Post–1971 Era Uranium Workers in New Mexico Have Significant Lung Disease Burden

To the Editor:

At the peak of uranium production during the Cold War, the Colorado Plateau of the American Southwest was the major source of uranium in the United States. Between 1949 and 1989, the Four Corners region (at the intersection of the borders of Colorado, Utah, Arizona, and New Mexico) had 4,000 mines that produced more than 225 million tons of uranium ore. Currently, uranium is still produced in the United States, but in more limited quantities (1). In 1990, the U.S. Congress approved the Radiation Exposure Compensation Act (RECA) to provide screening, medical and compensation benefits to diseased former uranium workers exposed from January 1, 1942, through December 31, 1971 (2). RECA does not cover health conditions resulting from uranium mining exposures after 1971, the date that ended the U.S. government's role as sole purchaser of uranium ore.

Although the U.S. government no longer screens for or compensates respiratory conditions in uranium miners exposed after 1971, recent evidence suggests that uranium miners are often poorly protected from mining dust, experience perceived health problems related to their work (3), and are at elevated risk of developing malignant and nonmalignant respiratory health conditions (4–7). In a recent study, the Four Corners region demonstrated among the highest mortality rates in the United States for interstitial lung disease and pneumoconiosis (8). Given these findings, we hypothesized that the respiratory disease and symptom burden would be similar between RECA era and post–RECA era uranium workers. If true, this would provide evidence for extending screening and medical benefits to workers employed after 1971 in an industry that mostly hired minority, rural, and underserved populations.

After obtaining institutional review board approval, we analyzed 169 eligible former surface and underground uranium workers from rural mining communities in New Mexico who voluntarily completed a free screening visit at community-based mobile clinics between 2015 and 2017 and had complete spirometry data (9). The screening visit included the following: a limited American Thoracic Society Diffuse Lung Disease (ATS-DLD) questionnaire completed by the workers and verified by a trained interviewer (10), history and physical examination, prebronchodilator spirometry performed using the American Thoracic Society guidelines by trained personnel using race/ethnicity-specific reference standards (11, 12), and a posterior–anterior chest radiograph interpreted by a certified B-reader using the International Labor Organization's International Classification of Radiographs of Pneumoconioses (13). The exposure variable was the RECA era employment status in the uranium industry. A post–RECA era worker was employed in the uranium industry for any duration but exclusively after December 31, 1971. The primary outcome was the presence of radiographic changes consistent with uranium workers' pneumoconiosis (defined by profusion score ⩾1/0 or ⩾1/1 subcategories of small pneumoconiotic opacities, usually irregular lower-zone opacities). Secondary outcomes included prebronchodilator forced expiratory volume in 1 second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC ratio; self-reported physician-diagnosed respiratory diseases (asthma, chronic obstructive pulmonary disease, and dust-related interstitial

Table 1. Comparison of demographic characteristics between Radiation Exposure Compensation Act and Post–Radiation Exposure Compensation Act era uranium industry workers

Demographics	RECA Era Group (*n* = *47*) (Worked ⩾1 Yr before December 31, 1971)	Post-RECA Era Group (*n* = *122*) (Worked Exclusively after December 31, 1971)
Race/ethnicity		
Non-American Indian, *n* (%)	17 (36.2%)	56 (45.9%)
American Indian, *n* (%)	30 (63.8%)	65 (53.3%)
Number missing race/ethnicity	0	1
Female sex*, *n* (%)	3 (6.4%)	28 (23.0%)
BMI*, kg/m^2, mean ± SD	28.9 ± 5.5	32.8 ± 6.8
Age*, yr, mean ± SD	71.1 ± 6.7	62.7 ± 6.0
Number missing age	0	1
Duration of uranium exposure, yr, mean ± SD	8.3 ± 8.4	6.3 ± 5.1
Number missing duration of uranium exposure	7	7
Duration of total mining exposure, yr, mean ± SD	10.7 ± 10.0	8.8 ± 8.7
Number missing duration of total mining exposure	2	2
Exposure to underground mining, *n* (%)	26 (54.2%)	66 (51.6%)
Current smoker, *n* (%)	3 (6.4%)	16 (13.1%)
Number missing smoking status	5	6

Definition of abbreviations: BMI = body mass index; RECA = Radiation Exposure Compensation Act; SD = standard deviation.
*Significant differences between the two groups ($P < 0.05$).

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Table 2. Comparison of primary and secondary outcomes between Radiation Exposure Compensation Act and Post–Radiation Exposure Compensation Act era uranium industry workers

Categorical outcomes		RECA Era (*n* = 47)		Post-RECA Era (*n* = 122)		Unadjusted Odds Ratio (95% CI)	*P* Value	Adjusted Odds Ratio* (95% CI)	*P* Value
		n	Events (*n* [%])	*n*	Events (*n* [%])				
Chest radiograph B reads	Abnormal chest radiograph (profusion score ⩾1/0)	45	34 (75.6%)	119	81 (68.1%)	0.69 (0.32 to 1.51)	0.35	0.73 (0.29 to 1.88)	0.52
	More severe chest radiograph abnormality (profusion score ⩾1/1)	45	10 (22.2%)	119	22 (18.5%)	0.79 (0.34 to 1.84)	0.59	0.70 (0.25 to 1.97)	0.50
Spirometric parameters	FVC < LLN	47	13 (27.7%)	122	24 (19.7%)	0.64 (0.30 to 1.40)	0.26	0.26 (0.09 to 0.77)	0.02
	FEV_1 < LLN	47	11 (23.4%)	122	23 (18.9%)	0.76 (0.34 to 1.72)	0.51	0.23 (0.08 to 0.71)	0.01
	FEV_1/FVC ratio < LLN	47	8 (17.0%)	122	19 (15.6%)	0.90 (0.36 to 2.22)	0.82	0.56 (0.18 to 1.73)	0.31
Lung diseases†	Ever asthma	42	7 (16.7%)	114	29 (25.4%)	1.71 (0.68 to 4.26)	0.25	1.42 (0.12 to 1.64)	0.52
	Current asthma	42	6 (14.3%)	114	23 (20.2%)	1.52 (0.57 to 4.03)	0.40	1.30 (0.42 to 4.01)	0.65
	Dust-related interstitial lung disease†	26	8 (30.8%)	59	7 (10.9%)	0.30 (0.10 to 0.95)	0.04	0.30 (0.08 to 1.16)	0.08
	COPD (emphysema/chronic bronchitis)	29	11 (37.9%)	82	24 (29.3%)	0.68 (0.28 to 1.65)	0.39	0.47 (0.16 to 1.41)	0.18
	Hypoxemia‡	47	1 (2.1%)	121	3 (2.5%)	1.17 (0.12 to 11.53)	0.89		

Continuous outcomes		N	RECA Era (mean ± SD)	N	Post-RECA Era (mean ± SD)	Unadjusted Mean Difference (95% CI)	*P* Value	Adjusted Mean Difference* (95% CI)	*P* Value
Respiratory symptoms	Cough-phlegm score	47	5.6 ± 3.7	120	5.0 ± 3.5	−0.56 (−1.77 to 0.65)	0.36	−1.42 (−2.89 to 0.05)	0.06
	Wheeze score	47	2.7 ± 2.2	121	2.7 ± 2.1	0.01 (−0.71 to 0.73)	0.98	−0.22 (−1.09 to 0.65)	0.62
	mMRC dyspnea score	29	2.3 ± 1.5	100	1.9 ± 1.5	−0.36 (−0.98 to 0.27)	0.26	−0.53 (−1.26 to 0.20)	0.15
	Total symptom score	47	9.6 ± 6.1	121	9.2 ± 5.2	−0.41 (−2.36 to 1.55)	0.68	−1.77 (−4.09 to 0.62)	0.15
Spirometric parameters	FVC, L	43	3.6 ± 0.8	114	4.5 ± 8.5	0.92 (−1.65 to 3.50)	0.48	−0.05 (−3.18 to 3.07)	0.97
	FEV_1, L	43	2.6 ± 0.6	115	3.5 ± 7.5	0.88 (−1.39 to 3.15)	0.45	0.04 (−2.73 to 2.82)	0.98
	FEV_1/FVC, ×100%	43	72.6 ± 5.8	114	74.9 ± 8.4	2.32 (−0.43 to 5.06)	0.10	1.82 (−1.39 to 5.03)	0.27

Definition of abbreviations: CI = confidence interval; COPD = chronic obstructive pulmonary disease; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; LLN = lower limit of normal; mMRC = modified Medical Research Council; Post-RECA era = exclusively worked after December 31, 1971; RECA = Radiation Exposure Compensation Act; RECA era = worked for at least 1 year before December 31, 1971 (referent group); SD = standard deviation.

*All models adjusted for age, sex, smoking status, and body mass index.

†Lung diseases are self-reported physician diagnoses, except for hypoxemia; dust-related lung diseases include silicosis, pneumoconiosis, and asbestosis.

‡Hypoxemia is defined on the basis of self-reported use of oxygen prescription or measured oxygen saturation as measured by pulse oximetry less than 89% at rest on room air. We did not include this outcome in the adjusted model, owing to the small number of events in both groups.

lung disease); self-reported respiratory symptoms (modified Medical Research Council questionnaire score for dyspnea and sum of subject responses to symptom-specific questions from the American Thoracic Society Diffuse Lung Disease questionnaire) (10, 14); and hypoxemia (self-reported use of supplemental oxygen or oxygen saturation as measured by pulse oximetry <89% at rest on room air). Multivariable analyses were performed using logistic and linear regression techniques for categorical and continuous outcomes, respectively, with adjustment for age, sex, smoking status, and body mass index (BMI). SAS software (SAS, Cary, NC) was used, and $P < 0.05$ was considered significant. The margins of error for a prevalence estimate in the RECA era and post–RECA era groups were ±20% and ±13%, respectively (exact Clopper-Pearson 95% confidence interval [CI]). We used the fully conditional specification method to impute missing covariate values for age ($n = 1$) and smoking status ($n = 11$) (SAS/STAT version 14.1 proc mi). Fifty complete datasets were generated and analyzed. Combined parametric estimates and hypothesis tests that reflect uncertainty due to missingness were obtained (SAS/STAT version 14.1 proc mianalyze).

Of the 169 uranium workers screened, 72.2% worked in the post–RECA era and 56.5% were American Indians. The distributions of race/ethnicity, current smoking status, duration of uranium exposure, and mine location were similar between groups (Table 1). The post–RECA era group had a significant burden of lung disease: 18.5% had a profusion score greater than or equal to 1/1 of small pneumoconiotic opacities on a chest radiograph, and 15.6% had airflow obstruction as defined by FEV_1/FVC ratio below the lower limit of normal. In unadjusted analyses, the prevalence of a profusion score ⩾ 1/0 was similar between RECA era and post–RECA era participants (76% and 68%, respectively; odds ratio, 0.69; 95% CI, 0.32 to 1.51) (Table 2). Similarly, the prevalence of a profusion score ⩾ 1/1 was similar between groups (22% and 19%, respectively) (Table 2). In unadjusted analyses, the prevalence of self-reported dust-related interstitial lung disease was lower in the post–RECA era group (31% and 11%, respectively; odds ratio, 0.30; 95% CI, 0.10 to 0.95). Although the magnitude of this association was identical in an adjusted analysis, the estimate was less precise (adjusted odds ratio, 0.30; 95% CI, 0.08 to 1.16). In additional adjusted analyses, the post–RECA era participants had lower odds of having reduced FEV_1 and FVC values (respectively, adjusted odds ratio, 0.23; 95% CI, 0.08 to 0.71; adjusted odds ratio, 0.26; 95% CI, 0.09 to 0.77). All other effect estimates were imprecise with CIs including the null value (Table 2).

Our study shows a high burden of respiratory disease in uranium workers. We also show that respiratory outcomes were similar between the RECA era and post–RECA era groups. Based upon lessons learned from the recent black lung epidemic in the United States (15–17), mining dust exposures are challenging to control and may not have been reduced substantially in uranium mines after 1971.

Limitations of our study include geographic coverage being limited to New Mexico, possible selection bias due to voluntary participation and potential for compensation benefit for RECA era miners, small numbers, and lack of objective exposure measurements. Recall bias is an unlikely explanation because our findings on self-report measures are largely confirmed using chest radiograph measures.

Uranium workers in New Mexico constitute an underserved, poor, rural population with a high proportion of American Indians and Hispanics. Unlike those employed during the RECA era, post–RECA era workers are not eligible for screening, medical, or compensation benefits (18). Similar to recent findings of increased incidence of black lung in coal miners (15, 19), our study findings support the conclusion that despite presumed improvement in exposure control, uranium miners continued to be exposed to harmful levels of mining dust, resulting in a high burden of respiratory disease among former uranium workers in New Mexico, employed after 1971. Our findings argue that medical screening for respiratory diseases under federally funded worker surveillance programs should be extended to post–RECA era uranium workers, especially if large epidemiologic studies confirm our results.

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Patient Preference to Accept Medical Treatment Is Associated with Spokesperson Agreement

To the Editor:

A foundational element of advance care planning (ACP) is designating a spokesperson to make medical decisions on behalf of incapacitated patients (1). However, studies assessing spokespersons' predictions of patients' treatment preferences have found only moderate agreement levels (50–70%) (2–4). To date, few variables have strong independent associations with spokesperson–patient agreement rates, and more work is needed to understand the sources of this disconnect (2). We compared agreement between patient and surrogate responses when patients chose to "accept" versus "decline" treatment in a randomized trial evaluating online ACP tools (5).

Methods

We conducted a *post hoc* analysis of a randomized controlled trial (project no. 5R01NR012757) of dyads of patients with advanced, chronic illness and their designated spokespersons. Patients were eligible if they received medical care at Penn State Hershey Medical Center or Brigham and Women's Hospital, were at least 18 years old and had either class III or IV congestive heart failure, stage III or IV chronic obstructive pulmonary disease, chronic kidney disease stage 4 or 5, or advanced cancer. Full descriptions of selection criteria, recruitment, randomization, and the interventions were published previously (5).

For this *post hoc* study, the prespecified primary analysis was comparison of agreement between patient and surrogate responses when patients "accepted" versus "declined" treatment for 28 decisions about potentially lifesaving treatments in six hypothetical vignettes. These included decisions about cardiopulmonary resuscitation, mechanical ventilation, surgery, hemodialysis, feeding tube, and intravenous antibiotics.

Each question was analyzed individually, and patients were classified as desiring to "accept" or "decline" treatment. Agreement between patients' choices and spokespersons' predictions was assessed as a categorical variable (yes/no), and the percentage agreement was calculated for each group. Median agreement was calculated across all 28 questions, as were median differences in agreement rates.

Multivariate logistic regression used the Wald chi-square test to assess the association between agreement and the independent variable of choosing to "accept" treatment. On the basis of historical data, patient and spokesperson demographics previously found to be associated with agreement, together with primary clinical diagnosis (cardiac, pulmonary, renal, cancer) and study site (Hershey, PA; Boston, MA), were included in the multivariate analysis. Median adjusted odds ratios between spokesperson–patient agreement and choosing to "accept" treatment were calculated for all 28 questions; results were considered significant if the P value was less than 0.05. The adjusted odds ratio represents the likelihood that a surrogate accurately represents a patient's preference for treatment when the patient agrees to accept treatment, compared with when the patient declines treatment.

Results

Overall, 267 patient–caregiver dyads enrolled, and 7,394 paired responses were analyzed. The average patient age was 64 years (standard deviation [SD], ±13.4), and 46% were female. The average spokesperson age was 56 years (SD, ±13.9), and 75% were female. The most common diagnosis was cancer (33%). Demographic and clinical characteristics of patients and spokespersons are presented in Table 1.

Spokesperson–patient agreement was higher when patients "accepted" versus "declined" treatment, with statistically significant differences for 24 of 28 questions (Figure 1 and Table 2). The overall median agreement rate was 87% when patients "accepted" versus 44% when patients "declined" treatment, and the median difference in agreement was 46% (Figure 1 and Table 2). In multivariate testing, "accepting" treatment was a significant independent predictor of spokesperson–patient agreement for 25 of 28 questions, with an overall median adjusted odds ratio favoring agreement when patients "accepted treatment" of 10.9.

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