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# Retention of Radiocobalt by Hair, Bone and Vascular Tissue[1,2]

William H. Strain,[3] William P. Berliner,[3] F. Thomas Tangeman,[3] Charles A. Lankau, Jr.,[3,4] and Walter J. Pories, Major, MC, USAF[5]

*Rochester, New York, and Wright-Patterson AFB, Ohio*

## INTRODUCTION

Studies on the tissue uptake of radioisotopes have shown that hair retains significant amounts of iodine-131 (1), selenium-75 (2), strontium-90 (3-6), sulfur-35 (7), vanadium-48 (8), and zinc-65 (9-12). The more recent investigations on strontium-90 indicate that the hair level reflects the body status of this radionuclide. This finding is being examined currently as a nondestructive method of determining the body burden of radiostrontium (5-6).

Since so many radioisotopes accumulate in hair, it is desirable to understand the factors that regulate the content of stable elements and radioelements in this and related structural proteins. An elaboration of the roles these high molecular weight proteins play as metabolic pools and spaces for radionuclides is pertinent to both nuclear medicine and radioecology. To initiate this elaboration it is necessary to study *in vivo* the distribution of radionuclides in specific organs which have a differential content of these structural proteins.

Radiocobalt is especially suitable for investigating the factors that regulate the differential retention of radionuclides in the various types of tissues, since the stable Co content of all tissues is extremly low.[1] Thus, the distribution of this radioelement may be contrasted with previous studies on radiovanadium (8), and radiozinc (12), whose stable forms are more abundantly present in the

[1]From the Department of Radiology, School of Medicine and Dentistry, University of Rochester, Rochester, New York, and USAF Hospital, Wright-Patterson AFB, Ohio.

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[3]School of Medicine and Dentistry, University of Rochester, Rochester, New York.

[4]Present address: Department of Surgery, Albert Einstein College of Medicine, Yeshiva University, New York, New York.

[5]USAF Hospital, Wright-Patterson AFB, Ohio.

[1]Data on the cobalt content of mammalian tissue are conflicting. The standard 70 kg. man may contain 1.1 milligrams of cobalt according to ICRP, but Yamagata, N., Murato, S., and Torii, T.: The Cobalt Content of Human Body. *J. Rad. Res., 3:4*, March 1962, suggest that the true value is only one-third as high.

tissues. Further, it is known that Co chelates dissociate *in vivo* (13), so that tissue distributions measured in experimental animals are probably realized qualitatively in man whenever radiocobalt preparations, such as cyanocobalamin, are employed clinically. Finally, the metabolism of this radioelement is important since cobalt-57, -58, and -60 are present in fallout (14), and cobalt-60 has been proposed as a constitutent of the superbomb.

The differential retention of radiocobalt by various structural proteins was studied by measuring the retention of cobalt-58 in the aorta, blood, femur, hair, kidney, and liver of young and old rats of both sexes. The retention studies were carried out with cobalt-58 (T/2, 70 days) chloride because disposal of radioactive tissues is much easier with this radioisotope than with the longer-lived cobalt-57 (T/2, 270 days). The investigations were conducted over a 20-day period in order to follow the redistribution of radiocobalt in selected rat tissues with the passage of time. These retention data have been evaluated with respect to: (i) previous studies on stable and radiocobalt retention and excretion in cattle (15-17), dogs (18), rabbits (16), rats (17, 19-23), sheep (24), swine (16, 25), and man (26-27); (ii) the stable element content of several tissues; and (iii) the effects of age and sex.

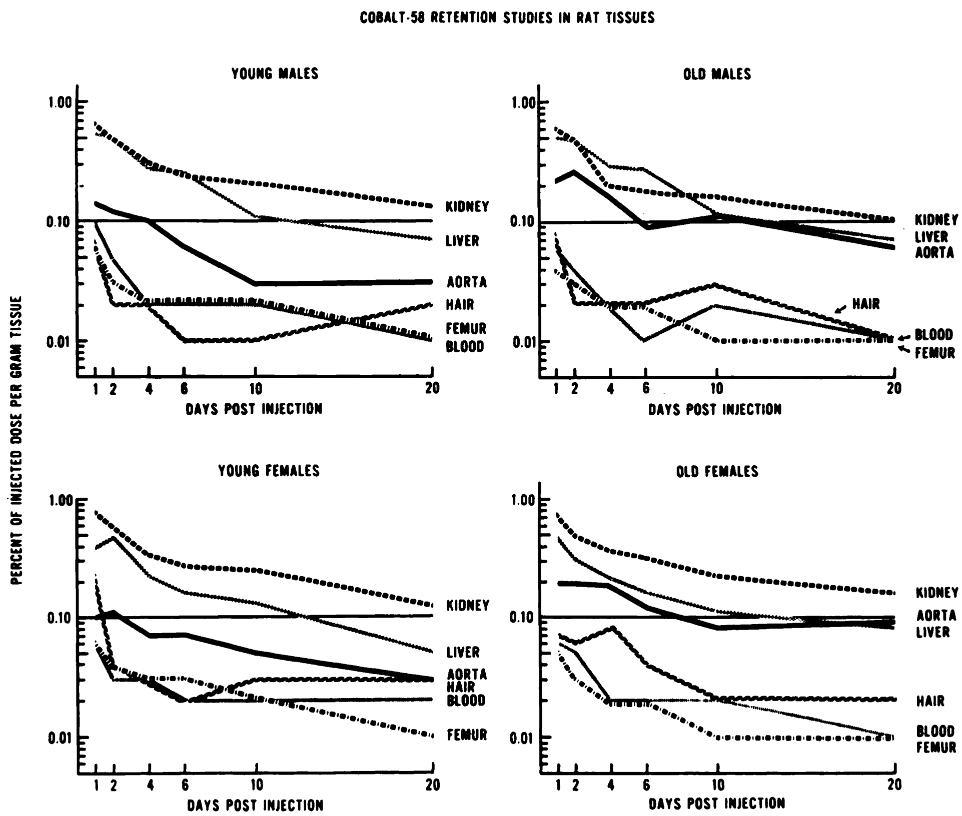


**Fig. 1. Cobalt-58 retention values for six tissues in young and old, male and female rats. The retention is relatively high in aorta, kidney, and liver. Only aorta shows the effects of age.**

TABLE I

COBALT-58 RETENTION IN PERCENT OF INJECTED DOSE PER GRAM TISSUE[1]

| *Days post injection* | *Young females* | *Old females* | *Young males* | *Old males* |
|---|---|---|---|---|
| | | A. Aorta | | |
| 1 | 0.10 ± 0.04 | 0.19 ± 0.11 | 0.15 ± 0.04 | 0.21 ± 0.05 |
| 2 | 0.11 ± 0.03 | 0.19 ± 0.05 | 0.12 ± 0.02 | 0.25 ± 0.06 |
| 4 | 0.07 ± 0.02 | 0.18 ± 0.12 | 0.10 ± 0.05 | 0.16 ± 0.06 |
| 6 | 0.07 ± 0.03 | 0.12 ± 0.04 | 0.06 ± 0.02 | 0.09 ± 0.05 |
| 10 | 0.05 ± 0.03 | 0.08 ± 0.02 | 0.03 ± 0.01 | 0.12 ± 0.04 |
| 20 | 0.03 ± 0.01 | 0.09 ± 0.02 | 0.03 ± 0.02 | 0.06 ± 0.02 |
| | | B. Blood | | |
| 1 | 0.06 ± 0.01 | 0.06 ± 0.01 | 0.06 ± 0.01 | 0.06 ± 0.01 |
| 2 | 0.03 ± 0.01 | 0.05 ± 0.01 | 0.05 ± 0.02 | 0.04 ± 0.02 |
| 4 | 0.03 ± 0.01 | 0.02 ± 0.01 | 0.02 ± 0.00 | 0.02 ± 0.00 |
| 6 | 0.02 ± 0.00 | 0.02 ± 0.00 | 0.02 ± 0.00 | 0.01 ± 0.00 |
| 10 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.02 ± 0.00 | 0.02 ± 0.00 |
| 20 | 0.02 ± 0.01 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 |
| | | C. Femur | | |
| 1 | 0.06 ± 0.02 | 0.05 ± 0.01 | 0.06 ± 0.00 | 0.04 ± 0.02 |
| 2 | 0.04 ± 0.01 | 0.03 ± 0.01 | 0.03 ± 0.01 | 0.03 ± 0.00 |
| 4 | 0.03 ± 0.01 | 0.02 ± 0.00 | 0.02 ± 0.01 | 0.02 ± 0.01 |
| 6 | 0.03 ± 0.01 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.02 ± 0.00 |
| 10 | 0.02 ± 0.01 | 0.01 ± 0.00 | 0.02 ± 0.00 | 0.01 ± 0.01 |
| 20 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 | 0.01 ± 0.00 |
| | | D. Hair | | |
| 1 | 0.20 ± 0.06 | 0.07 ± 0.08 | 0.06 ± 0.05 | 0.07 ± 0.06 |
| 2 | 0.04 ± 0.04 | 0.06 ± 0.03 | 0.02 ± 0.00 | 0.02 ± 0.01 |
| 4 | 0.03 ± 0.00 | 0.08 ± 0.09 | 0.02 ± 0.01 | 0.02 ± 0.00 |
| 6 | 0.02 ± 0.00 | 0.04 ± 0.01 | 0.01 ± 0.01 | 0.02 ± 0.00 |
| 10 | 0.03 ± 0.02 | 0.02 ± 0.01 | 0.01 ± 0.00 | 0.03 ± 0.01 |
| 20 | 0.03 ± 0.01 | 0.02 ± 0.01 | 0.02 ± 0.01 | 0.01 ± 0.01 |
| | | E. Kidney | | |
| 1 | 0.77 ± 0.16 | 0.71 ± 0.09 | 0.68 ± 0.08 | 0.63 ± 0.09 |
| 2 | 0.55 ± 0.04 | 0.48 ± 0.11 | 0.50 ± 0.05 | 0.49 ± 0.07 |
| 4 | 0.35 ± 0.01 | 0.36 ± 0.10 | 0.30 ± 0.03 | 0.20 ± 0.13 |
| 6 | 0.28 ± 0.06 | 0.31 ± 0.09 | 0.25 ± 0.01 | 0.18 ± 0.08 |
| 10 | 0.24 ± 0.05 | 0.21 ± 0.02 | 0.20 ± 0.01 | 0.16 ± 0.01 |
| 20 | 0.12 ± 0.02 | 0.16 ± 0.06 | 0.14 ± 0.03 | 0.10 ± 0.01 |

[1]All values given represent the mean of the four rats sacrificed for each group at the various time intervals, plus or minus the standard deviation.

TABLE I—Cont'd

COBALT-58 RETENTION IN PERCENT OF INJECTED DOSE PER GRAM TISSUE[1]

| *Days post injection* | *Young females* | *Old females* | *Young males* | *Old males* |
|---|---|---|---|---|
| | | F. Liver | | |
| 1 | 0.39 ± 0.10 | 0.46 ± 0.11 | 0.53 ± 0.08 | 0.50 ± 0.15 |
| 2 | 0.45 ± 0.07 | 0.30 ± 0.06 | 0.50 ± 0.16 | 0.48 ± 0.07 |
| 4 | 0.22 ± 0.06 | 0.21 ± 0.04 | 0.27 ± 0.07 | 0.30 ± 0.23 |
| 6 | 0.16 ± 0.02 | 0.17 ± 0.10 | 0.26 ± 0.03 | 0.27 ± 0.21 |
| 10 | 0.13 ± 0.07 | 0.11 ± 0.01 | 0.11 ± 0.05 | 0.12 ± 0.03 |
| 20 | 0.05 ± 0.00 | 0.08 ± 0.03 | 0.07 ± 0.03 | 0.07 ± 0.02 |

## METHODS

Sprague-Dawley rats, maintained on Purina Laboratory Chow with free access to food and water, were used. The experiments were conducted over a 20-day period with groups consisting of young males, young virgin females, old breeder males, and old breeder females. The young rats were three to four months old, the males weighing 350-450 gms and the females, 240-300 gms. The old breeder rats were over one year in age, the males weighing 400-540 gms and the females, 300-390 gms. The radioisotope was obtained from Oak Ridge as carrier-free $^{58}CoCl_2$ in HCl solution. All rats were injected without anesthesia, via the tail vein, with 1 ml of normal saline containing approximately 5 $\mu$C cobalt-58. Four rats from each group were sacrificed on the first, second, fourth, sixth, tenth, and twentieth day post injection. Aorta, blood, femur, hair, kidney, and liver samples were weighed fresh and analyzed for cobalt-58 content in a well-type gamma scintillation counter. Correction for decay was made by comparison against a standard. The data were analyzed by computer, using the *FORTRAN* program developed by Strain et al (28).

Commercially available bovine protein fractions and locally collected bovine and murine hair were analyzed spectrographically to determine the levels of stable element content of collagen, keratin, and elastin.[1]

## RESULTS AND DISCUSSION

The retention data, expressed as percent of injected dose per gram tissue for the individual tissues, are presented in Table I and illustrated graphically in Fig. 1. All values given represent the mean of the four rats sacrificed for each group at the various time intervals. The radiocobalt retention is low, chosen as less than 0.20 percent of the injected dose, in blood, femur, and hair. It is high,

[1]The bovine proteins were obtained from Nutritional Biochemicals Corporation, Cleveland 29, Ohio. The spectrographic analyses were performed by the National Spectrographic Laboratories, Inc., Cleveland 3, Ohio.

or greater than 0.20 percent, in aorta, kidney, and liver. These results agree well with the previous studies on cattle (15-17), rabbits (16), rats (17, 19-23), sheep (24), and swine (16, 25), which show that radiocobalt uptake is consistently high in kidney and liver, the main pathways of Co excretion.

Differences in retention of radiocobalt by aorta, femur, and hair may be interpreted as being related to the distribution and elemental composition of collagen, elastin, and keratin. Aorta contains both collagen and elastin; femur, which is rich in collagen, contains little or no elastin; and hair contains keratin, a unique structural protein, and is free of collagen and elastin. As determined by spectrographic analysis, the Co, V, and Zn content of five bovine or murine proteins is given in Table II. Cobalt is not detectable in the two collagens and keratins, and is found only to the extent of 0.1 parts per million (ppm) in elastin. Vanadium is present in variable quantities up to 2.0 ppm in bone gelatin. Zinc is detected in amounts ranging up to 400 ppm, depending on the protein. In recent retention studies by Strain et al (8, 12), it was shown that both aorta and femur retain relatively large amounts of vanadium-48 and zinc-65. The present investigations show that aorta similarly has a high uptake of cobalt-58, whereas, femur retains very little of this radioelement. It was also found in the earlier work that hair retains comparatively little vanadium-48, but continues to accumulate zinc-65 with the passage of time. The present data indicate that relatively little cobalt-58 is accumulated by hair, similar to vanadium-48. Thus, the differences in the retention patterns of cobalt-58, vanadium-48, and zinc-65 can probably be attributed to the proteins behaving like ion exchange resins: elastin binds all three elements; the collagens preferentially chelate V and Zn; and hair keratin selectively accumulates Zn.

Only aortic tissue shows the effect of age on the retention of radiocobalt. Aortas of old breeder male and female rats retain from two to four times more cobalt-58 than young rats. This increased retention may be due to mineralization of the aorta with age since old rats, especially old breeder females, show gross evidence of aortic sclerosis. The numerous investigations on spontaneous development of arteriosclerosis in repeatedly bred male and female rats were summarized by Wexler (29) in 1964. Arterial lesions were evidenced in both the male and female breeder rats, although the atheromata were more easily recognizable in

TABLE II

MINERAL CONTENT OF COLLAGEN, ELASTIN, AND KERATIN (in ppm)

| *Element* | *Elastin (Ligamentum Nuchae)* | *Collagen (Achilles Tendon)* | *Collagen (Bone Gelatin)* | *Keratin (Bovine Hair)* | *Keratin (Murine Hair)* |
|---|---|---|---|---|---|
| Cobalt | 0.1 | <0.1 | <0.5 | <0.1 | <0.2 |
| Vanadium | 0.7 | <0.1 | 2.0 | <0.1 | 0.04–0.05 |
| Zinc | 10. | 25. | <10–400 | 70. | 63–97 |

the latter groups. Lansing et al (30) have shown that in older rats there is a shift in the relative amino acid composition of elastin, producing an increased content of free carboxyl groups. Zinsser et al (31) have further found that aging is accompanied by an increased metal content in the aorta. Perhaps the greater uptake of radiocobalt by old male and female rats, the increase in the metal content of aorta with aging, and the sclerotic changes evidenced in the repeatedly bred male and female rats are related to an increased availability of metal-binding sites. This enhanced availability may be due to the change in elastin composition with aging which produces an alteration in the chemical and mechanical properties of this structural protein (32).

## SUMMARY

Cobalt-58 retention studies were conducted over a 20-day period in young and old rats of both sexes. The data show that the uptake of the radioisotope was relatively high in aorta, kidney and liver; relatively low in blood, femur, and hair; and age-dependent only in aortic tissue. These differences in retention of radiocobalt have been interpreted as being related to the distribution and elemental composition of the structural proteins. The results suggest that elastin retains more cobalt-58 than collagen or keratin. In agreement with this, the stable Co content has been found to be measurable only in elastin. The effects of age are shown by the enhanced uptake of cobalt-58 by aortic tissue of old rats. This finding correlates with previous evidence indicating an increased metal content and a change in amino acid composition of aortic tissue with increased age.

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