CONTROL OF ABSORBED DOSE IN RADIOTHERAPY WITH ^{60}Co UNITS

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Introduction: The harmonization in absorbed dose determination is essential to guarantee that the same physical quantity is determined worldwide in the various applications of ionizing radiation to human health. In certain applications, like in radiotherapy, high accuracy in the dose delivered to patients is required due to the critical balance between tumour eradication and complications in healthy organs. In all cases quality assurance programmes are an essential component in today's applications; key elements in quality assurance are detailed procedures for dose determination, and verification of the delivered radiation dose using independent quality audits.

Materials and methods: The Secondary Standard Dosimetry Laboratory – Sofia (SSDL) begun the quality assurance (QA) of ^{60}Co teletherapy units at late 60's when the first modern, at that time, unit "Rokus" (made in former USSR) was mounted in "Queen Giovanna" hospital. The QA consisted in acceptance testing, according to the manufacturer's protocol, and commissioning: depth dose and profiles measurements and preparation by the decrement line method of an Atlas of isodose charts [1,2], and calibration of the unit. Till now the SSDL is still carrying out the acceptance testing, commissioning or performance testing, and calibration of the ^{60}Co units in the country's hospitals after its installation and/or the exchange of the source. The local physicist(s) and service engineer(s) participate actively in these procedures and the local dosimeter, calibrated at SSDL is used. This way the local staff receives the training and skills necessary for performing periodically the QA tests by themselves.

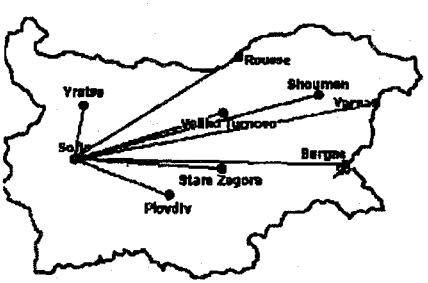

Figure 1. Bulgarian map and towns with ^{60}Co units

The SDDL-Sofia started a programme for dose inter-comparison with mailed TLD in 1975 as a quality audit of radiotherapy departments in the country. Fifteen runs have been accomplished till now. The map of Bulgaria and places of ^{60}Co therapy units are shown in Fig.1.

For the TLD postal dose inter-comparison we use a method [4] similar to that used by the IAEA [3]. The TL detectors are plastic capsules filled with LiF powder (TLD-100, Harshaw) calibrated against the SSDL standard. The participants are supplied with a set of 7 detectors (1 control and 6 to be irradiated) and one holder for detector alignment on the beam central axis and at a depth of 5 cm in a water phantom. They are requested to irradiate a set of three detectors with a dose of about 2 Gy, determined by the method they routinely use in treatment planning, at two SSD's: 60 cm and 75 cm with a field size of 10 x 10 cm^2 at the water surface.

The detectors are measured with a Harshaw 2000 TL Analyzer. The time between the irradiation and measurement of the detectors, used for the calibration, is kept as near as

possible to the corresponding time of the participant's detectors in order to avoid the influence of the fading.

The TL powder of each detector is sufficient for at least of five readings. The mean reading of each detector is calculated, the corresponding dose is determined and for each SSD the percentage deviation, Δ, between the mean dose and the dose stated by the participant is calculated:

$$\Delta = 100\,(D_m - D_p)/D_m \ , \quad \text{where:}$$

— D_m is the mean dose determined by SSDL;
— D_p – the dose stated by the participant.

On account of the uncertainties due to the TLD method, to detector's alignment, to beam calibration etc., an agreement within the limits of ± 5 % is considered acceptable. In case of greater deviation, the participant is immediately informed and asked to find the source of the error. If his effort fail a side inspection is made by the SSDL and the unit is thoroughly checked and, when necessary, adjusted and/or recalibrated.

In order to assure worldwide traceable measurement standards for radiotherapy the IAEA performs TL Dose Quality Audit programme for SSDLs. The regular participation in this programme is a part of the SSDL - Sofia QA system for therapy level measurements [5]. The IAEA audit is a tool to test of the long-term stability of the equipment and methods used by SSDL for measurements and absorbed dose to water determination. For this we make the irradiation of the TL capsules, supplied by the Agency, at the reference depth in the IAEA water phantom according to the following procedure:

a. alignment of the phantom in the horizontal photon beam;
b. determination according to TRS 277 [6] of the absorbed dose to water rate at the capsule's position by measurements with a secondary standard ionization chamber;
c. calculation of the time or monitor units (MU) necessary to irradiate the capsules with a dose of about 2 Gy;
d. irradiation of the ionization chamber three times with the calculated time or MU;
e. irradiation of the capsules;
f. repetition of the point d;
g. the mean dose determined on the base of the measurements in points **d** and **f** is stated as the dose to the capsules.

Results and discussion: The data from the fifteen runs carried out till now are given in table 1. In all, 285 beams have been checked of these 251 (88 %) are within the acceptance limits of ± 5 %. The mean deviation is 0.4 % with a standard deviation of ± 3.4 %.

Table 1. Data for fifteen runs of SSDL – Sofia programme

Run No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Year	'75	'76	'77	'78	'79	'80	'82	'83	'85	'87	'89	'92	'94	'97	'99	–
Number of participants	7	8	9	8	9	9	9	9	10	11	12	9	11	11	11	143
Number of beams	14	16	18	16	18	18	18	18	19	22	24	18	22	22	22	285
Participants outside acceptance limits	2	1	0	2	2	2	0	1	1	4	1	1	1	1	1	20
Mean deviation [%]	-0.1	1.7	0.7	2.4	2.2	0.6	1.0	2.8	1.5	-0.5	-0.4	-0.9	-0.9	-2.2	-0.3	0.4 ± 3.4

The histogram of deviations and the corresponding normal distribution are given in Fig 2. The results for Bulgarian hospitals are comparable with those of the IAEA for European countries [7]. From table 1 one can see that, in spite of the relatively good constancy of the run's mean values, there are always deviations outside the acceptable limits, excluding the '77 and '82 runs. Something more only two radiotherapy departments (these in Sofia) have never had deviations outside the limits.

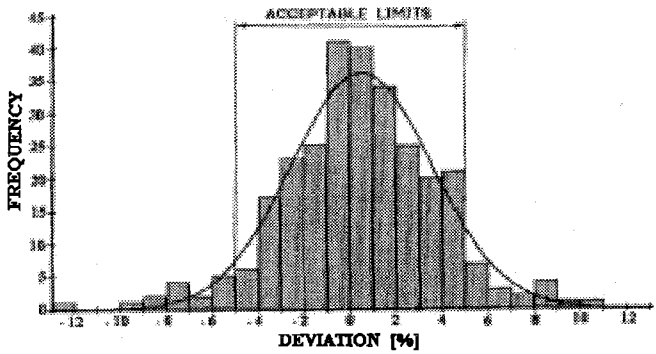

Figure 2. Frequency distribution of audit results for radiotherapy centres in Bulgaria

The most frequent cause for the unacceptable deviations has been an error in the SSD, due to the poor stability of the light telemeter of the "Rokus" units. That means that the local staff is not regularly performing even the simple QA tests. The analysis of data shows also the importance of staff turn-over: five different physicits have been employed in the radiotherapy department with worst results (30 % deviations outside of limits).

The results from the participation in the IAEA audit for SSDLs are given in Fig. 3 as a plot of our deviations relative to the IAEA dose. The deviations for ^{60}Co and those for high energy photons (43 MV) are within the IAEA acceptable limits of ± 3.5 % (95 % confidence level).

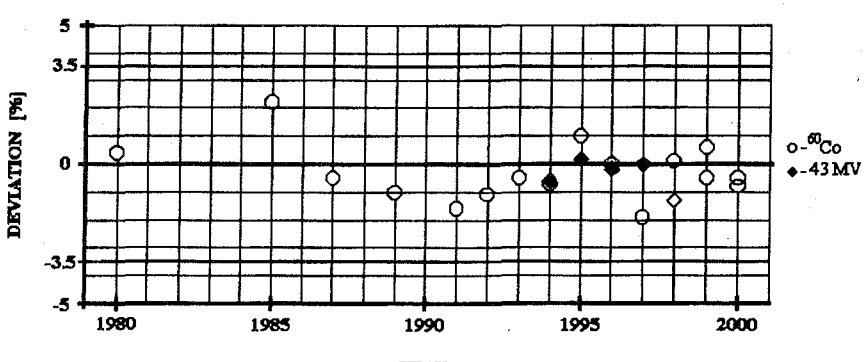

Figure 3. Plot of the SSDL – Sofia deviations relative to the IAEA dose

Conclusion: A Network for External Quality Audit has been developed and established in Bulgaria by the SSDL – Sofia. The results prove the usefulness of the TL Postal Dose programme in helping Bulgarian radiotherapy departments to improve and maintain the consistency of patient doses in a clinically acceptable level.

The participation of SSDL – Sofia in the IAEA Quality Audit Programme confirms the quite satisfactory accuracy of the therapy level dose measurements and determination achieved.

The role of the SSDL is crucial in providing traceable calibration to hospitals. This can only be achieved by developing a quality assurance system, which covers quality control of standards, calibration equipment, calibration procedures and external audits.

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