ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 173
20 December 1954

X-RADIOGRAPHY WITH BETA-EMITTING ISOTOPES*

*Subtask under Biological and Medical Aspects of Ionizing Radiation, AMRL Project No. 6-59-08-014, Subtask, Effects of Ionizing Radiation.

RESEARCH AND DEVELOPMENT DIVISION
OFFICE OF THE SURGEON GENERAL
DEPARTMENT OF THE ARMY

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J. G. Kereiakes and A. T. Krebs

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1. Radiology   2. Clinical diagnostic   3. Portable isotopic x-ray units

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X-RADIOGRAPHY WITH BETA-EMITTING ISOTOPES*

by

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RADIOBIOLOGY DEPARTMENT
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FORT KNOX, KENTUCKY
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Report No. 173
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Subtask AMRL, S-1
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ABSTRACT

X-RADIOGRAPHY WITH BETA-EMITTING ISOTOPES

OBJECT

To determine the possibilities of x-radiography using beta-emitting isotopes.

RESULTS AND CONCLUSIONS

Pure beta-emitting isotopes can be used for the production of radiographically applicable x-radiation. Radiographs of rat body and human hand with a weak Sr^{90}-Y^{90} source (Tracerlab Medical Applicator RA-25, Serial No. 546) show good contrast and definition in spite of the unfavorable focal spot size (5 mm diameter and of the low activity of the source (surface dosage rate of the applicator: $330 \pm 10\%$ roentgen-equivalent-betas).

RECOMMENDATIONS

Stronger Sr^{90}-Y^{90} sources and other beta sources should be tried and the characterisitic x-radiation as well as the bremsstrahlung produced in different encapsuling materials should be studied as to yield and quality of the radiation. Construction of portable isotopic x-ray units of this type should be considered, as well as further improvements by using high efficiency intensifying screens, image intensifiers and focussing devices

Submitted 30 November 1954:

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X-RADIOGRAPHY WITH BETA-EMITTING ISOTOPES

I. INTRODUCTION

The idea of using isotopes in clinical radiography has been strongly advocated in recent years (1, 2). As early as 1950, Spangenberg (3) published a radiograph of teeth, taken with cerium-139; Mayneord (4) demonstrated in 1952 the effectual use of thulium-170; and Dennis and DeLuca (5) reported the successful application of cerium-144 and thulium-170 in diagnostic radiology. The Argonne group (6) developed a portable isotopic x-ray source and Carpenter with co-workers (7) recently described a complete, portable isotopic x-ray unit, including isotope source and self-contained cassette, for field and emergency use.

In all cases, so far reported, isotopes have been used which by themselves and/or in connection with their decay products emit beta- and gamma-radiation. Pure beta emitters have not as yet been studied systematically in their applicability for diagnostic radiology. With beta-emitters the x-radiation is produced by the interaction of the beta rays with other material and is predominantly in the form of characteristic x-radiation and/or bremsstrahlung.

The present work was stimulated by that of Leboeuf and Stark (8) on the excitation of characteristic x-rays and the production of bremsstrahlung (internal as well as external bremsstrahlung) in proper target materials by beta radiation from Sr^{90} and Pm^{147}. Strontium-90-yttrium-90 complex was the source for radiographically applicable x-radiation.

II EXPERIMENTAL

A Source

The strontium-90-yttrium-90 source available for the studies was a Tracerlab RA-25 medical applicator.* It consists of the source with an active diameter of 5 mm (overall diameter 12.7 mm) mounted on the end of a 6-3/4 inch shaft. A circular plastic shield (4 inch diameter, 3/8 inch thick) protects against irradiation while handling

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*Applicator data and figures are taken from Tracerlab Instruction Manual for RA-25 Medical Applicator, Serial No. 546, dated 3-22-54.

the applicator. The source contains strontium -90 in equilibrium with yttrium -90 in such an amount that the surface dosage rate is 330±10% roentgen-equivalent-betas per second as measured with a Tracerlab extrapolation ionization chamber. The radiation emitted by the source consists of the 0.537 mev beta rays resulting from the disintegration of strontium -90 into yttrium -90 and 2.18 mev beta rays produced in the decay of yttrium -90 into stable zirconium. The average beta energies for strontium -90 are 0.22 mev and for yttrium -90 are 0.7 mev. The half life of strontium -90 is about 20 years, that of yttrium-90 about 62 hours.

The source has a metallic protective cover (2 mils of stainless steel, 10 mils of aluminum) equivalent to about 100 mg/cm^2 filtration and is sealed by a double hermetic seal. The covering reduces the number of beta particles resulting from the decay of strontium -90 and the decay of yttrium -90 to 3% and 60% of the original value, respectively. Thus the beta radiation emitted by the applicator has essentially the characteristic of a pure yttrium -90 spectrum, filtered by 2 mils of stainless steel and 10 mils of aluminum.

Due to the interaction of the beta rays with other material, however, the source in its normal form also emits x-rays, resulting primarily from <u>bremsstrahlung</u> and characteristic x-radiation produced in the source and absorber material. It is this x-radiation which will be used essentially for the radiographic studies, presented in this report. Preliminary knowledge of quantity and quality of this radiation was obtained by the use of proper absorbing material and a Geiger-Muller tube detector.

B. Radiographic Setup

Two arrangements were tried for taking radiographs of animal and human tissue. In the first one, proper target materials were bombarded with the yttrium -90 beta radiation and an attempt was made to use the excited x-radiation for radiographic studies. In the second method the applicator was taken in its normal form. The yttrium beta radiation and the small amount of strontium radiation transmitted by the protective cover were absorbed by 1.2 cm of lucite placed between the source and the body to be radiographed. Figure 1 shows the details of the experimental arrangement

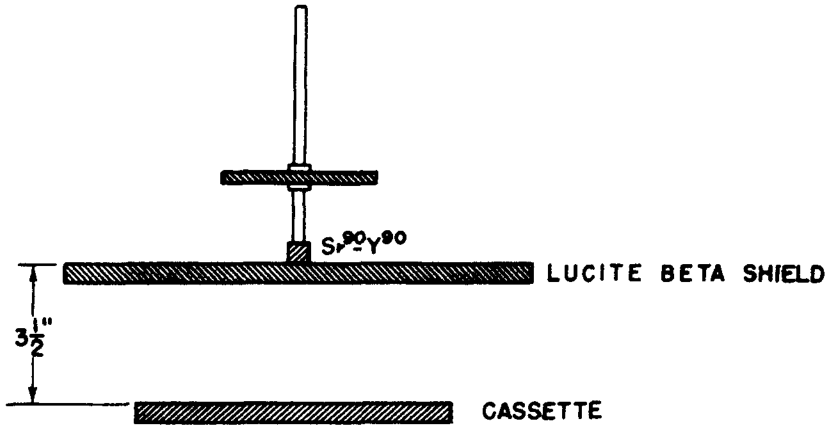

FIGURE I - EXPERIMENTAL ARRANGEMENT

III. RESULTS

Table 1 and Figure 2 give the results of the preliminary measurements.

TABLE 1

INTENSITY OF Sr^{90}-Y^{90} EXCITED X-RADIATION FROM TRACERLAB MEDICAL APPLICATOR RA-25, SERIAL NO. 546, PREFILTERED BY 1.2cm LUCITE

DISTANCE (cm)	7.5	15	30
DOSE RATE (mr/min)	6.4	1.6	0.4

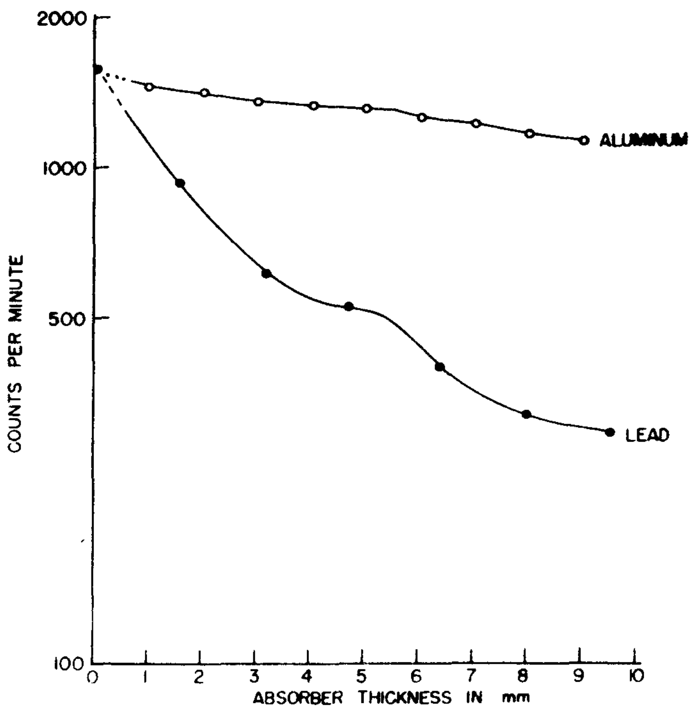

FIGURE 2 - ABSORPTION CURVES FOR Sr^{90}-Y^{90} EXCITED X-RADIATION FROM TRACER LAB MEDICAL APPLICATOR RA-25, PREFILTERED BY 12cm LUCITE.

Figure 3 shows a typical radiograph of a hand, taken with Patterson "Fluorazure" intensifying screens placed above and below the film (Eastman Kodak "Blue Brand") and with an exposure time of 2 minutes and a source--specimen distance of 6 cm. Figures 4 and 5 show radiographs of a rat body and of a hand with exposure times of 5 minutes and source--specimen distances of 10.0 and 10.5 cm., respectively. The pictures show surprisingly good definition and contrast for a relatively weak non-point source.

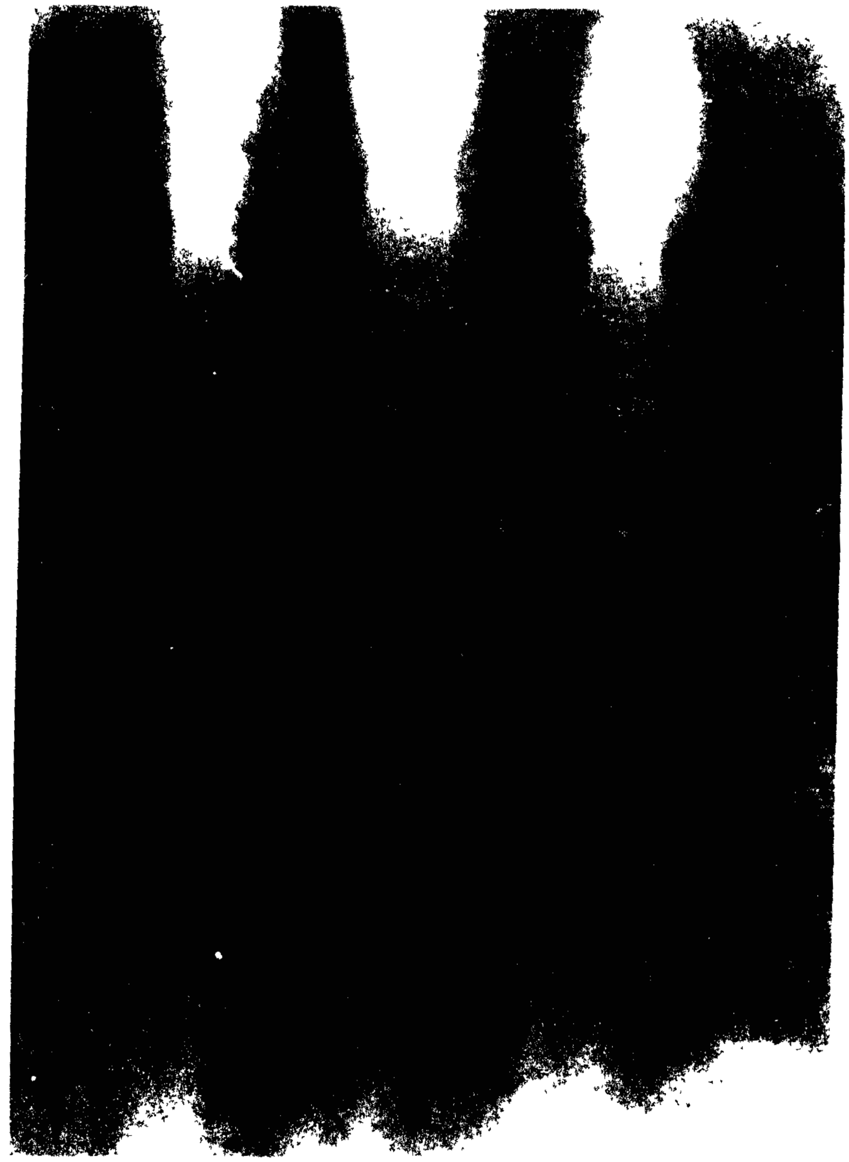

FIGURE 3 - HAND, SOURCE-SPECIMEN DISTANCE 6cm
PATTERSON "FLUORAZURE", EASTMAN KODAK
"BLUE BRAND", EXPOSURE TIME 2 MINUTES.

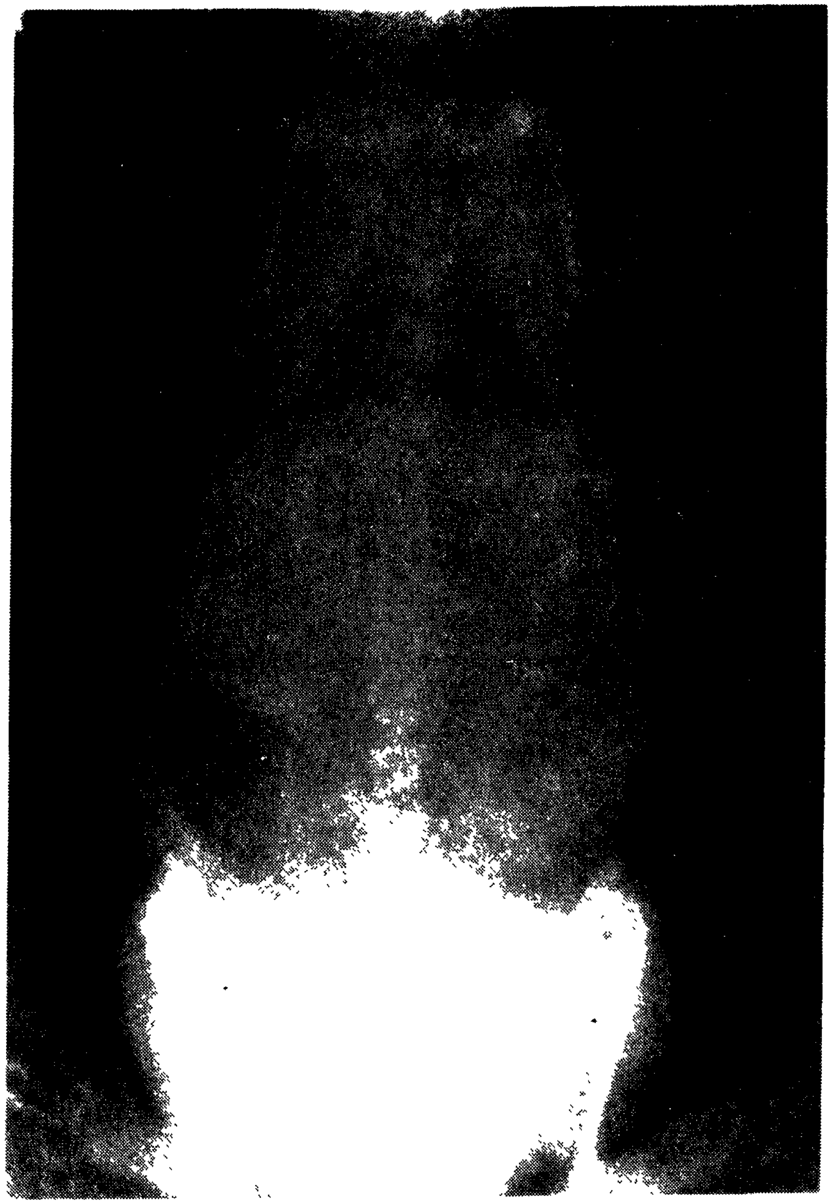

FIGURE 4 - RAT BODY, SOURCE - SPECIMEN DISTANCE 10 cm., PATTERSON "FLUORAZURE", EASTMAN KODAK "BLUE BRAND", EXPOSURE TIME 5 MINUTES.

IV DISCUSSION

The absorption measurements as well as the radiographic results show the existance of x-radiation, emitted by the medical applicator in its common form. This radiation may be composed of: 1) internal bremsstrahlung arising from interaction of the nuclear beta particle with the radiation field of the nucleus; 2) external bremsstrahlung produced in the deceleration process of the beta-particles by absorber nuclei, and 3) characteristic x-radiation produced by interaction of the beta particles with orbital electrons either of the source material or of the capsule and absorber material. The internal bremsstrahlung is produced in the strontium-yttrium complex, the external bremsstrahlung in absorbing layers of the source and surrounding material. Since only 3% of the strontium beta radiations are transmitted by the protective cover (100 mg/cm^2 filtration), it may be assumed that a certain part of the absorbed 97% of these betas are transferred into x-radiation; characteristic radiation as well as bremsstrahlung. According to Leboeuf and Stark (8) the yield for characteristic radiation provided by Sr^{90}-Y^{90} betas in foils is 1×10^{-2} photons per incident beta-particle and the yield for higher energy bremsstrahlung is approximately 6×10^{-2} photons per incident beta. The internal bremsstrahlung of Sr^{90}-Y^{90} extending from 10 kev to about 150 kev, shows a maximum at about 35 kev; the characteristic x-rays excited by Sr^{90}-Y^{90} betas in tin have a maximum at about 25 kev, followed by a bremsstrahlung peak at about 55 kev. The proper data for a steel-aluminum covered Sr^{90}-Y^{90} source are not yet known. The preliminary measurements presented (Figure 2) show that this radiation is heterogenous and that its detailed interpretation requires further study.

The radiographs so far obtained with this simple and relatively weak isotopic x-ray source show astonishingly good definition and contrast. Considering the source size of 5 mm diameter, it must be concluded that with better point sources, better radiographs will be obtained. With decreasing focal spot size the penumbra will decrease, overlapping of penumbras will be avoided and definition will improve. Contrast can be increased by proper filtration of the [illegible] of proper isotopes and/or target materials emitting radiations properly fitted to the requirements of the body parts to be radiographed. The use of grids and of proper distances in combination with stronger sources will also improve the radiographic picture. Stronger sources (the source used has a strength of several hundred millicuries only) will shorten the exposure times and it is possible that isotopic x-ray units with outstanding properties can be constructed, keeping the activity of the source under the activities of units which use x- and gamma-radiation emitting isotopes (3-7).

V. CONCLUSIONS

The reported facts and the presented radiographs show that pure beta emitters can be used for the production of radiographically applicable x-radiation. The radiographs, obtained with a relatively weak Sr^{90}-Y^{90} source show good contrast and definition in spite of the fact that the "focal spot" of the source is great (5 mm diameter) and that the source--specimen distance used in the exploratory studies is relatively short.

VI. RECOMMENDATIONS

To further study the possibilities of isotopic x-radiography with pure beta emitters, stronger Sr^{90} sources and other beta sources contained in small areas ("focal spot") should be used. Different encapsuling materials should be studied as to quantity and quality of the produced x-radiation. The construction of portable isotopic x-ray units of this kind should be considered, as well as further improvements by using better intensifying screens, image intensifiers, and focusing devices.

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