ORIGINAL RESEARCH

Radon Testing: Community Engagement By a Rural Family Medicine Office

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Objective: **Iowa has the highest average radon concentrations in the nation, with an estimated 400 radon-induced lung cancer deaths each year. Radon is the second leading cause of lung cancer death overall. The objectives of this study were (1) to educate the population attending a family medicine office about the dangers of radon, (2) to encourage homeowners to test for radon, (3) to work with the community to identify resources for mitigation, and (4) to assess the utility of working with a local family medicine office as a model that could be adopted for other communities with high home radon concentrations.**

Methods: **Participants obtained a US Environmental Protection Agency–certified activated charcoal short-term radon kit through their primary care office or by attending a seminar held by their medical office. Participants completed a short investigator-developed questionnaire about their home, heating, and demographics.**

Results: **Of 746 radon kits handed out, 378 valid results (51%) were received, of which 351 questionnaires could be matched to the kit results. The mean radon result was 10.0 pCi/L (standard deviation, 8.5 pCi/L). A radon result of 4 pCi/L or higher, the Environmental Protection Agency action level for mitigation, was found in 81% of homes (n = 285).**

Conclusions: **Four of 5 homes tested had elevated radon levels. This family medicine office/university collaborative educational model could be useful for educating patients about other environmental dangers. (J Am Board Fam Med 2015;28:617–623.)**

Keywords: **Environmental Medicine, Lung Cancer, Practice-based Research, Prevention & Control, Public Health, Radon**

Radon-222 (hereafter referred to as radon) is a colorless, odorless, and tasteless radioactive noble gas produced from the radioactive decay of radium-226 that is found in the soil and rock around the substructure of a home. Radon is classified by the International Agency for Research on Cancer as a group 1 carcinogen, with sufficient evidence of causing lung cancer in humans. Exposure is both environmental and occupational. As radon decays, it produces solid radioactive decay products that, when inhaled, can deposit in the pulmonary epithelium. α-Particles produced by these solid decay

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products, in particular polonium-218 and polonium-214, can damage the epithelium of the lung through a direct effect on DNA (ie, through single- and double-strand DNA breaks) and by causing oxidative damage to DNA. When hit with α-particles, cells in the lung can undergo changes that lead to cancer. A single (ie, monoclonal) bronchial epithelial cell that has had genetic damage can lead to lung cancer. Thus, it is unlikely that a threshold exists for α-particle-induced lung cancer.[1]

Radon concentration in the atmosphere is measured in becquerels per cubic meter, an SI unit. The most commonly used unit in the United States is picocuries per liter. One picocurie per L equals 37 Bq/m^3.[2] It is estimated that nearly half of an individual's exposure to radiation in the United States comes from exposure to radon-222 decay products; the other half comes from medically related procedures.[1] Radon enters a home through the lowest level in the home that is in contact with open ground through cracks in the foundation or gaps around service pipes. The only way to know whether your home has elevated radon concentrations is to test it.[2]

When radon and its radioactive products build up in enclosed spaces, radiation is released in forms that include α-particles, β-particles, and γ-radiation that can enter the body when breathed in or swallowed. These particles can combine with other molecules in the air and with particles of dust, aerosols, or smoke and deposit in the airways of the lung. Some radon decay products may remain in the lungs and emit ionizing radiation in the form of α-particles, which damage the cells lining the airways. Lung cancer is associated with exposure to radon and radon decay particles.[3] All individuals exposed to radon have an elevated risk of lung cancer, but the risk of lung cancer is higher among smokers exposed to radon than among nonsmokers exposed to radon. The Environmental Protection Agency (EPA) notes that the surgeon general stressed that action needs to be taken if indoor radon concentrations are ≥4 pCi/L.[4] Concentrations <4 pCi/L can also pose a health risk and in many cases can be reduced.[2] Residential radon is the second leading cause of lung cancer overall, estimated to cause 21,000 deaths in the United States each year.[5–7]

The state of Iowa is one of the states with the highest potential for exposure to elevated indoor radon concentrations.[8,9] Because Iowa has the highest average radon concentrations in the nation, with an estimated 400 radon-induced lung cancer deaths each year, novel outreach efforts are needed to reduce the public health burden of radon exposure. All counties in Iowa are classified as zone 1 by the EPA. Zone 1 counties have a predicted average indoor radon concentration of >4 pCi/L. The total average concentration in Iowa is 8.5 pCi/L air and in the United States is 1.3 pCi/L air. The EPA's action concentration is 4 pCi/L, although concentrations below that are associated with radon-induced lung cancer. Based on data collected in Iowa, the Iowa Department of Public Health estimates that 50% to 70% of homes across Iowa exceed the EPA's action level of 4 pCi/L.[10]

The purposes of this study were to (1) educate the population attending a family medicine office about the dangers of radon, (2) encourage homeowners to test for radon, (3) work with the community to identify resources for mitigation, and (4) assess the utility of working with a local family medicine office as a model that could be adopted for other communities with high home radon concentrations.

Methods

The Akron/Mercy Clinic in Akron, Iowa, and members of the University of Iowa, Department of Family Medicine, Roy J. and Lucille A. Carver College of Medicine, Iowa City, Iowa, collaborated on this project. The project and methods were approved by the University of Iowa Institutional Review Board and the Siouxland Institutional Review Board. Through grant funding from the Iowa Cancer Consortium, radon kits were purchased and shipped to the clinic for disbursement.

Subject Recruitment

Cynthia Wolff, MD, of the Akron/Mercy Medical Clinic, worked with her office to hand out radon test kits and instructions for use to their patients. Air Chek short-term activated charcoal test kits (Air Chek, Inc., Mills River, NC) were used for the study because they have been listed since 1986 with the national radon proficiency program (first run by the EPA and now run by a private EPA program). The tests are accredited in the state of Iowa (as well as multiple other states). The lab analysis is performed using γ-ray spectroscopy using sodium iodide detectors. Quality control measures include humidity and temperature correction for samples from various parts of the United States. Air Chek provides mailing envelopes and postage and provided results after development to the person mailing the kit in and to the investigators. Kits were numbered so that if patients failed to return them, they could be contacted by the Akron office for return of the kit. As a radon kit was handed to a patient interested in testing their home, the staff had the participant complete a radon questionnaire. Staff sent completed questionnaires to research team members for data entry and analysis.

Investigators at the University of Iowa received the results of the radon test, but no patient names or identifiers. Questionnaires were matched with the radon results by the kit identification number.

Questionnaire

A 13-item, 1-page, investigator-developed questionnaire was generated (by BTL) and reviewed by the research team for this project. The date the questionnaire was completed and the 7-digit number identifying the radon kit were placed on the top of the questionnaire. Demographic questions asked about age, sex, and household income. Questions about the home were related to the age of the home, the years lived in the home, whether the home had been tested for radon, whether they had radon mitigation in the past, the type of heating in the home, whether they felt their home was well-insulated, and the lowest level of the home (basement or ground level). In addition, the number of smokers living in the home, the number of persons living in the home, and the number of persons sleeping in the lowest level of the home were queried. If the home had been tested for radon in the past, the results of the previous test were requested.

Radon Information Sessions

The radon presentations were delivered by 2 authors (CKW and PN) who are health care providers at the Akron/Mercy Medical Clinic, as well as Matt Robbins, Marketing and Communications Manager, from Mercy Medical Center in Sioux City, Iowa. One author (PN) developed a 20-minute PowerPoint presentation, as well as a "How to Use a Radon Kit" video, which was viewed by all attendees. The video "Breathing Easier," from the University of Iowa, also was used during the presentations (http://canceriowa.org/breathingeasier.aspx). Depending on the format, the 12- or 23-minute version of the video was shown.[11] A typical presentation lasted approximately 1 hour, and each presenter provided ample time for a question-and-answer session at the end. Each attendee received a radon kit, radon questionnaire, a list of local certified radon mitigation specialists in Iowa, and the booklet titled "Radon & You: What You Need to Know to Protect You and Your Family."[12] One author (CSW) presented to the Akron Mercy Medical Clinic staff, Akron Friendship and Service Club, Akron Care Center, Mercy Medical Center Grand Rounds, local Iowa legislators, the Akron-Westfield High School students and staff, and the Akron City Council. A second author (PN) delivered presentations to the Akron Mercy Medical Clinic staff, Akron Lions Club, Parents of the Akron-Westfield School, City of Sioux City Utilities Department, and members of the Akron Museum Board. Matt Robbins presented to the employees of the Sioux City Foundry. A total of 14 presentations were delivered to 435 attendees during January through April 2013.

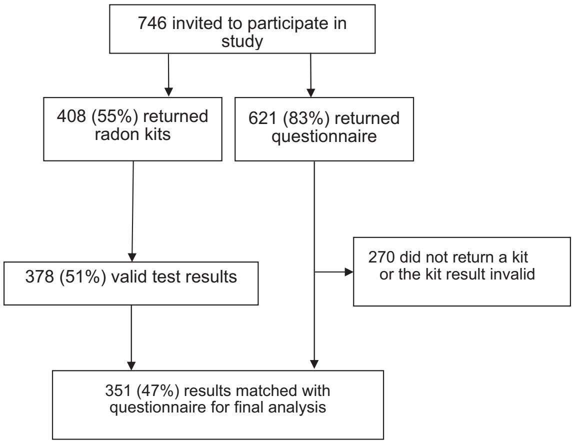
Patient Education at the Akron/Mercy Medical Clinic

To the extent possible in a busy medical office, all eligible patients attending the Akron/Mercy Medical Clinic during the study period (January to June 2013) were provided with information about the dangers of radon, given the American Lung Association's "Radon & You" pamphlet, and invited to participate in the study. No specific informed consent was required because no personal identifying information was collected. Questionnaires were linked to radon kits by the use of the kit identification number. The medical office kept track of the kits going to specific patients. Patients were shown a presentation on the dangers of radon prepared by one of the authors (HN), a health coach and nurse educator. This presentation was shown in the waiting room, as well as in the patient examination rooms.

Results

A total of 746 radon kits were handed out, with 408 radon results (54.7%) received. Of those 408 returned, 378 kits (92.6%) gave a valid test result. Of the 378 valid kits, 351 could be matched with a questionnaire. The study flow diagram is shown in Figure 1. Table 1 shows the demographics and home characteristics of the study population (n =

Figure 1. Flow diagram of study subjects.



351) compared with those who did not return a kit or who had an invalid result (n = 270).

The mean age of the subjects was 55.2 years (standard deviation [SD], 15.2 years). Among the subjects, 42% reported an annual income <\$50,000. The mean radon result of 351 kits was 10.0 pCi/L (SD, 8.5 pCi/L). The distribution of radon results is shown in Figure 2. Eighty-one percent (n = 285) of homes had a radon results of ≥4 pCi/L, meeting the EPA "action" level. The mean age of the homes was 54.0 years (SD, 36.3 years). The most common type of heating was gas (62%), followed by electric (25%), with geothermal (5%) and wood (4%) much less common. A total of 254 participants (72%) considered their homes to be well insulated. There were no significant differences in radon concentrations by type of home heating or income level. Homes considered to be well-insulated homes had a significantly higher radon concentration than those that were less well-insulated (10.7 vs 8.1 pCi/L; $P < .007$).

Those with valid radon results were older (mean age, 55 vs 48 years; $P < .0001$), had higher household incomes, and had lived in their homes longer (18 vs 14 years; $P < .0001$); they also were more likely to have tested for radon previously (17% vs 5%; $P < .0001$), have had previous mitigation (4.4% vs 0.4%; P = .004), have a basement (97% vs 92%; $P = .0009$), and have fewer smokers in the household (0.2 vs 0.5; $P < .0001$). There was no difference in gender, type of heating system, number of family members, or the percentage who had family members sleeping or spending significant time in the lowest level of the home.

CSW's office worked with local banks to help residents with concentrations above the EPA action level to obtain low-interest loans for mitigation, since the grant could not assist with these costs. In addition, 2 new radon mitigators became licensed, which may help to stimulate the local economy.

Discussion

Iowa has the highest mean residential radon concentrations (241 Bq/m^3 = 6.5 pCi/L) compared with other states surveyed in the United States.[8,9,13] Consistent with other studies in Iowa, >80% of homes tested had radon concentrations for which retesting or mitigation would be recommended.[9,10,14] Homes that were reported to be well-insulated had higher radon concentrations than those that were not. Nearly 55% of radon kits were returned. There was no charge to patients for the kits. Having a nominal charge might have increased the return rate. Those who returned kits compared with those who did not were slightly older, had lived in their home longer, and may have been more health conscious as evidenced by the fact that more had tested for radon and mitigated, and there were fewer smokers in those homes.

Strengths of the study included that >92% of individuals sending in a kit had a valid radon test result, indicating that almost all those who sent in kits were able to write clearly on the radon envelope and follow the instructions. Staff at the Akron/Mercy Medical Clinic enthusiastically educated patients about radon and encouraged patients to conduct radon testing. Two authors (CSW and PN) conducted over 14 forums, which reached more than 400 individuals in the community. Given that so many homes had elevated radon concentrations, arrangements were made with local banks to provide low-cost loans for mitigation. In addition to the 4 contractors already working in the region, 2 other contractors pursued certification in mitigation, which helped to stimulate the local economy.

This study was conducted in a motivated medical office in northwest Iowa. Other offices wishing to replicate this will need to devote significant time and energy to educating patients and providing or recommending radon kits.

Limitations

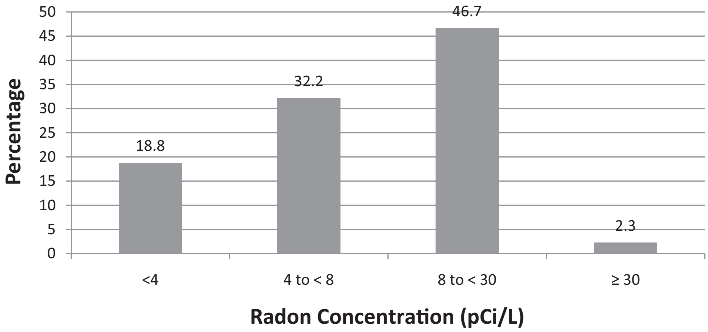
This was a relatively small study in 1 area of Iowa, a Midwestern state known to have the highest in-

Table 1. Demographics and Home Characteristics of Subjects With a Valid Radon Result (n = 351) Compared With Those Did Not Return a Kit or Had an Invalid Result (n = 270)

Variable	Valid Results (n = 351)	Kit Not Returned or Result Invalid (n = 270)	*P* Value
Current radon concentration (pCi/L)			
Mean (SD)	10.0 (8.5)	N/A	
Median	7.8	N/A	
Age (years), mean (SD)	55.2 (15.2)	48.4 (15.2)	<.0001
Sex			.5364
Female	206 (59.2%)	152 (56.7%)	
Male	142 (40.8%)	116 (43.3%)	
Household income			.008
<\$30,000	45 (14.0%)	46 (18.3%)	
\$30,000 to <\$40,000	45 (14.0%)	47 (18.7%)	
\$40,000 to <\$50,000	45 (14.0%)	49 (19.5%)	
≥\$50,000	187 (58.1%)	108 (43.0%)	
Other		1 (0.4%)	
Age of home (years)			.0546
Mean (SD)	54.0 (36.3)	59.7 (34.5)	
Median	47	58	
Years lived in the home			.0004
Mean (SD)	18.1 (15.6)	13.8 (13.9)	
Median	13	9	
Ever tested for radon			<.0001
Yes	58 (16.5%)	12 (4.5%)	
No	293 (83.5%)	255 (95.5%)	
Had radon mitigation in the past			.004
Yes	14 (4.4%)	1 (0.4%)	
No	306 (95.6%)	240 (99.6%)	
Heating system			
Gas	217 (61.8%)	161 (59.6%)	.5787
Electric	87 (24.8%)	78 (28.9%)	.2512
Geothermal	19 (5.4%)	10 (3.7%)	.3169
Wood	13 (3.7%)	7 (2.6%)	.4369
Other	49 (14.0%)	31 (11.5%)	.3607
Home well insulated			.0164
Yes	254 (72.4%)	173 (64.1%)	
No	82 (23.4%)	90 (33.3%)	
Don't know	15 (4.3%)	7 (2.6%)	
Lowest level of the home			.0009
Basement	341 (97.4%)	246 (91.5%)	
Ground	9 (2.6%)	23 (8.6%)	
Family members sleep or spend extended time in the lowest level of the home			.5303
Yes	129 (37.2%)	92 (34.7%)	
No	218 (62.8%)	173 (65.3%)	
Family members in the home			
Mean (SD)	3.4 (10.7)	3.1 (1.6)	.5697
Median	2	3	
Smokers in the home			
Mean (SD)	0.2 (0.5)	0.5 (0.8)	<.0001
Median	0	0	

N/A, not applicable; SD, standard deviation.

Figure 2. Radon distribution in 351 homes.



door radon concentrations in the nation. Results are likely representative of other nearby Midwestern states but not the country as a whole. The return rate of about 55% of kits was lower than we would have liked. We have no information on why individuals did not return kits, but it is possible that our return rate was related to the participants being concerned that their home would test high and that they would then be faced with a potentially expensive mitigation process. With the funding provided, it was not feasible to go back to a small sample and learn why individuals did not return kits. Another limitation of the study was the number of individuals with high radon concentrations who had mitigation was not tracked. Anecdotally, we know that many of those with high concentrations went on to have mitigation. However, knowledge of high radon levels does not necessarily motivate individuals to mitigate.[15]

Our testing rate was higher than that obtained in 2 primary care offices in Minnesota, which had a testing rate of 14.4% after providing information but no testing kits.[16] Even though Iowa is known to have high radon concentrations, the percentage of homes with actionable levels was higher than anticipated. As with many public health interventions, testing and learning about conditions affecting health often leads to increased costs. This study provides an excellent example of a community medical office–academic partnership on an important public health issue. The Akron/Mercy Medical Clinic provided many person-hours toward community-based engagement, educating the public, handing out kits, tracking kits to ensure return, working with local banks to provide low-interest loans, and working with mitigators to help them obtain appropriate training and licensing. The University of Iowa Department of Family Medicine was able to provide the grant-writing skills and the study expertise to collect and analyze the data. Individuals at the Akron Mercy Medical Office continue to provide to local groups presentations regarding the dangers of radon and have sought legislative action.

Take-Home Message

Overall, we found that >80% of homes tested in northwest Iowa had radon concentrations higher than the EPA actionable level of 4 pCi/L. Physicians and other health professionals are in an ideal position to educate patients about this potentially preventable cause of lung cancer death. Family medicine offices located in areas with high radon concentrations may be able to replicate this project. This project led to increased awareness of this public health danger. Work needs to continue in Iowa because the state has indoor radon concentrations that are the highest in the nation. Policymakers should consider laws regarding ensuring homes have a radon concentrations below the EPA action level before a home can be sold. Fourteen states have no laws regarding radon, or radon testing or disclosure in homes being sold.[17] Most states require disclosure of known environmental hazards before selling a home. Iowa and 4 other states require providing a prospective buyer with general information about the dangers of radon and disclosure of known radon results.

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