Radiation dosimetry in health care: Expanding the reach of global networks

The IAEA and WHO are jointly taking steps to improve quality assurance services for hospitals and radiotherapy centres

by Peter Nette and Hans Svensson

Back in 1968, a panel of international experts meeting in Caracas were given some disconcerting news: While more than 50 cobalt-60 radiotherapy units were in routine use throughout Latin America, there were only five qualified hospital physicists and no laboratory for performing instrument calibration. In other words, there was no system in place to ensure the accuracy of doses that patients under radiotherapeutic care were receiving.

The news from the Caracas meeting — jointly convened by the IAEA and World Health Organization (WHO) — triggered an action plan for improving the situation, not only in Latin America but in all regions of the world.

The plan featured three components: (1) establishment of an IAEA/WHO dose intercomparison service for hospitals in developing countries, to help them monitor and correct treatment doses; (2) establishment of an IAEA/WHO network of dosimetry laboratories to help standardize radiation measurements in radiotherapy centres; and (3) provision of training in radiation dosimetry through the IAEA.

Today, these three components are in worldwide service, playing important roles in supporting efforts to improve patient care and treatment involving radiotherapy.

In this article, the strides that have been taken, and problems that still remain, are reviewed in a global context. Also discussed are steps being taken toward a formidable goal, namely setting up a worldwide quality assurance programme covering dosimetry checks for millions of patients that undergo radiotherapy each year.

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Services and networks in dosimetry

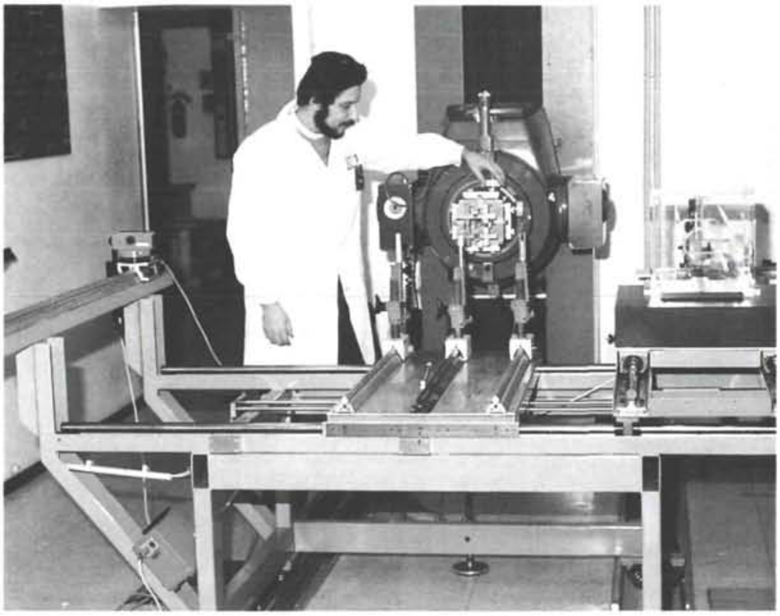
Malignant tumours — cancer — will affect many of us. In the industrialized world, generally 20% and 30% of the population gets cancer. The overall percentage right now is lower for developing countries, mainly because people there have such short expected lifetimes. That situation is likely to change as the causes of early death are reduced.

Cancer treatment includes surgery, chemotherapy, and radiotherapy, or any combination of the three. In many countries, radiotherapy plays a role in the management of 50% to 60% of all cancer patients, either as a curative treatment or as an agent to relieve pain.

For treatments with a curative aim, it is of great importance to concentrate the radiation to the solid tumour and surrounding tissue, including what is called the microscopic spread of cancer cells. The radiation effect is dependent on the amount of radiation energy that is transferred to the tumour or the healthy tissues — i.e the absorbed dose to the tumour and tissue. Since water absorbs radiation in a similar way as tissue, the physical quantity that has been agreed upon to specify the irradiation is therefore the absorbed dose to water. This quantity has to be determined with the highest achievable accuracy, taking into account the delicate balance of radiation damage (destruction of healthy tissue) and radiation benefit (tumour eradication or tumour growth control). The dose determination for each patient involves highly specialized work generally carried out by a medical physicist in close co-operation with a radiation oncologist. It is based on qualified measurements and computations.

Through various avenues, a number of services are available to assist countries in the field of radiation dosimetry.

The IAEA/WHO postal TLD dose intercomparison service. For participating hospitals,



At the IAEA's Dosimetry Laboratory: **Evaluation of irradiated TLDs** *(above)*, **and the calibration of an ionization chamber.**

the IAEA and WHO jointly offer an intercomparison service using small radiation dosimeters, technically called thermoluminescence dosimeters (TLDs). They consist of encapsuled lithium fluoride powder and are prepared and calibrated at the IAEA's Dosimetry Laboratory in Seibersdorf, Austria.

Through the service, the TLDs are mailed, together with a mountable irradiation stand, to WHO offices for distribution to participating radiotherapy hospitals in developing countries. There, under defined patient treatment conditions, they are exposed in the cobalt-60 beam of the treatment unit to what the resident physicist determines to be the specified dose. The TLD capsules are then returned to the IAEA's Laboratory for evaluation of the actual dose. The deviation between the hospital's quoted dose and the IAEA evaluated dose is reported through WHO to the hospital. A deviation of more than 5% is considered to be unacceptable and should result in a recalibration of the hospital's radiation beam used for patient treatment.

The IAEA/WHO network for secondary dosimetry laboratories (SSDLs). One of the recommendations of the Caracas panel was to establish conformity of radiation measurements in radiotherapy departments throughout the world. In industrialized countries, hospitals achieve conformity through calibration of their dosimeters to national primary standards. The heavy workload of the world's existing 13 Primary Standard Dosimetry Laboratories (PSDLs) unfortunately does not allow the calibration of reference dosimeters from thousands of other hospitals worldwide. Competent national authorities, therefore, have designated SSDLs to provide certified calibrations.

One requirement in the science of radiation measurements (radiation metrology) is that standardizing laboratories should compare their standards against each other at regular intervals. For primary standards, the organization of such intercomparisons is the responsibility of the International Bureau of Weight and Measures (BIPM) in Paris, France.

For SSDLs, the same need applies, and an international SSDL network was set up in 1976 by the IAEA and WHO. It includes a technical assistance arm, whereby most of the participating developing countries can receive financial support and expert guidance and advice. Today, the network extends to nearly 60 laboratories, most of them in developing countries. The administrative and co-ordinating work is shared by the IAEA and the WHO, with the IAEA being responsible for the technical development of member laboratories.

The IAEA's Dosimetry Laboratory in Seibersdorf functions as the network's central laboratory. Many national PSDLs and some international bodies — among them the BIPM, the International Office of Legal Metrology, and the International Commission on Radiation Units and Measurements (ICRUM) — support the work of the SSDL network. Additionally, a standing SSDL Scientific Committee is available for advice when needed. Consultants and advisory groups further can provide assistance in the implementation of specific projects, such as the drafting of technical reports, guidelines, and manuals.

The existing global distribution of SSDLs and PSDLs shows that most countries have established an infrastructure for standardization of radiation

A test programme for SSDLs: Results of an IAEA pilot study

Three SSDLs, those in Argentina, India, and Thailand, are participating in an IAEA pilot study designed to strengthen quality assurance services in radiotherapy. The study has involved quality control tests that the three SSDLs have successfully passed:

Test 1: The SSDLs were asked to calibrate a set of ionization chamber dosimeters. Their calibration factors were then compared with previously established ones from the IAEA. (This test still is to be completed by Thailand.)

Test 2: The SSDLs evaluated TLDs from hospitals during an intercomparison run, using their own calibration curves as well as one supplied by the IAEA. Results were then compared.

Test 3: The IAEA participated as a "hospital" in a national intercomparison run organized by each SSDL.

Test 4: TLDs were sent for irradiation to their respective national hospitals by the SSDLs and the IAEA, with the IAEA's TLDs going to 10% of the hospitals. The SSDLs evaluated their returned TLDs, while the IAEA evaluated its own, and the results were then compared.

measurements. However, additional efforts are necessary for expanding the network's reach, especially for the African continent.

The IAEA's dosimetry laboratory. As previously noted, the IAEA's Dosimetry Laboratory at Seibersdorf, about 30 kilometers from Vienna, Austria, is the Central Laboratory of the IAEA/WHO network of SSDLs. The laboratory's work covers the:

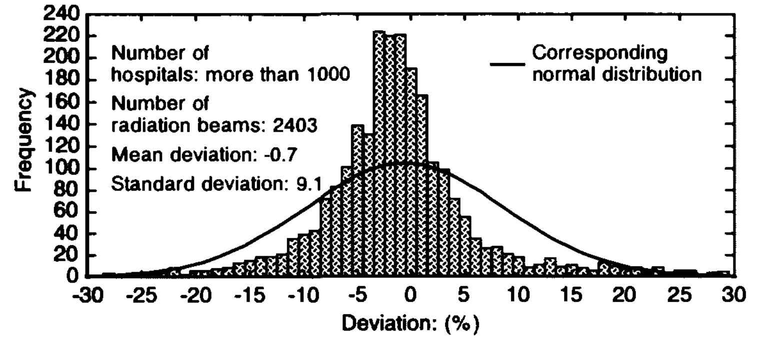
- organization of dose intercomparison measurements for SSDLs;
- performance of dose intercomparisons for some 100 radiation therapy centres each year;
- provision of calibration certificates for reference dosimeters from SSDLs and hospitals;
- acceptance of SSDL staff for on-site training;
- design and development of special methods and devices for use in hospitals and SSDLs;
- operation of the International Dose Assurance Service for radiation processing facilities in IAEA Member States.

The laboratory, for example, has prepared more than 80 batches of TLDs, sent them out and evaluated them through the postal dose intercomparison service. The service has reached about 1000 hospitals in developing countries.

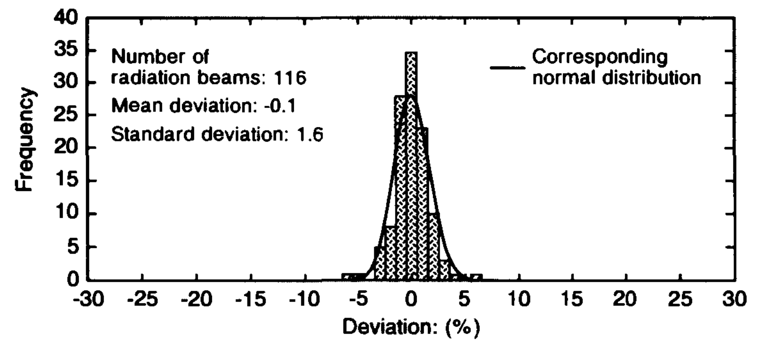
Until 1991 all results were from cobalt-60 irradiations. Since then, the service has been

Results of intercomparisons conducted by the IAEA's Dosimetry Laboratory: Frequency distributions

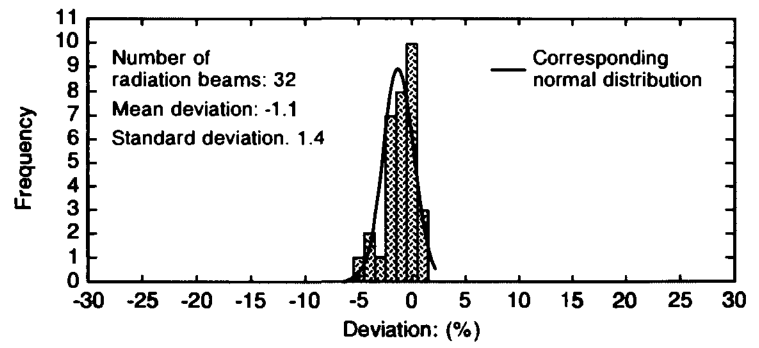
Hospitals worldwide up to 1994:



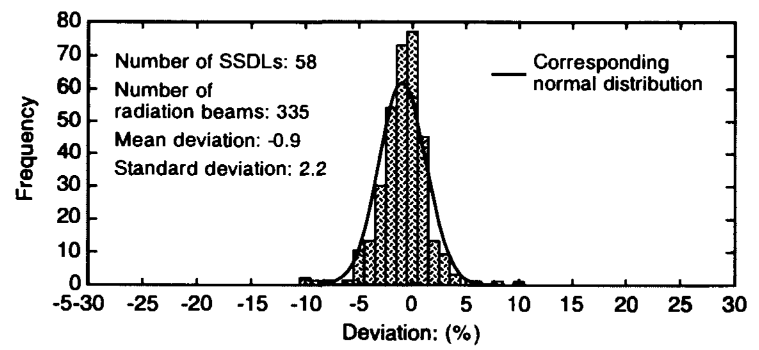
Hospitals in Europe and United States:



Radiotherapy departments in Australia:



Secondary Standards Dosimetry Laboratories up to 1993:



expanded to include X-ray beams from medical accelerators that increasingly are being installed in developing countries. This expanded service involved the support of medical physics departments in 12 renowned radiotherapy centres in Europe and the United States. These departments provided reference irradiations to the IAEA for evaluation. Two TLD intercomparison runs, one with 48 hospitals in Europe and the United States, and the other with all radiotherapy departments in Australia, were done. (*See graphs.*) They can be considered as representative samples of the situation regarding radiation beam calibration in industrialized countries.

Since 1991, the IAEA laboratory has sent a follow-up TLD set to those SSDLs and hospitals that have had poor results; they thus are asked to repeat the intercomparison measurements. Up to now, all follow-up measurements with SSDLs have shown improvement, providing results within the established acceptance limit. Follow-up measurements with hospitals in developing countries, however, have not been satisfactory in many cases, even after a second follow-up.

In all intercomparison runs, the quality of the IAEA's own performance is monitored. In that monitoring process, some TLDs are irradiated with a reference dose in the International Primary Dosimetry Laboratory of BIPM and/or at National Primary Laboratories and evaluated by the IAEA. The results indicate that the accuracy of dose determination with the IAEA's TLD system is about 1% — well below the acceptance limits for SSDLs (3.5%) and hospitals (5%).

A quality audit network

Today about 2000 cobalt-60 units and medical accelerators are in routine use in developing countries, based on responses to a survey being done by the IAEA. In addition, more and more accelerators are being installed that also produce electron beams for patient treatment. The TLD service, therefore, needs to expand accordingly by providing calibration checks for electron beams. The coverage of all machines, however, is beyond the capacity of the IAEA Dosimetry Laboratory's small staff.

As noted earlier, results clearly show that the calibration of radiation beams in developing countries has to improve considerably to reach the conformity prevailing in hospitals of industrialized countries and in SSDLs. Follow-up measurements of poor results only solved the problem in some of the hospitals. Consequently, more attention is required, as well as on-site measurements and discussion with hospital physicists. This, however, cannot be done with a quality control service centralized in the IAEA.

In addition, an effective quality control system for dosimetry involving patient treatment must look at more than just the calibration of the radiation beam. It also has to examine all dosimetric steps from dose prescription to dose delivery to the patient. Only then can the dose to the tumour in each individual patient be known with the required high accuracy, and only then can the different centres share their experiences to find the best treatment procedure.

A pilot study for a quality control programme is now being carried out by European centres with the IAEA's co-operation. Such a programme necessitates the use of dosimeters in human shaped phantoms that undergo radiotherapy as if they were patients. To include all European hospitals, the participation of several reference centres is required to operate a TLD service and to follow-up detected discrepancies.

The European scheme has been modified by the IAEA/WHO for implementation in developing countries. For several years, three SSDLs — those of Argentina, India, and Thailand — have been operating their own national TLD radiotherapy service based on the IAEA's methods. They have, therefore, been asked to participate in the pilot study using their TLD systems. (*See box.*) At these centres, the IAEA will continuously monitor the quality of TLD work, as a step toward achieving conformity worldwide in the determination of absorbed dose and the accuracy of the absorbed dose measurements.

In years ahead, radiotherapy is expected to increase in importance for cancer treatment, especially in the developing world. An improvement in the accuracy in dosimetry is needed to introduce modem treatment techniques. In principle, a quality assurance programme should ensure that all patients treated with a curative aim receive the prescribed dose within a margin of about 5%. Setting up a such a programme by the year 2000 is a formidable task, since it would have to include dosimetry checks for several million patients irradiated each year.

While the major work for such a programme must be decentralized, the IAEA and WHO through the organization of SSDLs are in the best position to co-ordinate the global effort. The pilot studies of the European quality assurance network and of the three SSDLs in IAEA Member States move into closer view the introduction of similar networks for SSDLs and hospitals in other regions. This could lead to a global programme having the potential to significantly improve patient care for millions inflicted with cancer. ❐