Checking Dosimetry Accuracy by Post

by Dr. H. Eisenlohr and Dr. R. Abedin-Zadeh (IAEA)

Radiotherapy, which is the treatment of patients with ionizing radiation, has an increasingly important role in the medical field. This is largely due to its growing use in the treatment of malignant diseases, such as cancer, which is increasing throughout the world, and particularly in the developing countries. While the main radiations for patient treatment are still X-rays and gamma rays, particle accelerators producing high energy electrons and photons have recently been used more and more for the treatment of deep-seated tumors.

In radiotherapy, more than in any other radiation application, dosimetry of maximum accuracy is essential. This is necessary to ensure effective treatment, and also to allow comparison of therapeutic methods and their results. It is, in fact, the most important aspect of radiation dosimetry.

Unfortunately evidence showed that many X-rays and cobalt-60 (^{60}Co) gamma-ray radiotherapy units used for the treatment of cancer are not being properly used, because of inadequate dosimetry.

Both the IAEA and WHO have long been aware of the need for improved dosimetry in radiotherapy, and for other medical applications of radiation.

The number of ^{60}Co units available for treatment per million population varies from 0.01 in some developing areas to 3 in highly industrialized countries. Table 1 shows the geographical distribution of ^{60}Co units.

A first inquiry in 1966, carried out by means of questionnaires and inspections by IAEA Regional Advisers, revealed the disturbing fact that in about 30% of the hospitals covered there was either no dosimeter at all, or the one in use had never been re-calibrated after its purchase. Of all the radiotherapy centres round the world, only a small fraction has ready access to national standardizing dosimetry laboratories.

In order to improve the accuracy of dosimetry the IAEA set up a postal dose intercomparison service for ^{60}Co radiation, utilizing thermoluminescent lithium fluoride (LiF) powder as dosimetry substance.

Thermoluminescent dosimetry was chosen because it offered several advantages over other possibilities, e.g. the capsules containing the LiF powder are relatively cheap and easy to mail. They also allow an estimated accuracy of ±5%, which was considered appropriate for the relatively large errors that had to be anticipated.

Prior to putting this scheme into operation, the IAEA in 1966 began a programme of comparative trials with the cooperation of 19 radiotherapy centres in 6 countries. The second trial run included 14 centres in Canada, the third 15 centres in 6 Asian countries.

TABLE 1. GEOGRAPHICAL DISTRIBUTION OF ^{60}COBALT RADIOTHERAPY UNITS (in 1969)

	Population (millions)	Number of ^{60}Co units	Number of ^{60}Co units per million of population
Africa	359	27	0.075
America (excluding Canada and USA)	275	146	0.53
Canada	21	48	2.28
USA	203	574	2.83
Asia (excluding Japan and China)	1218	77	0.06
Japan	102	325	3.19
Australia and New Zealand	15	21	1.40
Europe (excluding USSR)	513	1821	3.55

The figures were taken from: IAEA, Directory of high-energy radiotherapy centres, 1970 edition; UN, Demographic Yearbook 1969.

When WHO joined the programme in 1968 a great many more centres could be enlisted to cooperate. Questionnaires were sent out to some 300 centres in about 60 countries which had either already participated in the Agency's trials or had expressed their interest. Priority was given to developing countries. The questionnaire sent out asked for information on the radiotherapy equipment, staff and the dosimetry performed.

From the replies (up till the beginning of 1973, more than 300 centres have returned the completed questionnaire) it is clear that in advanced countries, almost all centres have a full-time radiotherapist; in developing countries, only about 75%. A very low number of centres in advanced countries employ only a part-time radiotherapist, but more than 20% of the centres in developing countries. There is a noticeable difference between the number of centres carrying out regular dosimetric measurements in advanced (55%) and in developing countries (43%). The number of centres not carrying out any dosimetric measurements at all is correspondingly lower in advanced (9%) than in developing countries (16%).

TABLE 2. DISTRIBUTION OF DEVIATIONS IN MEASURED DOSE FROM QUOTED VALUE AMONG INSTITUTIONS PARTICIPATING FOR FIRST TIME IN INTERCOMPARISONS, GROUPED ACCORDING TO LOCATION.

Location of Institution	No. of Institutions	← DEVIATION → ±0-5%	±5-10%	±10-20%	>±20%
Africa	12	8	4	-	-
Asia	71	36	18	9	8
Latin America	44	13	13	13	5
Australia & N.Z.	14	9	5	-	-
Europe	107	72	20	10	5

TABLE 3. DISTRIBUTION OF DEVIATIONS IN MEASURED DOSE FROM QUOTED VALUE AMONG INSTITUTIONS PARTICIPATING FOR SECOND OR HIGHER TIME IN INTER-COMPARISONS, GROUPED ACCORDING TO LOCATION

Location of Institution	No. of Institutions	← DEVIATION → ±0-5%	±5-10%	±10-20%	>±20%
Africa	6	5	1	-	-
Asia	23	19	3	1	-
Australia & N.Z.	3	3	-	-	-
Europe	20	18	2	-	-
Latin America	4	3	1	-	-

The procedure generally employed in this scheme is the following: after prior announcement, each centre in a group of between 30 and 40 receives 8 dosimeter capsules together with a capsule holder and precise instructions calling for irradiation of the capsules in a water phantom at 5 cm depth. Three of them are to be irradiated with a fixed dose, another 3 for a fixed period of time. The remaining 2 capsules are used for control purposes; they must not be irradiated but returned to the Agency together with the other capsules.

On a data sheet supplied to the centres all relevant details must be indicated, such as type and model of the ^{60}Co unit calibration measurements performed, dose rate, irradiation conditions of the LiF capsules, methods of calculation, etc.

After irradiation of the capsules and completion of the data sheets, both are returned, via WHO, to the Agency for measurement. The measurements are carried out within 20 to 30 days after irradiation time to eliminate any factors (such as the fading effect) which might influence the results. Since the sensitivity of the LiF detectors can vary considerably from batch to batch, it is checked for each new batch and also within one shipment. Other factors which play an important role in the evaluation are the precision of the measuring instrument, which must be periodically calibrated, the accuracy of determining the quantity of LiF powder used in the capsules, and the calibration of the dosimeter. Results are expressed in terms of deviation from the quoted values of absorbed dose and of the absorbed dose rate.

Table 2 shows the results of the intercomparisons. In a few cases (reported in column $> \pm 20\%$) deviations of the order of 50%, and in one case over 100%, were observed.

When the results have been evaluated by the Agency they are sent, strictly confidentially, through WHO to the participating centres. Institutes with large deviations or apparently insufficient knowledge of dosimetric procedures receive detailed instructions how to remedy their shortcomings.

Improvement of dosimetry after participation in the IAEA/WHO dose intercomparison scheme is clearly demonstrated in Table 3. These results show that, as a consequence of repeated participation in the scheme, the number of institutes with deviations exceeding 5% is decreasing. In fact, deviations exceeding 20% are no longer observed.

This survey has shown that in many countries the state of radiotherapy is not as good as it should be to achieve optimal results. It is difficult, however, to ascertain the real cause, or causes, of the sometimes rather poor results in big centres. Technical shortcomings might be one reason, but a more likely factor is the lack of appropriately trained personnel (medical physicists), and the lack of awareness on the users' side of the need for good dosimetry.

It is the aim of the present joint IAEA/WHO programme to continue to collect and evaluate information relating to dosimetry in radiotherapy centres, and to emphasize to the users the extreme importance of dosimetry. It is planned that in the future this work should be taken over and carried out by Regional Reference Centres for Secondary Standard Dosimetry, established with the support of both Organizations.