

in the measurement of soft x-rays in free air, but they must be eliminated before we can describe gamma rays under practical conditions without ambiguity and confusion. A possible interpretation of the roentgen for practical conditions, that is consistent with the international definition of the standard and is a property of the radiation only (not of the material that is irradiated), is described in detail in the hope of provoking discussion that will lead to agreement about the meaning of the unit.

The comparison of the physical details of treatment with its biological results is more difficult with gamma rays than with x-rays, in several respects. Some details that are commonly disregarded in x-ray therapy are important in gamma ray therapy. For example, the ratio of secondary effects such as ionisation density, to gamma ray intensity varies by a large percentage under some conditions between skin surface and underlying depths. Methods of estimating it are described. This is probably one contributing cause of the differences in skin tolerance to gamma rays and soft x-ray radiation. This and other physical factors, some of which are not well understood, have important effect on the results of treatment.

The Measurement of Back Scattered Radiation

L. D. MARINELLI.....New York, New York

Accurate measurements of x-rays scattered back to the skin are of primary importance in any comprehensive analysis of the radiation reaction of human skin. Heretofore measurements of this sort have been made almost exclusively with thimble chambers of the air wall type. Measurements thus performed, however, meet with definite objections arising from the fact that thimble chambers, by their very presence, alter considerably the physical conditions around the point at which the ionization is to be measured. It is important, therefore, to investigate the problem by a method which is free from these objections. For this purpose an ionization chamber of the extrapolation type, designed by Failla, was used in our investigation. Its construction will be described in the paper. A calibrated thimble chamber was also used for comparison and found to differ from the extrapolation chamber toward both limits of the quality range investigated.

The variation of back scatter due to different physical factors, within the ordinary ranges obtained in radiological practice, was investigated. In the range of x-ray qualities from 95 kv. unfiltered to 200 kv. filtered by 5 mm. of copper, the maximum back scatter occurs at a half value layer of 0.5 mm. of copper, irrespective of the voltage used. The variation with area of irradiated field is a function of quality in the soft x-ray region, and is practically independent of it for half value layers greater than 0.4 mm. of copper. The thickness of underlying material affects the skin dose considerably only for the first few centimeters, however, the thicknesses of maximum back scatter range from 6 to 15 cm. according to the hardness of the incident radiation. No variation in back scatter could be attributed to target-skin distance when the latter was varied from 30 to 125 cm.

A study of variation of back scatter with phantom material has shown slight but significant variations between paraffin, rice, and "presswood," a commercial product readily obtainable. The latter is by far the most satisfactory from the point of view of density and atomic composition. It is manufactured in sheets of different thicknesses: it can be machined readily, and is rugged.

A survey of the present status of measurement of back scatter will be presented.

The Significance of the Roentgen

W. V. MAYNEORD.....London, England

Recent extension of the wavelength range of electromagnetic radiations used for medical purposes has raised important problems of dosage, and in particular the question of the use of one unit of quantity over the whole series of wavelengths.

Evidence is submitted that the International Roentgen, with some modification, is suitable for use for all x-rays and λ -rays used in therapy. The advantages of uniformity are emphasized, together with the reasons for the choice of an ionization unit such as the Roentgen rather than arbitrary experimental standard. The theoretical and experimental agreement of "air wall" and appropriate parallel plate chamber results is noted.

The relationship between dose in Roentgens at a given point and the energy absorbed in ergs per cubic centimetre in a small unit of mass of tissues situated at that point is briefly discussed and shown to depend upon a variety of physical and geometrical factors. Use of the Roentgen corresponds to the measurement of electromagnetic radiation at a given place by the creation of arbitrary conditions of measurement, conditions which do not always occur in the biological or clinical circumstances of

While the U.S. A.E.C. has encouraged wider use of radiomaterials, it has also set up measures to assure their safe use. Requests for radioisotopes are carefully screened, especially as regards the health safety features of the proposed application, and use of the radiomaterial is allowed only for the purpose authorized. In conjunction with the National Bureau of Standards, radioisotope standards have been established whereby clinical investigators may correctly evaluate dosages. The Commission has also set up, within its Isotope Division, an Advisory Field Service Branch to advise users on health safety practices in handling radioactive materials. In addition it has encouraged and supported training programmes. Furthermore, the Commission has taken measures to decentralize its control and encourage local groups to assume responsibility for proper use of radiomaterials. These things have done much to bring about a steady, safe growth in radioisotope utilization.

106 Radioactive isotopes for clinical use from the Chalk River pile.

CIPRIANI, André J.

Chalk River, Canada.

A number of radioactive isotopes are being produced in the high-flux, heavy water pile at Chalk River. It is possible to produce material of relatively high specific activity with reasonable irradiation times. Steps have been taken to prepare isotopes for clinical use and special attention is being paid to suitability of these substances for parenteral administration. The absolute standardization of radioactive isotopes is being carried out in collaboration with other laboratories on an international scale. Techniques are being developed to estimate the amount of radioactive material in the human body with a view to estimating hazards due to ingestion and inhalation.

107 Ionization in the air surrounding beta ray sources.

MARINELLI, L. D.

Chicago, U.S.A.

In collaboration with S. S. Brar and R. K. Clark the ionization in air around point sources emitting β -rays has been investigated by means of ionization chambers with thin aluminium walls, under experimental conditions obviating scatter by surrounding objects. Correlation with theories of multiple scattering will be attempted.

108 Production and some data of pile made isotopes in England.

SELIGMAN, Henry.

Harwell, Gt. Britain.

The production and distribution of radio-isotopes made in the nuclear reactor will be discussed. The limits of specific activities which can be obtained will be given and the future outlook of the production of isotopes with higher specific activities will be outlined. Some limits of carrier-free materials will be given. The usefulness of isotopes with regard to medical and radiological uses will be discussed according to their physical properties.

able is concerned with radium poisoning, while animal toxicity studies have been performed with a variety of elements.

The human data are not as clear as might at first be thought, since in most of the cases we know only the radium content of the body at the time when serious pathology appears; since the possible contamination of administered preparation with mesothorium is difficult to evaluate; and since published series of cases have largely been selected on the basis of pathologic changes.

Extrapolation of comparative toxicity studies to man is made difficult also by virtue of the fact that human pathologic changes generally are manifest after many years, while the changes studied in experimental animals are those occurring within two to five years. The relation between life-span, duration of irradiation, animal size, and the development of malignant tumors is important and can be evaluated only by indirect means.

Comparative studies in laboratory animals indicate that in regard to acute and chronic toxicity and in bone tumor formation, plutonium is at least ten times as toxic as radium on a microcurie basis. The evidence at present available suggests that many other alpha-emitting elements are ordinarily more toxic than radium.

B8 The evaluation of gamma ray activities in living persons.

MARINELLI, L. D.

Lemont, U. S. A.

A part of a study of the Ra content in about fifty living persons, external measurements of gamma ray activity have been made by means of NaI scintillation counters.

In the techniques employed the role of the spectral sensitivity of the counter and of the scattered radiation in suitable phantoms has been investigated.

Accuracies of the order of $\pm 10\%$ have been obtained in the external measurements of the Na^{24} content of volunteers of different weights to whom known amounts of the element were administered at various times prior to the tests.

It is concluded that appropriate corrections to the method of Evans (1) can be formulated for the attainment of accurate as well as consistent results.

- (1) R. D. Evans: The quantitative determination of Ra content and Ra elimination rate of living persons. *Am. J. Roentgenol. & Ra. Therapy* 37, 368, 1937.

B9 The delayed toxicity of radium deposited in the skeleton of human beings.

HASTERLIK, Robert J.

LOONEY, William B.

Lemont, U. S. A.

A residuum of individuals who were injected with solutions of radium for therapeutic purposes between twenty and thirty years ago exists in the United States. This group is of fundamental importance in quantitating the neoplastic response of the skeleton to the alpha

a substantial economy in a Department. An example of this is the Processing Machine for films, which incorporates much up-to-date mechanical ingenuity. It enables the time-factor for processing to be greatly reduced, the film turnover increased and handling simplified.

The use of such a machine and other devices like the Cassette Conveyor, effects economy both in personnel and chemicals and even reduces film wastage, especially where a photo-timer is employed.

Modern Processing Machines deal more rapidly with the films, thus increasing the capacity and the efficiency of the Department. Long waiting times are avoided to the benefit of both the patient and the hospital.

508 Radiological Findings of Influenza Involving the Lungs

WALLGREN, S.

Stockholm (Schweden)

509 Spectral Distribution and Energy Absorption of 100 to 250 kV X-ray beams

HETTINGER, G.

Lund (Schweden)

LIDÉN, K.

Lund (Schweden)

The scattered radiation within a water phantom irradiated by semimonochromatic X-rays with the effective energies of 63, 113 and 184 keV was investigated by scintillation spectrometry. The experimentally determined spectra in different directions were used for the calculations of the angular components of the photon and dose buildup. The differential spectra were also integrated over the space giving the number flux of the scattered radiation. Some typical depths and field sizes were studied. Finally the data were normalized in order to secure absolute units for further calculations. As an application of the experimental results the spectral distributions of the scattered photons of 170 and 250 kV X-rays (H.V.L. 1.05 and 2.5 mm Cu respectively) within a soft tissue equivalent water phantom were calculated. With due allowance for the experimental error satisfactory agreement was obtained with data calculated from depth dose tables. The spectra thus obtained were used for energy absorption calculations in order to determine the average value of the f-factor, i. e. the absorbed dose in rad per roentgen integrated over the whole spectrum of primary and secondary photons.

510 The Effects of Chronic low Levels of Radiation on Man: The Contribution of Epidemiological Studies*

MARINELLI, L. D.

Lemont, Ill. (U.S.A.)

A realistic appraisal of the effects of prolonged, low level of radiation in man will require observations on human populations which have been exposed to them. Observations on doses, however small, delivered at high dose rates as in therapeutic or diagnostic radiology cannot be expected to hold at dose rates smaller by several orders of magnitude; neither can extrapolations be made with absolute confidence, nor more economically, by the use of mammalian species of comparable life span.

A few epidemiological surveys concerned with leukemogenic and life-shortening effects of radiation doses of the order of several hundreds roentgens, delivered in relatively short times, have already yielded data of respectable, if not perfect, quantitative import. Studies on effects of similar doses, but delivered at reduced dose rates, can be made on populations burdened with radium and thorium compounds. Gathering of the necessary data on an adequately large scale will require, however, the concerted efforts of many nations throughout the world. A survey of promising approaches to the problem will be discussed.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

RADIATION BIOLOGY

Queen Elizabeth Hotel, Duluth-Mackenzie Room

9 a.m. - 12 noon

Friday, 31st August

E 3 RADIOACTIVE BODY BURDENS

672 THE TRANSLOCATION OF THORIUM
DAUGHTERS TO THE SKELETON OF
THOROTRAST PATIENTSMARINELLI, L. D. (Original: English) Argonne, Ill., U.S.A.
LUCAS, H. F. (Jr.)

The thorium dioxide from Thorotrast injections is largely confined to the liver and spleen where most of the lesions also occur. Owing, however, to the translocation of the Th^{232} daughters, radioactivity is spread to the skeleton and other tissues.

The radiation dose from the skeletal deposit depends on the amount of Thorotrast injected and may be several orders of magnitude higher than that obtained from natural background. These Thorotrast patients, therefore, represent a unique, irreplaceable opportunity to study the effects of chronic radiation on man.

Measurements have been made at our Laboratory and elsewhere of the Th^{232} , Ra^{228} and Th^{228} in their bones. Extrapolating to the whole skeleton, and correcting for the state of radioactive equilibrium in the liver and spleen, a good correlation is obtained between measurement and theory. From measurements to date, the Ra^{228} content is in accord with known retention of Ra^{226} in humans. No excess of Th^{228} is found in bone to justify the assumption that "wash out" Th^{228} is translocated from the R.E.S. to bone mineral.

Measurements of Ra^{224} in bone have not been reported. Although whole body gamma ray and excretion measurements are consistent with the assumption that Ra^{224} is retained in the skeleton to a greater extent than Ra^{228} , reliable direct measurements of this isotope are needed to establish the chronic absorbed dose.

Practically no information is available on the radioactivity and, hence, on the dose absorbed by the marrow and the lungs of these patients. Epidemiological survey has been limited to a small group in Denmark and Sweden; an immediate and world-wide effort must be made to identify and follow-up this population.

A105 GAMMA SPECTROMETRIC STUDIES OF THE
DISTRIBUTION OF THORIUM 232 AND ITS DAUGHTERS
IN THOROTRAST PATIENTS AND DETERMINATION OF THE
ELIMINATION OF THORIUM DAUGHTERS FROM
THE BODY FOR DIFFERENT DISTRIBUTIONS OF
THOROTRAST DEPOSITS.KAUL, A. (Original: German) Frankfurt/M, Germany
RAJEWSKY, B.

An estimation of the radiation dose in patients who received diagnostic injections of thorotrast, many years ago, is only possible

XXVIII. MEDICINA NUCLEARE

Applicazioni della spettrometria gamma

(Abstr. 193-198)

Aula IV

Sabato 25 - ore 14,30

193. Applications of gamma-ray spectrometry *

MARINELLI, L.D., Argonne, Ill., U.S.A.

Scintillation pulse-height analysis has introduced the use of gamma-ray spectrometry into the measurement and localization of radionuclides in the intact animal, including man. Besides its pristine usefulness in the field of radiation protection, the technique is already contributing to the field of clinical research.

In addition to its most obvious application to the estimate of whole-body elimination and turnover rates of tracers in body organs, the technique of gamma-ray spectrometry, with suitable modifications of the apparatus and elements in use, will undoubtedly improve spatial resolution of localization in body organs and could conceivably alter radically current methods of scanning.

It must be realized, however, that the ultimate success of the technique at the clinical level is indissolubly linked to the improvement of specificity of compounds used in diagnosis and to the economic aspects of its implementation.

* Work performed under the auspices of the U.S. Atomic Energy Commission.

194. Applications cliniques de la spectrométrie gamma (Clinical applications of gamma-spectrometry)

GUÉRIN, R.A., Paris, Francia

La mesure directe « in vivo » de la radioactivité du corps humain — en entier, ou d'un segment de celui-ci — apporte au Biologiste et au Clinicien de nouvelles informations physiopathologiques, diagnostiques, pharmacologiques, médico-légales. Répétée à intervalles de temps définis en fonction du radioélément en cause et de son métabolisme, la Spectrométrie gamma permet l'obtention de documents « dynamiques » sur l'accrétion et l'élimination du radio-élément considéré. Le ^{47}Ca et le ^{85}Sr sont utilisés dans les affections diffuses du squelette : Ostéoporose, Ostéomalacie, Ostéose parathyroïdienne, maladie de Paget, myélomes, métastases. La Thyroxine marquée en pathologie thyroïdienne. Le ^{59}Fe et le ^{51}Cr , en hématologie (anémie pernicieuse, leucémies, myélofibroses). Le ^{24}Na et le ^{40}K , dans l'étude des électrolytes. Albumine et globulines marquées à ^{131}I , en cancérologie. Le ^{40}K dans les affections musculaires. Vitamine B_{12} marquée au ^{58}Co ou au ^{60}Co , dans les troubles de l'absorption intestinale. Néphropathies; affections hépato-biliaires, peuvent être également explorées par la Spectrométrie. Recherche d'une contamination accidentelle (surveillance du personnel des Centres isotopiques; contamination de la population du fait des retombées radioactives). Etude des corps chimiques « chélateurs ». Contrôle pharmacologique du devenir dans l'organisme de médicaments nouveaux, sont autant d'applications de la Spectrométrie gamma appelées à un développement rapide au cours des prochaines années.

therapy was applied as soon as possible, and irrespective of the patient's age. Radiation of the underlying bones was carefully avoided. Medium or short-distance radiotherapy was administered, depending upon the size of the tumour in fractionated doses ranging from 100 to 200 r every 3-5 days to a total dose of 800-1,200 r (skin dose). With these doses further growth of the hemangioma ceased and a slight regression was achieved. Radiotherapy was then discontinued and the hemangioma left to regress spontaneously. Recurrence or slow regression of the hemangioma was observed, but in no case did radiotherapy injure the surrounding tissues. The final therapeutic results were considered excellent in all cases.

LIV. RADIOBIOLOGIA

Protezioni radiologiche - Sorgenti interne

(Abstr. 1035-1042)

Aula VIII

Martedì 28 - ore 14,30

1035. Survey of radiation carcinogenesis in bone *

McCLEMENT FAILLA, P. and MARINELLI, L. D., *Argonne, U.S.A.*

A review will be presented of radiation carcinogenesis in bones of human beings and animals. The available data from both published and unpublished sources will be analyzed from a number of different viewpoints. Some of the radiation variables to be discussed include the influence of average dose, integral dose, dose rate, fractionation, and type and energy of radiation. Other aspects to be considered will involve the volume of irradiated tissue and the number of cells "at risk". The data will also be examined to assess the possible influence and importance of a transmutation effect and the recoil energy associated with the decay of the bone-seeking internal emitters. Time factors such as the latent period, age, and lifespan will be treated as well.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

1036. Calcul des doses en médecine nucléaire et en radioprotection. Étude d'un exemple: l'iode radio-actif (*Dose calculation in nuclear medicine and in radioprotection. A study of radioactive iodine as an example*)

DELPLA, M. J. A., *Paris, Francia*

On trouve dans la littérature médicale qu'il faut de 30 000 à 40 000 rads pour détruire une glande thyroïde fonctionnellement normale chez un sujet adulte. L'énormité de cette dose conduit à penser qu'il convient de reconsidérer les hypothèses de calcul qui conduisent à tel résultat.

Le médecin doit calculer les doses, pour chacun des malades traités qui ont absorbé l'isotope choisi, avec autant de précision que le lui permet l'incertitude sur les données anatomophysiologiques. Le radioprotecteur doit baser ses calculs avec prudence, de façon à attribuer à tout sujet contaminé, souvent par un mélange d'isotopes, d'une dose au moins égale à la dose reçue; cela le conduit, dans l'incertitude, à adopter les valeurs numériques des paramètres anatomiques et physiologiques qui majorent le résultat.