TLD AUDIT IN RADIOTHERAPY IN THE CZECH REPUBLIC

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ABSTRACT

Purpose: National Radiation Protection Institute in Prague organizes the TLD audit. The aim of the TLD postal audit is to provide a basic control of the clinical dosimetry in the Czech Republic for purposes of state supervision in radiotherapy, to investigate and to reduce uncertainties involved in the measurements of absorbed dose and to improve consistency in dose determination in the regional radiotherapy centers.
Materials and methods: The TLD audit covers absorbed dose measurements under reference conditions for ^{60}Co and ^{137}Cs beams, high-energy X-ray and electron beams of linear accelerators and betatrons. The TL-dosemeters are sent regularly to all radiotherapy centers. Absorbed dose measured by TLD is compared to absorbed dose stated by radiotherapy center. Encapsulated LiF:Mg,Ti powder is used for the measurement. Deviation of ±3% between stated and TLD measured dose is considered acceptable for photons and ±5% for electron beams.
Results: First TLD audit was started in 1997. A total of 135 beams was checked. There were found seven major deviations (more than ±6%), which were very carefully investigated. Medical physicists from these departments reported a set-up mistake. However, at most of those hospitals with major deviations, an in situ audit in details was made soon after TLD audit. There were found discrepancies of clinical dosimetry but also bad technical state of some of the irradiation units. In 1998, second course TLD audit was started. No major deviation was found.
Conclusions: Regular TLD audit seems to be a good way to eliminate big mistakes in the basic clinical dosimetry. Repeated audit in the regional radiotherapy centers that had major deviation during the first audit exhibited improvement of their dosimetry. It is intended to broaden the method and to control also other beam parameters by means of a multi-purpose phantom.

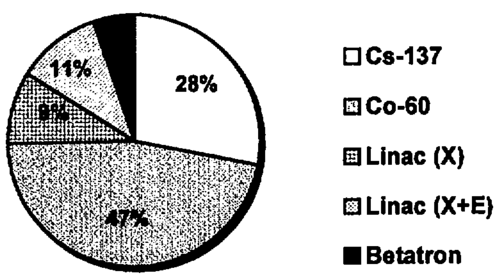
INTRODUCTION

There are 75 irradiation units operating at the present time in the Czech Republic, delivering radiation therapy to cancer patients: 35 Co-60 units, 21 Cs-137 units, 15 linear accelerators and 4 betatrons (Figure 1). These irradiation units are placed in 34 regional radiotherapy centers, but there are only 10 centers which are equipped conveniently (linear accelerator, CT, simulator, computer planning system, complete dosimetric equipment) to provide modern high quality radiotherapy. Structure of all irradiation units is shown in Figure 1. About 50% of all irradiation units are older than 10 years. In the Czech Republic (population approx. 10 million), the approximate number of new oncology patients, who require radiotherapy, either curative or palliative, reaches about 15 000 per year. It is generally accepted that ±5% uncertainty in dose delivery to the irradiated volume is a safe limit causing no severe treatment consequences. Due to the complexity of procedures involved in radiotherapy, from the beam dosimetry, patient data acquisition and treatment planning, to the irradiation of the patient, the development and application of relevant quality assurance (QA) and quality control (QC) programs seems to be a key factor in reducing overall uncertainty associated with subsequent steps of the radiotherapy chain.

According to a new law, which was recently implemented in the Czech Republic, each radiotherapy center has to undertake an independent quality audit every year. For performing audits, the State Office for Nuclear Safety (SONS), which is responsible for radiation protection in the Czech Republic, decided to establish an auditing group of experienced medical physicists working in the field, which is attached to the National Radiation Protection Institute (NRPI). It was decided by the auditing group that TLD postal audit combined with film dosimetry will alternate with "in situ" audit every two or three years. Therefore, a local TLD measuring network had to be established.

The Czech local measuring center for TLD postal audit in the radiotherapy was established in the NRPI in Prague. Activities of NRPI reside mainly in providing of measurements and expert opinions for SONS's requirements. Consequently, NRPI's TLD audit is intended not only to improve clinical dosimetry in the radiotherapy centers, but also becomes an important source of information for state supervision in the radiotherapy. In addition, regular audits could help to get out of the use some bad irradiation units, and to contribute to change the bad structure of the regional radiotherapy centers.

Figure 1: Structure of irradiation units in the Czech Republic



MATERIALS AND METHODS

Pertinent methods for TLD audit were taken from European Measuring Center [1] and EROPAQ- EURAQA projects [2,3] in 1996 and were adjusted to conform to the Czech local conditions. For purposes of calibration and testing was used ^{60}Co irradiation unit at Department of Oncology of 1. Medical Faculty – Charles University in Prague. First TLD audits were started in 1997. In the course of 1997 and 1998, a total of 135 beams was checked: 45 ^{60}Co beams, 27 ^{137}Cs beams, 29 X-rays beams and 34 electron beams.

TLD system

Lithium fluoride thermoluminescent virgin **powder** type **MT-N** (LiF: Mg, Ti — natural abundance, doped with magnesium and titanium) of Polish production was used for the irradiation and read with the **Harshaw TLD reader** - model 4000.

Annealing of the powder was made by using a temperature cycle **of 400°C/1hour and 100°C/2hours**. The powder was encapsulated in waterproof capsules in portions, large enough to obtain 9-10 independent readings.

Irradiated powder was dispensed into measuring containers (4 mm inner diameter, 20 mm inner length and 0.5 mm wall thickness) which were put onto reader's planchette. The following **time-temperature reading cycle** was used:

Temperature (preheat)		**130°C**
	(rate)	**10°C/s**
	(max)	**250°C**
Time	**(preheat)**	**8 s**
	(acquire)	**20 s**

During all readouts the glow curves were recorded in order to eliminate possible errors due to the temperature shift of the reader.

The TL-response of samples of irradiated powder to 2 Gy followed a Gaussian distribution with a mean value of 3503 nC and standard deviation of a single reading, $\sigma = 2.3\%$. Standard deviation of the mean (SD) for a single TLD capsule did not exceed 0.8%. (The experiment was made through reading of 20 capsules irradiated to 2 Gy on the same date, each capsule provided 9 samples).

Organization of TLD postal audits

Each participant (radiotherapy center) of the audit was provided with:

- an instruction sheet describing the method of irradiation of TLD capsules
- a data sheet to enter specifications of the therapy machine, dosimetry equipment, and details concerning TLD capsules' irradiation
- the IAEA holder stand, in which TLD capsules were placed for irradiation
- a group of TLD capsules

Composition of dosemeters for TLD postal audit of one beam was the following:

A/ Ancillary dosemeters

Laboratory dosemeter

- 1 capsule
- placed in NRPI TLD laboratory
- used for background measurement

Transport dosemeter

- 1 capsule

- sent to a hospital
- used for background measurement

Reference dosemeter

- 3 capsules for irradiation to 2 Gy by a ^{60}Co beam
- used for determination of calibration factor

B/ Audit dosemeters

Dosemeters for beam calibration check

- 3 capsules for irradiation
- sent to a hospital

Dosemeters for beam quality check

- 4 capsules (= 2 pairs) for irradiation
- sent to a hospital

The participants were requested to irradiate the capsules in sequence to the absorbed dose of 2 Gy and to check the beam output with their dosimetry system before irradiation of TLDs. The irradiation in participating centers was done during a determined time window. At the same time, the NRPI irradiated one reference sample per center with 2 Gy from ^{60}Co. The irradiation of all capsules during a determined time period helped to control the fading and made better the ordering of the audits. The time between irradiation and reading usually didn't exceed three weeks.

Irradiation

Gamma and X-ray beams

Capsules were irradiated in a water phantom using an IAEA holder stand.

A/ For **beam calibration check**; capsules were inserted into the upper hole of the IAEA holder [4] at the depth of 5 cm. In case of a need of the depth of 10 cm (dependent on beam quality) the holder was lengthened by a distance indicator. The water level was adjusted precisely to the top of the holder and the axis of the beam was aligned with the holder axis. Field size of 10 cm × 10 cm and common SSD were set up.

B/ For **beam quality check**, capsules were inserted into the both holes of the lengthened holder. After adjusting of the water level to the top of the holder, the upper capsule was at depth of 10 cm and the lower at depth of 20 cm. Field size of 10 cm × 10 cm and SSD = 100 cm were set up.

Electron beams

For **beam calibration check**, capsules were inserted into the hole of the special IAEA holder [4] to be irradiated at the depth of d_{max}. Correct positioning of the capsules at the depth of d_{max} was made setting a corresponding number of spacers. The water level was adjusted precisely to the top of the holder and the axis of the beam was aligned with the central holder axis. Field size of 10 cm × 10 cm and common SSD were set up.

Dose calculation

The absorbed dose to water, D (Gy), at the location of TLD was calculated from the TL signal, R, registered by the reader using the following formula

$$D = R\, K_{cal}\, K_{lin}\, K_{fad}\, K_{en}$$

where:

R is the TLD reading normalized to the mass of aliquot of the powder,
K_{cal} (Gy/nC) is the calibration factor determined for 2 Gy from ^{60}Co beam,
K_{lin} is the dose linearity correction determined on the basis of experimentally determined linearity function,
K_{fad} is the fading correction determined on the basis of experimentally measured fading function,
K_{en} is the X-ray energy response correction determined by comparing the TLD response to the same dose to water in a high-energy X-ray beam and ^{60}Co beam, under reference conditions.

Reporting and analysis of deviations

The TLD measured values were compared to the values stated by physicist, who irradiated the TLD capsules. For each capsule the mean reading value and standard deviation were determined. The average reading value of three capsules (evaluated absorbed dose) was calculated.

A/ For **beam calibration check**, a deviation between measured (TLD) and stated dose is reported:

$$\Delta_D = (D_{TLD}/D_s - 1)\cdot 100\%$$

B/ For **beam quality check**, a deviation between measured (TLD) and stated QI is reported:

$$\Delta_{QI} = (QI_{TLD}/QI_s - 1)\cdot 100\%$$

Analysis of deviations was based on values of Δ:

$\lvert\Delta\rvert \le 3\,\%$	means ***acceptance level, beam complies requirements of quality assurance program***
$3\,\% < \lvert\Delta\rvert \le 6\,\%$	means ***minor deviation***, investigating causes and/or repeating of TLD audit is necessary,
$\lvert\Delta\rvert > 6\,\%$	means ***major deviation***, "in situ" audit in details is necessary

Quality control of TLD system

The accuracy of TLD measurements has been verified regularly by means of different intercomparisons - mainly comparison of results measured by NRPI, IAEA and EROPAQ/EURAQA Measuring Center (University Hospital Gasthuisberg, Leuven) under the same conditions. Most of the Czech radiotherapy centers have been checked also by in-situ audit, so results measured by TLD and ionizing chamber are compared regularly [5]. All these intercomparison results showed very good agreement or at least compatibility.

The ^{60}Co unit that is used for calibration is regularly checked by ionizing chamber and by intercomparison measurements with the Czech Secondary Standard Dosimetry Laboratory.

RESULTS AND DISCUSSION

The results of the first course of TLD audit, which were done in the Czech Republic from 1997, are summarized in Figure 2. Figure 2 shows distribution of deviations Δ_D for beam calibration check during the first TLD audit. In the course of 1997 and first half of 1998, a total of 110 beams was checked: 33 ^{60}Co beams, 19 ^{137}Cs beams, 26 X-ray beams and 32 electron beams.

Most of the checked beams comply with the acceptance level, but there were seven beams with major deviations (2 ^{137}Cs beams, 2 ^{60}Co beams, 1 X-ray beam of betatron and 2 electron beams of betatron). The deviations were very carefully analyzed, and it was reported by medical physicists from the departments that they had made a set-up mistake. However, at most of those hospitals with major deviations, an in situ audit in details was made soon after TLD audit. There were found discrepancies of clinical dosimetry but also bad technical state of some of the irradiation units.

In 1998, second TLD audit was started - there were checked preferably beams with major and minor deviations that were found during the first TLD audit, also beams of old irradiation units and beams of radiotherapy centers with inconvenient equipment. Results are shown in Figure 3. A total of 25 beams was checked: 12 ^{60}Co beams, 8 ^{137}Cs beams, 3 X-rays beams and 2 electron beams. It is evident that the results exhibit better distribution of deviations. No major deviations were found. The TLD postal audit seems to be an efficient way to eliminate big mistakes in basic clinical dosimetry.

CONCLUSIONS

A new law for radiation protection in the Czech Republic has enforced the necessity of TLD network i radiotherapy. The TLD postal audit contributes to improvement of clinical dosimetry because its results are an important part of data for state supervision in the field of radiotherapy. The results can support the desirable change of the structure of the irradiation units in the Czech Republic. It is desirable to supplement some of the old ^{60}Co units and betatrons by new modern linear accelerators, and to get out most of the ^{137}Cs units from the clinical practice. The necessity and usefulness of TLD audit were sustained. The regular control can press regional radiotherapy centers to improve their dosimetry. The regional centers, which exhibited major deviations in the first course of TLD audit, had better results of the second audit.

The control made by TLD will be broadened in the future. It is intended to start TLD audit by means of a multi-purpose phantom in 1999, the TLD audit combined with a film dosimetry and a multi-purpose phantom could partly supplement an in-situ audit in the radiotherapy department, because basic beam data can be obtained from these

Figure 2 : Results of 1st TLD audit - distribution of Δ_D - beam calibration check

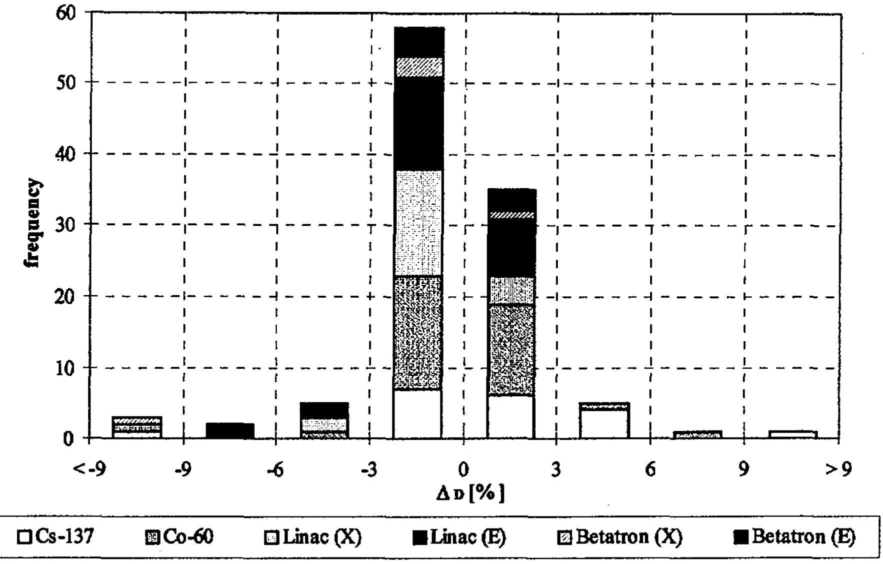
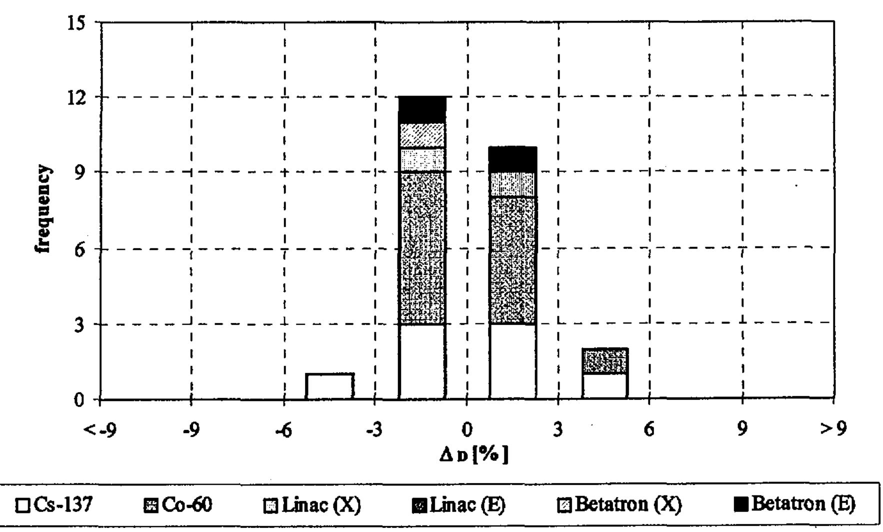


Figure 3 : Results of 2nd TLD audit - distribution of Δ_D - beam calibration check



measurements. In our country we propose that postal TLD audits will be performed every 1 or 2 years for each clinically used beam. In situ audit in details should be made within a period of 3 years. In the case that a department will exhibit permanently major deviation then in situ audit can be requested more frequently.

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