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Supplemental Material

Lung Cancer and Radon: Pooled Analysis of Uranium Miners Hired in 1960 or Later

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Table S1. Estimates of excess relative rate of lung cancer mortality (95% confidence intervals) by categories of cumulative exposure to radon progeny, lagged 5 years. Background stratified by study cohort, attained age, calendar period, and duration of employment as a uranium miner. Pooled Uranium Miners Analysis (PUMA) of uranium miners in Canada, Czech Republic, France, Germany, and USA, male miners hired in 1960 or later.

Exposure category (in WLM)	Estimate	(95% CI)
0 (reference)	0.	(--,--)
>0-10	0.12	(-0.09, 0.37)
>10-20	0.36	(0.06, 0.74)
>20-30	0.57	(0.18, 1.08)
>30-40	0.97	(0.44, 1.66)
>40-50	0.92	(0.32, 1.76)
>50-60	1.50	(1.73, 2.55)
>60-70	1.18	(0.42, 2.25)
>70-80	0.49	(-0.18, 1.52)
>80-90	1.41	(0.41, 2.89)
>90-100	1.86	(0.68, 3.63)
>100-110	1.49	(0.29, 3.38)
>110-120	2.31	(0.60, 5.10)
>120-130	1.88	(0.40, 4.30)
>130-140	1.37	(0.00, 3.77)
>140-150	2.24	(0.25, 5.86)
>150	2.35	(1.27, 3.85)

Table S2. Impact on goodness of model fit of inclusion of parameters describing the association between cumulative exposure to radon progeny and lung cancer mortality. PUMA study of uranium miners in Canada, Czech Republic, France, Germany, and USA, male miners hired in 1960 or later.

	Model		2LogL	d.f.
0	Null	$RR = 1$	-10651.368	69918
1	Linear	$RR = 1 + \beta D$	-10721.265	69917
2	Linear-Quadratic	$RR = 1 + \beta D + \gamma D^2$	-10722.396	69916
3	Study cohort-specific	$RR = 1 + \sum_{c=1}^{7} \beta_c D$	-10727.768	69911
4	Attained age[a]	$RR = 1 + \beta D exp\left(\sum_{j=1}^{4} \varphi_j x_j\right)$	-10733.824	69914
5	Attained age, age at exposure [a,b]	$RR = 1 + \beta D^* exp\left(\sum_{j=1}^{4} \varphi_j x_j\right)$	-10736.473	69913
6	Attained age, age at exposure, exposure rate[a,c]	$RR = 1 + \beta D^* exp\left(\sum_{j=1}^{4} \varphi_j x_j\right)$	-10747.675	69911
7	Time since exposure[d]	$RR = 1 + \beta D^{**}$	-10724.916	69915
8	Attained age, time since exposure[a,d]	$RR = 1 + \beta D^{**} exp\left(\sum_{j=1}^{4} \varphi_j x_j\right)$	-10734.648	69912
9	Attained age, time since exposure, exposure rate[a,e]	$RR = 1 + \beta D^{**} exp\left(\sum_{j=1}^{4} \varphi_j x_j\right)$	-10746.562	69910

2LogL: twice the log likelihood; RR: Relative Rate; d.f.: degrees of freedom

[a] $\varphi_1 = 0$ for attained age <55 years.

[b] where $D^* = w_{\geq 35} + \theta_1 w_{<35}$, letting w_{ae} index cumulative exposure in windows defined by age-at-exposure.

[c] where $D^* = w_{\geq 35,<0.5} + \theta_2 w_{\geq 35,0.5-<1} + \theta_3 w_{\geq 35,\geq 1} + \theta_1 w_{<35,<0.5} + \theta_1 \theta_2 w_{<35,0.5-<1} + \theta_1 \theta_3 w_{<35,\geq 1}$, letting $w_{ae,er}$ index cumulative exposure in windows defined by age-at-exposure and exposure rate.

[d] where $D^{**} = v_{5-14} + \vartheta_1 v_{15-24} + \vartheta_2 v_{\geq 25}$, letting w_{tse} index cumulative exposure in windows defined by time since exposure.

[e] where $D^{**} = v_{5-14,<0.5} + \vartheta_3 v_{5-14,0.5-<1} + \vartheta_4 v_{5-14,\geq 1} + \vartheta_1 v_{15-24,<0.5} + \vartheta_3 \vartheta_1 v_{15-24,0.5-<1} + \vartheta_4 \vartheta_1 v_{15-24,\geq 1} + \vartheta_2 v_{\geq 25,<0.5} + \vartheta_3 \vartheta_2 v_{\geq 25,0.5-<1} + \vartheta_4 \vartheta_2 v_{\geq 25,\geq 1}$, letting $w_{tse,er}$ index cumulative exposure in windows defined by time since exposure and exposure rate.

Table S3. Regression estimates of the excess relative rate of lung cancer mortality per 100 WLM with effect modification by attained age, age at exposure, and exposure rate. PUMA study of uranium miners in Canada, Czech Republic, France, Germany, and USA, male miners hired in 1960 or later. Restricted to person-time and events observed among those employed at least 1 or 5 years.

Person-time and events restricted to:	Employed ≥1 year[a,c]		Employed ≥5 years[a,d]		Employed ≥5 years[b,d]	
	Estimate	(95% CI)	Estimate	(95% CI)	Estimate	(95% CI)
ERR/100 WLM (95% CI)	8.49	(3.21, 19.94)	6.87	(2.43, 16.90)	5.56	(1.95, 13.28)
Age at exposure						
35+ years	1.		1.		1.	
<35 years	0.60	(0.30, 1.25)	0.65	(0.31, 1.47)	0.68	(0.31, 1.62)
Attained age						
<55 years	1.		1.		1.	
55-64 years	0.52	(0.22, 1.28)	0.59	(0.21, 1.64)	0.57	(0.21, 1.54)
65-74 years	0.19	(0.05, 0.52)	0.20	(0.05, 0.63)	0.20	(0.05, 0.63)
75+ years	0.14	(0.02, 0.64)	0.20	(0.03, 1.01)	0.30	(0.00, 1.40)
Exposure rate						
<0.5 WL	1.		1.		1.	
0.5-<1 WL	1.29	(0.51, 2.95)	1.61	(0.62, 3.93)	1.76	(0.67, 4.50)
1+ WL	0.37	(0.14, 0.85)	0.33	(0.07, 0.92)	0.36	(0.07, 1.00)
Lung cancers	1124		688		688	
Person-years (10^5)	17.18		9.07		9.07	

[a] Background stratified by attained age, calendar period, study cohort, and duration of employment as a uranium miner.
[b] Background stratified by attained age, calendar period, study cohort.
[c] restricted to person-time and events for which duration of employment ≥1 year
[d] restricted to person-time and events for which duration of employment ≥5 years

Table S4. Regression estimates of the excess relative rate of lung cancer mortality per 100 WLM with effect modification by time since exposure. PUMA study of uranium miners in Canada, Czech Republic, France, Germany, and USA, male miners hired in 1960 or later.

	Estimate	(95% CI)
ERR/100 WLM	2.86	(0.47, 6.71)
Time since exposure		
5-14 years prior	1.	--
15-24 years prior	0.72	(0.19, 5.05)
25+ years prior	0.39	(0.14, 2.45)