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UPTAKE AND RETENTION OF ^{133}Ba AND ^{140}Ba-^{140}La IN MOUSE TISSUES

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Among the fission products found in a reactor and in nuclear weapons are several isotopes of barium. Of these, ^{140}Ba with a fission yield of 6.3 per cent and a half-life of 12.8 days (Radiological Health Handbook, 1970), seems to constitute an initial biologic hazard connected with nuclear fission. The metabolism of barium isotopes has been investigated by impulse technique in several works (STATHER 1972, 1974, MOSKALEV 1961, LINIECKI & KARNIEWICZ 1971, CUDDIHY & GRIFFITH 1970, 1972) and it is known that barium accumulates mainly in the skeleton. In spite of the close relationship between barium and strontium, barium has been found to accumulate in high concentrations in pigmented areas of the mouse eye (GARNER 1959, SIMONOVIC & PIRIE 1963) whereas strontium is not found autoradiographically in the eye (NILSSON & ULLBERG 1962). Radium, also an alcaline earth metal has, however, been found in the melanocytes of the eye (TAYLOR et coll. 1964). The precise localisation of barium seems to be a knowledge of great value for evaluating the

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pathologic effects of barium isotopes. Since ^{133}Ba is short-lived it will also offer a good opportunity for evaluating the carcinogenicity and pathology after a relatively short initial irradiation (up to 70 days) as compared to nuclides giving a life-long irradiation. Probably valuable information could be obtained about the 'wasted irradiation', the role of which for nuclides with a very long physical half-life is debated and not fully understood. The knowledge of pathologic changes caused by barium nuclides is sparse and emanates mainly from STRELTSOVA & MOSKALEV (1961), who initially found agranulocytosis, anemia, bleedings and a reduction in spermatogenesis. The most obvious late effects were chondrosarcomas of the skeleton, leukaemia and papillomas of the urinary bladder.

The purpose of this communication is to report the localisation of ^{133}Ba as recorded by whole body autoradiography in pigmented as well as in non-pigmented mice and to measure the concentrations of ^{140}Ba and ^{140}La by two-channel scintillation technique and to calculate the radiation doses in the skeleton and in the eyes after injections of the two latter nuclides in equilibrium.

Material and Methods

Animal material. Pigmented (CBA) as well as albino (NMRI) mice were used, males weighing 25 to 30 g and females about 40 g, being in late gestation. The animals were kept on a complete pellet diet (AB Ewos, Sweden) at a room temperature of 25°C and had free access to water. Male and female mice were mated overnight. The day a mouse had a vaginal plug was considered as day 1 of pregnancy.

Whole body autoradiography was performed according to a method described previously (ULLBERG 1954, 1958). $^{133}BaCl_2$ with specific activity 292.3 MBq/mg (7.9 mCi/mg), dissolved in 0.5-N HCl (obtained from the Radiochemical Centre, Amersham, England) was injected intravenously in a tail vein, each animal receiving 63 μg Ba per kg body weight, containing 18.5 MBq (500 μCi) ^{133}Ba. Male pigmented mice were killed by chloroform anaesthesia 20 minutes, 4 hours and 4, 16 and 32 days after injection. Female pigmented mice were killed at 1, 4 and 24 hours after injection on the 18th day of gestation and 6 days after injection on the 13th day of gestation. Female albino mice in late gestation were killed at 1 and 48 hours after injection. Immediately after death the animals were embedded in a mixture of carboxymethyl cellulose and water, and immersed in n-hexane, cooled to −78°C with solid carbon dioxide. Sagittal 20 μm and 60 μm sections through the frozen animal were cut on tape (No. 810, Minnesota Mining and Manufacturing Co., U.S.A.) in a microtome at −15°C, and dried at this temperature. The dried sections were allowed slowly to attain room temperature and were pressed against films (Crystallex, Kodak). The time of exposure (at −15°C) ranged from 3 to 14 days. After separation of the films from the sections, the films were developed and selected sections were stained with hematoxylin and eosin or alizarinsulfonic acid, and mounted under cover glass in Euparal (Flatters & Garnett Ltd., Manchester, England).

Impulse counting technique. ^{140}Ba in equilibrium with ^{140}La was obtained from the Radiochemical Centre, Amersham, England. The measurements were carried out with a two-channel scaler (Picker Twinscale II). Due to the complex decay scheme of ^{140}Ba and ^{140}La the measurements of the γ-spectrum could only give fairly broad energy 'peaks' with maximum values around 480 keV and 850 keV, respectively, when the 'window-width' was 20 keV. The determination of activities was always made simultaneously in the 480 keV-channel and the 850 keV-channel. The higher of the two energy channels records only radiation from ^{140}La whereas the 480 keV-channel records contributions from ^{140}La as well as from ^{140}Ba.

The number of counts per minute in the 480 keV-channel, N (480), can be expressed by the formula:

$$N(480) = \alpha A_0(Ba) \cdot e^{-\lambda_1 t} + \beta A_0(La) \cdot e^{-\lambda_2 t} + \beta A_0(Ba) \frac{\lambda_2}{\lambda_2 - \lambda_1} (e^{-\lambda_1 t} - e^{-\lambda_2 t})$$

where A_0(Ba) and A_0(La) are the initial activities of ^{140}Ba and ^{140}La respectively and α and β the corresponding ratios between CPM and the activities of the two nuclides. The two parameters, λ_1 and λ_2 are the decay constants for ^{140}Ba and ^{140}La respectively.

In a similar way the N(850) can be given as

$$N(850) = \lambda A_0(La) \cdot e^{-\lambda_2 t} + \lambda A_0(Ba) \frac{\lambda_2}{\lambda_2 - \lambda_1} (e^{-\lambda_1 t} - e^{-\lambda_2 t}).$$

When the two nuclides were in equilibrium the N(480)/N(850) ratio was found to be 2.77. By precipitating ^{140}Ba by H_2SO_4 (after the addition of inactive $Ba(NO_3)_2$ and $La(NO_3)_3$) it was possible to obtain a pure ^{140}La solution, giving a N(480)/N(850) ratio of 1.96. Since $\lambda_2/(\lambda_2 - \lambda_1) = 1.15$ we have for the ^{140}Ba$-^{140}$La decay at equilibrium:

$$\frac{2.77 \cdot 1.15 \cdot \beta}{\alpha + 1.15 \cdot \beta} = \frac{\beta}{\lambda} = 1.96, \text{ and thus } \frac{\beta}{\alpha} = 2.1.$$

By measuring the samples at various times after the death of the animals and by comparison with standard solutions it was possible to determine the parameters and A_0(Ba) and A_0(La).

Results

Autoradiography

General observations

Following administration of $^{133}BaCl_2$, activity was rapidly taken up by various tissues. Already at the earliest observation time (20 minutes) a high accumulation of activity occurred in three definite tissues: calcified tissues, the cartilage and melanin containing tissues of the pigmented animals (e.g. the eye and the hair follicles). These tissues retained activity even at the longest survival time. In other tissues a rather

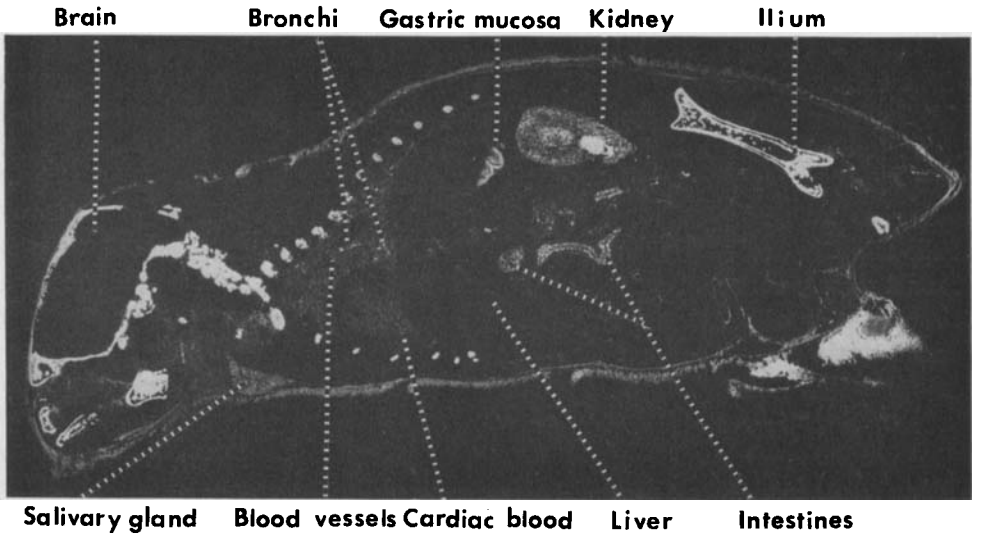

Fig. 1. Whole body autoradiography of a male pigmented mouse injected with $^{133}BaCl_2$ 20 min before death. High accumulation particularly in the skeleton, but also in the salivary gland, gastric mucosa, intestinal villi, kidney, bronchial walls and blood vessels. Moderate uptake in the blood and lung tissues.

rapid clearance of the isotope occurred. Four days after the injection, activity was found (in addition to the bone, cartilage and melanin) only in the intestinal content and the urinary tract—indicating excretion of the isotope. Also 32 days after the injection, a small amount was present in these organs.

The circulatory system

The initial concentration of the isotope in the blood was rather high. Also 4 hours after the injection, activity was present in the blood in concentrations higher than that in the liver and muscular tissues. At short survival time (up to 1 hour) a moderate uptake was seen in the walls of the large vessels (Fig. 1). The myocardium had a low content throughout the entire observation period.

Calcified tissues

In all bones of the body the isotope accumulated rapidly. In the long bones and vertebrae, at short time intervals, the accumulation in the epiphyseal region was predominant with a somewhat lower concentration in the periosteum and endosteum of the diaphysis (Fig. 2). At the longest survival times, however, the initial relations had changed. In the long bones the activity in the diaphysis dominated and the relations between the periosteum and endosteum differed from one region of a particular bone to another. The epiphyseal regions had a much lower concentration. In the vertebrae, however, the accumulation in the epiphyseal growth cartilage was still greater or was comparable to that in the diaphyseal areas.

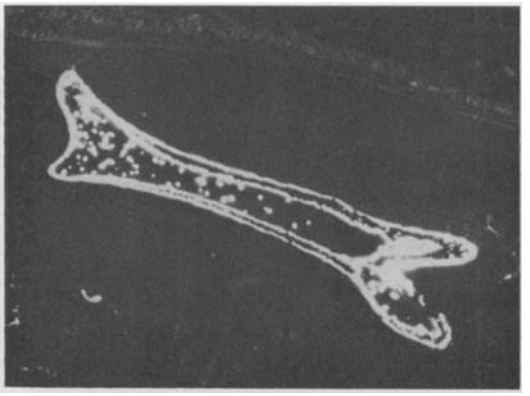

Fig. 2. Detail of Fig. 1, ilium. High accumulation especially in the epiphyseal growth cartilage and also in the periosteum and endosteum.

Skull. An accumulation similar to that of the vertebrae was found in the bones of the skull base. The membranous bones of the skull had a relatively high initial uptake, which then successively decreased—being rather low 32 days after the injection.

Teeth. The dentine had an early accumulation higher than that of the surrounding bone. A similar relationship was found between dentine and bone 6 days after injection but at 32 days the activity of the dentine had decreased considerably.

The cartilage. At short time intervals a high accumulation of the isotope was present in the cartilage of the articular surfaces and the tracheal rings, while the concentration in the cartilage of the external ear seemed to be lower, possibly depending on the delicacy of the structure. After 32 days activity was still retained in the articular and tracheal cartilage but the former cartilage seemed to have lost most of its activity.

The eye

Pigmented mice. At the first observation time the concentration of the isotope was already high in the uveal tract of the pigmented animals. This accumulation together with that of the calcified tissues and cartilage was the highest in the body. No correspondingly high activity was found in the eye of albino mice. The activity was also retained in the pigmented eye at the longest survival times, when the concentration still was comparable with the average of the bone (Fig. 3).

Albino mice. One hour after injection, the uveal tract of albino mice had an uptake that was somewhat higher than that of other soft tissues, but not of the magnitude of that found in pigmented mice. Two days after injection, the entire uveal tract except the corpus ciliare and iris had lost almost all activity (Fig. 4).

The digestive system

In the salivary system the submaxillary gland accumulated activity (Fig. 1). The secretory part of the gastric mucosa had a marked uptake, especially in the basal

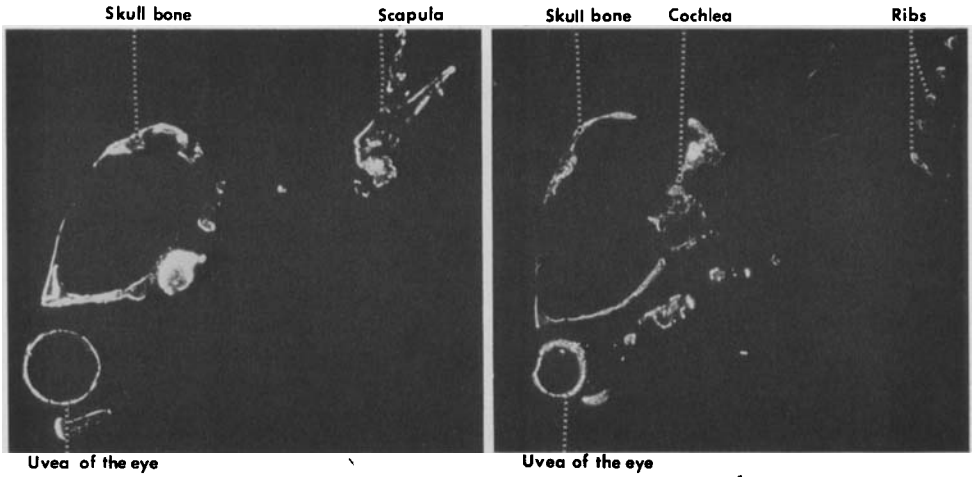

Fig. 3. Detail of the autoradiography of pigmented mice a) 6 days and b) 32 days after the injection of $^{133}BaCl_2$. Only in the skeleton and in the uvea of the eye is the uptake equally high in both structures. × 3

layers. The mucosa of the small intestine also accumulated activity at short survival times, while at longer times the intestinal content, especially that of the large intestine had a high content. After 48 hours, activity was still left in the salivary gland, the gastric mucosa and the intestinal contents. Also 32 days after injection, small amounts of activity was found in the content of the large intestine.

The liver and exocrine pancreas had a low concentration—lower than that of the blood. Four hours after injection, the activity was hardly discernible.

The respiratory organs

A faint uptake of activity occurred in the epithelium of the upper part of the respiratory apparatus. In the lungs the concentration was about the same as in the blood, but the bronchi and the large bronchioli had a marked uptake (Fig. 1). This accumulation persisted for 4 hours but not 24 hours after the injection.

The urinary system

Already 20 minutes after injection, the whole kidney had accumulated considerable amounts of activity. Especially a high content was seen in certain, not identifiable spots and streaks in the cortex, the collecting tubules of the medulla and in the pelvis. Also the urinary bladder and urethra contained high amounts of the isotope. After 24 hours the localised uptake in the cortex persisted and at 48 hours small amounts of activity was seen in the kidney as a whole. At 16 days after the injection, activity was still found in the urinary bladder.

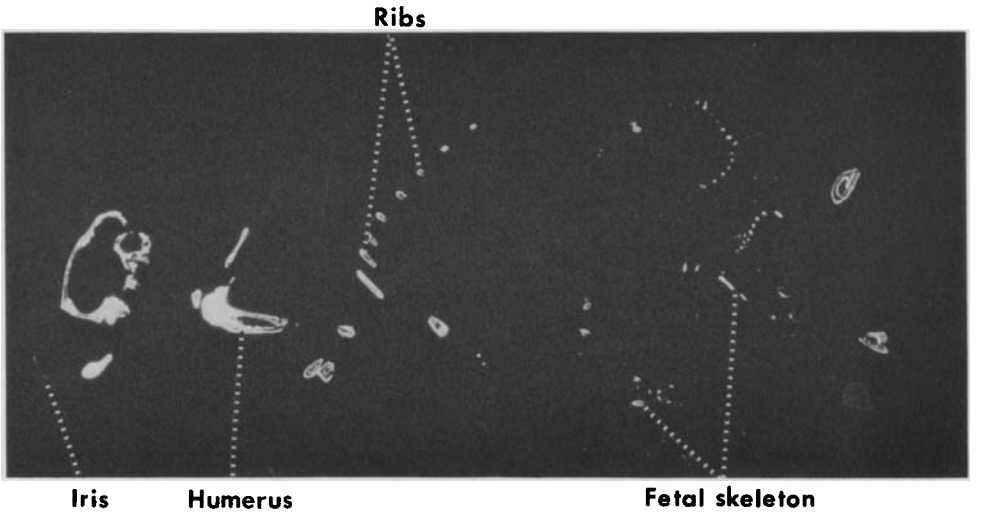

Fig. 4. Whole body autoradiography of an albino mouse in late gestation 2 days after the injection of $^{133}BaCl_2$. High accumulation in both the maternal and fetal skeleton. No activity in the uvea of the maternal eye except for a moderate uptake in the corpus ciliare and iris.

The reproductive system

Male. The uptake in the testes was lower than in the blood at all observation periods. No discernible uptake was found in the tubuli, while the interstitial part had a low uptake giving the testis a spotty appearance (Fig. 5). After 4 hours the activity in the testis was hardly visible. The epididymis, on the other hand, had a higher concentration of activity, comparable with that of the blood.

In the dorsal prostate a remarkably high uptake was present at 20 minutes but not later, while the concentration in the ventral prostate and the seminal vesicles did not reach that of the blood.

Female. All female mice were in a late stage of pregnancy. The interstitial tissue of the ovaries was at the level of the blood, while the corpora lutea had a lower concentration. In some follicles, however, parts of the walls had a considerably higher concentration than the surrounding interstitium (Fig. 6). This was also observed at 4 hours but at 24 hours no activity was present in the ovary.

The alveolar part of the mammary gland accumulated activity and 6 days after injection it still retained moderate amounts.

The endocrine organs

The hypophysis had a higher concentration of activity than the surrounding nervous system, comparable with that in the blood. The thyroid had an equivalent uptake and retained some of its activity 2 days after injection when the blood did

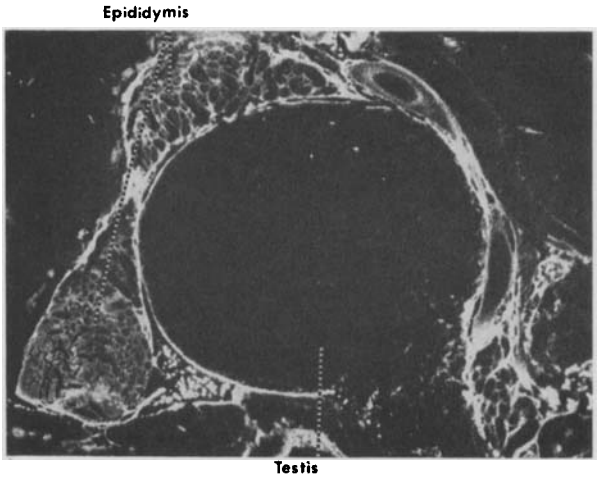

Fig. 5. Detail of an autoradiography of a male mouse 20 min after the injection of $^{133}BaCl_2$. Testis and epididymis. Low uptake in the interstitial tissues of the testis and a higher uptake in the epididymis.

not have any detectable activity. The adrenal gland had a low concentration at all survival times. In the medulla and in a thin rim of the outer cortex close to the capsula a somewhat higher uptake was present that persisted for only 1 hour after injection. In the pancreatic islands a considerable uptake was present, high at 24 hours after injection and also significant at 2 days.

The nervous system

In the plexa choroidea, activity could be seen from the first observation time and up to 4 days after injection when it was very faint. From the beginning the concentration in the central nervous system was very low but at 4 and 24 hours detectable amounts were present, especially in the brain stem and medulla oblongata. Due to cross radiation from the bone, the uptake in the spinal cord could not be evaluated.

The lymphatic system

The thymus had a low activity in all animals. Also the spleen had a low concentration, that of the red pulp being higher than that of the white. At 2 days, activity was still retained in a narrow zone of the red pulp surrounding the white pulp of the spleen. The lymph nodes did not seem to accumulate the nuclide.

The muscles and skin

At all observation periods a low concentration was present in the muscular tissues. Connective tissues had a concentration comparable with that of the blood. Also the epidermis had a moderate uptake seen also 24 hours after injection.

In the pigmented animals activity remained in the hair follicles of the nose (vibris-

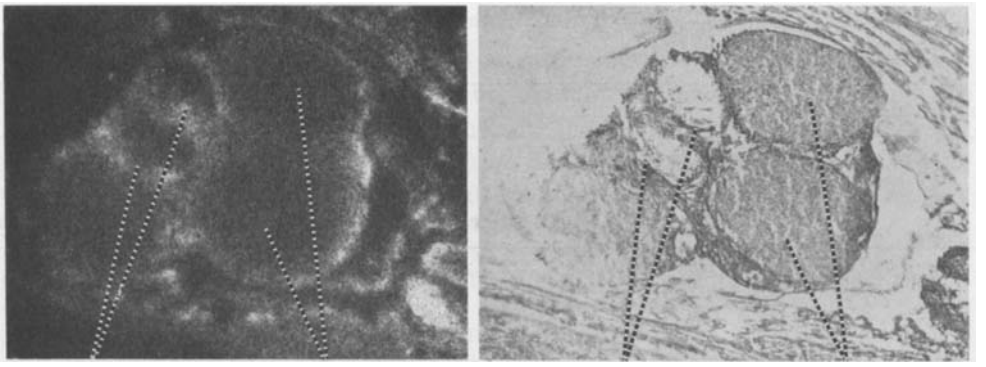

Fig. 6. a) Detail of an autoradiography, b) the corresponding section of a pregnant pigmented mouse 1 hour after the injection of $^{133}BaCl_2$. Slight uptake in the interstitium and the walls of the follicles, while low in the corpora lutea.

sae) 32 days after injection, while no similar accumulation was found in the albino mice even at 48 hours.

The placentae and fetuses

One hour after injection, on the 18th day of gestation. Already at this first observation time the skeleton completely dominated the distribution within the fetus. The skeletal uptake, however, was considerably lower than the maternal one. The cartilage had a considerable lower activity and the soft tissues were hardly discernible. Within the bone, the growth zones predominated.

Of the melanin-containing organs only the eye had any uptake and this was restricted to the ciliary body where the amount of melanin at this stage of development is high in comparison with the choroid (personal observation). The pelvis of the kidney and the urinary bladder also contained small amounts of activity.

The placenta had an activity comparable with blood and certain spots within the placenta an uptake comparable with bone. These spots were restricted to the sinus area (where the fetal vessels and the yolk sac enters the chorio-allantoic placenta) and to the decidua basalis.

Four hours. At this survival time the uptake in the skeleton was even more dominating compared with the soft tissues but was still lower than that in the maternal one. In the soft tissues activity was seen in the lungs, especially in the bronchi, the gastric mucosa and the renal pelvis. A moderate uptake was present in the cartilage and the ciliary body.

Table

Activity concentration × 10^3/injected activity

Time after injection	Sternum			Femur			Lumbar vertebrae			Eyes		
	^{140}Ba/g	^{140}La/g	La/Ba (per cent)	^{140}Ba/g	^{140}La/g	La/Ba (per cent)	^{140}Ba/g	^{140}La/g	La/Ba (per cent)	^{140}Ba/g	^{140}La/g	La/Ba (per cent)
45 minutes				63.1	14.5	23				9.58	1.44	15
3 hours	44.6	19.6	44	76.7	33.7	44	51.9	22.8	44	32.9	11.5	35
24 hours	22.7	22.7	100	56.0	32.2	58	41.1	22.6	55	39.0	20.2	52
6 days	14.4	16.2	112	40.5	40.6	100	26.1	26.1	100	36.8	33.3	91
14 days	9.27	10.7	115	23.8	27.4	115	14.9	17.1	115	25.1	28.9	115
21 days	4.34	4.98	115	13.9	15.9	115	7.77	8.93	115	15.0	17.3	115
28 days	3.72	4.27	115	10.2	11.8	115	5.45	6.27	115	10.2	11.7	115
58 days	0.480	0.554	115	1.52	1.75	115	0.793	0.912	115	1.54	1.77	115
92 days	0.005	0.063	115	0.226	0.260	115	0.096	0.110	115	0.178	0.206	115

Twenty-four hours. The soft tissues were at this survival time almost completely cleared from activity but the bone and the ciliary body of the eye still contained activity.

Forty-eight hours. (Albino mouse in late gestation, Fig. 5.) Only the skeletal tissues retained the isotope. The concentration was lower than that of the maternal skeleton. No accumulation was found in the ocular tissues.

Six days after the injection on the 13th day of gestation. In comparison with the animals injected in late gestation, this mouse had a low uptake of activity in the fetal skeleton. A slight uptake was also found in the ciliary body. At this survival time like all the others, the spotty uptake of activity observed in certain placental structures was high, indicating that the spots corresponded to calcified loci.

Impulse counting technique

Uptake and retention of ^{140}Ba and ^{140}La

The uptake and retention of ^{140}Ba and ^{140}La in the femur, sternum lumbar vertebrae and in the eyes at different times after the injection of the two nuclides in equilibrium are given in the Table.

At two weeks after the injection equilibrium between ^{140}Ba and ^{140}La has been achieved in all the organs examined. Initially, the concentrations of ^{140}Ba were higher than those of ^{140}La. This discrimination was most obvious in the eyes.

By regression analysis of the figures from the 14th day after the injection and onwards, the biologic half-lives of Ba in the organs could be determined: femur 129 days, sternum 67 days, lumbar vertebrae 73 days and eyes 78 days.

Dose calculations

The dose calculations have been based on the retention curves. Between day 0 and 14, the surfaces under the curves have been determined planimetrically. From the second week after the injection and onwards the retention curves have been approximated by exponential curves that have been received by regression analysis of the retention figures. The total dose to a certain organ can be expressed by

$$D(tot) = 0.512 \left[\int_0^\infty F_{Ba}(t) \cdot \bar{E}_{Ba} \cdot \phi_{Ba}(x)\, dt + \int_0^\infty F_{La}(t) \cdot \bar{E}_{La} \cdot \phi_{La}(x)\, dt \right] \text{Gy}$$

where F(t) are the retention functions (remaining activity per g organ at time t), $\bar{E}$ the mean energies and ϕ the ratio between the true mean dose in the organ 'x' and that in an infinite medium of the same density and in which the concentration of the activities of ^{140}Ba and ^{140}La are the same as those found in the organs. The dose contribution from the γ-radiation is negligible as compared to the β-radiation and the mean energies are accordingly equal to the mean β-energies from ^{140}Ba and ^{140}La respectively. The numerical values of the mean β-energies ($\bar{E}_{Ba} = 0.282$ MeV and $\bar{E}_{La} = 0.490$) have been derived from Radiological Health Handbook (1970).

The ϕ-parameters are unknown. The absorbed β-energy from ^{90}Sr–^{90}Y is 32 per cent (PARMLEY et coll. 1962). The corresponding figure for ^{140}Ba–^{140}La should be around 45 per cent if the activity distribution can be regarded as equal for the two nuclide systems. This might be approximately true for the bone tissue but certainly not for the eyes. The micro distribution of the dose in bones is uncertain for ^{90}Sr and ^{90}Y and unknown for ^{140}Ba and ^{140}La.

The injection of 37 kBq (1 μCi) ^{140}Ba in equilibrium with ^{140}La would give the following doses:

Sternum: $4.9 \cdot \phi_{Ba}(S) + 9.2 \cdot \phi_{La}(S) = 0.061$ Gy (6.1 rad)

Femur: $13.5 \cdot \phi_{Ba}(F) + 23.4 \cdot \phi_{La}(F) = 0.166$ Gy (16.6 rad)

Lumbar vertebrae: $8.3 \cdot \phi_{Ba}(LV) + 14.1 \cdot \phi_{La}(LV) = 0.101$ Gy (10.1 rad)

Eyes: $12.4 \cdot \phi_{Ba}(E) + 21.1 \cdot \phi_{La}(E)$ (see below)

The figures obtained are rough doses calculated on basis of the β-spectra for the systems ^{90}Sr–^{90}Y and ^{140}Ba–^{140}La and the absorption value (45 per cent) may differ in different parts of the skeleton.

The ratios $\phi_{Ba}(E)$ and $\phi_{La}(E)$ can be calculated a little more accurately on basis of the choroid concentration of the two nuclides. The dose to the inner surface of the choroid (= the dose to the retina) has thus been calculated under the assumptions of a uniform distribution of activity in the approximately spherical shell of the choroid (Fig. 3), unit density of the eye (ICRP 23, 1975), and according to the formulas for the β-doses from spherical shells as given by LOEVINGER et coll. (1956). The γ-dose has been considered negligible. The β-spectra of ^{140}Ba and ^{140}La have been derived from the Radiological Health Handbook.

The mean concentrations of the nuclides ^{140}Ba and ^{140}La in the eyes as given in the Table, have to be multiplied by 7.5 to correct for the fact that the activity is concentrated in the choroid and not homogeneously distributed over the entire eye.

The calculations gave for the outer surface of the retina (i.e. the inner surface of the choroid):

$$\phi_{Ba}(E) = 1.56 \quad \text{and} \quad \phi_{La}(E) = 1.24$$

The dose to this region will accordingly be 0.455 Gy (45.5 rad) after an injection of 37 kBq (1 μCi) ^{140}Ba in equilibrium with ^{140}La. The dose decreases towards the centre of the vitrious body of the eye. The central dose is 27 per cent of that in the retina, i.e. 0.12 Gy (12 rad).

Discussion

The distribution of ^{133}Ba is similar to that of ^{90}Sr as regards the high uptake in the skeleton. Thus there is initially a high concentration in the epiphysial regions and in the periosteum and endosteum, later followed by a predomination of the activity in diaphysial parts of the bones. In the membraneous bones of the skull ^{133}Ba (like ^{90}Sr) was taken up strongly initially but was retained to a lesser degree than in the long bones.

On the other hand ^{133}Ba seems to have less specific affinity to the hard tissue than ^{90}Sr. Four hours after injection of ^{90}Sr activity had practically completely disappeared from the soft tissues with the exception of the excretory pathways. However, ^{133}Ba could still, 48 hours after administration, be discerned in the mammary gland. In the pancreatic islands, the thyroid and red pulp of the spleen the activity remained at 2 days. The most marked soft tissue uptake was in pigmented tissues of the eye and hair follicles. In pigmented tissues the activity seemed to be almost as high and long lasting as in the skeleton. In albino mice no such uptake was found.

^{90}Sr does not accumulate in significant amounts to be detected by autoradiography of the eye. Radium on the other hand (TAYLOR et coll.) seems to be taken up in dogs in significant amounts in the iris and in combined retinal and choroid samples.

Lesions were also observed within 20 days after single and intravenous injection of 370 kBq (10 μCi) of ^{226}Ra per kg body weight. These lesions consisted in partial or complete loss of the tapetum and depigmentation of the choroid and iris. After relatively low doses, 1.85–12.95 kBq (0.05–0.35 μCi) ^{226}Ra/kg, the lesions were limited to the iris and consisted of hyperpigmented plaques. Results of microscopy of the eyes are not yet available, but inspection indicates opacity of the eyes and possible blindness.

LAMBERTS & VON ANDEL (1965) have found a fluctuating concentration of ^{133}Ba in the aortic wall of rats. The concentration started to rise on the 35th day after the administration of the nuclide, then began to decrease on the 49th day, rose again on the 63rd day, reached a top on the 77th day, fell again and commenced to rise on the 91st day, reaching a maximum level on the 98th day. On the 105th day the

concentration was practically 0. The duration of the present autoradiography was unfortunately too short to observe this effect. Scintillation counting revealed an activity concentration in the aorta of about 10 per cent of that in the femur 3 hours after the injection. The activity in the aorta disappeared, however, rapidly and could not be measured during the period 2 weeks to 3 months after the injection.

The calculated radiation doses to the sternum, femur, lumbar vertebrae and pigmented structures of the eye were of a great interest as compared to the carcinogenic ^{90}Sr-doses. Preliminary results indicate that ^{140}Ba is able to produce tumours of the skeleton (C_{57} Bl-mice) at significantly lower dose levels than ^{90}Sr (CBA-mice) and that female mice of this strain are much more susceptible to irradiation than males, as has been found for ^{90}Sr in the CBA strain (NILSSON 1967). In a group of 50 C_{57}Bl female mice given 55.5 kBq (1.5 μCi) ^{140}Ba per g body weight, 28 per cent had macroscopic bone tumours mainly in the long bones and the spine against 2 per cent in the control group. The approximate irradiation dose to the femur in this group was about 5 Gy (500 rad) and 3 Gy (300 rad) to the vertebrae. In female CBA mice sarcomas were found in 6 per cent of the mice at a dose level of 1.85 kBq (0.05 μCi) ^{90}Sr/g body weight and in 15 per cent when 3.7 kBq (0.1 μCi) ^{90}Sr/g body weight was given. The majority of these tumours were sited in the femur and the doses calculated were 33 and 56 Gy (3 300 and 5 600 rad), respectively. One possible explanation for this dose-response difference may be 'wasted irradiation', i.e. the irradiation exposure to the organ after the formation of the initial malignant clones. Such a 'wasted irradiation' may even hamper further growth of the cellular proliferation in the clones. The initial dose rate from 55.5 kBq (1.5 μCi) ^{140}Ba/g body weight is of course much higher than that after injections of 3.7 kBq (0.1 μCi) ^{90}Sr/g body weight. There might also be some strain differences.

Acknowledgement

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SUMMARY

The distribution of barium in the mouse has been determined qualitatively by whole-body autoradiography after i.v. administration of $^{133}BaCl_2$ solution. The quantitative distribution of ^{140}Ba and ^{140}La has been analyzed after i.p. injections of the two nuclides in equilibrium by measuring the activity in excised organs in a two-channel scintillation counter. Approximate doses to the eyes and different parts of the skeleton have been calculated.

ZUSAMMENFASSUNG

Die Verteilung von Barium in der Maus durch Gesamtkörper Autoradiographie nach intravenöser Administration von $^{133}BaCl_2$-Lösung wurde qualitativ untersucht. Die quan-

titative Verteilung von ^{140}Ba und ^{140}La wurde nach i.p. Injektionen dieser beiden Nuclide im Gleichgewicht durch Aktivitätsmessungen der entnommenen Organe in einem Zwei-Kanal Scintillationsrechner analysiert. Die ungefähren Dosen für die Augen und die verschiedenen Teile des Skeletts wurden berechnet.

RÉSUMÉ

La distribution du baryum dans des souris a été déterminée qualitativement par autoradiographie corporelle totale après administration intra-veineuse d'une solution de $^{133}BaCl_2$. La distribution quantitative de ^{140}Ba et de ^{140}La a été étudiée après injection intrapéritonéale de ces deux nuclides en équilibre en mesurant l'activité d'organes prélevés au moyen d'un compteur à scintillation à deux canaux. Les auteurs ont calculé la dose approximative aux yeux et à différentes parties du squelette.

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