Reducing the Risks From Radon:
Information and Interventions

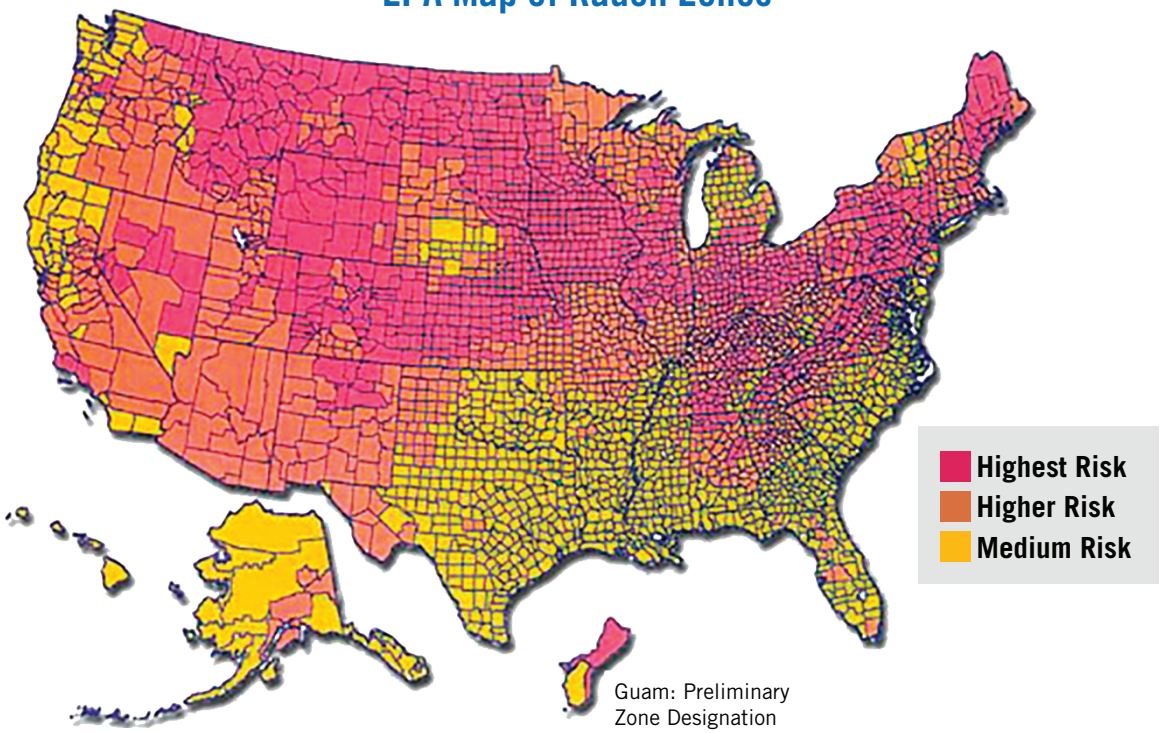
A Guide for Health Care Providers

Indoor Air Quality (IAQ)

What Is Radon?

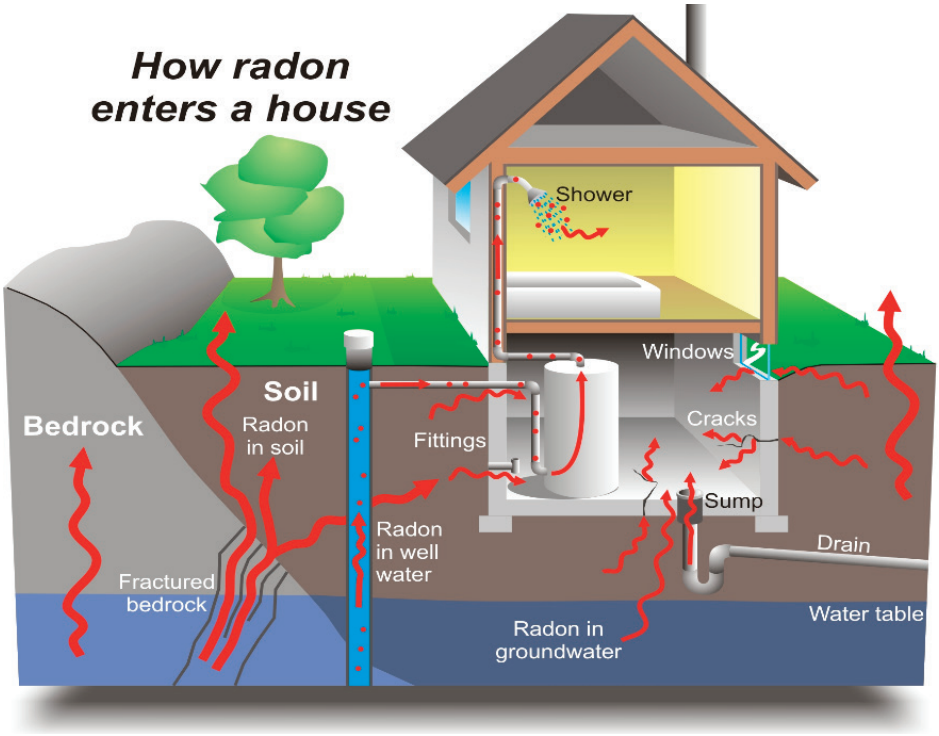
Radon-222 (radon) is a radioactive gas with a half-life of 3.8 days that is released during the decay of uranium-238 and subsequently radium-226, which are naturally occurring elements found in varying amounts in rock, soil and groundwater. Odorless, invisible and without taste, radon cannot be detected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

EPA Map of Radon Zones



How Does Radon Enter the Home?

Outdoors, where it is diluted to low concentrations in the air, radon poses significantly less risk than 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 pumps, construction joints, and tiny cracks or pores in hollow-block walls. Radon concentrations are generally highest in basements and ground floor rooms that are in contact with the soil. 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, in most cases, be a small source of risk.



Radon-Decay Products

Radon undergoes radioactive decay into a series of solid radioactive decay products. 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

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. 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.

> *"Radon is estimated to cause about 21,000 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."*

Scientifically rigorous peer-reviewed epidemiologic studies (described in the section "The Science Behind the Risk Estimates") performed over the past 30 years provided a solid scientific foundation for the U.S. Environmental Protection Agency's (EPA) 2003 risk assessment, 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 ranks ninth overall and is considered the leading environmental cause of cancer mortality in the United States. Even combined, the rates of radon-resistant new home construction and radon mitigation system installation in existing homes have not kept pace with the overall rate of new home construction. More homes exceed EPA's action level of 4 picocuries of radon per liter of air (pCi/L) today than did in 1995, when the EPA risk estimate of 21,000 was released.

Cancer Mortality 2016	
Cancer Type	Estimated U.S. Deaths in 2016
1. Lung and Bronchus	158,080
2. Colon and Rectum	49,190
3. Pancreas	41,780
4. Breast	40,890
5. Liver and Intrahepatic Bile Duct	27,170
6. Prostate	26,120
7. Leukemia	24,400
8. Lymphoma	21,270
>>>>> Radon	21,100
9. Urinary Bladder	16,390
10. Esophagus	15,690
11. Ovary	14,240
12. Kidney and Renal Pelvis	14,240
13. Myeloma	12,650
14. Stomach	10,730

Radon and Smoking Combined Effects

The combined 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 83 percent of cases occurring in people older than 60. 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 carried the greatest risk per unit exposure. Because 64 percent of men and 43 percent of women have smoked at some point in their life, reducing radon exposure in this large segment of the population—even if the smoking cessation occurs later in adulthood—can reduce the risk of lung cancer considerably.

EPA Radon Risk

Lifetime Risk of Lung Cancer Death (Per Person) From Radon Exposure in Homes

RADON LEVEL (pCi/L)	NEVER SMOKERS	CURRENT SMOKERS	GENERAL POPULATION
20	36 out of 1,000	26 out of 100	11 out of 100
10	18 out of 1,000	15 out of 100	56 out of 1,000
8	15 out of 1,000	12 out of 100	45 out of 1,000
4	73 out of 10,000	62 out of 1,000	23 out of 1,000
2	37 out of 10,000	32 out of 1,000	12 out of 1,000
1.25	23 out of 10,000	20 out of 1,000	73 out of 10,000
0.4	73 out of 100,000	64 out of 10,000	23 out of 10,000

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

Never Smokers 7/1000 | Smokers 6/100

At the time of diagnosis, approximately 79 percent of lung cancers have either spread to regional lymph nodes (22%) or metastasized (57%). 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. Furthermore, 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. Screening is not recommended after a person has not smoked for 15 years. 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 in cases where a person is not eligible for the screening.

> *"The National Comprehensive Cancer Network guidelines recommend low-dose CT 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 smoke or have smoked about radon, a rigorous radon education effort is needed for patients who have never smoked tobacco products. While health care providers encounter fewer lung cancer patients in their practice who never smoked than those who have, it is noteworthy that lung cancer in "never smokers" is the seventh-leading cause of cancer mortality in the United States. A "never smoker" refers to an individual who has smoked fewer than 100 cigarettes in his or her lifetime. Each year, 16,000 to 24,000 Americans die of lung cancer even though they have never smoked. Protracted radon exposure is the leading cause of lung cancer in individuals who have never smoked.

> *"If considered its own disease category, lung cancer in individuals who have never smoked tobacco products is one of the top 10 most deadly cancers in the United States. Radon is the leading cause of lung cancer in nonsmokers."*

The Science Behind the Risk Estimates

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

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. 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. Subsequent findings from scientifically rigorous epidemiologic case-control studies performed in North America and Europe 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 of those who are not occupationally exposed. The evidence for radon carcinogenicity is consistent among different study types and populations.

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. In 1999, the National Research Council's Biological Effects of Ionizing Radiation (BEIR) VI Committee pooled 11 of the studies that included 68,000 uranium and other underground miners (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 followup and nearly 2,800 lung cancer deaths. The BEIR VI committee estimated that 39 percent of lung cancer deaths among individuals who smoked and 73 percent of lung cancer in deaths in the population of miners who never smoked were attributable to radon.

The findings from the pooled analysis also were interpolated to estimate the risk posed by radon in the general population. The BEIR VI committee predicted that radon causes about 18,600 lung cancer deaths each year in the United States. EPA updated the BEIR VI risk estimates in 2003 using more complete demographic information: EPA estimated that out of the 146,400 lung cancer death in 1995, 21,100 were attributable to protracted radon exposure. Details concerning the BEIR VI and EPA risk estimates are available at EPA's website for health care practitioners: www.epa.gov/radon/docs.

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 in Europe, and two in China. Investigators from 19 of the 22 case-control studies reported increased lung cancer risk at the World Health Organization's radon reference concentration of 2.7 pCi/L (100 becquerels per cubic meter [Bq/m^3]). If radon were not causally related to increased cancer risk at this concentration, 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 100.

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. 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, 8 percent (95% CI: 3–16%) in Europe, and 13 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. Note that these increased lung cancer risk estimates are from protracted radon exposure 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 contractor to perform the testing. Radon test kits can be purchased at local health departments, from hospital cancer consortiums, by mail order, or in hardware stores and other retail outlets. The kits can also can be ordered by calling 1–800–SOS–RADON (1–800–767–7236). Because of the serious health risk posed by radon, EPA recommends that all homes be tested for radon. Homeowners should take action to lower radon levels indoors when levels are at or above the 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 concentrations below 4 pCi/L.

Radon Reduction

The primary method to reduce radon in a home is by installing a vent pipe system and fan that pulls radon from beneath the house and vents it to the outside. This system, known as a soil suction radon reduction system, does not require major changes to a home. Similar systems also can be installed in houses with crawl spaces. Methods to reduce radon in homes are discussed in EPA's Consumer's Guide to Radon Reduction (www.epa.gov/radon/publications-about-radon).

The cost of reducing radon in a home depends on how the home was built and the extent of the radon problem. Most homes can be fixed for about the same cost as other common home repairs. In addition, radon reduction costs are often an eligible expense covered under Healthcare Flexible Spending Accounts. Most states maintain names of certified radon contractors within the state. If contractors are not licensed by the state, patients can contact private radon proficiency programs for lists of privately certified radon professionals in their area. For more information on private radon proficiency programs, visit www.epa.gov/radon/find-radon-test-kit-or-measurement-and-mitigation-professional. 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.

Sample Guidance to Patients Regarding Radon Testing and Mitigation

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've been exposed to the radon, as well as other risk factors—like whether you have ever smoked. The current EPA recommended radon reduction level is 4 picocuries of radon per liter (pCi/L) of air. Technically, there is no safe level of radon exposure, because all exposure carries some risk; however, the EPA action level is the guideline used in the United States. The average indoor radon level is estimated to be about 1.3 pCi/L, and about 0.4 pCi/L of radon is normally found outdoors. 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, most homes today can be reduced to 2 pCi/L or less.

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?

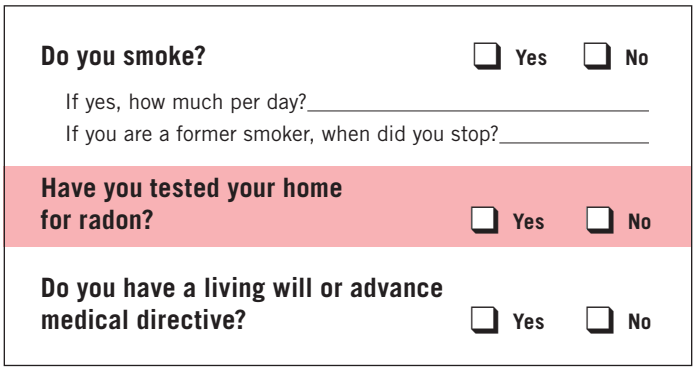
- **If the answer is no**—It is recommended you retest your home's living spaces periodically, such as every 5 years or after any major home renovation or change to the home's heating or cooling system.
- **If the answer is yes**—Action is recommended.
  - If your test result is greater than 8 pCi/L, 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 longterm 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 lung cancer risk 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 once 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 the 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



The homes of health care providers have some of the highest rates of radon testing. Testing for radon reduces the risk of developing lung cancer. Lung cancer's very high incidence rate and associated mortality rate are even more tragic because lung cancer 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 of their homes. One way to do this is for physicians and other health care providers to include questions about radon testing on their patient history forms. A brief encounter and resulting intervention can have lifelong consequences 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.

Educational Resources

Radon educational materials (publications, pamphlets and videos) are available on EPA's special website for health care practitioners: www.epa.gov/radon/docs. The website also includes an educational video for health care providers, along with scientific publications supporting the radon risk estimates. 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 at www.epa.gov/radon/whereyoulive.html or by calling the National Radon Hotline at 1–800–SOS–RADON (1–800–767–7236).

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.
- ☑ Team up with the Centers for Disease Control and Prevention-funded comprehensive cancer control program in your state. These programs have aligned the priorities, goals and activities of cancer coalitions with practices that reduce of radon-induced lung cancer: www.cdc.gov/cancer/ncccp/practices/what_cccp_can_do.html.
- ☑ Provide information in your offices and clinics that promotes radon testing and mitigation, which can be obtained from the following sources:
  - Health care providers' portal—http://breathingeasier.info
  - EPA—www.epa.gov/radon/pubs/citguide.html
  - State radon offices—www.epa.gov/radon/whereyoulive.html
- ☑ 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, screening represents a teachable moment 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 view the short educational video at http://breathingeasier.info, where they can learn about the experiences of other health care providers in regard to radon and find links to the papers that provide the scientific foundation for radon's risk estimates.