ESTIMATE OF RADIATION DOSE TO THYROIDS OF

THE RONGELAP CHILDREN FOLLOWING THE BRAVO EVENT

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December 16, 1964

ABSTRACT

An estimate is made of the radiation dose to the thyroids of children following the Bravo event of March 1, 1954. The available mental data are used to estimate the dose under two alternate assumptions mode of intake: (a) all of the intake was by inhalation, and (b) all of intake was by oral ingestion. It is concluded that the most probable dose the thyroid of a 3 - 4 year old girl is in the range 700 - 1400 rad.

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General Information

The cloud arrival time is given[1] as H + 4 to 6 hours. The end of the cloud passage is less well known but probably lies in the range 8 - 16 hours. In all calculations we will assume that cloud passage was in the interval H + 6 to H + 18.

The residents of Rongelap were evacuated at H + 51 hours. Reliable dose rate measurements were not obtained at that time but the gamma dose rate 3 feet above the ground was measured as 375 mr/hr seven days after the detonation. Assuming $t^{-1.2}$ decay the H + 24 hour dose rate was then ~3.8 R/hr.

The sources of exposure to the thyroid which must be considered are:

(1) Whole body gamma dose.

(2) Internal deposition of iodine isotopes.

Whole Body Gamma Dose

The whole body dose was estimated[1] to be 175 R. The exact method of making this estimate is not given, so an independent estimate is made below. In particular, it appears that this estimate does not include the dose from the cloud but only from fallout.

If we assume a linear buildup of fallout from H + 6 to H + 18, $t^{-1.2}$ decay during this interval and use the reading of 375 mr/hr at seven days, the estimated dose from fallout during cloud passage is 47 R. The dose from the fallout from H + 18 to evacuation at H + 51 is 114 R. Experience from Sedan indicates that the dose from the cloud, itself, is approximately equal

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to the dose from fallout during stay in the lagoon and on the island,

then 47 + 47 + 114 = 208 R.

Within the error of the measurements and the assumptions used in the calcula-

tions, this estimate, which does not contain any correction for the

effect of time indoors, does not differ significantly from the 175 R estimate.

We will, therefore, take the average whole body gamma dose as 175 R.

Internal Deposition of Iodine Isotopes

Unfortunately, no direct measurement was possible of the

iodine content of individuals from Rongelap. Urine samples were obtained from

which the average thyroid burden of I^{131} has been estimated. The Los Alamos

Scientific Laboratory collected pooled 24-hour samples 15 days post detona-

tion and estimated[2] the 1-day thyroid content as 11.2 μc of I^{131}. The NRDL

collected samples from each member of the exposed group 43 and 46 days post

detonation and, by an indirect method, estimated the average thyroid content

as 6.4 μc I^{131} at 1 day.[3,4] The LASL estimate of 11.2 μc was obtained by

direct counting of I^{131} in the urine and should be more reliable than the

NRDL estimate. The value of 11.2 μc will be used as a basis for all follow-

ing considerations. This estimate was based on the assumption of 0.1% of

the maximum thyroid burden being excreted in the urine on the 15th day.

Variation in the biological half-life and other factors indicate that a range

of 0.05 - 0.2% should be placed on this number[5] (see appendix). We, there-

fore, take 5.6 - 22.4 μc as the range of adult I^{131} thyroid burden.

The pooled samples represent all age groups. The number of individuals

in these age groups and the volume of urine from each age group is approxi-

mately as follows:[3,4]

Age Group		
< 5		
5 - 16		
>16		

The urine samples are typical of adult ... presumably also those of adults.

Associated with this I^{131} are the shorter lived isotopes I^{135}. If the iodine entered by way of inhalation, the time of ... to H + 18. On the other hand, if water (and food) ... the time of ingestion would be extended from H + 6 to ...

Three items contribute to the differences in dose from ... iodine isotopes. These are: (1) radioactive decay before inhalation or ingestion, (2) differences in the fission yields of the chains, ... average energy deposited in the thyroid per disintegration. These factors ... presented in Table I for I^{133} and I^{135}. In the case of inhalation, uniform distribution in the cloud was assumed. For oral ingestion it was assumed that, on the average, 1/3 of the intake occurred at H + 10 and 2/3 at H ...

Table I

Ratio of Doses for the Two Modes of Intake

	Inhalation		Oral Ingestion	
	I^{133}/I^{131}	I^{135}/I^{131}	I^{133}/I^{131}	
Decay	0.68	0.31		
Fission yield[6]	1.38	1.23		
Energy	2.00	1.50		
Net Factor	1.85	0.57	1.35	

(1969)

The dose to the thyroid in rad from all isotopes is 3.4 times the dose due to I^{131} alone for inhalation and 3.7 times for ingestion. Delay in reaching the thyroid after inhalation would lower these factors somewhat. However, the decay of I^{133} has been neglected and would approximately compensate for the I^{135} before reaching the thyroid.

We can now proceed to estimate the dose to the thyroids of 3 - 4 year old girls assuming (1) inhalation as the mode of intake and (2)

1. Inhalation: The ratio of volume of air respired by a 3 - 4 year old to that of an adult can be estimated in two ways: (a) from the maximum of oxygen intake[7] and (b) from the vital capacity[8] and maximum respiration rate.[7] Both methods give a ratio of ~0.3. The thyroid burden of the children would then be ~3.4 µc with a range of 1.7 - 6.8 µc.

Assuming the Rongelap children are similar to those of New York, children, the mass of the thyroid of the children is 2.5 ± 0.6 grams.[9]

The most probable dose from I^{131} is then 150 rad and the dose from all isotopes is 510 rad. If we consider the range of thyroid burden (1.7 - 6.8) and the variation in thyroid weight (1.9 - 3.1 gms), the dose is in the range of 200 - 1350 rad.

2. Oral Ingestion: At the time of the event the Rongelap people were on a water ration of one pint per day. They were warned not to drink water after the event but most of them admitted they drank water anyway.[10] The method of collecting water by runoff from roofs into cisterns makes it very likely that this was the main source of oral ingestion. There are reports that it "rained a little" on the afternoon of March 1 (D-Day). The village doctor reported that the "water turned yellow." As far as food is concerned, the most likely source is dried fish. Fish were dried on open racks. However

in the interviews none of them listed drinking water during
the time before evacuation.[10] Under these circumstances it
to assume that children drank the same amount of water and received
the same intake as adults; i.e., their thyroid
I^{131} (range 5.6 - 22.4 μc).

The most probable dose from I^{131} is then 490 rad and the
(1270 rad.) Considering a range in the thyroid burden (5.6 - 22
thyroid weight range of 1.9 - 3.1 gms, the range of
rad.

Incidentally, LASL assumed this mode of intake and calculated
of 150 rad.[2] The thyroid weight used was not given but was probably 10
grams. We would calculate 160 rad, in very good agreement with the LASL
estimate.

Summary

Thyroid Dose (Rads) to Rongelap Girls Ages 3 - 4

	Inhalation			Oral Ingestion		
	Min	Max	Most Probable	Min	Max	Most Probable
Whole Body	150	200	175	150	200	175
Radioiodine	200	1350	510	520	3300	1270
Total	350	1550	685	670	3500	1445

The actual intake was undoubtedly a combination of the two modes of
intake. The most probable dose is, therefore, in the range 700 - 1400.

[1] Sondhaus, Sharp, Bond and Crocker, "Radiation Characteristics of Fallout Material and Determination of..." TID-5358, Some Effects of Ionizing Radiation...

[2] P. Harris, personal communication, cited by Bond and Crocker.

[3] Cohn, Rinehart, Gong, Robertson, Milne, Bond and Cronkite, "Internal Deposition of Radionuclides in Human Beings and Animals," Chapter... TID-5358.

[4] Cohn, Rinehart, Gong, Robertson, Milne, Chapman and Bond, "Internal Radioactive Contamination of Human Beings Accidentally Exposed to Radioactive Fallout Material," USNRDL-TR-86.

[5] Ng, Yook, private communication (1964).

[6] The fission yields for U^{238} with high energy neutrons as given by Weaver, Strom and Kileen, NRDL-TR-633, were used.

[7] Handbook of Biological Data, William B. Spector, Editor, p 352 (W. B. Saunders, Philadelphia, 1956).

[8] Document Geigy Scientific Tables, 5th Ed., p 254 (S. Karger, Basel, Switzerland, 1959).

[9] Mochizviki, Mowafy and Pasternack, Health Physics, 9, 1299-1301 (1963)

[10] Sharp and Chapman, "Exposure of Marshall Islanders and American Military Personnel to Fallout," WT-938, 1957.

Calculation of urinary radioiodine excretion following single exposure

Radioiodine appearing in urine over a relatively short period following exposure, originates in the thyroid. In the calculation for urinary radioiodine it was assumed that iodine is released from the thyroid only as thyroxine, and that the release of thyroxine and its subsequent degradation in the extrathyroidal hormonal space can be described by assuming first order kinetics. Ranges for normal biological half-life of iodine in the thyroid and normal turnover rate of extrathyroidal thyroxine were selected from the best available data in the literature. The uptake of radioiodine was assumed to be exponential with a half-period of approximately 4.5 hours, and 60% of the iodine released when extrathyroidal thyroxine was degraded was assumed to be excreted in urine.

Rates of urinary radioiodine excretion were calculated from the resulting expression shown below.

$$\frac{dI_U}{dt} = 0.60 LKI_{Tf} \left[\frac{e^{-(K+\lambda)t} - e^{-(L+\lambda)t}}{L-K} - \frac{e^{-(J+K+\lambda)t} - e^{-(L+J)t}}{L-J} \right]$$

I_U = radioiodine content of urine

L = rate of turnover of extrathyroidal thyroxine

K = rate constant for the release of iodine from the thyroid

I_{Tf} = peak radioiodine content of the thyroid

λ = physical decay constant for I^{131}

J = rate constant for the uptake of radioiodine in the thyroid

t = time

A summary of the calculations for
urinary radioiodine excretion at 15 days appears below.

Urinary Radioiodine Excretion

J day^{-1}	K day^{-1} x 10^3	L day^{-1} x 10^2	
3.7	4.85	7.2	
3.7	4.85	13.8	0.066
3.7	17.15	7.2	0.16
3.7	17.15	13.8	0.21

On the basis of these calculations the normal range of urinary
iodine excretion at 15 days was estimated to be 0.05 to 0.2% of the peak
thyroid content.

The problem outlined above is a practical application of an analytic
study on the uptake and excretion of iodine in man which will be described
more fully in a UCRL report entitled, "The Dynamics of Iodine in Man."