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Editorial Note



Pedro Andreo

Professor Pedro Andreo, the former Head of the IAEA Dosimetry and Medical Radiation Physics Section, had left the Agency in November 2000 and replaced in August 2001 by Dr. Ken Shortt. Three years after his departure (December 2003), Professor Andreo was recruited again by the Agency as the Director of the Human Health Division. This includes, in addition to Dosimetry and Medical Radiation Physics, the sections Applied Radiobiology and Radiotherapy, Nuclear Medicine, and Nutrition and Health Related Environmental Studies. Information on the activities of the Division is available in the web site:

<http://www-naweb.iaea.org/nahu/external/>

This issue of the SSDL Newsletter starts with a report of the first Research Co-ordination Meeting of the Co-Ordinated Research Project (CRP) on the development of TLD-based quality audits for radiotherapy dosimetry in non-reference conditions. The meeting was held at the IAEA's Headquarters in Vienna during 30 September – 4 October 2002. The meeting gathered the CRP participants from Algeria, Argentina, Austria, Bulgaria, China, India, France and Poland.

The second article is also a meeting's report on the development of quality assurance procedures for dosimetry calculations in radiotherapy. The meeting was held at the IAEA's Headquarters in Vienna during 13-18 October 2003. Three consultants from Austria, the Netherlands and the USA have attended the meeting and made specific recommendations to the Agency on the initiation of a CRP on Quality Assurance for dosimetry calculations in radiotherapy.

Finally, the editor wishes to inform the readers that the Proceedings of the International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry (held in Vienna in November 2002) have been published on the Agency's web site:

<http://www-pub.iaea.org/MTCD/publications/publications.asp>

The pdf files of the 2 volumes can be downloaded from the web site. The printed version of the two-volume set will be available for distribution by 8 April 2004.

The information contained in this Newsletter is intended to assist communication among members of the IAEA/WHO SSDL Network.

In preparing this publication for press, staff of the IAEA have made up the pages from the original manuscript(s). The information provided in the articles is the responsibility of the authors and views expressed do not necessarily reflect those of the IAEA, the governments of the nominating Member States or the nominating organizations. However, some assistance may have been provided by the IAEA in editing, particularly for length. The articles have not been refereed.

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International Atomic Energy Agency

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SERVICES PROVIDED BY THE IAEA PROGRAMME IN DOSIMETRY AND MEDICAL RADIATION PHYSICS

The IAEA's Dosimetry and Medical Radiation Physics programme is focused on services provided to Member States through the IAEA/WHO SSDL Network and a system of dose quality audits. The measurement standards of Member States are calibrated, free of charge, at the IAEA's dosimetry laboratory. The audits are performed through the IAEA/WHO TLD postal dose assurance service for SSDLs and radiotherapy centres, and the International Dose Assurance Service (IDAS) for SSDLs and radiation processing facilities, mainly for food-irradiation and sterilisation of medical products.

The range of services is listed below.

Services	Radiation quality
1. Calibration of ionization chambers (radiotherapy, diagnostic radiology including mammography and radiation protection, including environmental dose level).	x-rays (10-300kV) and gamma rays from ^{137}Cs and ^{60}Co
2. Calibration of well-type ionization chambers for Low Dose Rate (LDR) brachytherapy.	γ rays from ^{137}Cs
3. Comparison of therapy level ionization chamber calibrations (for SSDLs).	γ rays from ^{60}Co
4. TLD dose quality audits for external radiotherapy beams for SSDLs and hospitals.	γ rays from ^{60}Co and high energy x-ray beams
5. TLD dose quality audits for radiation protection for SSDLs.	γ rays from ^{137}Cs
6. ESR-alanine dose quality audits for radiation processing (for SSDLs and industrial facilities), through International Dose Assurance Service (IDAS).	γ rays from ^{60}Co , dose range: 0.1-100 kGy
7. Reference irradiations to dosimeters for radiation protection (for IAEA internal use).	x-rays (40-300 kV) and γ rays from ^{137}Cs and ^{60}Co

Member States who are interested in these services should contact the IAEA/WHO Network Secretariat for further details, at the address provided below. Additional information is also available through the Internet at the web site: <http://www.iaea.org/programmes/nahunet/e3/>

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**REPORT OF THE FIRST RESEARCH
CO-ORDINATION MEETING
(E2.RC 885) ON THE CRP E2.40.12
“DEVELOPMENT OF TLD-BASED
QUALITY AUDITS FOR
RADIOTHERAPY DOSIMETRY IN
NON-REFERENCE CONDITIONS”**

30 September – 4 October 2002, IAEA
Headquarters, Vienna

CRP Participants:

M.S. Bali, Algeria
M. Saravi, Argentina
D. Georg, Austria
V. Staykova, Bulgaria
Kaibao Li, China
F. Garcia Yip, Cuba
A. Dutreix, ESTRO¹
G. Ramanathan, India
W. Bulski, Poland

Scientific Secretary: Joanna Izewska

1. BACKGROUND

It is estimated that not more than 60% of the existing radiotherapy facilities worldwide have participated in some level of independent external dose quality audit. To extend the fundamental step of dose check in reference conditions to as many hospitals as possible throughout the world, a Co-ordinated Research Programme (CRP), “Development of a Quality Assurance Programme for Radiation Therapy Dosimetry in Developing Countries” (E2.40.07), was initiated in 1995 to assist IAEA Member States to develop national programmes for TLD based QA audits in radiotherapy dosimetry to assure proper calibration of radiotherapy beams. Using the Agency’s 30 years’ experience in TLD audits

of beam calibrations as a primary input, the aim of the CRP was to disseminate a uniform TLD methodology to the countries which set-up national TLD-based QA audit networks for radiotherapy dosimetry. Twelve Member States were involved in the CRP, i.e. Algeria, Argentina, Colombia, Cuba, China, Czech Republic, India, Israel, Malaysia, Philippines, Poland and Vietnam.

Considering that significant numbers of deviations in non-reference situations, as used clinically on patients, have been observed in international audit networks operating worldwide, a group of consultants, in their meeting convened in 2001, advised the IAEA to initiate a new CRP “Development of TLD-Based Quality Audits for Radiotherapy Dosimetry in Non-Reference Conditions”. The new CRP (E2.40.12) builds upon the previous CRP “Development of a Quality Assurance Programme for Radiation Therapy Dosimetry in Developing Countries”, and extends the scope of activities of the national External Audit Groups (EAGs) from TLD audits in reference conditions, i.e. simple TLD checks of radiotherapy beam calibrations, to complex audit measurements in a variety of clinically relevant irradiation geometries, i.e. in non-reference conditions.

The objective of the CRP is to assist Member States in developing a general strategy for the TLD-based quality audit program for radiation dosimetry in non-reference conditions and in addressing the specific needs of the individual participating countries, including new developments, e.g. a methodology for the new audit programme.

The new technologies are being developed with the active input from participants, including testing of new phantoms, developing new TLD irradiation procedures, instructions for hospitals and data sheets, and mechanisms for reporting the results to hospitals. Upon the successful development of the audit methodology, the EAGs will conduct a pilot TLD run for local hospitals in their countries.

¹ ESTRO is the European Society for Therapeutic Radiology and Oncology

The participants of the CRP E2.40.12 are: Algeria, Argentina, Austria, Bulgaria, China, Cuba, France, India, and Poland.

The scientific scope of the CRP covers the following implementation steps, which have been planned for accomplishment in 2002-2006.

- The feasibility tests of the holders and phantoms and methodology for external audit in a variety of non-reference situations. This work is done by CRP participants (i) under Research Agreements between the IAEA and two laboratories with extensive experience in dosimetry audits, and (ii) under Research Contracts at the national level by the measuring laboratories of the selected EAGs.
- Pilot studies at national level are required to test the methodology for the dosimetry measurements and the documentation, and the practical operation of the audit systems. The EAGs will conduct feasibility studies to assess the functionality and accuracy of the quality audit TLD holders and documentation to measure the outlined dosimetric parameters for non-reference conditions proposed by the CRP. In parallel to the above activities, comparisons of the EAG TLD system with the Agency's TLD system will be conducted.
- Development of an EAG manual outlining the specific steps and measurements needed, instructions, data forms and logistics of operating the quality audit for radiation therapy in non-reference conditions in its country.
- Implementation of national TLD audits in non-reference conditions for radiotherapy hospitals.

The expected research outputs from this CRP are the following:

- A specific set of written guidelines to perform the quality audits and guidelines for the evaluation of these audits for radiation dosimetry in non-reference conditions will be developed and adapted to

the local situation of each participating country,

- A set of extensively tested photon quality audit dosimeter holders capable of assessing a hospital's radiation dosimetry practices for non-reference conditions will be available,
- A new methodology and procedures to monitor electron dosimetry using a TLD based quality audit will be developed,
- Expertise and technology developed under this CRP will be validated by the national organizations or networks and will be available for transfer to other Member States.

These expected research outputs will contribute to the overall increase in radiation dosimetry expertise and to reducing the number of potential misadministrations of dose to radiotherapy patients. Hence, better cooperation and standardization of radiation dosimetry practices is expected at the national level for these countries participating in the CRP. The project will also benefit other developing countries in two ways. Firstly, there will be direct experience available, gained by the countries involved, on the practical methods and procedures to extend measurements to parameters other than the beam output in reference conditions. Secondly, the network structures, extended to include this new activity, will be available as examples of how to develop the infrastructure to implement those methods and procedures and with whom experience and results can be shared and transferred.

2. PRELIMINARY DISCUSSIONS

The meeting started with the opening address by the Head of the DMRP Section. The first presentation, delivered by the Scientific Secretary, gave an overview of the IAEA activities in support to the national audit networks for radiotherapy dosimetry and the introduction to the CRP E2.40.12 "Development of TLD-Based Quality Audits

for Radiotherapy Dosimetry in Non-Reference Conditions” with the focus on possible directions of the development of TLD audits in non-reference conditions. It was followed by presentation of the results of the EQUAL/ESTRO (ESTRO Quality Assurance Network) TLD network operating in the European Union, that conducts TLD dose audits in reference and non-reference conditions. The presentation was delivered by Prof. A. Dutreix.

A series of presentations on the research relevant to the CRP and future plans were given by the meeting participants. They described in detail the situation in individual countries with respect to the infrastructure in radiotherapy and medical physics, including the existing national QA programmes and new developments in the dosimetry audit systems. The status of the development of methodology and procedures for QA audits for radiotherapy hospitals in the participating countries was discussed at length including measuring procedures, structure of the national EAGs and relations with other relevant national organizations or bodies. The participants are in different stages of the process of adapting the procedures developed by the previous CRP E2.40.07 and some started pilot studies for the photon beam audits on-axis, in non-reference conditions. Each CRP participant submitted a written contribution, which are presented below.

3. STATUS REPORTS FROM THE PARTICIPANTS

A. DUTREIX, ESTRO

The ESTRO Quality Assurance network for radiotherapy (EQUAL) was set up in 1998 for the countries of European Union. This TLD postal dose service includes photon and electron beam checks in reference and non-reference conditions. By September 2002, the service has provided audits to more than 450 radiotherapy centres by checking about 2200 beams. Dosimetric problems in the beam calibration, errors in beam data used as input to

the treatment planning system (TPS) and uncertainties in the algorithms used in the TPS can be detected in the EQUAL audit.

The participating centres are instructed to irradiate the TLD (LiF) capsules to a dose of 2 Gy based on calculations using the treatment planning system applied routinely in clinical use. For photon beams, four dosimetric parameters were checked: the beam output in the reference conditions, the percentage depth doses, the beam output variation for open and wedged fields and the wedge transmission factor. Measurements with electron beams were carried out for 3 different field sizes and two source-skin distances (SSD).

About 13% of all beams had to be rechecked due to deviations larger than 5%. In some of these cases the deviations could be traced to set-up errors or other mistakes, e.g. wrong SSD, wedge forgotten, and wrong depth. It was proven that 6% of the deviations were due to real dosimetry problems. Site visits were then offered and have been carried out in 13 centres.

Most of the large deviations in dose were for non-reference conditions. For the reference geometry the deviations have progressively decreased. Thus for photon beams in the checks between 1998-1999, 3.1% of the centres were outside 5% and only 1.2% between 1998-2002. The real improvement is even larger as the latter value also includes the early period. The effort in Europe including the introduction of new dosimetry protocols, training-courses by ESTRO, etc. seems to have paid-off.

The EQUAL programme is extended in parallel with changes in radiotherapy techniques. Recently checks were included for photon fields shaped with multileaf collimators (MLC). In the MLC dose audit, five fields were checked with shapes and dimensions defined by the MLC. Since launching the programme in early 2002, the MLC dose checks were performed for 76 beams, showing the great interest of radiotherapy centres for this new service.

M.S. BALI, ALGERIA

A quality assurance programme for external radiotherapy was set up at the Secondary Standards Dosimetry Laboratory of Algeria, in the framework of the establishment of an EAG co-ordinated by the IAEA within the CRP E2.40.07. In the first step of the programme, the IAEA methodology using TLD-100 LiF powder was adapted. The parameters of the TLD readout system were optimized at the beginning of the project, e.g. the variation of the TL readings with the PM voltage, the nitrogen flow, the variation of the standard deviation with time delay after irradiation. Capsules containing an amount of about 160 mg of LiF powder used as dosimeters were calibrated in terms of absorbed dose to water by comparison with an ionisation chamber whose calibration coefficient is traceable to BIPM. The calibration curve was validated with irradiations performed by the IAEA, the radiotherapy centres of Leuven (Belgium) and IGR (France) and the primary laboratory of NRC (Canada). Furthermore, the consistency of the calibration curves among three phantoms (IAEA water, PMMA and polystyrene phantoms) has been studied. The calibration curves obtained following this procedure, are perfectly consistent.

The other step of the programme deals with the energy dependence of the LiF dosimeters, which was studied using high-energy electron beams from two Algerian linear accelerators and with capsules irradiated by the institutions cited above. Irradiations were performed with the IAEA standard electron holder.

Five absorbed dose calibration checks for each photon beam in Algeria were performed from 1997 to 2002 in the reference conditions. The results are all within the acceptance limit of 5%, except for two Cobalt-60 beams where deviations were observed due to beam calibration and a mechanical timer failure.

In 2002, a feasibility study was undertaken for the audit of the Algerian radiotherapy centres for photon beams, on-axis, in reference and non-reference conditions. The parameters studied were: beam output in reference

conditions, depth dose data for a 10 cm x 10 cm beam at 5 cm and 10 cm depth, the beam output variation with collimator opening for the beams: 7 cm x 7 cm, 7 cm x 20 cm and 20 cm x 20 cm at 5 cm depth, and the wedge transmission factor for the most often clinically used wedge for a 10 cm x 10 cm beam. Nine dosimeters are irradiated for every beam. Four institutions took part in this feasibility study, and for all the studied parameters the results were within 5%.

The audit programme in non-reference conditions on-axis will be implemented in Algeria for all photon beams. For Cobalt-60 and X-ray beams of 4 MV-10 MV, the parameters to check will be:

- beam output in reference conditions, 10 cm x 10 cm field, 5cm depth
- depth dose data for 10 cm x 10 cm and 20 cm x 20 cm fields at 5cm and 15cm depths
- beam output variation with the collimator opening for 7 cm x 7 cm, 7 cm x 15 cm and 20 cm x 20 cm fields at 15 cm depth
- wedge transmission factor for 45 deg. wedge, 10 cm x 10 cm and 7 cm x 15 cm fields at a depth of 15 cm.

For X ray beams of 15 MV and 18 MV, the same parameters will be checked but the depths will change from 5 cm and 15 cm to 10 cm and 20 cm, respectively, and field sizes will change from 7 cm x 15 cm to 7 cm x 20 cm.

Furthermore, a feasibility study will be undertaken for non-reference conditions with off-axis measurements in photon beams with the new IAEA TLD holder, as well as a feasibility study of the audit of electron beams in reference conditions at the depth of dose maximum, d_{max} .

M. SARAVI, ARGENTINA

The EAG is composed of the SSDL, belonging to the National Atomic Energy Commission, and two medical physicists of the same institution. A total of 90 radiotherapy centres are registered in the EAG data base, with 69 Cobalt-60 units and 42 linacs operating in the country, of which 18 linacs produce X-ray and electron beams. A total 111 high energy photon beams are available. In accordance with the national regulations all centres equipped with a linac must have a medical physicist within its staff. Centres that have Cobalt-60 units only must be supervised by a medical physicist.

For QA of the TLD system, internal quality control (QC) procedures are implemented and external QC is provided regularly by the IAEA Dosimetry Laboratory (blind tests, irradiation to different doses for TLD calibration curve). The Prague University provided a blind test to check the energy correction factor applied for high energy X-ray beams.

TLD dose audits in reference conditions are intended to be used on each high energy photon beam at least once a year. All centres are invited to participate in this programme but in fact, only 75/90 centres have so far participated.

The acceptance limit for the dose deviation is 5%. For Cobalt-60 units the percentage of the successful checks were, from 1998 to 2001, year by year, : 97%; 89%; 98% and 95%. The mean dose ranges from 1,976 Gy to 2,016 Gy and the standard deviation of dose distribution decreased from 5% to 3%. For 42 high energy

X-ray beams, the percentages of results within 5% limit were 98%, 99%, 100% and 95%, for the same period if time, with the standard deviation ranging from 2% to 3%. Starting from 1999, no deviations greater than 10% have occurred in any checks of calibrations of Cobalt-60 or high energy X-ray beams.

All data sheets are analysed by the EAG group. Follow up of the centres with poor results is made immediately after the deviation occurs. Once the centre has taken corrective actions, a second TLD check is performed. If a discrepancy persists, a medical physicist of the EAG performs an on-site visit. From 2000, five follow-up visits have been made.

Percentage depth dose was verified in 17 Cobalt-60 machines by irradiating TLD capsules in reference conditions (5 cm depth, 10 cm x 10 cm field size) and at 10 cm depth. Successful results were obtained for the audited beams.

Measurements on-axis in non-reference conditions, for open and wedged beams of a varying field size, were performed on 25 linacs and 17 Cobalt-60 units. In reference conditions, 39/42 results were within the acceptance limits; for other field sizes the number of successful results was: 39/42 for 7 cm x 20 cm field, 34/42 for 5 cm x 5 cm field; 37/42 for 20 cm x 20cm; and 38/42 for a 10 cm x 10 cm field with a wedge.

The first step of TLD audits involving photon beams in reference conditions, has been implemented in Argentina. Further audit steps are planned for photon beams in non-reference conditions and electron beams on-axis.

Table 1. Audits for photon beams in non-reference conditions to be performed for at least 10 Cobalt-60 beams

Checks to be performed	Depth in water	Irradiation distance	Field size	Accessory in the beam	Number of TLDs	Dose
Reference conditions	5 cm	SDD or SSD	10 cm x 10 cm	No	2 TLDs	2 Gy
Depth dose data	5 cm and 15 cm		10 cm x 10 cm	No	2 TLDs	2 Gy 2 Gy
Beam output variation	15 cm	SDD or SSD	7 cm x 7 cm 7 cm x 15 cm 15 cm x 15 cm	No	3 TLDs	2 Gy
Wedge transmission	15 cm	SDD or SSD	7 cm x 15 cm	Wedge	1 TLD	2 Gy

Table 2. Audits for photon beams in non-reference conditions to be performed for 10 linacs

Checks to be performed	Depth in water	Irradiation distance	Field size	Accessory in the beam	Number of TLDs	Dose
Reference conditions	10 cm	SDD or SSD	10 cm x 10 cm	No	2 TLDs	2 Gy
Depth dose data	10 cm and 20 cm	SSD	10 cm x 10 cm 20 cm x 20 cm	no	2 TLDs	2 Gy
Beam output variation	20 cm	SDD or SSD	7 cm x 7 cm 7 cm x 20 cm 20 cm x 20 cm	no	3 TLDs	2 Gy
Wedge transmission	20 cm	SDD or SSD	10 cm x 10 cm 7 cm x 20 cm	Wedge	2 TLDs	2 Gy

In order to extend the TLD audits to electron beams on-axis, the response of TLD for various electron beam energies has been determined with a Cobalt-60 beam used as the reference beam. A pilot TLD run for 3 linacs, for 3 energies at d_{max} will be performed. Before starting this audit step, the energy correction will be validated through a blind test made with the collaboration of a reference center, such as ESTRO/EQUAL.

Further, it is expected to implement off-axis audits for photon beams by using a new IAEA TLD holder for off-axis checks. The use of dosimetric films for relative measurements has to be decided upon.

V. STAYKOVA, BULGARIA

The Laboratory of Clinical Dosimetry and Metrology of Ionizing Radiation, SSDL-Sofia, started TLD postal dose audits in 1975 and fifteen runs have been carried out until now. All available high-energy photon beams were included.

For a TLD postal dose audit, the methodology similar to the IAEA's methodology is used. TLD capsules are irradiated at 5 cm depth in water on the beam axis, using the TLD holder for vertical photon beam set-up. TL-dosimeters are LiF powder (TLD-100) in plastic capsules, which are designed at the SSDL.

Two sets of 3 dosimeters are irradiated at 10 cm x10 cm field with a dose of 2 Gy (determined by the method used in treatment planning). The control dosimeter is also posted. The specific feature of this audit is that beam output is checked at two distances: SSD = 60 cm and SSD = 75 cm, typical for Co-60 units in Bulgaria.

Actions are taken when the deviations between the dose stated by the participant and the dose measured by EAG are greater than 5 %, including rechecks and site visits.

The distribution of the deviations for 285 checks of beam calibration from fifteen TLD audit runs carried out until now has a mean deviation of 0.4% and standard deviation of 3.4%. From these 285 results, 251 (88%) are within the acceptance level of 5%. Extreme deviations were: +13% and -9.7%.

For extending the TLD quality audit to non-reference conditions, the EAG considers it

necessary to separate the recommended methodology for these measurements with respect to the source type and technological level of the unit, and with respect to the most commonly used treatment techniques in radiotherapy departments, concerning both the number of dosimetry parameters checked and the conditions for these checks.

Before starting the feasibility study for the audits in non-reference conditions, the evaluation of the TLD system performance has to be done, including the uncertainties. Because Co-60 units are prevalent in Bulgaria, the EAG will start the research with the feasibility study in clinical conditions for Co-60 beams. The dosimetry parameters of interest are:

- the beam output in reference conditions with the existing methodology (5 cm depth in water, 10 cm x10 cm field);
- beam variation with field size and shape for the most commonly used fields for typical treatment techniques;
- the depth dose for at least two fields;
- wedge transmission for two wedges.

The issues concerning the organization of the TLD audit, which have to be solved within the period of the pilot study, involve the approval of the EAG by the Ministry of Health and the establishment of the operational principles (in written form) of the TLD QA network, which will be discussed by the Bulgarian Society of Radiotherapists involving both medical physicists and radiation oncologists. The criteria for reporting the results of the audit to the authorities will also be discussed, regarding the aim and the principles of the audit. Actions for the modernization of the TLD equipment will be taken.

The next step will involve expanding the audit programme to dosimetry parameters off-axis.

KAIBAO LI, CHINA

Since 1983, the Laboratory of Industrial Hygiene (LIH), Ministry of Health has been involved in the IAEA/WHO TLD postal dose quality audit activities for hospitals in China. The SSDL of LIH has participated in a yearly IAEA SSDL postal TLD dose comparison since 1989, with all results within the 3.5% acceptance limit.

In 1995, the SSDL started co-operation with the Beijing Cancer Hospital, the Chinese Academy of Medical Science, to join the IAEA CRP. An EAG was established in 1996 with the responsibility of operating a TLD based quality audit for radiotherapy dosimetry. Since then, TLD audits have been carried out in seven provinces of China. The results for 132 ⁶⁰Co units and 86 high energy X ray beams checked from 1996 to 2000 indicated that 78% of the hospitals were within the acceptance limit of 5%. Assistance was provided to 21 hospitals with poor results, including five on-site visits. All deviations were corrected.

In addition to the work above, national programmes for brachytherapy and stereotactic radiosurgery dosimetry were initiated in 2001. At the end of 2000 there were 41 gamma knives and 92 X knives in use in Chinese hospitals. So far 31 of these machines have been checked for dose rates and field dose profiles using dosimetric film and miniature ionization chambers (0.015 cm³). The preliminary results indicate that problems exist with some of these machines.

On the basis of the report of the IAEA Consultants' Meeting of June 2001, a preliminary work plan for implementation of the CRP at the national level is outlined. It is divided into three steps, including measuring procedures, research, feasibility studies and equipment required.

Step 1. TLD audits for photon beams in reference and non-reference conditions on the beam axis.

Beam quality and reference point dose: TLDs at 10 cm and 20 cm depth; 10 cm × 10 cm field; this measurement will be carried out twice .

Field size variation of output and dose at depth: TLDs at 10 cm and 20 cm, irradiated simultaneously with 7 cm × 7 cm, 20 cm × 20 cm, 7 cm × 20 cm fields.

Dose variation with a wedge: TLDs at 10 cm and 20 cm, irradiated simultaneously with 45°wedge; 10 cm × 10 cm and 7 cm × 20 cm fields.

Step 2. TLD audits for photon beams in reference and non-reference conditions off-axis.

Point dose checks of beam profile using TLDs. Feasibility tests of the IAEA modified TLD holder for off-axis dose measurements and comparison studies will be performed by the national EAG .

Dose profile checks using both TLD and film. A multipurpose solid phantom will be considered for tests of the practical operation of the system by the national EAG.

Step 3. TLD audits for electron beams in reference and non-reference conditions at the depth of dose maximum.

The checks will be carried out with the TLD capsules positioned at the depth of dose maximum for the selected electron beams and field sizes. The national EAG will conduct research on the TLD electron energy dependence and will perform a feasibility study of the system and methodology.

F. GARCIA YIP, CUBA

At present, there are 10 high energy radiotherapy units in Cuba to cover a population of about 11 millions inhabitants. There are 9 Co-60 machines and a recently installed linear accelerator. Another Co-60 unit and a second linac are to be installed shortly. All the units are located in public hospitals run by the Ministry of Public Health.

Five years ago, Cuba started a National Program of Quality Assurance in Radiotherapy that covered all Cuban radiotherapy centers. The main achievement of the program was the creation of a nationwide system for quality assurance and the development of human resources and equipment capacity geographically distributed in the country. Simultaneously, a National Committee for Quality Assurance was created with the responsibility, among others, to conduct systematic radiotherapy audits. These audits are based mainly on on-site visits to check not only dosimetry parameters but also to review the practices and documentation of the whole radiotherapy process.

The implementation of the QA programme was possible thanks to the cooperation between the Cuban Ministry of Health and the IAEA Technical Co-operation programme. Cuba has taken part in the IAEA/WHO TLD postal dose audits for more than 20 years. Recently, Cuba participated in the IAEA Co-ordinated Research Project (CRP) E2.40.07, to create a national network of TLD dose postal audits in reference conditions. At the same time, the work of the External Audit Group (EAG) was consolidated.

The EAG is composed of experts from the National Control Center for Medical Devices (CCEEM), as the regulatory entity for the control and supervision of the medical devices in the country, from the Institute of Oncology and Radiobiology (INOR) and other hospitals representing the National Group of Oncology (GNO) and from the Cuban SSDL (CPHR). All radiotherapy services in the country are audited. A team of the EAG that performs the visit typically includes 2 physicists. They carry with them a complete set of instruments to perform dosimetric and mechanical QC of the radiotherapy units. Physicists from the EAG also take part in the commissioning of the new units.

During the previous CRP (E2.40.07), a pilot study was conducted with 5 radiotherapy centers to check the dose in reference conditions. The deviations between the user prescribed dose and that measured with TLD were within 5% for all checks.

The EAG intends to include the linac of INOR (Havana) in external (international) audits: IAEA/WHO (for the 2 photon beams) and EQUAL (for 3 of its 5 electron energies). The national postal dose audits will then cover the Co-60 units of the country. The EAG is ready to start dose audits other than reference conditions for a range of field sizes (10 cm x 10 cm, 7 cm x 7 cm, 7 cm x 15 cm, 20 x 20 cm), at depths 5 cm and 15 cm and with beam modifiers (wedge).

The detailed work plan for the implementation of the audit programme off-axis is being developed. To check the beam profile parameters off-axis the EAG plans to use the solid PMMA phantom, with TLD and film dosimeters.

G. RAMANATHAN, INDIA

In India, the quality audit programme for dosimetry in radiotherapy is being implemented since the recognition of BARC as a Secondary Standards Dosimetry Laboratory (SSDL) by IAEA/WHO in 1976. Presently the programme covers approximately 250 Co-60 teletherapy units and about 35 linear accelerators primarily in India, but also in some of the neighboring countries such as Nepal, Myanmar, Sri Lanka and Syria. In India, 15 to 20 new machines are being added every year. In a year, two to three national runs of the quality audits are conducted involving about 50 hospitals each time. In addition to this,

we also coordinate the direct participation of 20 hospitals in the IAEA TLD comparison.

The IAEA TLD methodology has been adopted in the quality audit. Presently, LiF:Ti,Mg (TLD-100) powder provided by IAEA is being used. The uncertainties in the evaluation have been reduced to less than 2% by optimization of the TLD procedure. Follow-up actions are taken for those hospitals whose deviations in the audit are outside the acceptance limit of 5% by sending detailed worksheets analyzing the discrepancies and by repeat TLD audit. If needed, visits to the hospitals are performed in order to improve the local dosimetry practices.

The SSDL participates in a reciprocal comparison with the IAEA every year and has also had comparisons with external audit groups in Malaysia, Korea and Argentina. The results have shown good agreement.

The results of the recent audits have shown that about 80% of the hospitals have results within acceptance limit of 5%. To improve the dosimetry in the hospitals with larger deviations, the possible reasons have been identified. The reasons are: calculation mistakes, improper dosimetric measurements, malfunctioning of auxiliary equipment and defective machine parameters. The EAG makes efforts to help hospitals to reduce these errors.

The establishment of the national EAG has been carried out under the previous CRP (E2.40.07). The EAG is now in a position to take up the following plan of action for the present CRP of Quality audit of photon and electron beams under non-reference conditions.

For Co-60 beams the following checks will be taken up for on-axis measurements

1) For depth-dose checks:

Measurement at reference depth of 5 cm and field size of 10 cm x 10 cm, followed by measurement at depth of 15 cm for the same field size

2) For checks of the dose variation with field size:

Measurements at depth of 15 cm and field sizes of 7 cm x 7 cm, 20 cm x 20 cm and 7 cm x 15 cm

3) For wedge transmission checks:

Measurement at depth of 15 cm for field size of 7 cm x 15 cm without wedge and with the thickest wedge normally used in the clinical practice at the collimator rotation angles of 0° and 180°.

For high energy photons from linear accelerators a similar set of measurements will be performed at the depths of 10 cm and 20 cm.

This plan of action will be carried out through a pilot study at 10 hospitals, which may include on-site visits, followed by a run of mailed dosimeters to 50 hospitals. Later, a study on photon beam checks off-axis will be initiated.

It is also planned to start the quality audit of electron beams at the reference depth for three representative energies for 20 hospitals using the special holder designed by IAEA. The EAG will take up for the electron audit only those hospitals who have already taken part in photon audits.

W. BULSKI, POLAND

The radiotherapy infrastructure database for Poland has been updated by the national EAG. The database contains the up-to-date information on the number and technical data of radiotherapy equipment in Poland (both tele- and brachytherapy): radiotherapy machines, simulators, treatment planning systems, CT and MRI scanners, dosimeters, phantoms, staffing (medical physicists).

The instruction and data sheets for TLD audits in reference conditions, which are sent out to participants together with the TLD capsules, have been revised, updated and finalized. They are included to the external TLD audit standard procedures (in Polish) as the appendices. They have been prepared for the audits of Co-60, photon and electron beams with the dose value stated by the participants on the basis of the ionizing chamber measurements.

The appropriate data sheets are being prepared for the audits with the dose value stated by the participants on the basis of the treatment planning system (TPS) calculations.

A TLD pilot audit run of electron beams was performed and the results evaluated. The sources

of errors have been reviewed and the ambiguities of the instruction sheets have been identified and corrected.

The results of the TLD postal audits in Poland were presented at the ESTRO Congresses (Seville 2001 and Prague 2002), as well as at various national meetings in Poland.

An upgrading of the TLD laboratory is underway. The first activity is the commissioning of the new TLD reader (PCL3) with a new TL powder batch.

The following audit checks are planned in the order of priority (in all audits the participant stated dose value is based on TPS calculations):

1) An audit for Co-60 beams in reference conditions

2) An audit for high energy X-ray beams on-axis, involving:

reference conditions: 10 cm x 10 cm at 10 cm depth;

non-reference conditions: 10 cm x 10 cm at two depths: 10 cm and 20 cm;

non-reference conditions: field size 7 cm x 7 cm, 10 cm x 20 cm at 10 cm depth.

3) MLC checks: pilot feasibility study with 5 radiotherapy centres.

4) Electron beam run (all centers).

The recommendations on the audits in non-reference conditions are going to be prepared along with the instruction and data sheets for the different types of audit runs.

After the successful completion of the above listed activities further audits are planned for Co-60 beams and linac photons on axis for wedged fields and off-axis for field sizes 10 cm x 10 cm, 7 cm x 7 cm, 10 cm x 20 cm, at 10 cm depth.

D. GEORG, AUSTRIA

The scope of the research agreement was (i) to test a prototype TLD holder developed by the IAEA with high-energy photon beams in a variety of geometric conditions, and (ii) to measure a set of corrections for the new TLD holder for clinical photon beams.

In the very beginning, the feasibility study of the modified TLD holder was performed using a single photon beam energy. Measurements were conducted following a test program specified during an IAEA consultant meeting held in June 2001. The workload for this ambitious program was very high and considered to be too extensive for medical physicists in a busy radiotherapy department. For that reason, the test program was reduced substantially in order to reach a workload acceptable for a hospital physicist. The reproducibility of measurements was verified with ionization chambers and TLDs. As the agreement between ionization chamber and TLD measured data was good, the measurement procedure itself was considered to be adequate for the purpose of dosimetric audits in non-reference conditions.

In the second phase, the prototype TLD holder was used for a test series in four different photon beam qualities: Cobalt-60 as well as 6 MV, 10 MV, and 25 MV photon beams from a linear accelerator. The number of fields and measurement points of the reduced test program were as follows: symmetric 10x10 cm² field for open and wedged beams (each 1 TLD), open and wedged asymmetric 10x10 cm² field with the beam axis shifted 2.5 cm off-axis (each 2 TLDs), and open and wedged 20x20 cm² field (each 3 TLDs). Prior to detailed studies, the relevant correction factors were determined for the prototype holder.

After finishing the feasibility study, recommendations will be published for dosimetric audits in non-reference conditions on- and off-axis. These recommendations will include data on correction factors for TLD holder perturbation and scatter influence as a function of depth and photon beam quality.

4. SUMMARY OF THE GENERAL DISCUSSION ON TLD AUDITS IN NON-REFERENCE CONDITIONS

The meeting was dedicated to the discussion of the strategy for the duration of the CRP, including development of the methodology and the action plan for TLD audits in non-reference conditions and a workplan for the feasibility study for measurements on- and off-central beam axis. For this, a new type of TLD holder was designed at the IAEA and tested using hospital beams at AKH, Vienna and IGR, Villejuif. The next step discussed was a methodology for dosimetry audits

of electron beams, and the operating procedures for the photon and electron quality audits including development of the instruction sheets, irradiation forms, discrepancy analysis forms and results reporting forms.

Special emphasis was given to issues related to the admission criteria for a hospital to participate in a QA audit. It was decided that the basic TLD audit (step 1) should be open to all facilities in the country and the audit in non-reference conditions (step 2) will be available to those facilities that have completed the basic audit successfully. Attention was given to the reporting of audit results, involving confidentiality issues, and publication of the global results.

The composition of the national EAGs was discussed and optimal structures for the individual countries recommended with special emphasis on the role of the radiation oncologist in the EAG as he/she has a liaising role with the radiation oncology community. The decision on which oncologist should represent the community depends on the country, but the community should make the choice. The oncologist role will be to advise on the dose reporting procedure as well as on priorities for the implementation of different steps in the audits (e.g. photons off-axis or electrons). His/her primary responsibility, however, should relate to the contacts with the radiation oncologist of the local centre if there is a dosimetry problem that affects cancer treatment of the patient at that centre. The meeting recommended that efforts should be taken to bring radiation oncologists to the audit groups and encourage their active participation. The radiation oncologists community should be kept informed about EAG activities and, especially, the TLD audit results.

**REPORT OF A CONSULTANTS’
MEETING ON THE DEVELOPMENT OF
PROCEDURES FOR QUALITY
ASSURANCE FOR DOSIMETRY
CALCULATIONS IN RADIOTHERAPY**

13–18 October 2003, IAEA Headquarters
Vienna

Consultants:

D. Georg (Austria)

B. Mijnheer (The Netherlands)

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Scientific secretary: S. Vatnitsky

SUMMARY

The first objective of this Coordinated Research Project (CRP) is to create a set of simple and practical acceptance and commissioning tests, defined in a dedicated protocol, which can be easily followed at the hospital level. Such QA tests for dosimetry calculations in radiotherapy are needed not only by small hospitals with limited resources, but also in large (university) centres having a high patient load or limited staff. There is an urgent need for a “practical” document describing a minimum number of benchmark cases, to be performed by a user in a hospital, which can be carried out in a reasonable amount of time. Such benchmark cases should help to avoid severe errors in the treatment planning process in a specific institution. With the introduction of more sophisticated treatment techniques or the start of special (for instance dose escalation) studies, this set of basic tests should be extended to guarantee the safe and consistent implementation of these more advanced techniques and special studies. The practicality of developed quality assurance guidelines will be assured through trial use in clinical facilities of varying size. Reduction of extensive published quality assurance recommendations in a QA program feasible in all hospitals will be achieved without loss of comprehensiveness by appropriate and optimum division of effort between treatment planning system vendors and hospital staff.

The expected outputs will be an increase in the safe use of radiation therapy treatment planning systems

for external beam therapy and a reduction of the number of potential miss-administrations of the dose to patients undergoing radiotherapy treatments.

Three Research Contracts and four to five Research Agreements will be awarded. The recommended duration of this CRP to accomplish all of its objectives is 4 years.

**1. BACKGROUND SITUATION
ANALYSIS**

1.1 Introduction

Treatment planning systems are widely available in developed and developing countries. Computer-based treatment planning is now considered to be a standard of practice that can significantly elevate the quality of radiation treatment. However, the complexity of planning systems has led to their misuse, while the process of testing their accuracy remains a task that is beyond the capabilities of most radiation therapy facilities. In the past, some major accidental exposures to patients undergoing radiation therapy have occurred, which were related to the misuse of a treatment planning system (TPS) and/or to a lack of understanding of how the TPS works. More details related to the incidence of accidents in radiotherapy can be found in several reports (IAEA 2000a, IAEA 2000b, ICRP 2001). In many of these accidental exposures, a single cause could not be identified but usually there was a combination of factors contributing to the occurrence of the accident. The most prominent factors were deficiencies in education and training, and a lack of quality assurance (QA) procedures. With respect to treatment planning systems, major accidents were related to:

- Inconsistent or incorrect basic beam data in the TPS.
- Confusion of patient related data.
- Data transfer issues.
- Insufficient understanding of the dose calculation algorithms.
- Misapplication of treatment distance correction in the monitor unit calculation.
- Erroneous or no decay correction in treatment time calculations for cobalt units.

After an investigation of one of these accidental exposures of radiotherapy patients (IAEA 2000), the IAEA developed procedures for on-site review visits for QA in external radiotherapy treatment planning (IAEA 2003). Part of these procedures is the on-site application of a test package consisting of: 1) water phantom cases to compare calculated dose values with measured values, and 2) anatomical cases to trace differences in dose calculations performed with the clinically applied system and those determined with a reference TPS. These visits can be performed by a team of experts at the request of a *specific institution* having a problem related to treatment planning but do not concern general QA procedures valid for *all institutions* applying a computerized TPS.

Even if a treatment planning system is used by a well-trained qualified person, various types of errors, for instance, due to inaccuracies in the in- and output data or limitations of the algorithms, may represent a safety hazard to patients. Therefore, formal acceptance testing and commissioning of the TPS, i.e., a comprehensive series of operational tests before using the TPS for treating patients, is required. These tests, which should partly be performed by the vendor and partly by the user, do not only serve to ensure the safe use of the system in a specific clinic, but also help the user in appreciating the possibilities of the system and understanding its limitations.

1.2 Available documents on QA of TPS

Many reports on radiotherapy treatment planning or on treatment planning systems mention the importance of performing QA tests before starting to use the system clinically. Probably a Nordic group presented the first detailed document discussing QA of treatment planning systems (Dahlin *et al.*, 1983). The emphasis in that report was on user requirements for CT-based treatment planning systems. Later, a number of national and international reports were published in which issues related to QA of treatment planning systems are described. These reports are: the Canadian report (Van Dyk *et al.*, 1993), the UK reports (Shaw, 1996, Mayles *et al.*, 1999), the Swiss report (SSRPM, 1997), the American report (Fraass *et al.*, 1998); the Dutch report (NCS, 2003) and the ESTRO booklet (ESTRO, 2004). Quality assurance of a number of dosimetric and non-dosimetric

aspects of a TPS is discussed to a different degree of sophistication in these reports. The earlier documents are mainly dealing with dosimetric aspects of QA. Later reports do provide more extensive recommendations on many issues related to QA of treatment planning systems, but no clear guidelines are given as to which specific tests should be performed before the clinical use of a TPS could start. Also, it was difficult for a TPS-user to decide which tests have to be performed by an individual user, or by the vendor or a user group. For that reason an attempt was made in the ESTRO booklet to give suggestions for such a division of tests.

In November 2000, the International Electrotechnical Commission (IEC), published an International Standard on “Requirements for the safety of radiotherapy treatment planning systems”(IEC 2000). Similar to other IEC documents concerning medical equipment, e.g. for linear accelerators, this International Standard defines a number of requirements to be complied with by manufacturers of such equipment in order to provide protection against the occurrence of safety hazards to patients. Compliance with these requirements should be checked by testing by the vendor and demonstrated to the customer. A large number of these tests can already be performed before the system is installed in the hospital, i.e., before the acceptance testing of the system starts. For instance, benchmarks that demonstrate the accuracy of dose computation within the bounds of the described numerical algorithms should be made available by the vendor. The results of these tests should be described in documents accompanying the system, and should only be spot-checked by an individual user. Although vendor responsibilities for system safety have been established by IEC Standard 60283, manufacturers and customers do not often apply the guidelines mentioned in this document to guarantee the safety of treatment planning systems as defined in this industry standard.

1.3 Action needed

A forthcoming publication in the IAEA Technical Report Series on Quality Assurance of Radiotherapy Treatment Planning Systems (TRS on QA RTPS) contains a wealth of information on commissioning, and quality assurance of computerized treatment planning (IAEA 2003). It

provides a general framework on how to design a QA programme for all kinds of TPS, both for external therapy and brachytherapy. It describes a large number of tests and procedures that should be considered and should in principle fulfil the needs for all TPS-users. However, due to the complexity of the treatment planning process, this TRS publication does not provide a simple protocol that can be followed step-by-step by a user at a hospital for the commissioning and QA of a TPS. Because of its completeness, it might therefore be difficult for a user to choose those tests that are most urgently needed for the situation in that particular institution. Also a number of the tests presented in the TRS refer to testing the system itself, and are not specific for an individual user. These detailed system tests may therefore better fit in the testing programme to be performed by a manufacturer of a TPS as outlined, in general terms, in the IEC document. Although QA of treatment planning systems is recognized in all reports as an important subject to prevent misadministration of radiation, the consultants have the opinion that the implementation of QA of a TPS at the hospital level, as well as at the vendor level, remains a challenge and an unresolved issue. The IAEA TRS publication discussed above can at this moment be considered as the most complete reference work in the field of QA of treatment planning systems. It is, however, too comprehensive as it covers many aspects, ranging from patient data management issues through dose computation to data output issues. The workload for the implementation of all these guidelines would be enormous and require far more personnel and instrumentation resources than is available in most facilities, particularly within smaller hospitals.

The first objective of the CRP is therefore to use this TRS publication as the basis to create a set of simple and practical acceptance and commissioning tests, defined in a dedicated protocol, which can be easily followed at the hospital level. Such QA tests for dosimetry calculations in radiotherapy are needed not only by small hospitals with limited resources, but also in large (university) centres having a high patient load or limited staff. There is an urgent need for a “practical” document describing a minimum number of benchmark cases, to be performed by a user in a hospital, which can be carried out in a reasonable amount of time. Such benchmark cases should help to avoid severe errors in the treatment planning process in a specific

institution. With the introduction of more sophisticated treatment techniques or the start of special (for instance dose escalation) studies, this set of basic tests should be extended to guarantee the safe and consistent implementation of these more advanced techniques and special studies.

In order to demonstrate compliance with the requirements of the IEC standard, the vendor can also use a number of the tests described in the IAEA TRS. The second aim of the CRP is therefore to separate tests for QA for dosimetry calculations in radiotherapy that should be the responsibility of the vendor, from those that must be performed by the user. Ultimately the tests should be defined in such a way that there is an unambiguous division between the tasks of the vendor and the user. Although the user must bear final responsibility for accurate use of the planning system and accurate application of the planned treatment, the vendor should be responsible for assurance that the planning system functions as described to the customer.

The consultants have found that patient specific QA aspects of the treatment planning process/outcome have only been addressed in a limited way in the existing documents. However, this is a critical link between treatment planning and treatment delivery. It is therefore recommended that the third action to be undertaken by the CRP should be the formulation of a set of recommendations for quality assurance checks of individual patient treatment plans.

2. OVERALL OBJECTIVES

The broad objective of the proposed project is improved safe use of radiation therapy treatment planning systems for external beam therapy. This will be achieved by implementation of quality assurance guidelines developed by the CRP and distributed to hospitals within Member States. The guidelines will be formulated for practical application in hospitals with limited resources as well as for use in larger institutions. Practicality will be assured through trial use in clinical facilities of varying size. Reduction of extensive published quality assurance recommendations to a feasible QA program in all hospitals will be achieved without loss of comprehensiveness by appropriate and

optimum division of effort between treatment planning vendors and hospital staff. Vendor adherence to the IEC Standard 62083 assures that documentation of absorbed dose computation accuracy for conditions of normal use is provided to the customer. Compliance with the IEC Standard also assures that tests for correct system functionality will be made at the time of installation. To assist this process the document to be developed within this CRP should contain a detailed description of items from the IEC Standard to be provided to the customer.

Thus, the complete IAEA package will contain the following components:

1. A description of tests expected to be included in the vendor's documentation of the accuracy of the dose computation algorithms.
2. A list of items expected to be included in the vendor's on-site acceptance test procedure.
3. A description of recommended dosimetry calculation and other tests for the commissioning of new planning systems and system updates.
4. Guidelines for establishment of an ongoing treatment planning quality assurance program including QA of individual patient treatment plans.

3. SPECIFIC RESEARCH OBJECTIVES

The IAEA TRS publication along with other existing documents on quality assurance of treatment planning systems must be reviewed. The consultants have the opinion that a description of most required tests for quality assurance of dosimetry calculations can be found from the collection of referenced reports. Information from other sources may be necessary to formulate recommendations for patient-specific treatment planning quality assurance.

The CRP should focus on conventional external beam therapy using high-energy photon and electron beams. It is recommended that brachytherapy and advanced external beam therapy techniques, such as intensity-modulated radiotherapy (IMRT), should be added in a second phase.

Vendor related components should be developed with industry feedback. One or more members of the CRP should have a close but un-conflicted relationship with a vendor such as through a treatment planning users group. Vendor test recommendations should be extracted whenever possible from the IAEA TRS publication and other reference documents. Recommendations to vendors should be consistent with the industry standard: IEC 60283.

Tests should include evaluation criteria taken from the reference reports. Consideration may be given to setting different criteria for basic and advanced treatment practices. The CRP may suggest actions to be taken if certain tests cannot pass the evaluation criteria.

The consultants recognize the potential danger in using computerized treatment planning systems without a basic understanding of its algorithms and system functionality. For that reason, tests proposed by the CRP should simultaneously address educational aspects by including descriptions that assist the training of users. The user should be familiar with the details of the algorithms in the system before clinical use. This knowledge should be obtained from the documentation described above, by training provided by the vendor, from general training in the use of the algorithms, and by getting information from other institutions having the same system. Additional training may be gained by user participation in recommended vendor-guided acceptance tests and from recommended commissioning tests performed independently by the user.

All proposed on-site test procedures need to be evaluated carefully in a pilot study covering the range of hospital settings. The evaluation of results and the feedback from such a pilot study may lead to a redesign of some test situations. The pilot study will give an impression of the workload of the proposed tests for different planning systems and different levels of clinical practice.

After successfully passing the pilot study phase, the test package needs to be sent out for a feasibility study to participants from Member States. Based on this experience, tests should be fine tuned but not primarily redesigned.

At the final phase of this CRP, dosimetry calculation quality assurance guidelines should be produced and published by the IAEA (e.g. as a TRS document).

3.1 Documentation of dose computation algorithm accuracy

The CRP should include recommendations for dose calculation algorithm verification tests to be completed and documented by the vendor prior to installation. Each algorithm used by the planning system for dosimetry computation should be described at a conceptual level along with enough mathematical detail to allow basic understanding by the user. Each algorithm also should have a technical description that states the accuracy of the algorithm relative to measured data for at least one set of pre-defined conditions. The description should include, in addition, the limitations of the algorithm under the most extreme conditions of input variables (IEC 2000).

3.2 On-site acceptance tests

The CRP should provide recommendations for tests to be included in vendor-guided acceptance test procedures. The CRP should consider a range of dosimetric and non-dosimetric system function tests in their recommendation. The consultants recommend that the procedure for acceptance testing of treatment planning systems should be made more similar to that of other equipment used in a radiotherapy department. After installation of a planning system in a hospital, the vendor should perform a series of tests, together with the user, to demonstrate that the system performs according to its specifications. Such a procedure implies that the vendor should make available to the customer a document describing the correct functioning of the system. The vendor also should include an acceptance test guide that describes the tests to be performed and provides for formal acceptance by the customer. Recommendations for the contents of this guide document are to be made by the CRP.

3.3 Commissioning tests to be performed in the hospital

Recommended commissioning test cases should be categorized into basic level tests and advanced tests. Basic level tests will include dose and monitor unit calculation accuracy verification for the normal range of rectangular fields plus other simple test conditions as developed by the CRP. The basic test series should verify that the institution's beam data have been properly adapted to the treatment planning system. Commissioning tests may be limited to the basic level for radiotherapy centres that limit their practice to treatment with rectangular fields. Advanced level commissioning tests should be added to the basic test set to address the needs of centres performing more conformal radiotherapy. The CRP should consider tests for the advanced set that validate the use of CT data, beam intensity modifiers, custom field-shaping blocks or multi-leaf collimators.

Tests requiring physical measurements should be designed for performance with instruments normally found in the hospital. Total system tests should start with the acquisition of anatomical data and end with transfer of treatment planning output data to the treatment unit.

3.4 Ongoing treatment planning quality assurance

The CRP participants should formulate guidelines for ongoing treatment planning QA programs, including QA checks of individual patient plans. The consultants find that there may be insufficient information on these topics within the referenced reports. Periodic system checks should include all aspects of the planning process that are subject to variation such as beam database integrity, CT performance, and hard copy output. Individual patient QA should include independent monitor unit verification and a checklist of other items as developed by the CRP.

4. EXPECTED RESEARCH OUTPUT

The output of the research program will be a report that provides specific guidelines for implementation of quality assurance measures that will enhance the safe use of radiation treatment planning systems. The document will include recommendations for

clinical treatment planning system verification of dose calculation algorithms, acceptance testing, commissioning and ongoing quality assurance.

The final version of the report will be influenced by on-site trials that assure its recommendations are both practical and adequate for normal clinical needs. Once complete, the report will be distributed to Member States and made generally available through the IAEA web site.

5. ACTION PLAN

Upon the formation of the CRP group in 2004, a total of five consultants and Research Co-Ordination Meetings will be required during the course of this CRP in 2004-2007 to assist in development of the specific tests and procedures and implementation of the tests in hospitals by TPS users to accomplish the objectives of this CRP. The specific tasks that will be carried out are:

Activity 1 Formation of a group of institutions participating in the CRP

The CRP will involve a maximum of six institutions, and a maximum of three of these will come from developed countries. These institutions will participate in the CRP having close interaction with the vendors in order to separate tests for QA for dosimetry calculations in radiotherapy that should be the responsibility of the vendor, from those that must be performed by the user. A maximum of three institutions will come from developing countries either from large (university) centres having a high patient load or limited staff, or from the small hospitals with limited resources. These institutions will be involved in on-site trials that assure the developed recommendations and protocols are both practical and adequate for normal clinical needs. Selection will be based on qualification of counterparts, ability to carry out QA tests, and the quality of the proposals received. (2004).

Activity 2 Hold 1st RCM to review the existing national and international QA procedures in dosimetry calculations in radiotherapy.

Participants will review the existing national and international QA procedures in dosimetry calculations in radiotherapy and industry standards and distribute the tasks to develop a feasible QA program in all hospitals that will be achieved without loss of comprehensiveness by appropriate and optimum division of effort between treatment planning vendors and hospital staff. (mid 2004)

Activity 3 Hold Consultants' meeting to develop verification tests of dose computation algorithm accuracy and recommendations for tests to be provided and included in vendor-guided acceptance test procedures at the hospital.

The consultants will develop recommendations for dose calculation algorithm verification tests to be completed and documented by the vendor prior to installation. The consultants will provide recommendations for tests to be included in vendor-guided acceptance test procedures at the hospital. If possible one or two representatives from vendors should participate in the meeting, as the vendor should perform a series of tests, together with the user, to demonstrate that the system performs according to its specifications. Such a procedure implies that the vendor should make available to the customer a document describing the correct functioning of the system. The vendor also should include an acceptance test guide that describes the tests to be performed and provides for formal acceptance by the customer. (early 2005)

Activity 4 On-site acceptance tests

The CRP participants conduct dosimetric and non-dosimetric system function tests included in vendor-guided on-site acceptance test procedures. If possible the testing will be carried out in close cooperation with the vendors. (2005)

Activity 5 Hold Consultants' Meeting to review the results of on-site acceptance testing and to develop commissioning tests and periodic QA tests of dosimetry calculations to be performed in the hospital

The consultants will review the results of testing of the vendor-guided acceptance test procedures at the

hospitals and develop a protocol with commissioning test cases categorized into basic level tests and advanced tests and formulate

Activity 6 On-site trials of the commissioning tests and periodic QA tests of dosimetry calculations, preparation of the draft report

The participants conduct on-site trials of the commissioning test cases categorized into basic level tests and advanced tests including QA checks of individual patient plans. (2006 – mid 2007)

guidelines for ongoing treatment planning QA programs, including QA checks of individual patient plans. (early 2006)

Activity 7 Hold 2nd RCM to review results and finalize the draft of the TECDOC on tested procedures and protocols for QA of dosimetry calculations in radiotherapy.

Participants will review the results of on-site trials and finalize the draft of a TECDOC, which will provide specific guidelines for implementation of quality assurance measures of dosimetry calculations in radiotherapy hospitals. (late 2007)

It is anticipated that this CRP will require 4 strategy meetings over its lifetime. The following is a list of the meetings, year, participants and topic of discussion.

Year	Meeting	Participants	Topics of Discussion
2004	RCM	Research Agreement and Contract Holders	Implementation of QA testing procedures
2005	CT	International experts	Verification tests of dose computation algorithm accuracy and tests to be provided and included in vendor-guided acceptance test procedures at the hospital
2006	CT	Selected Research Agreement Holders, International experts	Progress Report; Commissioning tests and periodic QA tests of dosimetry calculations
2007	RCM	Research Agreement and Contract Holders	Summary Report of CRP; Draft of TRS

6. IMPORTANT ASSUMPTIONS

There are several assumptions made for the implementation and completion of this CRP on the development of procedures for Quality Assurance for dosimetry calculations in radiotherapy. These assumptions include:

1. Each participating institution must have functioning treatment planning systems and staff with the necessary expertise in computerized treatment planning.
2. Several CRP participants shall have the capability of non-conflicting interaction with TPS vendors, or participate in vendor-organized user's group activity.

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COURSES, MEETINGS AND CONSULTANCIES TO BE HELD DURING 2004

Courses and workshops

Regional Training Course on Quality Assurance of Physical and Technical Aspects in Radiotherapy, Argonne National Laboratory, Illinois (USA), 12-23 January 2004

Regional Training Course on X-ray Dosimetry, Johannesburg, South Africa, 20-24 September 2004

Regional Training Course on Dosimetry of High Energy Photons Beams using TRS-398, Khartoum, Sudan, 14-18 November 2004

ESTRO courses under RER/6/012

Radiotherapy Treatment Planning: Principles and Practice, Dublin, Ireland, 7-11 March 2004

Modern Brachytherapy Techniques, Bled, Slovenia, 21-25 March 2004

Imaging for Target Volume Determination in Radiotherapy, München, Germany, 18-22 April 2004

Dose Determination in Radiotherapy: Beam Characterization, Dose Calculation and Dose Verification, Nice, France 2-6 May 2004

Evidence-based Radiation Oncology: Basis and Clinical Application, Moscow, Russia, 13-18 June 2004

Physics for Clinical Radiotherapy, Leuven, Belgium, 29 August – 2 September 2004

Basic Clinical Radiobiology, Lausanne, Switzerland, 19-23 September 2004

Meetings and consultancies

Peer Review Meeting on the Quality System of the Agency's Dosimetry Laboratory, IAEA Headquarters and Agency Laboratories in Seibersdorf, 2-6 February 2004

Consultants' Meeting on Development of Guidelines for Comprehensive Audit of Radiotherapy Practice for Developing Countries (organized jointly by Dosimetry and Medical Radiation Physics Section and Applied Radiobiology and Radiotherapy Section), IAEA Headquarters, Vienna, 16-20 February 2004

11th Biennial Meeting of the SSDL Scientific Committee for the Evaluation of and Recommendations on the Dosimetry Programme and the IAEA/WHO Network of Secondary Standards Dosimetry Laboratories (SSC-11), IAEA Headquarters, Vienna, 2-5 March 2004

Consultants' Meeting on Development of Methods and Guidelines for improving the Resolution of Discrepancies Detected in SSDLs, IAEA Headquarters, Vienna, 26-30 April 2004

Second IAEA/ICRU Meeting of the ICRU Sub Committee on Proton Therapy, Vienna General Hospital and IAEA Headquarters, Vienna, 19-21 June 2004

Consultants' Meeting to develop operational procedures for Medical Physics Investigation Team (MPIT), IAEA Headquarters, Vienna, dates not yet known

Consultants' Meeting on Harmonization of Quality Assurance Practice for Nuclear Medicine Radioactivity Measurements, IAEA Headquarters, Vienna, dates not yet known

Consultants' Meeting to develop procedures for in-vivo dosimetry, IAEA Headquarters, Vienna, dates not yet known

First Research Co-ordination Meeting on Development of Procedures for Quality Assurance for Dosimetry Calculations in Radiotherapy, IAEA Headquarters, Vienna, 28 June – 2 July 2004

Consultancy visit to review and edit IAEA TECDOC on the Implementation of the International Dosimetry Code of Practice TRS-398, IAEA Headquarters, Vienna, July 2004

Research Co-ordination Meeting on Testing the New Code of Practice for X-ray Dosimetry in Diagnostic Radiology, IAEA Headquarters, Vienna, dates not yet known

Second Research Co-ordination Meeting on Development of TLD-based Quality Audits for Radiotherapy Dosimetry in Non-reference Conditions, IAEA Headquarters, Vienna, 4-8 October 2004

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International Bureau of Weights and Measures (BIPM)
International Commission on Radiation Units and Measurements (ICRU)
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International Organization of Legal Metrology (IOML)
International Organization of Medical Physics (IOMP)

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National Institute of Standards and Technology (NIST)	Gaithersburg, USA



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