ORIGINAL RESEARCH

Radon Knowledge and Practices Among Family Physicians in a High Radon State

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Background: **Exposure to radon at home is the largest cause of lung cancer after smoking, and the combination of smoking and radon increases lung cancer risk several-fold. North Dakota has some of the highest residential radon levels in the United States. Although family physicians in North Dakota commonly counsel patients about smoking cessation, little is known about their knowledge and practices concerning radon.**

Methods: **We mailed a questionnaire to 350 North Dakota family physicians regarding radon knowledge, beliefs, their own radon testing, and radon counseling of patients. The responses were analyzed by descriptive statistics, analysis of variance, and logistic regression.**

Results: **Sixty-one percent of the surveys were completed. Seventy percent of family physicians correctly identified radon as radioactive; 67% reported that they do not inform patients about radon; and 80% reported never discussing the combined hazards of radon and smoking. Conversely, 35% of family physicians reported that they tested their own homes for radon.**

Discussion: **Most North Dakota family physicians are knowledgeable about radon, and more than one third have tested their own homes. However, only a minority transmit this knowledge to their patients. Future efforts should educate physicians about communicating radon risks, especially in conjunction with smoking. (J Am Board Fam Med 2021;34:602–607.)**

Keywords: **Family Physicians, Logistic Models, Lung Cancer, North Dakota, Radon, Smoking Cessation, Surveys and Questionnaires**

Introduction

Radon gas is a form of ionizing radiation that results from the natural decay of radioactive elements present in rocks and soils. For most individuals, exposure to radon at home is their largest source of exposure to ionizing radiation. Radon ranks second to cigarette smoking as a cause of lung cancer and causes more than 21,000 lung cancer deaths per year in the United States.[1]

North Dakota has one of the highest levels of residential radon in the United States. For example, the average radon level in homes in Grand Forks, ND, the location of the University of North Dakota's School of Medicine & Health Sciences, is 11.7 pCi/L.[2] That value is 10 times the average radon level in US homes (1.3 pCi/L) and 3 times the level (4 pCi/L) for which the Environmental Protection Agency recommends remediation of homes.[3]

The root cause of deaths caused by radon is the failure to test and remediate homes for radon, a result of the public's poor understanding of this hazard. Most US respondents do not know that radon causes lung cancer; indeed, most indivuals younger than 30 do not even know what radon is.[4]

One venue where individuals could learn about radon is from their family physicians.[5] Family physicians commonly provide counseling to their

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patients about smoking cessation.[6] Given that radon potentiates the effects of smoking on lung cancer several-fold, family physicians ideally should also provide counseling about radon, especially in high radon areas.[7] However, to counsel patients effectively about radon, family physicians themselves must be radon knowledgeable. We therefore studied radon knowledge and behaviors concerning radon among ND family physicians.

Methods

We surveyed ND family physicians, a population defined by membership in the American Academy of Family Physicians, via a mailed questionnaire. The membership list was obtained from the North Dakota Academy of Family Physicians (NDAFP), which estimates that the list identifies 75% of the family physicians licenced in North Dakota. This research was approved by the University of North Dakota School of Medicine and Health Sciences Institutional Review Board, #201905-312.

We modified a questionnaire used by Nwako in his survey of radon knowledge among public health workers.[8] The modified survey added questions regarding professional behaviors related to counseling of patients. Awareness was evaluated in several domains, for example, knowledge about radon in general, health concerns related to radon, and radon testing and remediation. Radon knowledge was assessed via 12 true/false questions. Beliefs were assessed via 12 questions that were measured on 1-to-5-point Likert scales. Demographic data included physician age, gender, location of medical school or residency training (in ND vs elsewhere), current status as a resident physician in training, recent activity in patient care, and time practicing in ND.

The package sent to respondents contained a cover letter (printed on NDAFP letterhead and signed by its president), a questionnaire, a computer-readable response form, and a $5 bill, as several trials of questionnaires sent to health professionals indicate that a small incentive improves response rates.[9] The mailers required signature with return receipt and were coded for tracking purposes. Recipients who did not respond within 2 weeks received a mailed reminder with an additional copy of the questionnaire and a preaddressed, stamped, return envelope. This process was repeated a second time for individuals who did not respond to the first reminder.

Data were analyzed using χ^2 for categorical variables and independent t test or one-way analysis of variance (ANOVA) for continuous variables. Logistic regression was used to estimate how knowledge and belief influenced actions while controlling for demographic factors such as physician age. P values ≤ 0.05 were considered significant.

Results

Surveys were mailed to 350 physicians. The initial response rate was 46%. After the 2 reminder mailings, 204 questionnaires were returned completed and 17 were returned undeliverable, for an overall response rate (204/[350–17]) of 61.3%.

Fifty-five percent of the respondents were male, 35% were female. Ten percent of respondents did not disclose gender. Most were at least 40 years old; their age distribution is presented in Table 1. Thirty-four percent attended medical school in ND, and 27% completed residency there. Twenty percent were currently residents, 94% were actively practicing, and 76% had practiced in ND for more than 3 years.

Thirty-five percent of respondents answered all radon knowledge questions correctly. The questions that resulted in fewer than 90% of respondents answering correctly were: "1 in 15 homes have high radon" (83% correct); "Radon is radioactive" (70% correct); and "Radon is leading cause of lung cancer in nonsmokers" (67% correct). Table 1 shows associations between these 3 low-scoring questions and total radon knowledge by age, gender, current resident, and time practiced in ND.

Physicians who answered correctly that "1 in 15 homes have high radon" were more likely to have practiced in ND more than 3 years ($P < .001$). Those who correctly identified radon as a leading cause of lung cancer in nonsmokers were more likely to be 60 or older (85%). The lowest overall knowledge scores (Table 2) came from respondents 21 to 40 years old ($P < .001$), females ($P = .045$), residents ($P = .037$), and physicians with 3 or fewer years of practice in ND ($P < .001$; see Table 2).

Figure 1 shows a summary of results for physicians' use of a radon test kit, informing patients about radon, encouraging testing for radon, and informing patients about the combined effects of radon and smoking. Sixty-seven percent of physicians reported that they did not inform patients about radon; 72% reported never having encouraged patients to test their homes, and 80% reported never informing

Table 1. Associations Between Knowledge of Radon and Demographic Characteristics of North Dakota Family Physicians

	"Radon Is Radioactive"			"1 in 15 Homes Have High Radon"			"Radon a Leading Cause Lung Cancer in Nonsmokers"		
	N	%	P	N	%	p	N	%	p
Age									
21 to 30	10	55.56	0.178	16	88.89	0.3626	12	66.67	0.004
31 to 40	29	63.04		37	80.43		21	45.65	
41 to 60	58	69.05		65	77.38		56	67.47	
60 or older	28	82.35		31	91.18		29	85.29	
Gender									
Female	46	64.79	0.430	58	81.69	0.951	42	59.15	0.195
Male	79	71.17		91	81.98		76	69.09	
Resident									
Yes	31	83.78	0.051	22	59.46	<0.001	24	64.86	0.784
No	94	64.83		127	87.59		94	65.28	
Years practice									
<3	33	76.74		27	62.79	<0.001	25	58.14	0.154
3 or more	92	66.19		122	87.77		93	67.39	

patients about the joint effects of radon and smoking. Conversely, 35% of the physician respondents reported testing their own homes for radon. Physicians who believed that the risk of radon was low were unlikely to test. Of physicians who tested, 54% reported counseling their patients to test.

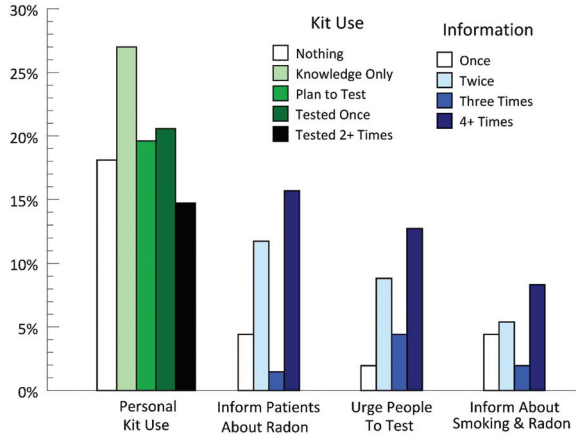
Discussion

We studied knowledge, beliefs, and practices regarding radon among family physicians in ND, a state with exceptionally high radon levels. Most ND family physicians were radon knowledgeable and more than a third (35%) have tested their own homes. However, only 28% counseled patients about the need for radon testing and mitigation. By comparison, of those respondents who themselves tested for radon, over half (54%) encouraged patients to do so. Although nearly all (90%) respondents knew that radon increased the risk for cancer among smokers, only 20% discussed radon in the context of patient smoking. Our findings in

Table 2. Association of Total Knowledge Scores with Demographic Data among North Dakota (ND) Family Physicians

	6–10		11		12		
	N	%	N	%	N	%	P
Age							
21 to 30	8	44.44	7	38.89	3	16.67	<0.001
31 to 40	26	56.52	10	21.74	10	21.74	
41 to 60	22	26.51	37	44.58	24	28.92	
60 or older	3	8.82	11	32.35	20	58.82	
Gender							
Female	31	43.66	23	32.39	17	23.94	0.045
Male	28	25.45	42	38.18	40	36.36	
Resident							
Yes	17	45.95	14	37.84	6	16.22	0.037
No	42	29.17	51	35.42	51	35.42	
Years practice in ND							
0 to 3	18	41.86	21	48.84	4	9.30	<0.001
>3	41	29.71	44	31.88	53	38.41	

Figure 1. Percent of family medicine physicians that engaged in personal and public activity regarding radon.



this regard are similar to those reported by Nwako among public health workers. In his study of health educators, health officers, nurses, and environmental health specialists, only 18% reported informing the public of the risks of radon and/or its combined effects with smoking. Conversely, our physician population was more radon knowledgeable than the public health workers, only 35% of whom reported that they knew how to test for radon and only 16% reported that they had tested their own homes.[6]

Despite their high radon knowledge overall, only 70% of ND family physicians correctly identified radon as radioactive and only 67% correctly identified it as a leading cause of lung cancer among nonsmokers. These findings echo the high prevalence of misunderstanding about radon among the general public.[6] The lower radon knowledge overall among younger respondents is consistent with the timing of radon awareness campaigns in the United States, which peaked in association with the passage of the Indoor Radon Abatement Act in 1988 and declined dramatically thereafter.[10] Females were significantly less radon knowledgeable than males, a finding consistent with some[11,12] but not all studies.[13] However, the effect for gender was largely accounted for by older respondents, as it was no longer significant when physicians aged 60 and older were removed from the analysis.

Although screening for hazards like smoking, hypertension, and depression are routine elements of primary care practice, radon education is not. This is a gap that could be filled by family physicians.[14] In addition to being a proven cause of lung cancer, radon is a suspected cause of other cancers, for example, chronic lymphocytic leukemia and malignant melanoma.[15,16] Moreover, the annual number of lung cancer deaths caused by radon, 21,000, approximates the number of suicides using guns (23,854) and exceeds the number of deaths caused by drunk driving (17,400), 2 hazards about which physicians commonly counsel patients.[3,17] Radon counseling has been shown to be effective in promoting radon testing and remediation in areas where radon levels are high.[18]

The costs of definitive radon remediation (sub-slab depressurization with active ventilation) vary between ~ $500 and $2500, depending on the size of the home, an expense that would be prohibitive for many homeowners. However, high residential radon levels often can be lowered via less costly (albeit less effective) interventions that restrict the entry of radon gas into the home, for example, via sealing cracks in the floor and gaskets that cover sump pumps.[19] Economic assistance in radon remediation may be available in some areas via Community Development Block Grants (CDBGs) and other federal programs.[20] Because mobile homes typically are 1 foot or more above the ground, the average radon levels in mobile homes is low.[21] Renters have fewer options with respect to radon remediation than homeowners. However, because radon is heavier than air, apartment dwellers generally are not at risk of radon for apartments above the third floor.[20]

Several groups have studied the cost-effectiveness of radon remediation. The most cost-effective programs target geographical areas where radon exposure is high and where smoking is prevalent. For example, at a radon level of 10pCi/L, the lifetime risk of lung cancer is 18 per 1000 among nonsmokers but is 15 per *100* among current smokers.[22] Preventing radon in new homes is more cost-effective than remediating radon in existing homes; the estimated cost per quality adjusted life year (QALY) in new versus remediated homes is $16,913 versus ~ $30,000.[23] However, these costs compare favorably with the costs of other preventive interventions, for example, breast cancer screening for average-risk women, the cost of which was recently estimated at $40,135/QALY.[24]

In summary, exposure to radon at home is the leading environmental cause of cancer in the

United States. Our findings indicate a need for increased radon education among family physicians who practice in high radon areas. Our data suggest that physicians' personal experiences with radon testing could reinforce their own knowledge and promote counseling about this preventable cause of cancer with their patients.

Limitations

Because not all family physicians in ND are members of the American Academy of Family Physicians, our mailing likely missed some ND family physicians. However, any bias caused by this sampling is likely to be small. Conversely, our response rate of 61.3% compares favorably with the average response rate (57.5%) reported in a review of 350 postal and electronic surveys sent to health care professionals.[25]

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