

THE ERYTHEMA EFFECTS OF A POLONIUM PLAQUE (AN ALPHA
EMITTER) ON HUMAN SKIN*

VICTOR H. WITTEN, M.D., WILLIAM S. WOOD, M.D.
AND ROBERT LOEVINGER, Ph.D.†

The topical application of thorium X was introduced into dermatologic therapy in 1913 (6), and has been in use since that time. Its biological effectiveness has been repeatedly demonstrated both clinically (3, 6, 7, 9, 11, 12, 13, 14) and histopathologically (4, 5, 6, 8).

The erythema effect of thorium X on human skin is largely due to alpha radiation, although some is due to the small amount of beta and gamma radiation emitted. Lomholt (4) was the first to demonstrate this effect of the alpha particles. This was accomplished by applying thorium X solution to the surface of a layer of gutta percha sufficiently thick to absorb the alpha rays and allow only the beta and gamma radiation to pass through. Each time this experiment was repeated a marked reduction in the usual erythema resulted.

This simple but impressive demonstration of the biologic effectiveness of the alpha particles of topically applied thorium X received scant notice for many years thereafter. It was believed that, because this type of radiation could be stopped with a thin sheet of paper, it could not penetrate the epidermis and consequently could not produce biologic effects.

In considering the mechanisms which might explain the biologic effectiveness of topically applied thorium X, it is necessary to take into account the form in which the alpha radiation contacts the skin. When thorium X is applied in a vehicle such as alcohol it is carried into the epidermis and its appendages, thus permitting the alpha radiation to bombard the skin intensely from without and within (15, 16). This is in contrast to the application of thorium X in plaque form, which allows the alpha particles to bombard the skin from the surface only. In the latter instance the erythema effect is *markedly less* than that produced by an equal amount of thorium X applied to the surface of the skin in alcoholic solution (17).

In view of the findings that alpha rays are capable of producing a biologic effect on human skin even when they bombard it only from the surface, and because these findings are contrary to common belief, the present study was undertaken to clarify further the phenomena concerned. For our purpose, we selected polonium²¹⁰ in the form of a sealed plaque, thus permitting irradiation

* From the Department of Dermatology and Syphilology of the New York University Post-Graduate Medical School (Dr. Marion B. Sulzberger, Chairman), and the Skin and Cancer Unit of the New York University Hospital, New York, N. Y.

This study was performed under Contract AT(30-1)-1535 between New York University and the Atomic Energy Commission.

Presented at the Seventeenth Annual Meeting of the Society for Investigative Dermatology, Inc., Chicago, Illinois, June 10, 1956.

† Consultant Physicist, New York, N. Y.

1260190

of the skin from the surface with a pure alpha emitter. In preliminary studies, Earle W. Brauer and one of us (V.H.W.) demonstrated that erythema of human skin could be produced with a polonium plaque if adequate doses were given.

Description of the sources and their calibration

Special polonium plaques were prepared by a commercial supplier.* These plaques consisted of a nickel disc, 1 cm in diameter and approximately 1 mm thick, on one face of which the polonium was plated. The active deposit covered the entire face of the disc. Approximately 1 micron of pure gold was plated on top of the polonium. Two such plaques were prepared containing approximately 10 and 15 mc of polonium each. Preparatory studies were performed with the first, on which the active deposit was found to be quite non-uniform. The present reported work was done with the second plaque, which was shown by autoradiographic studies to have a relatively uniform distribution of the polonium.

The radioactive isotope of polonium used here was ${}_{84}\text{Po}^{210}$ (RaF). It has a half-life of 138 days, and emits only alpha particles of 5.3 Mev energy. It is obtained essentially free of contamination with any other radioactive material.

The gold is plated on the polonium in order to reduce the loss of polonium from the surface of the nickel disc. The gold covering must be made very thin, for if it is too thick it will absorb the emitted alpha particles completely. As a result of the very thin and perhaps irregular plating of gold there is some leaking of the polonium atoms through the gold. Since small amounts of ingested polonium²¹⁰ are potentially harmful,† it is necessary to handle the plaques with care to avoid contamination. The polonium plaque used in the present study was in all instances wrapped in one layer of 25 gauge Mylar film.‡ After each use the plastic film was discarded.

The polonium plaques were calibrated with an extrapolation chamber, which has been described elsewhere (2). This ionization chamber can be set to very thin air gaps, making it suitable for the measurement of alpha particle sources. The thin electrode on one side of the extrapolation chamber consists of 25 gauge Mylar film. When calibrating the plaques, the active surface was brought into contact with this thin electrode. Thus, the "surface" dose rate measured by the extrapolation chamber corresponded to that at the surface of the skin, since the thin electrode attenuated the alpha radiation to the same extent as the film wrapped around the polonium source when it was applied to the skin of the human volunteers.

The average surface dose rate of the polonium plaque used for the present

* Canadian Radium and Uranium Corporation, New York, N. Y.

† The International Commission on Radiological Protection gives $0.02 \mu\text{c}$ as the maximum permissible amount of polonium²¹⁰ in the human body (1).

‡ "Mylar" is the trade name of a DuPont polyester film made from polyethylene terephthalate. It is a tough, flexible, and highly impermeable plastic material. While it is available in a range of thicknesses, the thinnest film (25 gauge) is 0.00025 inches, or 0.0064 mm thick. This is found by measurement to equal 0.9 mg/cm^2 , which indicates a specific gravity of 1.4 gm/cm^3 .

FIG. 1. Dep
range. The dep
ness in mg/cm:

FIG. 2. De
alpha-partici
plotted again

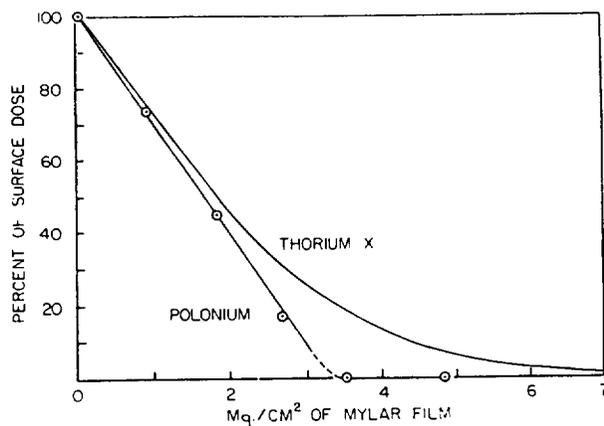


FIG. 1. Depth-dose curves for polonium and thorium X plaques, within the alpha-particle range. The depth-dose relative to 100% at the surface is plotted against the absorber thickness in mg/cm².

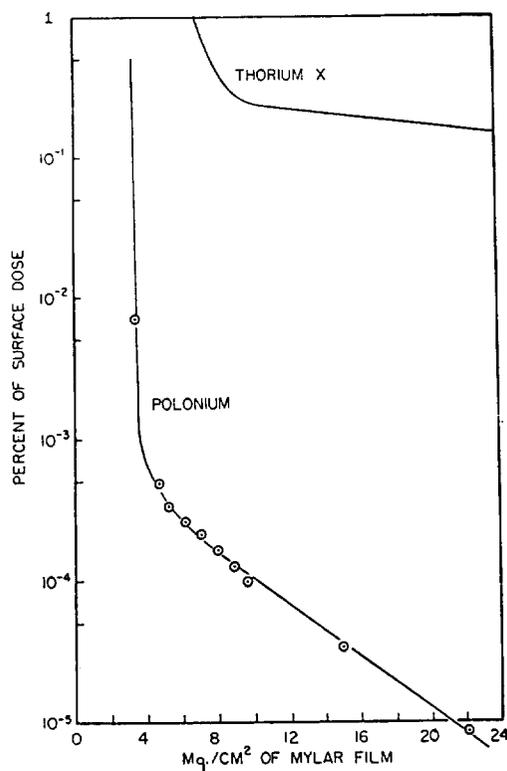


FIG. 2. Depth-dose curves for polonium and thorium X plaques, beyond the end of the alpha-particle range. The logarithm of the depth-dose relative to 100% at the surface is plotted against absorber thickness in mg/cm².

inary studies,
hema of human
s were given.

applier.* These
ximately 1 mm
leposit covered
was plated on
approximately
ormed with the
m. The present
nown by auto-
he polonium.
RaF). It has a
y energy. It is
tive material.
ss of polonium
ade very thin,
ompletely. As a
is some leaking
ingested polo-
ques with care
r study was in
r each use the

hamber, which
be set to very
article sources.
sts of 25 gauge
is brought into
easured by the
skin, since the
ent as the film
the skin of the

for the present

as the maximum

ade from poly-
plastic material.
is 0.025 inches,
which indicates

12500192

study was found to be 300,000 rad* per minute, on the reference date. The dose rate on subsequent days (for a period of about two months) was computed using the half-life of 138 days.

The extrapolation chamber also served to measure the relative depth dose of the radiation from the plaque, using Mylar film as the absorber. The results are shown in Figures 1 and 2. The depth dose of the alpha particles from the polonium plaque is shown in Figure 1 to decrease linearly with absorber thickness. This result is expected from theoretical considerations (10). The same figure gives the relative depth dose measured on a similar thorium X plaque. By way of contrast, the thorium X curve is distinctly non-linear, since the alpha particles of thorium X and its daughter products are emitted with the beta particles of Th B, Th C, and Th C'', as well as with the gamma rays of Th C''.

The relative depth dose of the two plaques, beyond the end of the alpha particle range, is shown in Figure 2. The polonium plaque has a relative dose of only 0.0002% of the surface dose, at a depth of 7 mg/cm², dropping to 1/20 of that value at 20 mg/cm². Again by way of contrast, the thorium X has a relative dose of 0.7% and 0.2% at 7 and 20 mg/cm² depth, respectively.

In interpreting Figures 1 and 2, it is assumed that 1 mg/cm² of Mylar film is, in absorption, equivalent to 10 microns of tissue thickness. This comes about as follows: The absorption of alpha particles in all material of low atomic number (air, plastic, water, tissue, etc.) is approximately the same, provided the thickness is measured in mass units (e.g. mg/cm²). Thus, 1 mg/cm² of plastic film is equivalent in absorption to 1 mg/cm² of tissue. Since tissue has a specific gravity very close to 1 gm/cm³, it follows that absorption in 1 cm of tissue thickness = 1000 mg/cm², and hence 1 mg/cm² = absorption in 10 microns of tissue thickness.

From these considerations, it is concluded that a dose of one million rad to the skin surface would deliver only about 2.0 and 0.1 rad at depths of 70 and 200 microns, respectively. The same surface dose from a thorium X plaque would deliver a dose at these depths 3000 to 10,000 times larger. From the known absence of sequelae for thorium X (7, 9, 11, 12, 13, 14), it was concluded that a surface dose up to one million rad from the polonium plaque would be safe.

EXPERIMENT 1

Procedure

This experiment was designed to ascertain whether or not alpha radiation from a solid polonium plaque applied to the surface of the skin would regularly produce erythema.

The subjects used for this study were 5 healthy white males between the ages of 23 and 39 years. The polonium plaque was applied to the skin on the flexor aspect of the right arm. The sites to be irradiated were located in a linear fashion along the long axis of the arm and were spaced so the center of each was 2.5 to

* 1 rad equals 100 ergs of absorbed energy per gram. This is approximately equivalent to 1 rep or 1 roentgen.

3 cm from
and 660 kil

In order
covered wit
cation, sme
were count
there any o

The irrad
cation of th
Erythem.

When pign:

The obs
The mean
in graphic

The eryt
and return

After 28
thema, so
faint trace-

Observ

Surface 1

55 kil

110 kil

660 kil

3 cm from the center of the adjacent site. The surface doses were 23, 55, 110 and 660 kilorad.

In order to avoid contamination of the skin by the polonium plaque it was covered with a sheet of 25 gauge Mylar film. Before and following each application, smears of the covering Mylar were taken and the areas of irradiated skin were counted with a thin end-window Geiger-Mueller tube. In no instance was there any observable contamination.

The irradiated sites were examined at 4, 8, 24, and 28 hours following application of the plaque and thereafter at daily intervals for at least one week.

Erythema was estimated on a scale from 0 to 4 as follows:

- $\frac{1}{2}$ —barely perceptible
- 1—easily perceptible, light intensity
- 2—easily perceptible, moderate intensity
- 3—easily perceptible, heavy intensity
- 4—very heavy intensity.

When pigmentation was noted it was recorded.

Observations

The observed erythema intensities for the first 28 hours are given in Table 1. The mean of the observed erythema intensities for the 5 subjects are presented in graphic form in Figure 3.

The erythema produced in the irradiated sites faded completely on diascopy, and returned with release of the pressure.

After 28 hours there was a gradual admixture of pigmentation with the erythema, so that by 4 days the erythema had disappeared in 3 subjects and only faint traces remained in the other 2. The pigmentation faded gradually, lasting

TABLE 1
Observed erythema intensities in Experiment 1 with varying surface doses of Po²¹⁰

Surface Dose	Time	Observed Erythemas					Average
		Subjects					
		1	2	3	4	5	
55 kilorad	<i>hrs.</i>						
	4	0	0	0	0	0	0
	8	$\frac{1}{2}$	0	0	0	0	0.1
	24	$\frac{1}{2}$	0	0	0	0	0.1
110 kilorad	28	$\frac{1}{2}$	0	0	0	0	0.1
	4	0	0	0	0	0	0
	8	1	0	1	1	$\frac{1}{2}$	0.7
	24	1	0	1	$1\frac{1}{2}$	$\frac{1}{2}$	0.8
660 kilorad	28	1	0	$\frac{1}{2}$	1	$\frac{1}{2}$	0.6
	4	$1\frac{1}{2}$	1	$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{2}$	1.2
	8	$3\frac{1}{2}$	2	2	$2\frac{1}{2}$	1	2.2
	24	3	$1\frac{1}{2}$	2	$2\frac{1}{2}$	1	2.0
	28	3	$1\frac{1}{2}$	$1\frac{1}{2}$	2	1	1.8

1260194

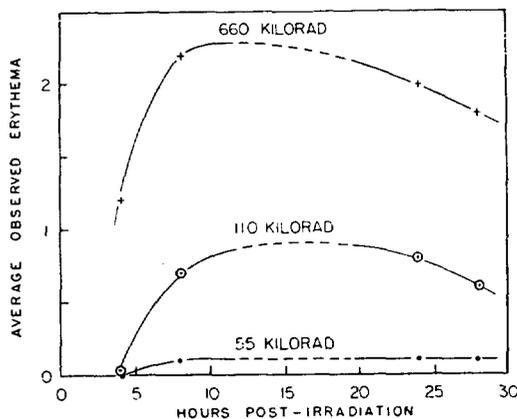


FIG. 3. The average observed erythema of the 5 subjects of Experiment 1, plotted against time after irradiation.

up to 2 weeks, when a branny scaling occurred which lasted up to 6 weeks. No second wave of erythema (as is often noted with conventional X-radiation) was noted in any of the subjects.

EXPERIMENT 2

This experiment was designed to find the smallest dose of alpha radiation from the polonium source which would produce a barely perceptible erythema. Figure 3 suggests that erythema reaches a maximum between 8 and 20 hours following application of the polonium plaque. Therefore, in this experiment, 7 sites were irradiated and erythema readings carried out 16 hours post-irradiation. The surface doses were 12.5, 25, 50, 75, 100, 150, and 200 kilorad.

Observations

The observed erythema intensities with varying surface doses are presented in Table 2, and the averages of the observed erythemias for the 5 subjects are presented in graphic form in Figure 4.

Although there is great variability in the erythema response of human skin to a given dose of alpha radiation, the average response of the 5 subjects gives approximately a linear relationship between observed erythema and dose delivered to the surface of the skin. If this linear relationship can be extrapolated to the axis of abscissae (representing zero erythema), that point might be considered as representing the "theoretical threshold erythema dose."* According to Figure 4 this dose would be approximately 20 kilorad.

If the barely perceptible erythema is taken to be " $\frac{1}{2}$ " according to our criteria, then Figure 4 indicates that the barely perceptible erythema dose is approximately 75 kilorad.

* We have used the term "theoretical threshold erythema dose" to designate that dose below which no erythema whatsoever would be noted, no matter how sensitive the method of mensuration.

Observed Erythema	Surface Dose (kilorad)
0	12.5
0.5	25
1.0	50
1.5	75
2.0	100
2.5	150
3.0	200

FIG. 4. The average observed erythema of the 5 subjects of Experiment 2, plotted against surface dose.

This experiment shows that a dose of Po^{210} appears to produce erythema readings of approximately 1.0 at 100 kilorad.

The observed averages of erythema in Figure 4 are in the form of a straight line. These figures indicate that the theoretical threshold erythema dose is approximately 20 kilorad.

TABLE 2
Observed erythema intensities in Experiment 2, 16 hours post-irradiation

Surface Dose (kilorad)	Observed Erythemas					Average
	Subject					
	1	2	3	4	5	
12.5	0	0	0	0	0	0
25	0	0	0	0	0	0
50	1	0	0	0	1/2	0.3
75	1/2	0	1/2	0	1/2	0.5
100	1 1/2	0	1/2	1/2	1	0.7
150	2 1/2	1/2	1/2	1	1/2	1.2
200	3	1	1/2	1/2	2	1.6

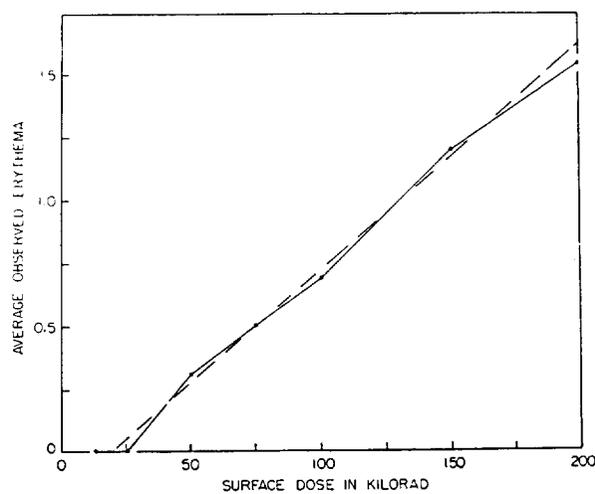


FIG. 4. The average observed erythema of the 5 subjects of Experiment 2, plotted against surface dose.

EXPERIMENT 3

This experiment was designed to ascertain the relationship between the surface dose of Po^{210} and time of appearance of erythema. Figure 3 suggests that erythema appears earlier at the site receiving the larger dose, so in this experiment the readings of erythema were made at half-hour intervals up to 8 hours post-irradiation. The surface doses were 55, 110, and 660 kilorad.

Observations

The observed erythema intensities are presented in Tables 3 and 4, and the averages of the observed erythema for the 5 subjects are presented in graphic form in Figure 5. No erythema was observed with a surface dose of 55 kilorad.

These findings demonstrate that erythema appears sooner with the larger

1260196

TABLE 3
Observed erythema intensities in Experiment 3, with 110 kilorad surface dose

Time (hours)	Observed Erythemas					
	Subject					Average
	1	2	3	4	5	
4 ¹ / ₂	0	0	0	0	0	0
5	0	1 ¹ / ₂	0	0	0	0.1
5 ¹ / ₂	0	1 ¹ / ₂	0	0	1 ¹ / ₂	0.2
6	0	1 ¹ / ₂	0	0	1 ¹ / ₂	0.2
6 ¹ / ₂	0	1 ¹ / ₂	0	1 ¹ / ₂	1 ¹ / ₂	0.3
7	0	1 ¹ / ₂	0.4			
7 ¹ / ₂	0	1 ¹ / ₂	1 ¹ / ₂	1 ¹ / ₂	1	0.5
8	1 ¹ / ₂	1	0.6			

TABLE 4
Observed erythema intensities in Experiment 3, with 660 kilorad surface dose

Time (hours)	Observed Erythemas					
	Subject					Average
	1	2	3	4	5	
1 ¹ / ₂	0	0	0	0	0	0
1	0	1 ¹ / ₂	0	1 ¹ / ₂	0	0.2
1 ¹ / ₂	0	1	0	1 ¹ / ₂	1 ¹ / ₂	0.4
2	0	1	0	1 ¹ / ₂	1 ¹ / ₂	0.4
2 ¹ / ₂	0	1	0	1 ¹ / ₂	1 ¹ / ₂	0.4
3	0	1 ¹ / ₂	0	1 ¹ / ₂	1	0.6
3 ¹ / ₂	0	1 ¹ / ₂	0	1	1	0.7
4	1 ¹ / ₂	1 ¹ / ₂	0	1	1 ¹ / ₂	0.9
4 ¹ / ₂	1 ¹ / ₂	1.1				
5	1	2	1 ¹ / ₂	1 ¹ / ₂	1 ¹ / ₂	1.3
5 ¹ / ₂	1	2	1	1 ¹ / ₂	1 ¹ / ₂	1.4
6	1 ¹ / ₂	2	1	1 ¹ / ₂	1 ¹ / ₂	1.5
6 ¹ / ₂	1 ¹ / ₂	2	1	2	2	1.7
7	1 ¹ / ₂	2	1 ¹ / ₂	2	2	1.8
7 ¹ / ₂	1 ¹ / ₂	2	1 ¹ / ₂	2	2	1.9
8	2	2	1 ¹ / ₂	2	2	1.9

surface dose. While the data is rather scanty, it is possible to speculate that there is a threshold time for the appearance of erythema with each dose, and that the erythema intensity is for a certain period roughly proportional to the elapsed time following the appearance of the erythema. This linear increase holds only for the first 8 hours, after which the erythema intensity levels off.

EXPERIMENT 4

This experiment was designed to determine whether or not the alpha radiation from a polonium plaque acting at the surface of the skin is totally absorbed within the epidermis, or whether it traverses the epidermis and bombards the small blood vessels of the papillary zone. Two factors had to be considered: (1)

FIG. 5. T
time after i

The range
epidermis.

1. Range o

The de
proximate

2. Thickn

Epider
fixation of
the shrink
these diffi
following

The su
procaine :
at a site a
660 kilora
from the :
excised tis
freezing n

The fin
Assumi
then at a

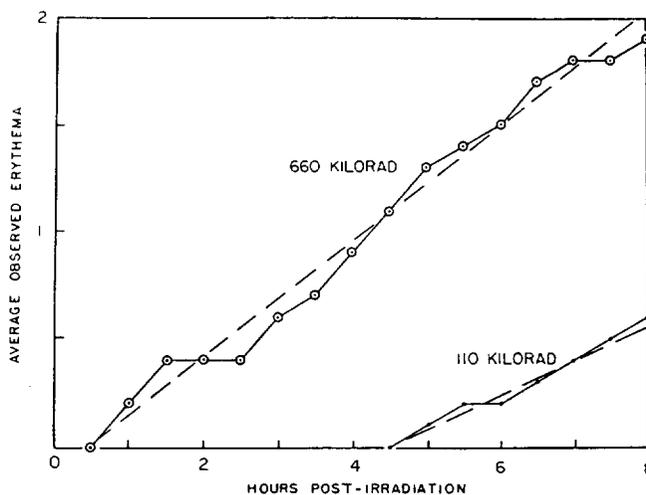


FIG. 5. The average observed erythema of the 5 subjects of Experiment 3, plotted against time after irradiation.

The range in tissue of the alpha particles from Po^{210} , and (2) the thickness of the epidermis.

1. Range of alpha particles in tissue

The depth-dose measurements in Mylar indicate that at a thickness of approximately 4.0 mg/cm^2 the dose is only 0.001% of the surface dose (Fig. 2).

2. Thickness of epidermis

Epidermal thickness is highly variable from one skin area to another. The fixation of tissue makes the measurement of skin thickness difficult because of the shrinkage of tissue volume which usually occurs. In the attempt to overcome these difficulties in ascertaining the thickness of epidermis we carried out the following procedure.

Procedure

The subjects were 2 of the 5 persons used in Experiment 1. Under local 2% procaine anesthesia a scalpel specimen for biopsy was taken from each subject at a site adjacent to the area on the flexor aspect of the right arm which received 660 kilorad. The procaine was injected in the form of a "block" at least 2 cm from the area to be excised in order to avoid edema of the tissue specimen. The excised tissue was immediately frozen with carbon dioxide and sectioned on the freezing microtome. The sections were stained with hematoxylin and eosin.

Observations

The findings are presented in Table 5.

Assuming that 1 mg/cm^2 of Mylar is equivalent to a thickness of 10μ of tissue, then at a depth of 40μ only 0.001% of the surface dose would remain (according

surface dose

Average

0
0.1
0.2
0.2
0.3
0.4
0.5
0.6

surface dose

Average

0
0.2
0.4
0.4
0.6
0.7
0.9
1.1
1.3
1.4
1.5
1.7
1.8
1.9
1.9

ulate that there
se, and that the
to the elapsed
case holds only
f.

alpha radiation
totally absorbed
bombards the
considered: (1)

TABLE 5

Thickness of epidermis from flexor aspect of arm. Measurements made from surface to tips of dermal papillae

		Thickness (microns)		
		Stratum Corneum	Other Layers	Total Epidermis
Subject #1	Thinnest	10.00	20.00	30.00
	Average thickness	18.50	32.75	51.25
	Thickest	25.00	50.00	75.00
Subject #2	Thinnest	15.00	15.00	30.00
	Average thickness	14.50	31.50	46.00
	Thickest	25.00	50.00	75.00

The rete pegs in each subject averaged 100-120 μ in thickness.

to Fig. 2). If this assumption is correct, then the figures in the preceding table suggest that the alpha particles delivered by the polonium plaque are in general unable to traverse the epidermis. It is possible, however, that some penetration may occur in a few areas where the thickness of the epidermis is less than 40 microns.

DISCUSSION AND SUMMARY

The irradiation of normal human skin from its surface has been carried out with polonium²¹⁰, a pure alpha particle emitter. The observed response of the skin may be summarized as follows:

- (1) There is a clinical biologic effect of erythema and pigmentation.
- (2) The erythema fades on diascopy, indicating that it probably results from dilatation of the superficial blood vessels of the dermis.
- (3) The erythema appears within 2 to 8 hours, reaches a maximum between 8 and 20 hours, and then fades and becomes mixed with pigmentation.
- (4) No second wave of erythema was observed.
- (5) It may be speculated that there is a "theoretical threshold erythema dose" for alpha radiation of about 20,000 rad.
- (6) The barely perceptible erythema dose for polonium alpha radiation is approximately 75,000 rad.
- (7) The larger the dose the shorter the latent period of the appearance of erythema.
- (8) There is considerable individual variation in erythema response to polonium²¹⁰.
- (9) Almost all of the alpha radiation from polonium²¹⁰ is absorbed within the epidermis.
- (10) Many of the gross characteristics noted for the erythema produced by polonium²¹⁰ resemble closely those of ultra-violet radiation. In contrast, however, they bear little resemblance to the erythema caused by beta, gamma and x-radiation.

The mechanism by which these highly ionizing, short trajectory alpha par-

ticles produce visible biological effects is primarily of a physical nature. It is possible that some penetration of alpha particles might be possible in areas where the epidermis is diffusible surface.

It is worth noting that the response of the skin has been in the past, and is still, a subject of considerable interest. The sequelae such as the formation of skin cancer are not uncommon. This marked response may be functionally significant.

For these reasons, the study of the effects of alpha particles applied to the skin is of great interest.

1. I.C.R.P. Report No. 1, Protection of Man Against Ionizing Radiation.
2. LOEVING, G. *Scient. Rep.* 1936.
3. LOMHOLT, J. *Acta Med. Scand.* 1936.
4. LOMHOLT, J. *Acta Med. Scand.* 2: 437.
5. MIESCHER, G. *Arch. Exp. Path. Pharmacol.* 1936.
6. NAEGELI, C. *Arch. Exp. Path. Pharmacol.* 1936.
7. NAGELSON, M. *Arch. Exp. Path. Pharmacol.* 19: 31.
8. PECK, S. *Arch. Exp. Path. Pharmacol.* 19: 31.
9. PINKUS, H. *Arch. Exp. Path. Pharmacol.* 12: 61.
10. ROSSI, F. *Arch. Exp. Path. Pharmacol.* 7: 21.
11. SHER, J. *Arch. Exp. Path. Pharmacol.* 19: 31.
12. SULZBERG, M. *Arch. Exp. Path. Pharmacol.* 19: 31.
13. THOMAS, J. *Arch. Exp. Path. Pharmacol.* 72, 194.
14. WISE, F. *Arch. Exp. Path. Pharmacol.* 19: 31.
15. WITTENBERG, L. *Arch. Exp. Path. Pharmacol.* 19: 31.
16. WITTENBERG, L. *Arch. Exp. Path. Pharmacol.* 19: 31.

from surface

Total Epidermis
30.00
51.25
75.00
30.00
46.00
75.00

ticles produce erythema is unknown. If our speculations are correct, and the visible biologic effects of erythema and pigmentation are the result of irradiation primarily of the epidermis, then the thinking regarding the biophysics of superficial irradiation of the skin warrants reconsideration. For example, in order to account for the visible erythema which results from such superficial radiation, it might be necessary to consider the epidermal production and liberation of a diffusible substance which in turn acts to dilate the dermal blood vessels.

It is worthy of note that although alpha radiation in the form of thorium X has been in clinical use for over 40 years, there are no known cases of serious late sequelae such as ulceration and the formation of malignancies. Such sequelae are not uncommon with large doses of conventional gamma and x-radiation. This marked difference in effect suggests that the biophysics of alpha radiation may be fundamentally different from that of conventional X-radiation.

For these reasons, as well as others, the biologic effects of alpha radiation applied to the surface of the human skin must receive further careful study.

REFERENCES

1. I.C.R.P.: Recommendations of the International Commission on Radiological Protection (Revised Dec. 1, 1954), Brit. J. Radiol., Supplement No. 6, 1955.
2. LOEVINGER, R.: Extrapolation chamber for the measurement of beta sources. Rev. Scient. Instruments, **24**: 907, 1953.
3. LOMHOLT, S.: Alpha and beta ray therapy in dermatology. Brit. J. Dermat., **48**: 567, 1936.
4. LOMHOLT, S.: On the employment of radio-active matter in solution. Acta radiol., **2**: 437, 1923.
5. MIESCHER, G.: Fluoreszenzmikroskopische Untersuchungen zur Frage der Penetration von fluoreszierenden Stoffen in die Haut. Dermatologica, **83**: 50, 1941.
6. NAEGELI, O. E. AND JESSNER, M.: Ueber die Verwendung von Mesothorium und Thorium X in der Dermatologie. Therap. Monatsh., **27**: 765, 1913.
7. NAGELSCHEIDT, K. F.: External and internal thorium X therapy. Brit. J. Radiol., **19**: 31, 1946.
8. PECK, S. M.: Pigment (melanin) studies of human skin after application of thorium X, with special reference to origin and function of dendritic cells. Arch. Dermat. & Syph., **21**: 916, 1930.
9. PINKUS, H.: Alpha ray treatment of dermatoses with thorium X. J. Invest. Dermat., **12**: 61, 1949.
10. ROSSI, H. H. AND ELLIS, R. H., JR.: Dosimetry of thin polonium sources. Nucleonics, **7**: 21, 1950.
11. SHER, J. J. AND HOWES, W. E.: Thorium X treatment of skin epithelioma, keratoses, and delayed radiation changes. Radiology, **56**: 39, 1951.
12. SULZBERGER, M. B. AND BAER, R. L.: Editors, Some advances in dermatologic management. The 1946 Year Book of Dermatology and Syphilology, p. 54. Chicago, The Year Book Publishers, Inc., 1947.
13. THOMAS, E. W. P.: Superficial radiotherapy with thorium X. Brit. J. Phys. Med., **8**: 72, 1945.
14. WISE, F. AND SULZBERGER, M. B.: Editors. The 1939 Year Book of Dermatology and Syphilology, p. 511. Chicago, The Year Book Publishers, Inc., 1940.
15. WITTEK, V. H., ROSS, M. S., OSHRY, E. AND HYMAN, A. B.: Studies of thorium X applied to human skin. I. Routes and degree of penetration and sites of deposition of thorium X applied in selected vehicles. J. Invest. Dermat., **17**: 311, 1951.
16. WITTEK, V. H., ROSS, M. S., OSHRY, E. AND HOLMSTROM, V.: Studies of thorium X

applied to human skin. II. Comparative findings of penetration and localization of thorium X when applied to alcoholic solution, in ointment and in lacquer vehicles. *J. Invest. Dermat.*, **20**: 93, 1953.

17. WITTEN, V. H., BRAUER, E. W., HOLMSTROM, V. AND LOEVINGER, R.: Studies of thorium X applied to human skin. III. Relative effects of alpha and beta-gamma irradiation in production of erythema. *J. Invest. Dermat.*, **21**: 249, 1953.

DISCUSSION

DR. MYRON H. KULWIN (Champaign, Ill.): I think this brings out one particular point of interest. In theory, at least, it is conceivable that any type of radiobiologic response could be produced by any type of ionizing radiation, provided that exposure conditions and proximity to the target substance were suitable. The presence of erythema or any other radiobiologic effect is not a defining characteristic of any given type of radiation. Ultimately the response will depend on many factors, such as dose-intensity, the length of time over which it is delivered, the size of the areas to which it is delivered, and the condition of the target substance such as its degree of hydration, temperature and degree of oxygenation, etc.

DR. A. DOMONOKOS (New York, N. Y.): I was interested in hearing this paper because it parallels closely the type of radiation work done with the Phillips contact x-ray. Anyone who has done erythema studies will appreciate the difficulties met in a problem like this. Previously when we talked about the threshold erythema dose it was customary, using the conventional x-rays, to wait 24 to 48 hours for the appearance of erythema, but in this work and with the Phillips contact x-ray the reaction is very prompt. It appears as early as 30 minutes. Whether this erythema is really a radiation effect we are not sure; it probably is but you get a very early response in comparison to the conventional x-rays.

DR. F. KALZ (Montreal, Canada): This interesting report is the first one, to my knowledge, dealing with the cutaneous reactions of a pure alpha emitter. Thorium X produces chiefly alpha radiation and I have seen 2 erythema waves resulting from exposure to this substance; it does not produce penetrating ulcers but telangiectasis and epidermal atrophy may occur.

I would not know why no second erythema wave occurred with the polonium plaques, it may be chiefly a question of the dosage used.

One must also keep in mind that some damage may result if very high dosage would be used.

DR. WILLIAM S. WOOD (in closing): I wish to thank the discussors. In response to Dr. Kalz, I particularly mentioned that we had not seen late and serious sequelae with the use of thorium X. In our observations thus far a second wave of erythema has not been noted with polonium. Perhaps the second wave which you have noted with thorium X was due to the beta and gamma emanations from that substance. Finally, we do not know whether the effects of alpha radiation are the same as beta and gamma radiation. It is true that on the basis of our clinical observations, polonium irradiation closely parallels ultraviolet radiation.

PERCUT.

FRED

The ear: quite disa; been fairly particulari between th there are : that anti-substance-

Since th had been reported f ous absorp and metal

The stu ject #1, spondyloli sixty-six-y operated : first patie: thoracolum except for This comp at the tim 13 days l direct 0.7 7.6 units of liver fu 7.5 mic a specific radioactiv

* From
† Present
Present
tology, In
This stu
‡ This i
Sam R. H.