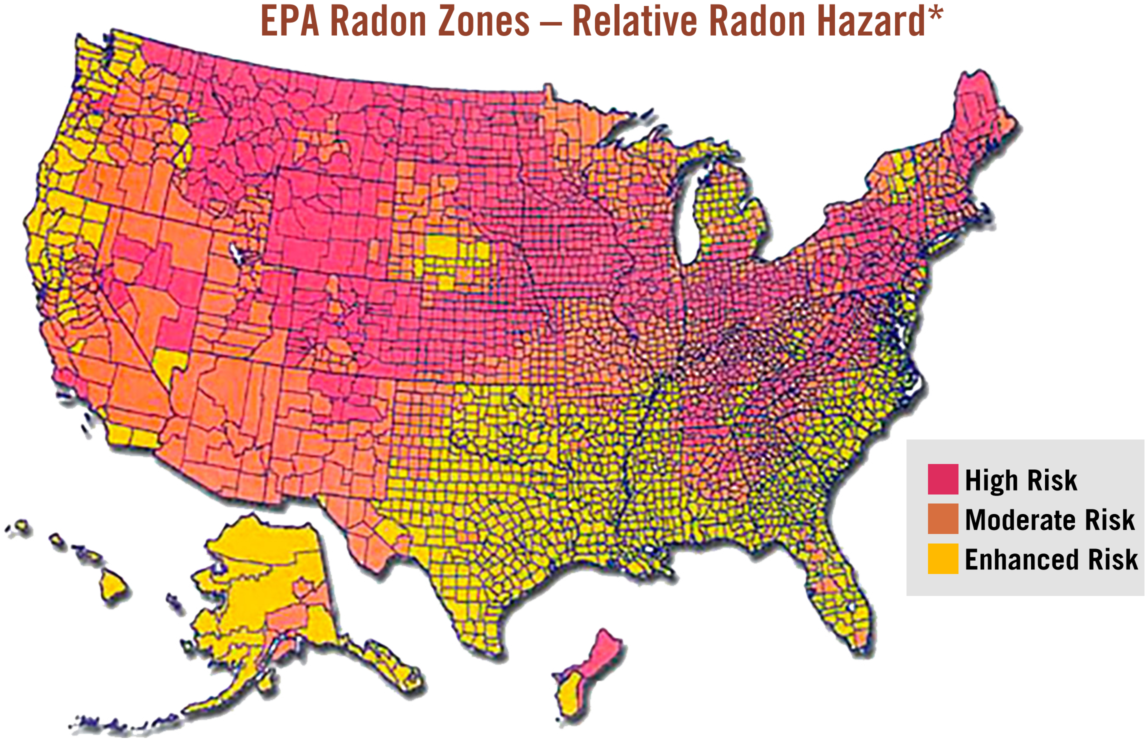
What Is Radon?

Radon is a naturally occurring radioactive gas that has been identified as the second leading cause of lung cancer. Radon-222, with a radioactive half-life of 3.8 days, is the main radon isotope of health concern. It is released during the decay of uranium-238 and subsequently radium-226, which are found in varying amounts in rock, soil and groundwater. Odorless, invisible and without taste, radon cannot be detected with the human senses. Radon is naturally occurring outdoors, but often is substantially concentrated indoors because homes are not normally built to be radon resistant. The potential for radon exposure varies by geographic area; however, even buildings constructed in areas considered to have low radon potential can exhibit greatly elevated radon concentrations.

EPA Radon Zones – Relative Radon Hazard*

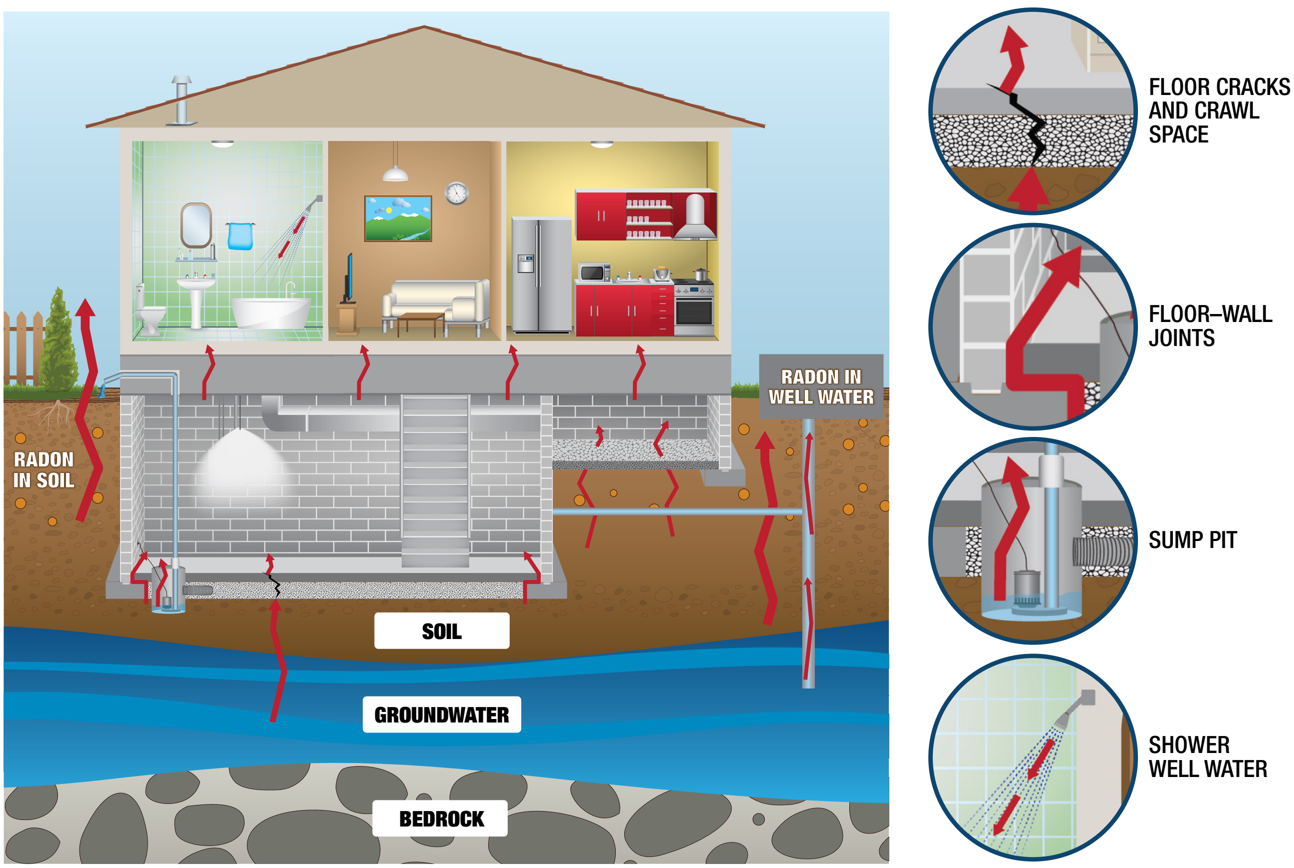


* The purpose of this map is to assist national, state and local organizations in their efforts to target their resources and to implement radon-resistant building codes. All buildings should be tested for radon. High radon concentrations frequently are found even in moderate and enhanced radon zones.

U.S. EPA map of radon zones in the United States and Guam.[2]

How Does Radon Enter the Home?

Outdoors, where it is diluted to low concentrations in the air, radon poses a significantly smaller risk than it does indoors. In the indoor air environment, however, radon can accumulate to high concentrations. The magnitude of radon concentration indoors depends primarily on a building's construction and the amount of radon in the underlying soil. The soil composition under and around a house affects radon levels and the ease with which radon migrates toward a house. Normal pressure differences between the house and the soil often create a slight vacuum in the home that can draw radon gas from the soil into the building. Radon gas can enter a home from the soil through cracks in concrete floors and walls, floor drains, sump pits, construction joints, around pipe penetrations, and through tiny cracks or pores in hollow-block walls. While radon concentrations generally are highest in basements and ground floor rooms that are in contact with the soil, radon levels often are high in main floor and upper floor rooms as well. Another source of radon indoors may be radon gas released by well water during showering and other household activities. Compared to radon entering the home through soil, radon entering the home through water will be, in most cases, a small source of risk.



Radium, which naturally occurs in soils and rocks from the radioactive decay of uranium, produces radon gas that can move through the soil into a home or other building through these common entry points. Because the air pressure inside a home is often lower than the pressure in the soil around the foundation and basement floor slab, radon is easily drawn into a home due to these air pressure differences.

Radon Decay Products

Radon undergoes radioactive decay into a series of solid radioactive decay products. A large percentage of the decay products attach to ambient airborne aerosols, while some of the decay products remain unattached. The attachment rate depends on numerous factors, such as the size and concentration of ambient particles. Deposition of radon decay products in the lung also depends on numerous factors, including the particle size, breathing frequency, tidal volume and lung volume. Once inhaled and deposited on the bronchial epithelium, two of these solid decay products, polonium-218 and polonium-214, deliver the majority of the radiogenic dose to the lung. These alpha-emitting radon decay products have been clearly identified as the primary cause of radon-induced lung cancer. Radon and radon decay products both will be called "radon" throughout this guide.

The Numbers and Public Health Impact

> *Radon is estimated to cause about 21,100 lung cancer deaths per year, according to EPA's 2003* **Assessment of Risks from Radon in Homes** *(EPA 402-R-03-003), making it one of the top 10 causes of cancer mortality in the United States.*

Despite enormous progress in reducing smoking rates over the past 50 years, lung cancer remains the leading cause of cancer mortality for both men and women in the United States, accounting for more than 26 percent of all cancer deaths. The Centers for Disease Control and Prevention estimates that more than 80 percent of lung cancer deaths are causally related to smoking.[3] In part because of the magnitude of smoking-induced cancers, the risk posed by the second leading cause of lung cancer—radon—often is overlooked or diminished in comparison.

Scientifically rigorous peer-reviewed epidemiologic studies (described in the section "The Science Behind the Risk Estimates") performed since the 1960s provided a solid scientific foundation for the U.S. Environmental Protection Agency's (EPA) 2003 risk assessment,[4] which estimates that out of a total of 157,400 lung cancer deaths nationally in 1995, 21,100 (13.4%) were radon related. More recent direct estimates of the risk posed by radon, obtained from residential case-control studies performed globally, closely align with the 2003 EPA risk estimates. When compared to cancer mortality from all causes, radon-related lung cancer, if it were treated as a distinct disease category, would rank among the top 10 causes of cancer mortality and is considered a leading environmental cause of cancer mortality in the United States.[1]

Cancer Mortality 2018

Cancer Type	Estimated U.S. Deaths in 2018[4,5]
1. Lung and Bronchus	154,050
2. Colon and Rectum	50,630
3. Pancreas	44,330
4. Breast	41,400
5. Liver and Intrahepatic Bile Duct	30,200
6. Prostate	29,430
7. Leukemia	24,370
Radon-Induced Lung Cancer	**21,100***
8. Non-Hodgkin Lymphoma	20,960
9. Urinary Bladder	17,240
10. Esophagus	15,850
11. Kidney and Renal Pelvis	14,970
12. Ovary	14,070
13. Myeloma	12,770

* The 21,100 radon-induced lung cancer deaths also are included in the estimate of lung and bronchus cancer deaths. The 21,100 estimate is based on risk estimates using U.S. demographic information from 1995.

Radon and Smoking—Combined Effects

The combined health effects of radon and tobacco exposure are synergistic, so reducing either of the exposures substantially reduces lung cancer risk. The median age of lung cancer diagnosis is 70 years, with approximately 91 percent of cases occurring in people older than age 55.[6] Studies of radon-exposed underground miners have demonstrated that the minimum latency period for lung cancer is 5 years and that radon exposure occurring 5 to 15 years prior to the development of lung cancer carries the greatest risk per unit exposure.[7] Because approximately 37 percent of U.S. adults have smoked at some time in their life, reducing radon exposure in this segment of the population—even if smoking cessation occurs later in life—can reduce the risk of lung cancer considerably.[8]

Lifetime Risk of Lung Cancer Death From Radon Exposure in Homes

Risk Is Shown per 100,000 Individuals

RADON LEVEL (pCi/L)	NEVER SMOKERS	CURRENT SMOKERS	GENERAL POPULATION
20	3,600	26,000	11,000
10	1,800	15,000	5,600
8	1,500	12,000	4,500
4	730	6,200	2,300
2	370	3,200	1,200
1.25	230	2,000	730
0.4	73	640	230

Estimated Risks at the EPA Action Level (4 pCi/L)

Never Smokers 7/1000 | Smokers 62/1000

At the time of diagnosis, approximately 79 percent of lung cancers have either spread to regional lymph nodes (22%) or metastasized (57%).[6] National efforts to increase low-dose computed tomography (LDCT) screening should significantly improve survival rates. The U.S. Preventive Services Task Force (USPSTF) recommends annual screening for lung cancer with LDCT screening in adults ages 55 to 80 who have a 30-pack-year smoking history and who currently smoke or have quit within the past 15 years.[8] Furthermore, the National Comprehensive Cancer Network (NCCN) guidelines recommend LDCT screening beginning at age 50 for individuals with at least 20 pack-years of exposure if they have documented high radon exposure.[9] The USPSTF and NCCN do not recommend LDCT screening after a person has not smoked for 15 years.[8,9] Because patients turn to their health care provider for guidance on cancer prevention, interviews for LDCT screening eligibility present opportunities to educate the public about the risks posed by smoking and radon, even if a person is not eligible for the screening.

> *"The National Comprehensive Cancer Network guidelines recommend LDCT screening beginning at age 50 for individuals with at least 20 pack-years of exposure if they have documented high radon exposure."*

Radon Health Risks for Individuals Who Have Never Smoked

In addition to educating patients who are current or former smokers, a rigorous radon education effort is needed for patients who have never smoked tobacco products. A "never smoker" refers to an individual who has smoked fewer than 100 cigarettes in his or her lifetime. While health care providers encounter fewer lung cancer patients in their practice who never smoked as compared to those who have smoked, it is noteworthy that lung cancer in "never smokers" is in the top 10 causes of cancer mortality in the United States. Each year, 16,000 to 24,000 Americans die of lung cancer even though they have never smoked.[10] Protracted radon exposure is the leading cause of lung cancer in individuals who have never smoked.[7]

> *"If considered its own disease category, lung cancer in individuals who have never smoked tobacco products ranks among the top 10 causes of cancer mortality in the United States. Radon is the leading cause of lung cancer among individuals who have never smoked."*

The Science Behind the Risk Estimates

Radon is one of the earliest described human carcinogens. Carl Lebrecht Schefflers's seminal 1770 publication on the health of underground miners in Schneeberg and Annaberg, in present-day Austria, provided an early description of morbidity likely attributable to radon gas exposure.[11] However, it was not until the 19th century that the disease was established as lung cancer, and reports later in the 20th century linked radon exposure to lung cancer during underground uranium and hard-rock mining.[11] In 1988, the International Agency for Research on Cancer listed radon as a known human carcinogen.[12]

Radon is one of the most comprehensively investigated human carcinogens. Laboratory studies have documented that an alpha particle (e.g., from radon decay products polonium-218 and polonium-214) can cause both single- and double-strand DNA breaks and can produce indirect genotoxic and nongenotoxic effects on both traversed and neighboring nontraversed cells. Experimental animal exposures to radon clearly demonstrate that radon decay products cause lung cancer.[7]

Retrospective occupational cohort studies of radon-exposed miners, which have been performed around the world for more than 50 years, have provided clear evidence that radon is a potent occupational carcinogen.[7] Subsequent findings from scientifically rigorous epidemiologic case-control studies performed in North America[13,14] and Europe[15,16] of individuals exposed to radon in their home have provided conclusive evidence that radon also is one of the leading environmental causes of lung cancer mortality in the general population. The evidence for radon carcinogenicity is consistent among different study types and populations.[12]

Retrospective Cohort Epidemiologic Studies of Radon-Exposed Miners

Fifteen large epidemiologic cohort studies of miners have been conducted in metal, fluorspar, shale and uranium mines in the United States, Canada, Australia, China and Europe. Each of the studies reported a significantly increased risk for lung cancer with increasing radon exposure, including the studies with ranges of cumulative exposures that overlapped with the cumulative exposures occurring in the residential setting. In 1999, the National Research Council's Biological Effects of Ionizing Radiation (BEIR) VI Committee[7] pooled 11 of the studies that included 68,000 miners of uranium and other underground ores (e.g., tin, fluorspar, iron) from various parts of the world. Each of the 11 studies reported significantly increased lung cancer mortality with increasing cumulative radon exposure, despite differences in study populations and methodologies. The pooled analysis included approximately 1.2 million person-years of follow-up and nearly 2,800 lung cancer deaths. For the population studied, the BEIR VI Committee estimated that 39 percent of lung cancer deaths among miners who smoked and 73 percent among those who never smoked were attributable to radon.[7]

The findings from the pooled analysis also were utilized to estimate the risk posed by radon in the general population. The BEIR VI Committee projected that radon causes about 18,600 lung cancer deaths each year in the United States.[7] EPA updated the BEIR VI risk estimates in 2003 using more complete demographic information, concluding that out of the 157,400 lung cancer deaths in 1995, 21,100 were attributable to protracted radon exposure.[4] Additional information on radon risk is available at www.radonleaders.org.

Case-Control Epidemiologic Radon Studies

To help assess the validity of the lung cancer risk estimates for the general population derived from the miner-based cohort studies and to directly assess the risk, more than 25 case-control epidemiologic studies have been performed since 1985.

Seven of the more scientifically rigorous case-control studies were performed in North America,[13,14] 13 in Europe[15,16] and two in China.[17] Investigators from 19 of the 22 case-control studies reported increased lung cancer risk at the WHO's radon reference concentration of 2.7 picocuries of radon per liter of air (pCi/L) (100 becquerels per cubic meter [Bq/m^3]).[12] The probability of 19 of 22 case-control studies reporting an increased lung cancer risk at 2.7 pCi/L is less than 1 in 1000.

In addition to the individual study findings, risk estimates were obtained from a collaborative pooling of the case-control studies in North America, Europe and China.[13–17] The investigators of the pooled analyses reported an increased lung cancer risk at 2.7 pCi/L (100 Bq/m^3) of 11 percent (95% confidence interval [CI]: 0–28%) in North America, 16 percent (95% CI: 5–31%) per 100 Bq/m^3 in Europe, and 33 percent (95% CI: 1–36%) in China. These risk estimates are in close agreement with the risk estimates at 2.7 pCi/L of 12 percent (2–25%) that were projected from cohort studies of radon-exposed miners.[7] Note that these increased lung cancer risk estimates are from protracted exposure to radon at concentrations below EPA's action level of 4 pCi/L.

Radon Testing

Radon gas can be measured easily through inexpensive do-it-yourself testing or by hiring a trained radon professional to perform the testing. Radon test kits can be purchased at local health departments, from state cancer consortia, online, or in hardware stores and other retail outlets. The kits also can be ordered by calling 1–800–SOS–RADON (1–800–767–7236). Testing for radon in houses is discussed in EPA's *A Citizen's Guide to Radon* and other EPA publications (see links at www.epa.gov/radon). Because of the serious health risk posed by radon, EPA recommends that all homes be tested for radon. Homeowners should take steps to lower radon levels indoors when levels are at or above EPA's radon action level of 4 pCi/L. However, because any radon exposure carries some risk, significant lung cancer risk reduction can be achieved by reducing radon concentrations to less than 2 pCi/L. EPA also recommends homeowners consider lowering radon levels when found to be between 2 and 4 pCi/L.

Radon Reduction

The primary method to reduce radon in a home is installing a vent pipe system and fan that pulls radon from beneath the building and vents it to the outside. This system, known as an active soil depressurization system, does not require major changes to a home. Radon reduction systems can be installed in homes with or without basements, as well as in homes with crawlspaces. Methods to reduce radon in homes are discussed in EPA's *Consumer's Guide to Radon Reduction* (see links at www.epa.gov/radon).

The cost of reducing radon in a home depends on how the home was built and the extent of the radon problem. The vast majority of homes can be fixed for about the same cost as other common home repairs. In addition, radon reduction costs often are an eligible expense covered under a health flexible spending arrangement (FSA). The majority of states maintain names of certified radon contractors within their state. However, if contractors are not licensed by the particular state, your patients can contact private radon proficiency programs for lists of certified radon professionals in their area. For more information on private radon proficiency programs, see links at www.epa.gov/radon. Selecting someone to fix a radon problem is much like choosing a contractor for other home repairs—your patients may want to get references and more than one estimate. In addition, new homes can be built to resist radon entry. The additional cost at the time of construction is minimal. When installed properly, the basic radon-resistant new construction techniques greatly reduce the lung cancer risk that may occur from radon in the home.

Sample Guidance for Use in Health Care Settings

The following content and questions are intended for patients, but health care providers also should answer them to evaluate their own risk of exposure to radon.

You may have heard that exposure to radon gas is the second leading cause of lung cancer. Your actual risk of lung cancer depends on the radon concentration and how long you have been exposed to the radon, as well as other risk factors—such as whether you have ever smoked. The current level of radon at which EPA recommends taking action is 4 picocuries of radon per liter of air (pCi/L). Technically, no level of radon exposure is safe because all exposure carries some risk; however, the EPA action level is the guideline used in the United States. EPA estimates that the average indoor and outdoor radon concentration in the United States is 1.3 pCi/L and 0.4 pCi/L, respectively.[18,19] The U.S. Congress has set a long-term goal that indoor radon levels be no more than outdoor levels. While this goal is not yet technologically achievable in all cases, radon concentration in most homes today can be reduced to 2 pCi/L or less. EPA recommends considering lowering radon levels when found to be between 2 and 4 pCi/L.

The questions below may be useful for developing tailored guidance for patients.

Have you tested your home for radon?

- **If the answer is no**—Action is recommended: Either obtain a do-it-yourself radon test kit or hire a certified radon professional to assess the home for radon gas concentrations. Test kits are available at most hardware stores and from local health departments, or they can be ordered by calling 1–800–SOS–RADON.
- **If the answer is yes**—

Was the radon test result in your home 4 pCi/L or greater?

- **If the answer is no**—It is recommended you retest your home's living spaces periodically, such as every 5 years or after any major home renovation or change to the home's heating or cooling system.
- **If the answer is yes**—Action is recommended.
  - If your test result is greater than or equal to 8 pCi/L, it is suggested that you contact a certified radon professional to install a radon mitigation system.
  - If your test result is between 2 pCi/L and 8 pCi/L, it is suggested that you perform another radon measurement to improve the reliability of the estimate of your home's average year-long radon concentration. You can use another short-term screening test kit. Another option at these levels is to perform a long-term radon measurement in your primary living space spanning two seasons—one when your home's heating or cooling system is active and one when it is not. This will give you a relatively good estimate of your home's average radon concentration.

Have you taken steps to reduce your home's radon level?

- **If the answer is no**—Action is recommended: To reduce the risk of lung cancer from radon exposure in your home, it is suggested that you have a radon mitigation system installed to reduce the radon concentration in your living spaces to less than the EPA radon action level of 4 pCi/L.
- **If the answer is yes**—Have you conducted a radon test to confirm the radon concentration in your home has been reduced to below the EPA radon action level? You should conduct a radon test every 2 years to ensure the radon concentration remains below EPA's action level.

If you have questions about radon testing or mitigation, you can call the National Radon Hotline at 1–800–SOS–RADON or consult EPA's radon web page at www.epa.gov/radon.

The Role of Health Care Providers in Reducing the Burden of Radon-Induced Lung Cancer

Lung cancer's very high incidence rate and associated mortality rate are even more tragic because lung cancer usually is preventable.

This is why, in addition to encouraging patients to stop smoking, it is important for health care providers to educate their patients about radon and encourage radon testing in their homes. Pointing out that health care providers have some of the highest rates of radon testing and mitigation helps promote these actions among patients. Physicians, other health care providers, and medical institutions also should consider including questions about radon testing as part of the electronic medical record questionnaire. A brief encounter and resulting intervention can have lifelong implications for patients and their families. Because health care providers are the primary advisors on health and disease prevention, they are in a unique position to play a vital role in informing the public about the serious risk posed by protracted radon exposure and in providing educational resources and contacts for radon testing and remediation methods for reducing elevated indoor radon levels.

Do you smoke? ☐ **Yes** ☐ **No**

If yes, how much per day?____________________

If you are a former smoker, when did you stop?____________

Have you tested your home for radon? ☐ **Yes** ☐ **No**

Do you have a living will or advance medical directive? ☐ **Yes** ☐ **No**

Educational Resources

Radon educational materials (resources, blogs, discussion forums) are available at www.radonleaders.org, an EPA-supported website that helps facilitate action and radon risk reduction. Additional information on radon testing and mitigation is available from radon offices operated by the Department of Public Health in most states; these offices can be found using EPA's search tool linked at www.epa.gov/radon or by calling the National Radon Hotline at 1–800–SOS–RADON (1–800–767–7236). Free educational fliers and brochures to prompt discussion between health care providers and patients, as well as educational videos and many of the scientific papers cited above, are available at www.canceriowa.org/breathingeasier.

Interventions to Reduce the Burden of Radon-Related Lung Cancer

- ✔ Ask your patients if they have tested their home for radon. If they have not, inform them about the health risk posed by radon and urge them to test their home for radon.
- ✔ Add radon testing questions to the routine electronic medical record questionaire.
- ✔ Team up with the Centers for Disease Control and Prevention (CDC)-funded comprehensive cancer control program in your state. These programs have aligned the priorities, goals and activities of cancer coalitions with practices that reduce radon-induced lung cancer: www.cdc.gov/cancer/dcpc/prevention/policies_practices/radon/what_cccp_can_do.htm.
- ✔ Provide information in your offices and clinics that promotes radon testing and mitigation; information can be obtained from the following sources:
    - Iowa Cancer Consortium—www.canceriowa.org/breathingeasier
    - Online learning and action network—www.radonleaders.org
    - EPA—www.epa.gov/radon
    - CDC—www.cdc.gov/radon
    - State radon offices—www.epa.gov/radon/find-information-about-local-radon-zones-and-state-contact-information
- ✔ The USPSTF recommends annual LDCT screening for lung cancer in adults ages 55 to 80 who have a 30-pack-year smoking history and currently smoke or have quit within the past 15 years. For individuals who do not have lung cancer or do not qualify for screening, interviews for LDCT screening eligibility represent teachable moments to discuss efforts to reduce lung cancer risk, such as testing their homes for radon.
- ✔ Share information about the health risks of protracted radon exposure with other health care providers. For example, encourage your colleagues to participate in the discussion forums at www.radonleaders.org, where they can learn about the experiences of other health care providers regarding radon and find links to the research that provides the scientific foundation for radon risk estimates.

References

1. Field, R. W., and B. L. Withers. 2012. "Occupational and Environmental Causes of Lung Cancer." *Clinics in Chest Medicine* 33 (4): 681–703.
2. EPA (U.S. Environmental Protection Agency). 1993. *EPA's Map of Radon Zones, National Summary*. EPA 402-R-93-071. Washington, D.C.: EPA.
3. CDC (Centers for Disease Control and Prevention). 2017. "What Are the Risk Factors for Lung Cancer?" Last modified May 31, 2017. www.cdc.gov/cancer/lung/basic_info/risk_factors.htm.
4. EPA. 2003. *EPA Assessment of Risks from Radon in Homes*. EPA 402-R-03-003. Washington, D.C.: EPA. www.epa.gov/sites/production/files/2015-05/documents/402-r-03-003.pdf.
5. Siegel, R. L., K. D. Miller, and A. Jemal. 2018. "Cancer Statistics, 2018." *CA: A Cancer Journal for Clinicians* 68: 7–30. www.onlinelibrary.wiley.com/doi/10.3322/caac.21442/epdf.
6. Howlader, N., A. M. Noone, M. Krapcho, D. Miller, K. Bishop, C. L. Kosary, M. Yu, J. Ruhl, Z. Tatalovich, A. Mariotto, D. R. Lewis, H. S. Chen, E. J. Feuer, and K. A. Cronin (eds). 2017. "SEER Cancer Statistics Review, 1975–2014." Bethesda, MD: National Cancer Institute. www.seer.cancer.gov/csr/1975_2014.
7. National Research Council. 1999. *Health Effects of Exposure to Radon: BEIR VI*. Washington, D.C.: The National Academies Press. www.nap.edu/catalog/5499/health-effects-of-exposure-to-radon-beir-vi.
8. Moyer, V. A., on behalf of the U.S. Preventive Services Task Force. 2014. "Screening for Lung Cancer: U.S. Preventive Services Task Force Recommendation Statement." *Annals of Internal Medicine* 160: 330–338.
9. National Comprehensive Cancer Network. 2017. "NCCN Clinical Practice Guidelines in Oncology: Lung Cancer Screening." Version 1. www.nccn.org/professionals/physician_gls/default.aspx.
10. Samet, J. M., E. Avila-Tang, P. Boffetta, L. M. Hannan, S. Olivo-Marston, M. J. Thun, and C. M. Rudin. 2009. "Lung Cancer in Never Smokers: Clinical Epidemiology and Environmental Risk Factors." *Clinical Cancer Research* 15 (18): 5626–5645.
11. Blanc, P. 2012. "Historical Perspective of Occupational and Environmental Lung Disease." In *A Clinical Guide to Occupational and Environmental Lung Diseases*, edited by Huang, Y. T., A. J. Ghio, and L. A. Maier. pp. 1–26. New York, NY: Humana Press.
12. World Health Organization. 2009. *WHO Handbook on Indoor Radon: A Public Health Perspective*. Edited by Zeeb, H., and F. Shannoun. Geneva, Switzerland: World Health Organization.
13. Krewski D., J. H. Lubin, J. M. Zielinski, M. Alavanja, V. S. Catalan, R. W. Field, et al. 2005. "Residential Radon and Risk of Lung Cancer: A Combined Analysis of 7 North American Case-Control Studies." *Epidemiology* 16 (2): 137–145.
14. Krewski D., J. H. Lubin, J. M. Zielinski, M. Alavanja, V. S. Catalan, R. W. Field, et al. 2006. "A Combined Analysis of North American Case-Control Studies of Residential Radon and Lung Cancer." *Journal of Toxicology and Environmental Health, Part A* 69 (7): 533–597.
15. Darby S., D. Hill, A. Auvinen, J. M. Barros-Dios, H. Baysson, F. Bochicchio, et al. 2005. "Radon in Homes and Risk of Lung Cancer: Collaborative Analysis of Individual Data From 13 European Case-Control Studies." *British Medical Journal* 330: 223–227.
16. Darby, S., D. Hill, H. Deo, A. Auvinen, J. M. Barros-Dios, H. Baysson, et al. 2006. "Residential Radon and Lung Cancer—Detailed Results of a Collaborative Analysis of Individual Data on 7,148 Persons With Lung Cancer and 14,208 Persons Without Lung Cancer From 13 Epidemiologic Studies in Europe." *Scandinavian Journal of Work, Environment & Health* 32 (Suppl. 1): 1–83.
17. Lubin, J. H., Z. Y. Wang, J. D. Boice, Z. Y. Xu, W. J. Blot, L. D. Wang, et al. 2004. "Risk of Lung Cancer and Residential Radon in China: Pooled Results of Two Studies." *International Journal of Cancer* 109 (1): 132–137.
18. Marcinowski, F., R. M. Lucas, and W. M. Yeager. 1994. "National and Regional Distributions of Airborne Radon Concentrations in U.S. Homes." *Health Physics* 66: 699–706.
19. Hopper, R. D., R. A. Levy, R. C. Rankin, and M. A. Boyd. 1991. "National Ambient Radon Study." In *Proceedings of the 1991 International Symposium on Radon and Radon Reduction Technology*, April 2–5, 1991, Philadelphia, PA. Research Triangle Park, NC: EPA.

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This publication was supported in part by grant number XA-83576001 from the U.S. Environmental Protection Agency.