Stress-Test of the Two-Fold Increase of Radon Risk Factor in dwellings

François O. Bochud (1), Jean-Pascal Laedermann (1), Georg Kropat (1), Claude J. Bailat (1), Christophe Murith (2), and Sébastien Baechler (1)

(1) IRA, Lausanne University Hospital, Switzerland
(2) Federal Office of Public Health, Bern, Switzerland

Purpose

WHO and ICRP recently lowered their reference levels for radon concentration in dwellings because of a doubling of the risk factor estimate (β) by the last European meta-analysis. This correction is explained by the measurement uncertainty and the fact that more subjects are exposed to low than high doses. Several government bodies involved in the implementation of the new reference levels struggle to understand the rationale of this increase and would like to be confident in the soundness of the effect. Our paper describes how the measurement uncertainty could double the risk factor and ascertains the confidence we could have in this factor through the use of Monte Carlo simulation.

Method

We start by describing the details of the underlying Bayesian calculations performed by the European analysis, with special emphasis on the distributions of the prevalence of expositions and the measurement uncertainties. Then we artificially generate seven data sets compatible with the European observed data, simulated with relative measurement uncertainties ranging from CV=5% to CV=100%, and assuming a true risk factor of β=0.0016 (Bq/m³)⁻¹. On each of these populations, we estimate the risk factor either directly from the observed simulated data or with the Bayesian calculation.

Symbols

x : natural log of radon concentration

y : disease indicator (1 or 0)

$\pi(y=1\,|\,x,\alpha,\beta)$: probability of disease in presence of x

$$\frac{\pi(y=1\,|\,x,\alpha,\beta)}{\pi(y=0\,|\,x,\alpha,\beta)} = e^{\alpha+\beta e^{x}} \approx e^{\alpha}(1+\beta e^{x})$$

x^{mes} : result of the measurement

x^{true} : underlying true value

$p_0(x^{true})$: a priori for log concentration (normal)

$p(x^{mes}\,|\,x^{true})$: measurement model (normal and unbiased)

$p'(x^{mes}) = \int p(x^{mes}\,|\,x^{true})p_0(x^{true})dx^{true}$: measurements marginal

$p_1(x^{true}\,|\,x^{mes}) = \dfrac{p(x^{mes}\,|\,x^{true})p_0(x^{true})}{p'(x^{mes})}$: a posteriori

Bayesian estimation

N_0 : number of controls

N_1 : number of cases

$$P_{Bayes}(\beta) \propto \frac{\prod_i \int \pi(y_i\,|\,x,\beta)p_1(x\,|\,x_i^{mes})dx}{\left(\int \pi(y=0\,|\,x,\beta)p_0(x)dx\right)^{N_0}\left(\int \pi(y=1\,|\,x,\beta)p_0(x)dx\right)^{N_1}}$$

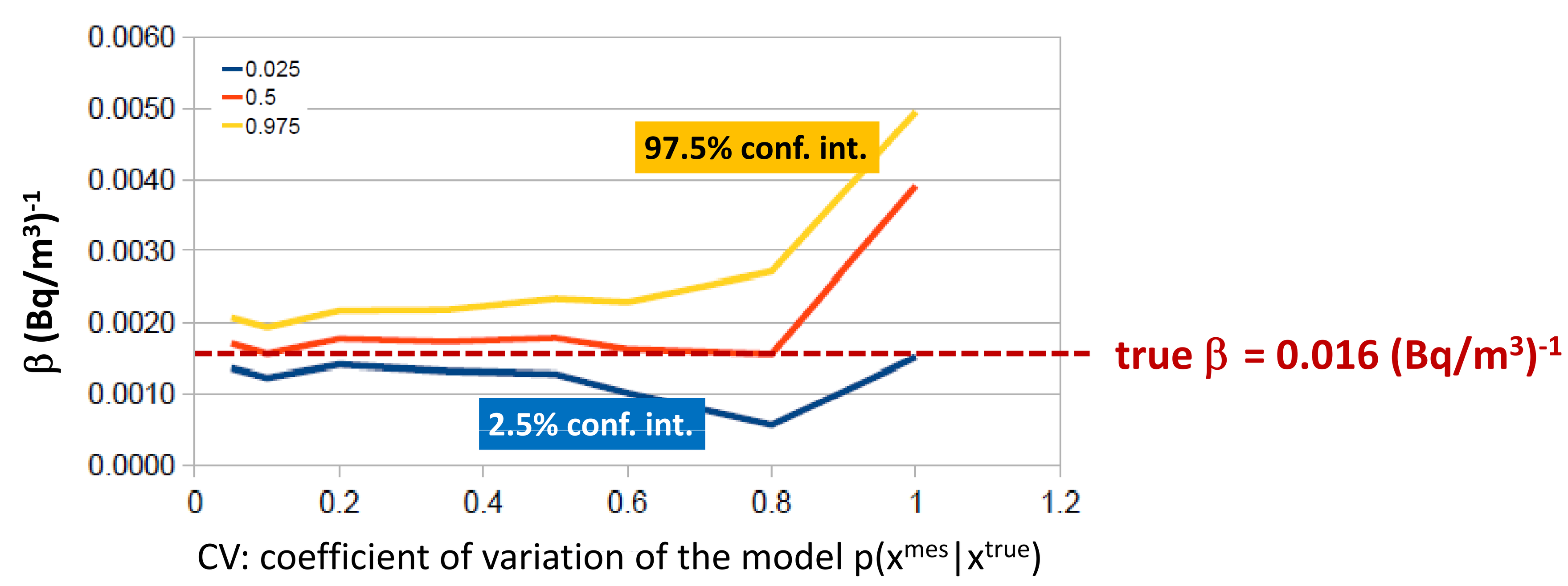
Estimation directly from observed data

$$P_{direct}(\beta) \propto \prod_i \frac{\pi(y_i\,|\,x_i^{mes},\beta)}{\int \pi(y_i\,|\,x,\beta)p'(x)dx}$$

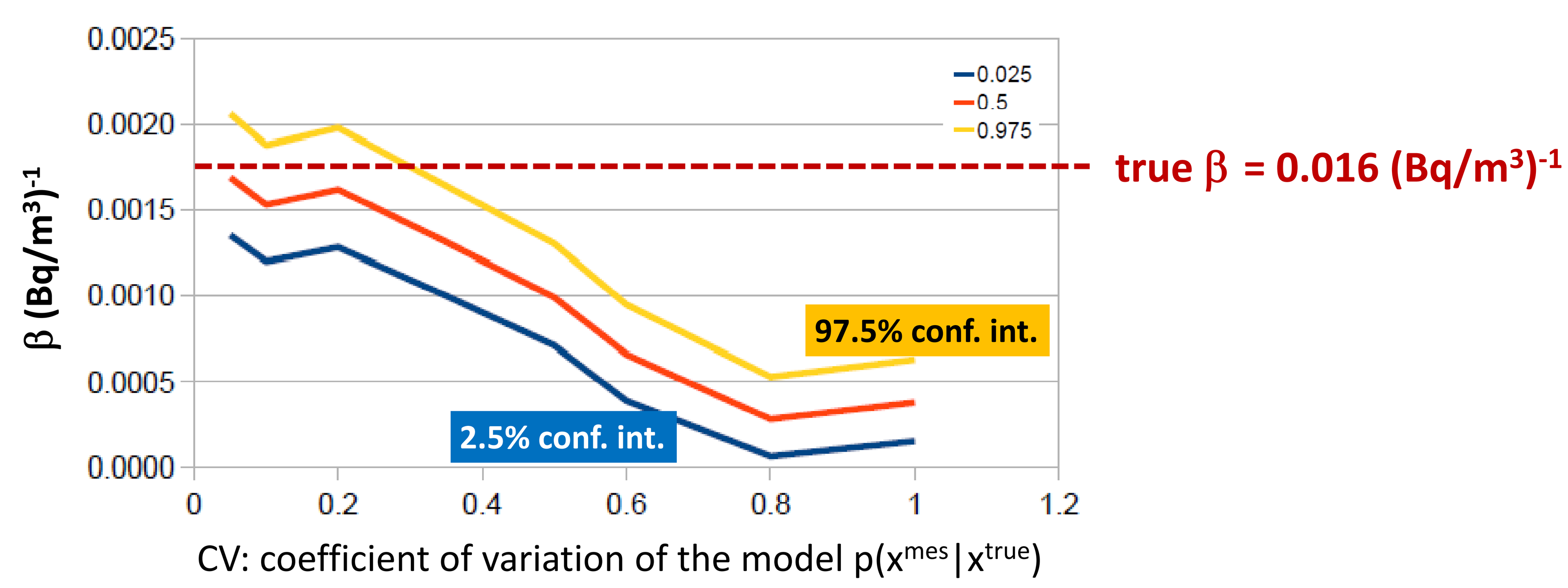
Results

For small measurement uncertainties, the estimation of the risk factor without Bayesian calculation is correct. For measurement uncertainties higher than 10%, the estimated risk decreases and becomes rapidly not compatible with the true risk factor. Conversely, when the Bayesian calculation is performed the estimated risk is correct.

Bayesian estimation



Estimation directly from observed data



Country	CV	Beta raw multiplier
Italy	0.17	1.20
Czech	0.35	1.53
Austria, France ...	0.40	1.66
United Kingdom	0.50	1.98
Finland	0.60	2.47

Discussion

The large uncertainties associated to radon exposition measurements have a distinct effect on the estimation of the risk factor. Our simulations show that the risk is correct if the measurement uncertainty is well estimated.

Conclusion

We confirm that the observed data of radon in dwellings have to be corrected for measurement uncertainties in order to estimate the risk. Our simulations show that the two-fold increase of the European risk is in the correct order of magnitude, but that the value of the uncertainty has a large influence. Unfortunately, we know that the uncertainties are large, but no thorough evaluation has been performed yet.

References

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[3] Scand J Work Environ Health 2006; 32 suppl 1:1-84