RADIOBIOLOGY

Long-term *in vivo* Retention of Cerium-144 by Beagles

CERIUM-144 is a high yield ($\sim$ 5 per cent) product of nuclear fission that can be readily detected in debris from fission reactions. From about the first to the fourth year after fission, cerium-144 contributes most to total radioactivity[1]. Because each nuclear disintegration of cerium-144 and its daughter praseodymium-144 can result in deposition of the effective equivalent of more than 6 MeV in bone[2], cerium-144 ranks among the more hazardous fission products. Although cerium-144 is only poorly absorbed from the gut[2,3], it has been detected at low concentrations in foods, including clams and animal bone[4]. Liebscher *et al.*[5] detected it in both lung tissue and pulmonary lymph nodes from man. Other workers also identified cerium-144 in lung tissue ash[6]. A similar situation was observed for plutonium-239 by Bair[7]. To assess properly radiation protection guides, it is essential also to consider the bodily retention of the element in question. Virtually nothing is known about the retention of cerium-144 by mammals other than rodents. The purpose of this work was to study the long-term *in vivo* retention of cerium-144 following a single dose to adult beagles.

Four adult male beagles with an average weight of 13·4 kg (range 12·0–15·27 kg) were used. Ages ranged from 60 months to 76 months. Because the animals had been maintained in our colony since birth, they were known to be free from disease. Each dog was well acclimated to periods of confinement in metabolism cages. Immediately after a cage conditioning period of 2 weeks, each dog received about 28 μc. of carrier-free cerium-144 as cerium chloride in 1 ml. sterile solution by injection into an antecubital vein. The *p*H was adjusted to 3·5, because Aeberhardt *et al.*[8] have been able to demonstrate complete ionization and lack of colloid formation for *p*H values less than 4·5. Also, it has been demonstrated that both *p*H and carrier affect deposition patterns of lanthanons in the body[9]. Water and commercial dog food were always available. Within 30 min of injection, each dog was placed in a large volume radiation detector designed to measure the γ-ray activity of the entire animal[10]. The almost 4π steradian geometry of the detector virtually eliminates the effect of tracer redistribution. About 1 yr after injection the dogs were measured (whole-body counted) in an improved counting system[11]. Between day 369 and day 425 whole-body counts in both counters were made on each dog on five different occasions; after day 425, measurements were made only in the improved counter; the overlap period allowed for normalization of the counting data. A polyethylene bottle containing about 28 μc. of cerium-144 and tap water to make a total weight of 13 kg was used as a reference standard. Each dog was counted for 200 sec for each measurement, and appropriate corrections were made for pre-experimental γ-ray activities (caesium-137 and potassium-40). The percentage of biological retention (PBR) was calculated from the following relation:

$$(\mathrm{PBR})_n = 100 \cdot A_n/S_n \cdot S_i/A_i$$

where (PBR) is the percentage of biological retention on day n, and A and S are count rates of an animal or standard at the nth or ith (initial) measurement, respectively. All data processing was carried out on an IBM model 7094 computer; the data reduction and analysis techniques used have already been reported in detail[12].

Table 1 gives whole-body retention parameters for each dog. During the 1,050 day experiment each dog was measured 126 times. A simple exponential model was used because of the observed linear reduction of log retention as a function of time after injection. At least two power functions ($y = ax^b$) were needed to describe retention after day 1; one power function described the data reasonably well from days 100 to 1,050. Effective half-lives (T) approach the maximum value of 285 days, which is the physical half-life (T_r) of cerium-144 (that is, if no biological turnover occurred, the serial changes in body activity would result from physical decay of cerium-144 alone). That only two parameters are needed to describe retention over approximately four effective half-lives is of considerable interest, because cerium-144 is known to be deposited in tissues other than bone (for example, kidneys, liver and spleen) when injected into rodents at *p*H 3·5 (ref. 13). Probably the half-life observed is a reflexion of reasonably similar turnover rates from more than one site.

Table 1. COMPUTER-DERIVED WHOLE-BODY RETENTION PARAMETERS FOR CERIUM-144 INJECTED INTRAVENOUSLY INTO MALE BEAGLES

Dog. No.	a* (per cent)	$-k$* (day^{-1})	T_b (days)	T† (days)
19	97·7	$1{\cdot}789 \times 10^{-4}$	3,873 ± 623‡	265
21	97·8	$2{\cdot}032 \times 10^{-4}$	3,411 ± 263	263
24	99·1	$1{\cdot}861 \times 10^{-4}$	3,723 ± 501	265
31	99·3	$2{\cdot}141 \times 10^{-4}$	3,283 ± 378	262

* $R_t = a\ e^{-kt}$, for $t \geq 0 \leq 1{,}050$ days.

† $T = \frac{T_r \cdot T_b}{T_b + T_r}$, where T_r, the physical half-life for cerium-144, is 285 days.

‡ Best value ± one standard deviation. $T_b = 0{\cdot}693/k$; $\sigma_{T_b} = \frac{0{\cdot}693\ \sigma_k}{(k)^2}$.

Biological turnover is extremely slow with an apparent biological half-life of about 10 yr. The biological half-life (T_b) of 1,500 days currently listed for bone by the International Commission on Radiological Protection[14] would seem to be too small. For cases involving internal deposition of cerium-144 in human beings, it would seem prudent and conservative to assume that physical decay alone would account for subsequent changes in the body burden of cerium-144. Furthermore, it is possible that following previous atmospheric nuclear weapon tests small quantities of fall-out cerium-144 might have been deposited in human bone. To our knowledge this conjecture has not been verified.

This work was performed under the auspices of the U.S. Atomic Energy Commission.

C. R. RICHMOND
J. E. LONDON

Los Alamos Scientific Laboratory,
University of California,
Los Alamos, New Mexico.

[1] Hunter, H. F., and Ballou, N. E., *Nucleonics*, **9** (11), C-2 (1951).
[2] Durbin, P. W., Williams, M. H., Gee, M., Newman, R. N., and Hamilton, J. G., *Proc. Soc. Exp. Biol. and Med.*, **91**, 78 (1956).
[3] Van Dilla, M. A., *Science*, **131**, 659 (1960).
[4] Nezu, N., Asano, M., and Ouchi, S., *Science*, **135**, 102 (1961).
[5] Liebscher, K. L., Schonfeld, T., and Schaller, A., *Nature*, **192**, 1308 (1961).
[6] Wegst, A. V., Pelletier, C. A., and Whipple, G. H., *Science*, **143**, 957 (1964).
[7] Bair, W. J., *Inhaled Particles and Vapors*, edit. by Davies, C. N., 192 (Pergamon Press, London, 1961).
[8] Aeberhardt, A., Nizza, P., Remy, J., and Boilleau, Y., *Intern. J. Radiat. Biol.*, **5**, 217 (1962).
[9] Magnusson, G., *Acta Pharm. Toxicol.*, **20**, Suppl. 2 (1963).
[10] Anderson, E. C., Schuch, R. L., Perrings, J. D., and Langham, W. H., *Nucleonics*, **14** (1), 26 (1956).
[11] Van Dilla, M. A., and Anderson, E. C., *Whole Body Counting*, 41 (International Atomic Energy Agency, Vienna, 1962).
[12] Richmond, C. R., Furchner, J. E., Dean, P. N., and McWilliams, P., *Health Phys.*, **10**, 3 (1964).
[13] Spode, E., and Gensicke, F., *Z. Naturf.*, **16**, 684 (1961).
[14] Cited as a personal communication from Hamilton, J. G., to Morgan, K. Z. (February 9, 1956).

Recovery Effect of Heterologous Deoxyribonucleic Acid from Various Organs on Irradiated Mice

WE have previously shown that native homologous deoxyribonucleic acids (DNAs) can be used as therapeutic agents in irradiated animals. We showed that, for example, native homologous testes DNA significantly increases the percentage of survival of infantile rats and mice (8 and 17 days old), irradiated with a dose of 600 r.[1]. Furthermore, we obtained a positive therapeutic effect in infantile rats of the same age injected with liver DNA after irra-