MEDICAL FOLLOW-UP IN THE MARSHALL ISLANDS: AN OVERVIEW OF SIXTY YEARS OF CLINICAL EXPERIENCE

Presented by: Ashok N. Vaswani, MD
US Department of Energy, Washington, DC
and International Outreach Services, Honolulu, Hawaii

International Radiation and Thyroid Cancer Workshop
Tokyo, Japan
February 21st – 23rd, 2014

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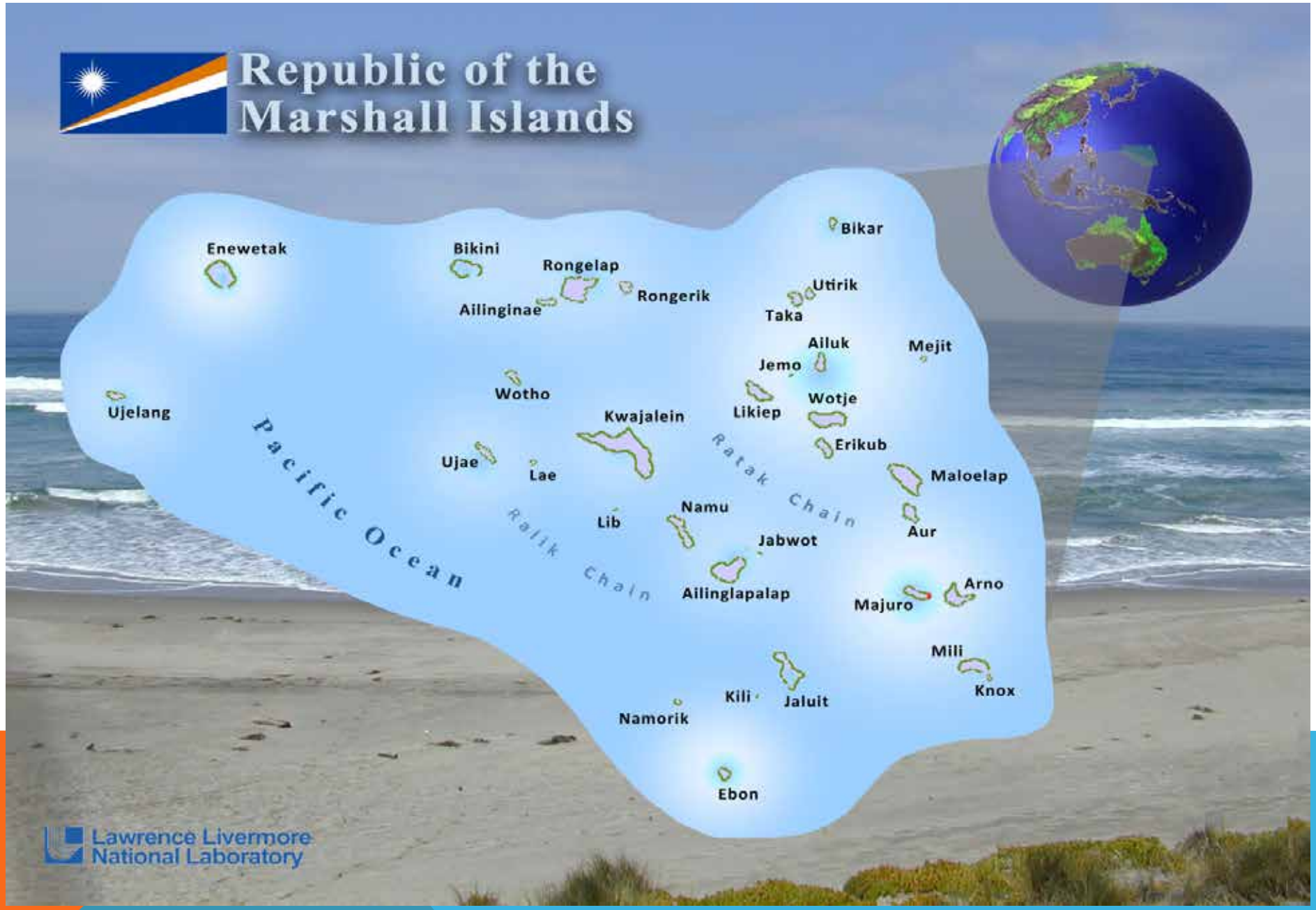

Republic of the Marshall Islands
Enewetak
Bikini
Rongelap
Rongerik
Ailinginae
Bikar
Utirik
Taka
Ailuk
Mejit
Jemo
Wotho
Ujelang
Kwajalein
Likiep
Wotje
Erikub
Pacific Ocean
Ujae
Lae
Ratak Chain
Maloelap
Namu
Lib
Aur
Jabwot
Ralik Chain
Ailinglapalap
Majuro
Arno
Mili
Knox
Kili
Jaluit
Namorik
Ebon
Lawrence Livermore National Laboratory

OPERATION CASTLE

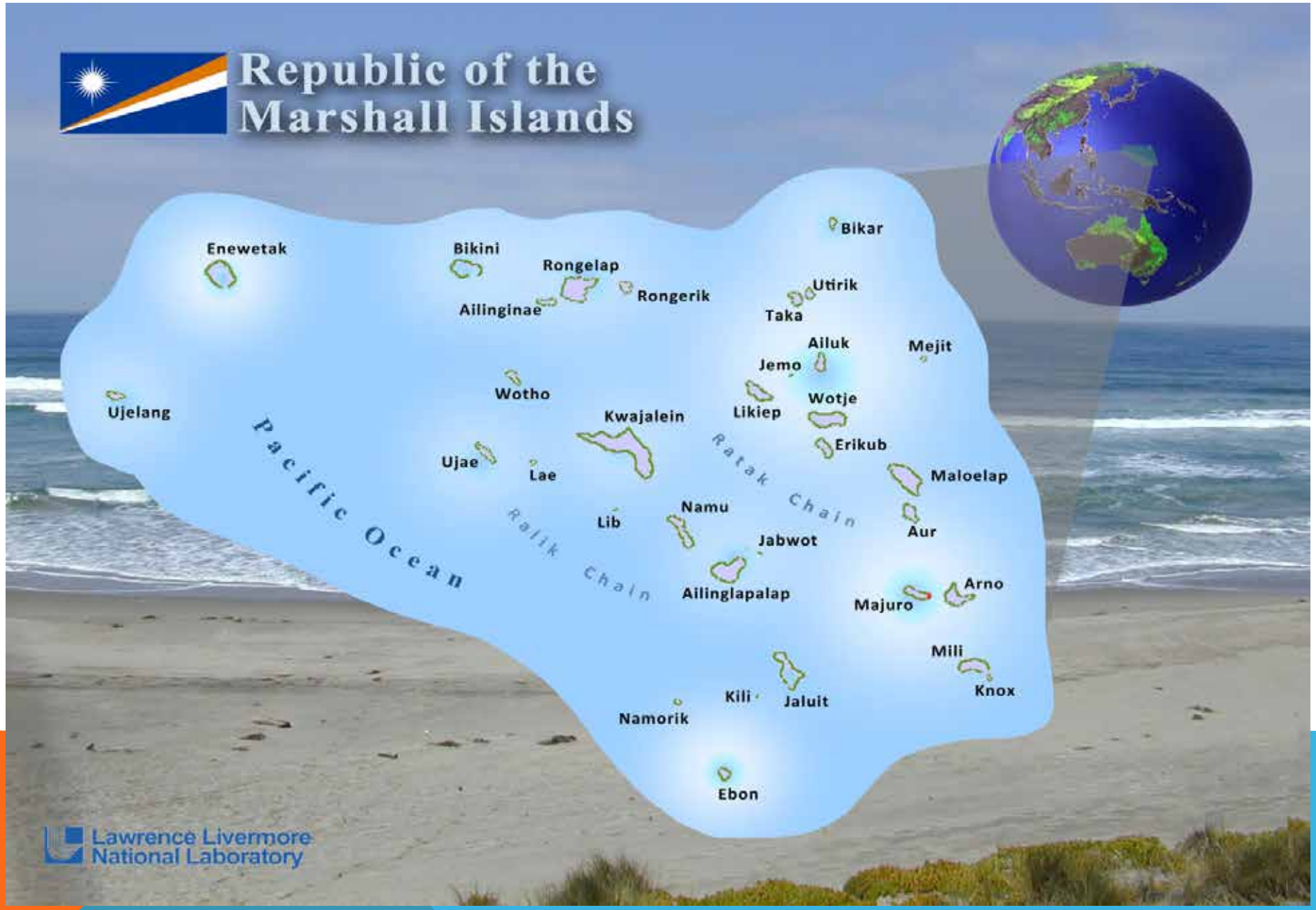
Between 1946 and 1958 the US conducted nuclear tests in the Pacific Islands. The population that was potentially at risk from the testing had been relocated to safer islands or locations that were remote from the testing sites.

On March 1, 1954 during operation Castle, higher levels of fallout reached inhabited atolls than predicted. Model assumptions during planning operations did not correctly account for the higher partitioning and more rapid fallout of radioactive debris.

OPERATION CASTLE (CONT.)

The range of the fallout and the ash from the detonation spread approximately 150 miles (240 km) from the island of Bikini and covered the islands inhabited by people from Rongelap and Utrik. The ash made its appearance from a west to east direction and fell for a total of about 12 hours.*

***A twenty year review of medical findings in a Marshallese population accidentally exposed to radioactive fallout. Robert A. Conard, et al. BNL 50424,1975.**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EFFECTS OF EXPOSURE TO THE LOCAL FALLOUT

Children consuming the ash out of curiosity or ingesting it as incorporated in the food chain had the highest exposure and were at greater risk than adults.

Overall, the people from Rongelap received a higher amount of radiation while the people from Utrik had about a 10 fold lower exposure. This was equally a function of the distance between the detonation site and the time taken for the fallout to reach the island of Utrik.

Short-lived radioisotopes of iodine (I-133 and I-135) accumulate in the thyroid. The Rongelapese were exposed to all three radioisotopes (I-131, I-133 and I- 135), with a higher dose contribution of I-133.

CUMULATIVE INTERNAL AND EXTERNAL DOSES TO ADULTS IN RONGELAP AND UTRIK (BEST ESTIMATES*)

Organ (mGy)	Mode	Rongelap	Utrik
Thyroid	Internal	7600	760
RBM, Stomach, Colon	Internal	3382	294
Whole Body	External	1600	130

RBM – Red Bone Marrow
1 Gy = 100 Rad
*Recalculated from Table 19, Simon et al., Health Physics, Vol 99(2), p 186, 2010,

CLINICAL EFFECTS AS A FACTOR OF DOSE AND TIME

The immediate medical effects of the fallout included itching, scaling and lesions of the skin and scalp, including burns.

With longer exposure times or greater dosage, the patients experienced nausea and abdominal discomfort, with loss of appetite and some weight loss.

In the early months post-exposure, the White cell count declined, but stabilized and returned to normal in a few months.

One child had persistently low white counts and eventually developed and died from acute myelogenous leukemia.

ACTIVITIES POST-FALLOUT

Immediate:

Medical care facility established at Kwajalein for the exposed population.

Long term:

Brookhaven National Laboratory, New York:

Medical Team established.

Health care teams sent to Marshall Islands at least twice a year .

Lawrence Livermore National Laboratory:

Environmental monitoring/dosimetry for radiation effects.

Sampling of soil, plants and aquatic life.

Remediation of topsoil and supplementation with potassium.

Post fallout activities have been memorialized in the Compact of Free Association between the US and the RMI.

GROUPS INCLUDED IN FOLLOW-UP FOR THYROID DISEASE AND OTHER CONDITIONS

Exposed patients were grouped by the atoll of exposure (Rongelap and Utrik) and by default the total internal and external dose.

A comparison group of unexposed individuals was matched as closely as possible with the Rongelap exposed group for age and gender. These patients were not in the immediate vicinity of the radioactive fallout.

DEMOGRAPHICS

Group	Original no. of patients	Currently Alive	Mean age of living pts	Mean age of deceased pts
Rongelap	86	25	65	71
Utrik	167	42	64	69
Comparison	147	53	66	69
Total	400	120		

THYROID NODULES AND HYPOTHYROIDISM

Thyroid nodules were detected as early as 8 years after the fallout and the first two children underwent surgery for the nodules at the age of 13, about 10 years post exposure, both of these were benign adenomatous nodules.

Mild hypothyroidism was detected in two children who had not reached their expected height for age, and these children corrected their metabolic abnormality with thyroid hormone replacement.

Summary of Thyroid Nodules and Outcome –1

Group	No. of Patients	Gender	Age in 1954	Age at Surgery	Yrs post Exposure
Rongelap	20	F	12.5	28.8	16.3
	8	M	3.1	18.5	15.4
Utrik	19	F	18.7	43.8	24.6
	6	M	9.2	39.2	30.0
Comparison	12	F	22.3	45.7	23.4
	7	M	20.8	45.6	25.0

Summary of Thyroid Nodules and Outcome -2

Group	No. of Patients	Gender	Adenomatous	Adenoma	Occult	Overt
Rongelap	20	F	12	2	1	5
	8	M	8	0	0	0
Utrik	19	F	9	2	4	4
	6	M	0	3	2	1
Comparison	12	F	8	1	2	1
	7	M	3	0	0	4

PAPILLARY THYROID CANCERS IN CHILDREN LESS THAN 18 YRS OF AGE IN 1954

Gender	Rongelap	Utrik	Comparison
Female	23	34	38
Papillary cancers	3	3	0
Male	18	38	34
Papillary cancers	0	1	3
Children *in utero*	4	9	4
Papillary cancers	0	0	0

OBSERVATIONS REGARDING THYROID NODULES

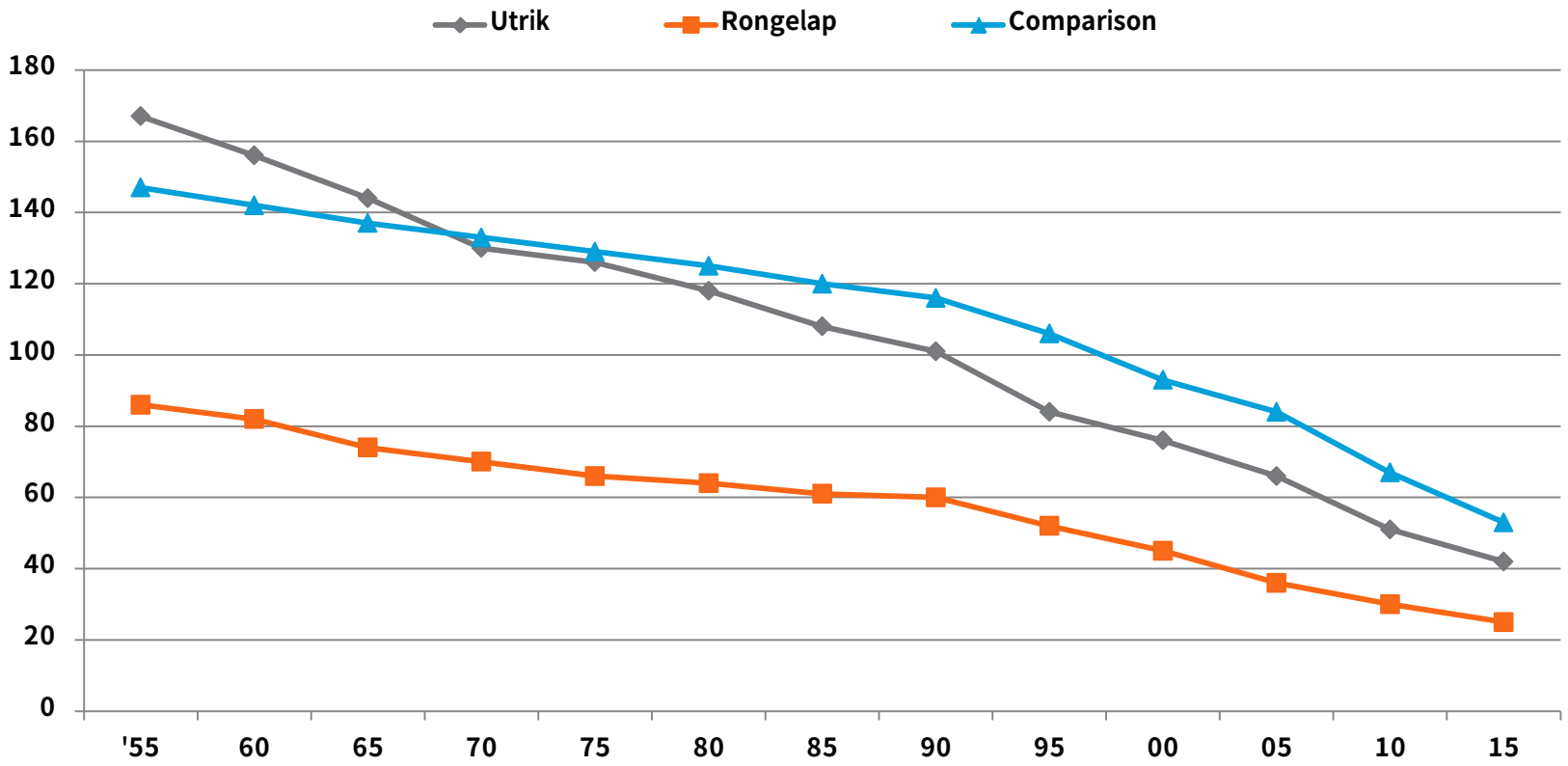
In each group of patients there were more women who underwent surgery.

Men were younger at the time of fallout in 1954.

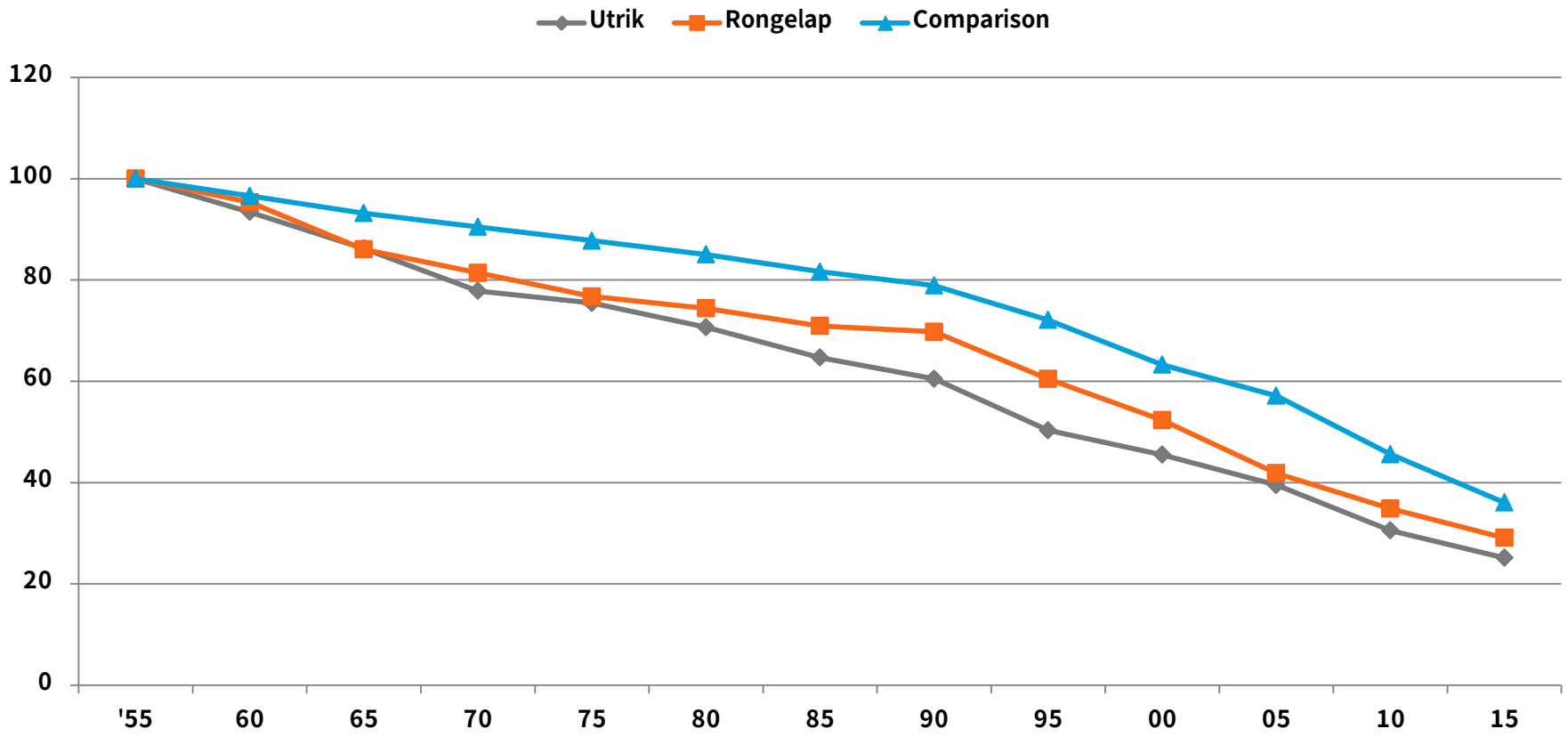
In spite of a greater potential for malignancy in younger men, there was only one overt papillary thyroid cancer in the exposed groups .

The mean age at surgery and the number of years post exposure at the time of surgery was similar in the lower exposure group (Utrik) and comparison group.

DEATHS BETWEEN 1954-2014 GROUPED AT 5 YEAR INTERVALS



DEATHS BETWEEN 1954-2014 GROUPED AS PERCENTAGE OF ORIGINAL POPULATION



CAUSES OF DEATH

Cardiovascular

Chronic renal failure due to Diabetes Mellitus or Hypertension

Hepatocellular disease, mainly due to Hep B

Breast cancer

Prostate cancer

Lung cancer

There have been no deaths reported directly to thyroid cancer among the Rongelap and Utrik populations.

OTHER COMMON AILMENTS KNOWN AND SUSPECT

Type 2 Diabetes Mellitus

Hypertriglyceridemia

Thyroid nodules

Benign colonic polyps

Cirrhosis of the liver

Septicemia

Cerebrovascular events

CURRENT THYROID EXAMINATION PROTOCOL

The patients are offered medical exams at least annually, with additional visits scheduled for abnormal findings detected during the annual visit.

Blood tests include routine chemistry profile, CBC, Free T4, Total T3, ultrasensitive TSH, thyroglobulin and anti-thyroglobulin antibodies.

Thyroid ultrasound (GE –LOGIQ e) is done for all patients at least once or twice a year. FNA's are scheduled for nodules > 1cm **or clinically suspicious nodules.**

Thyroid hormone replacement is provided for all hypothyroid and post-operative patients.

GENERAL MEDICAL EXAMINATION PROTOCOL

Diabetic care for the 71 out of 120 remaining subjects is ongoing. Patients have been provided with personal glucose monitors and given test strips every 3 months at follow up. (Glyco)Hemoglobin A1c is determined at least twice a year.

Other medical tests are offered as clinically relevant to monitor the presence or occurrence of other cancers.

Treatment for all cancers is provided as they occur.

ENVIRONMENTAL MONITORING

Aggressive remediation of the environment with potassium may reduce the uptake of Cesium into the food chain.

Establishment of vegetable farming areas where population relocation is underway.

Whole body Counting program for measuring Cesium-137 exposure were developed at Majuro (Capital of RMI), Enewetak (Environmental Monitoring Facility) and Rongelap (WBC Facility),

ENVIRONMENTAL MONITORING (CONT.)

Body composition measurements are being done at strategic locations in the Marshall Islands. The instruments and techniques for the determination of naturally occurring K-40 were initially developed at Brookhaven National Laboratory. The general public should avail themselves of this test to ensure that there is no cumulative body burden of Cesium-137 over the years. This non-invasive test can be used as routinely as measurement of blood glucose monitoring or glycohemoglobin determination for diabetes.

Over 5,500 volunteer WBC measurements in the LLNL database show that while low detectable levels of Cesium-137 have been seen in residents of the northern atolls, by comparison detectable levels for volunteers residing on Majuro and other southern atolls is very low.

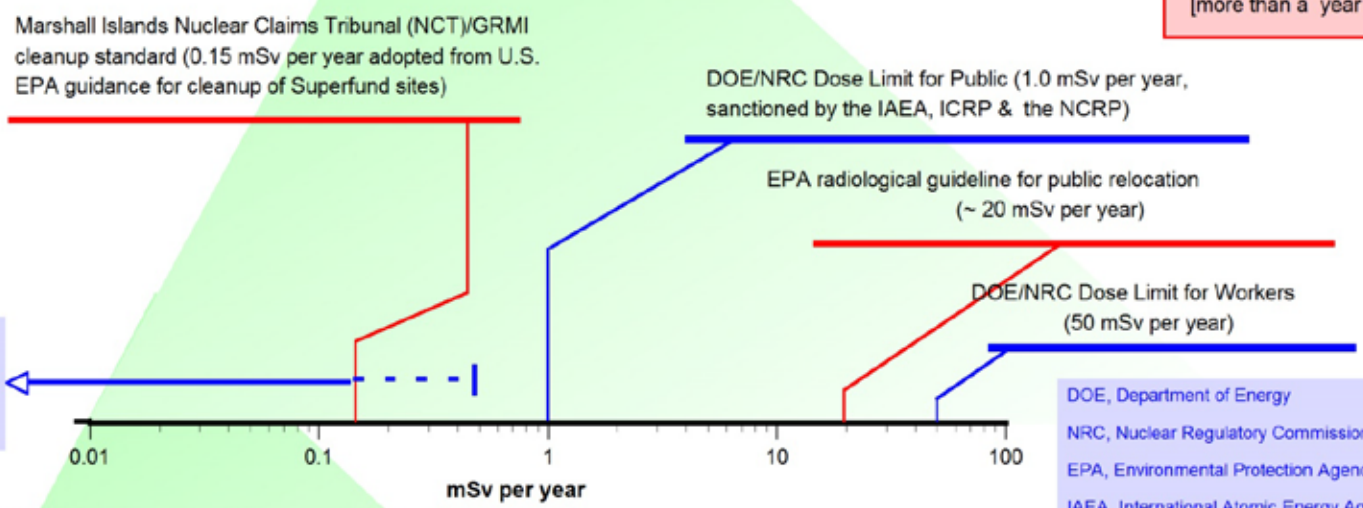
Radiation in the Marshall Islands
- Dose Ranges -

Dose Equivalent : expressed in Sievert (Sv)

1 Sv ~ 1 Gy for x-rays and gamma-rays
1 Sv = 1000 mSv
1 Gy = 100 Rad (conventional units)
1 mSv = 100 mrem (conventional units)

acute exposure = all at once
chronic exposure = over a long time
[more than a year (for humans)]

Regulations and Guidelines

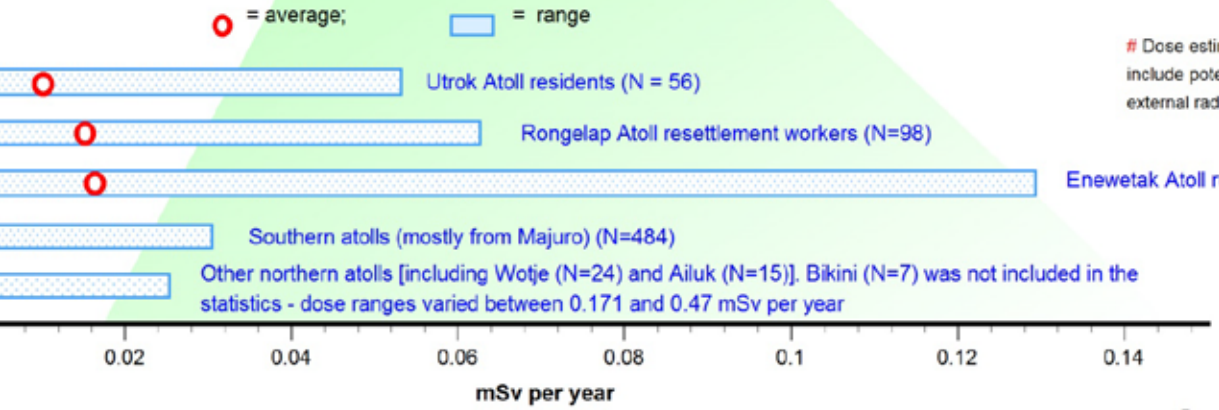


nge of doses delivered by
ally deposited cesium-137 in
arshall Islands (2001-2011)

DOE, Department of Energy
NRC, Nuclear Regulatory Commission
EPA, Environmental Protection Agency
IAEA, International Atomic Energy Agency
ICRP, International Commission on Radiological Protection
NCRP, National Council on Radiation Protection and Measurement
GRMI, Government of the Republic of the Marshall Islands

RMI Whole Body Counting (WBC) Program

[2011 calendar year dose from internally deposited cesium-137]#



Dose estimates from cesium-137 based on the whole body counting program do not include potential contributions from other internally deposited fallout radionuclides or from external radiation exposure.

Prepared by LLNL under Contract DE-AC52-07NA27344. This chart is a simplified view of radiation quantities of potential interest to scientists, students, stakeholders, and the general public. Compiled by Terry Hamilton, LLNL (modified after Metting, 2008).

LLNL-POST-562295

REDUCING THE RISK OF DISEASE: MANAGING THE ENVIRONMENT AND HUMAN BEHAVIOR

There does not appear to be any higher incidence or occurrence or other types of tumors, i.e., the population of exposed people seems to develop other diseases based on non-radiogenic risk factors, such as smoking for lung cancers, exposure to Hepatitis B for the development of cirrhosis and hepatocellular damage, chronic renal failure from complications of diabetes and hypertension.

The ubiquitous scourge of obesity, diabetes and the metabolic syndrome as part of the lifestyle change is perhaps of greater clinical and medical significance than the potential for thyroid cancer.

SUMMARY

Surgery and follow up without sophisticated equipment in the early stages accomplished a satisfactory outcome for the patients.

None of the patients received RAI as an adjunct and have done well 50 years post exposure, without any evidence of recurrence of thyroid cancer.

This would suggest that (at least in our cohort) the radiation induced tumors are not typically aggressive variants of papillary cancers.

The longevity of the comparisons and exposed appears to be the same.

Total number of thyroid cancers in all groups were identical numerically, although may be slightly higher as a percentage of the exposed population.

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ACKNOWLEDGEMENTS

All patient care and environmental surveys are supported by the US Department of Energy, Office of Health, Safety, and Security under several cooperative agreements and contracts.

Thank you!