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MASTER**CHEST CLEARANCE OF INHALED COBALT-60 OXIDE***

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ABSTRACT

Chest counting data have been collected for about four years for a case which involved inhalation of ^{60}Co -oxide. The measured chest burden, which decreases with successively increasing half-times (about 10 months at early times to about 60 months after three years), may be calculated almost precisely with an expression related directly to the model of the Task Group on Lung Dynamics. Only the delayed transfer half-time and the long-term fraction retained in pulmonary lymph nodes of the Class Y model need be adjusted to fit this case. With the exception of the long-term fraction in the lymph nodes, only one rate of elimination seems to be present, 225 days, throughout the period of observation.

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Key

INTRODUCTION

The ORNL Whole Body Counter has been used to count a man who was exposed to ^{60}Co -oxide by inhalation during a period of about six months prior to the initial count, and following which there was no subsequent exposure. Counting data have been collected for almost four years and the chest burden as a function of time has been determined. Figure 1 is a plot of the measured chest burden which has decreased with increasing clearance half-times through the period of observation. The biological half-time for chest clearance increased from about 10 months at early times to about 60 months at three years after the initial count, and has continued to increase with time.

METHOD

Exponential expressions, not shown here, were derived to fit the half-times of chest clearance for comparison with those observed by others.^{1,2} However, in the model for Class Y materials in the Report of the Task Group on Lung Dynamics,³ it is postulated that a single biological half-life applies to all modes of pulmonary transfer except initial clearance to the G.I. tract, so the observed data were compared with the predictions of the lung model.

With reference to the lung model, consider a time scale with deposition in the pulmonary region at time $t = 0$, say of unit amount, 1 nCi, with a radioactive decay rate λ_r . A fraction f_h of this is eliminated via pathway h at rate λ_h , going to the lymph nodes. Thus, the amount entering lymph nodes in time interval dt

Figure 1

is

$$f_h e^{-(\lambda_h + \lambda_r)t} \lambda_h d\tau.$$

Of this amount a fraction f_i is eliminated from lymph nodes at a rate λ_i and a fraction $(1 - f_i)$ remains subject only to radioactive decay. Thus, at time $t > \tau$ we have

$$\int_0^t \left(f_h e^{-(\lambda_h + \lambda_r)\tau} \lambda_h d\tau \right) \left[f_i e^{-(\lambda_i + \lambda_r)(t - \tau)} + (1 - f_i) e^{-\lambda_r(t - \tau)} \right] \quad (1)$$

as the burden in the lymph nodes. This equals

$$\begin{aligned} L(t) &= f_h \lambda_h \left[f_i e^{-(\lambda_i + \lambda_r)t} \int_0^t d\tau e^{-(\lambda_h - \lambda_i)\tau} \right. \\ &\quad \left. + (1 - f_i) e^{-\lambda_r t} \int_0^t d\tau e^{-\lambda_h \tau} \right] \\ &= f_h \lambda_h \left[f_i \frac{e^{-(\lambda_i + \lambda_r)t} - e^{-(\lambda_h + \lambda_r)t}}{\lambda_h - \lambda_i} \right. \\ &\quad \left. + (1 - f_i) \frac{e^{-\lambda_r t} - e^{-(\lambda_h + \lambda_r)t}}{\lambda_h} \right] \quad (2) \end{aligned}$$

and is the burden in the lymph nodes at time t if 1 nCi enters the pulmonary region at time 0.

The amount in the pulmonary region at time t , $P(t)$, is

$$P(t) = P_0 e^{-\lambda_r t} (f_e e^{-\lambda_e t} + f_f e^{-\lambda_f t} + f_g e^{-\lambda_g t} + f_h e^{-\lambda_h t}), \quad (3)$$

where P_0 is the initial pulmonary deposition at $t = 0$, and the pathways e , f , g and h are those of the lung model.

The chest burden, $C(t)$, following initial clearance of the T-B region is assumed to be

$$C(t) = P(t) + L(t). \quad (4)$$

Various values of fractions transported and rates of transport were tested in these equations to find a good fit of the chest burden as calculated from equation (4) to the chest burden as observed with the whole body counter. It was found that an almost exact fit was obtained if only two of the parameter values in the Class Y model were changed, viz., the delayed clearance half-time to 225 rather than 360 days, and the fraction $(1 - f_i)$ to 0.4 rather than 0.1.

RESULTS

The revised formulae for calculation are then from (2)

$$\begin{aligned}
 L(t) &= 0.15 P_o e^{-\lambda_r t} \left[f_i \lambda_h t e^{-\lambda_h t} + (1 - f_i) (1 - e^{-\lambda_h t}) \right] \\
 &= 0.15 P_o e^{-\lambda_r t} \left[(0.6)(0.0031)t e^{-0.0031t} + 0.4 (1 - e^{-0.0031t}) \right], \quad (5)
 \end{aligned}$$

and from (3)

$$\begin{aligned}
 P(t) &= P_o e^{-\lambda_r t} \left(0.4 e^{-0.693t} + 0.4 e^{-0.0031t} \right. \\
 &\quad \left. + 0.05 e^{-0.0031t} + 0.15 e^{-0.0031t} \right) \\
 &= P_o e^{-\lambda_r t} \left(0.4 e^{-0.693t} + 0.6 e^{-0.0031t} \right), \quad (6)
 \end{aligned}$$

where t = days and λ_r is the radioactive decay rate of ^{60}Co in da^{-1} .

The calculated pulmonary, pulmonary lymph node and chest burdens as functions of time are shown in Figure 2, with the midpoint of the period of exposure taken as the effective date of the exposure, and including extrapolation of the burdens to that date. The estimated initial pulmonary deposition is 2300 nCi. It is predicted that five years after the effective date of exposure the chest burden will be about 69 nCi, of which 66 nCi will be in the lymph nodes. Values from the curve of measured chest burden are shown for comparison. (The permissible lung burden is 1.2 μCi .)

^{60}Co Oxide, Calculated Chest Burden.

Figure 2

DISCUSSION

The parameter values for the Class Y lung model have been suggested as typical values for clearance of insoluble compounds, but one must expect a rather wide range of these parameter values in individual cases. This variability may be associated with many factors, such as particle size, degree of transferability and solubilization, physiology of the individual, etc. Thus, it is quite interesting, in view of all the potential variations that only small differences apparently exist between the predictions for the lung model and an actual case. The values used in this case are within a factor of 2 or 3 of those of the lung model.

Although the ORNL Body Counter is unable to differentiate pulmonary burden from pulmonary lymph node burden, the lung model is derived from many experiments and studies and it seems reasonable that the calculated quantities are close to actual quantities.

CONCLUSION

The lung model prediction, modified by chest count data, applies quite well in this case. It is demonstrated that chest clearance of Class Y radioactive materials which have been inhaled can be described by a single value for biological half-life, as proposed for the lung model.

REFERENCES

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