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MATHEMATICAL DETERMINATION OF THE DOSE RECEIVED BY HUMAN FOREARM DURING MEASUREMENT OF BONE MINERAL CONTENT (BMC) WITH A NARROW BEAM OF MONOENERGETIC GAMMA RAYS

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A mathematical method for the evaluation of a radiation dose during measurement of bone mineral content in the forearm exposed to a narrow beam of gamma rays is described. Bone mineral content was measured with the Cameron Sorenson method modified by Nilsson. The method was found to be very convenient, simple and relatively fast. Mathematically the exposure of 0.64 mR to which each point of the forearm is subjected during measurement proved negligible in comparison with the ICRP Recommendations (6).

The method of gamma ray absorption developed by *Cameron* and *Sorenson* (1, 2)) and modified by *Nilsson* (3), which is based on attenuation of radiation from radionuclides in the matter, was used for the »in vivo« determination of bone mineral content. The skeletons of the hand and forearm have been and probably will remain for a considerable time in the future the most popular sites for the estimation of bone mineral mass.

The measurements were done with a commercially available instrument for BMC determination (Gambro, Lund-Sweden) connected to a single channel analyser and to a computer-printer Wang 600. A 2"× 2" NaI(T1) scintillation crystal was used as detector and ^{241}Am of 45 mCi served as a radiation source.

The measurements were performed at two measuring sites, distal and proximal. The distal measurements were carried out at a one centimetre distance from the styloid process of the ulna (found by palpation), whereas the proximal measurements were performed at a six centimetre distance from the same point. Both way scans were used at both sites and the average value was taken as BMC for the site concerned.

The purpose of this work was to find out the dose level received by the subject during the measurements.

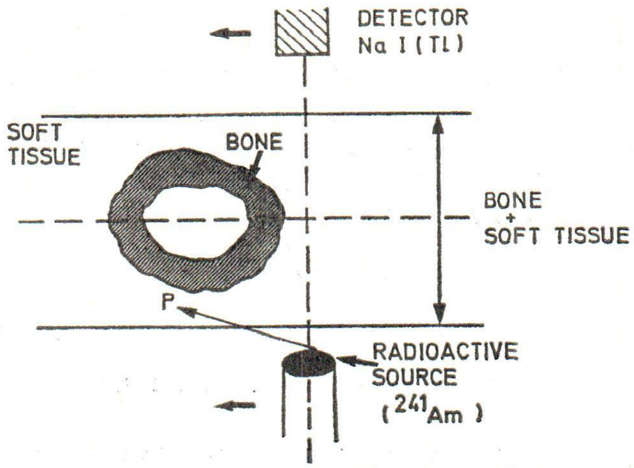

Fig. 1. *Schematic diagram for a cylindrical collimated beam of photons scanning continuously across the bone and soft tissue of the forearm*

A circular collimator with a radius »a« emitting a monoenergetic beam of photons which scan the sample of constant bone and tissue thickness is presented in Fig. 1. The same figure gives a schematic diagram for a cylindrical collimated beam of photons scanning continously across the bone (beam diameter — 3 mm, scanning speed — 30 mm/min). If we take the source as a point source of 45 mCi strength the dose rate at a distance h (4 cm) from the forearm will be:

$$I_P = \Gamma \, 45/h^2 \qquad (1)$$

where Γ is the gamma-ray dose rate constant expressed as

$$\Gamma = \Sigma P_j \Gamma(E\gamma)_j$$

P_j being the percentage gamma ray abundance per desintegration and $\Gamma(E\gamma)$ the dose rate constant for the specific gamma ray ($E\gamma$) concerned. In our case Γ is 0.0682 cm^2 R/mCi hr*.

The points at the central axis (highest exposure) along the line traversed by the axis of the beam during the measurement will be subject to an exposure of 0.32 mR during a single pass of the beam (3 mm beam diameter divided by 30 mm/min = 0.1 min multiplied by 3.2 mR/minute

* For americium-241 with two gamma-rays of energy ($E\gamma$) of 60 keV and 26 keV, corresponding to 36% and 2.5% abundances respectively, Γ will be: $\Gamma/cm^2\ r\ mCi^{-1}h^{-1}$ $0.12 \cdot 0.36 + 1.0 \cdot 0.025 = 0.0432 + 0.025 = 0.0682$.

= 0.32 mR). With two passes along the same line the exposure at any point on the line will be 0.64 mR. By summing up distal and proximal measurements we obtain the overall exposure during the measurement 0.64 × 2 = 1.28 mR. If compared to the ICRP Recommendations (6) which give 75 mRems allowance for hands and forearms for exposed adults this exposure is negligible. The mass of the exposed tissue is so small and the chance that the body would suffer any recognizable effect from irradiation is reduced on this ground just as much as on the ground of the dose which is much below ICRR limits. However there is a difference in absorption of these low energy gamma rays between air (or tissue) and bone which cannot be neglected. For difference see (4, 5) tables of *O'Brien* where the absorption of the energy of 60 keV is about twice as high in the bone as in the skin. In spite of this fact the exposure remains negligible.

References

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Sažetak

ODREĐIVANJE DOZE ZRAČENJA KOJU PRIMA PODLAKTICA TOKOM GAMA DENZITOMETRIJE PODLAKTICE U ČOVJEKA

Opisana je matematička metoda određivanja doze zračenja kojoj je izložena podlaktica čovjeka tokom određivanja gustoće koštanog minerala podlaktice fotonskom apsorpciometrijom. Za analizu koštanog minerala »in vivo« metoda apsorpciometrije fotona, koju su razvili Cameron i Sorenson, a modificirao Nilsson pokazala se vrlo prikladna za kliničke studije određivanja kalcija u kostima skeleta bilo u normalnom bilo u patološkom stanju. Ta jednostavna »in vivo« metoda omogućuje mjerenja koštanog minerala distalnog i proksimalnog dijela podlaktice, a dobiveni rezultati mogu se ekstrapolirati na cijeli skelet. Metoda Camerona i Sorensona uvodi se na Institutu za medicinska istraživanja i medicinu rada u Zagrebu. Metoda se pokazala vrlo prikladna, relativno brza, posve bezbolna a ekspozicija izvoru zračenja tokom mjerenja u svakoj točki podlaktice beznačajna je (0.64 mR) u usporedbi s preporukama Međunarodne komisije za radiološku zaštitu (ICRP) (6).