

International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry – Recommendations

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Abstract

The Symposium took place at the IAEA headquarters in Vienna from 25 to 28 November 2002. More than 250 participants representing 62 countries attended the four-day meeting at which 140 presentations were delivered covering a broad range of topics in medical radiation dosimetry. Recommendations following the papers and discussions were prepared by the chairs, co-chairs and rapporteurs of each session and presented to the participants of the symposium in the final session for their approval. Although many of these recommendations concern the scientific community, some are directed to governments and industry, as these affect practical application in developing countries. However, as was pointed out during Session 15, some of the developed countries would also benefit from following these latter recommendations. The IAEA would obviously be a good choice to take the lead in many of these actions.

Session 1: Setting the scene

After the description of the operation of the mutual recognition arrangement (MRA), it was clear that developing countries would benefit from being included in MRA comparisons and declaring their calibration and measurement capabilities (CMCs), as this would encourage them to clarify their methods and uncertainties. As it is a matter for individual countries to decide whether they should sign the MRA, the symposium simply recommended that:

1. Secondary standards dosimetry laboratories (SSDLs) holding national dosimetry standards for signatories of the MRA should be encouraged to participate in comparisons and to declare their CMCs through their regional metrology organization (RMO).

To support the SSDLs in this dosimetry work, it was recommended that:

2. Additional RMO comparisons should be developed and participation in these comparisons by Member States should be encouraged.

For more than 30 years the IAEA has developed dosimetry codes of practice pertinent to external beam radiotherapy and has arrived at a situation in which all forms of dosimetry measurements are linked together in one coherent protocol. Consequently, the symposium recommended that:

3. Organisations recommending the use of the IAEA dosimetry code of practice in Technical Report Series No. 398 (TRS 398) should encourage users to follow its most recently released version.
4. The use of TRS 398 should be encouraged in all Member States.
5. The translation of TRS 398 should be encouraged.

It was recommended that, through the maintenance and support of the IAEA/World Health Organization (WHO) SSDL network:

6. The dissemination of dosimetry standards and expertise in the developing world should continue.
7. The consistency and quality of dosimetry standards should be maintained and developed through comparisons.

Session 2: Absorbed Dose Standards and Calorimetry

Absorbed dose to water is the necessary quantity for dosimetry measurements for radiotherapy. Many papers were presented on the different methods of determining absorbed dose to water using primary methods. However, there are many issues related to this that need to be addressed by the primary standards dosimetry laboratories (PSDLs) in the national metrology institutes. The symposium recommended that:

8. Absorbed dose to water should be derived from as many independent methods as possible.
9. Direct comparisons of water and graphite calorimeters should be encouraged.
10. Uncertainties assigned to absorbed dose to water primary standards should be examined in detail, preferably by a working group of the international Consultative Committee for Ionizing Radiation (CCRI), in order to rationalize any apparent discrepancies.
11. Research should be supported for all forms and new applications of calorimetry, for example for brachytherapy.
12. Absorbed dose standards for electron beams should be developed further.
13. Development of absorbed dose to water standards for kilovoltage X rays should be encouraged.
14. More PSDLs should participate in the high energy X ray comparison piloted by the Bureau international des poids et mesures (BIPM).

Session 3: Air Kerma and Absorbed Dose to Water Standards for Photons

Currently, most dosimetry measurements are made in terms of air kerma. However, as all these measurements are related to a common primary method using cavity ionization chambers, it is particularly important that the physical constants used in the measurement equations, and the corrections necessary for cavity ionization chambers, be well understood. Consequently, the symposium recommended that:

15. PSDLs and the International Commission on Radiation Units and Measurements (ICRU), as appropriate, should address the unresolved issues pertaining to air kerma dosimetry standards, including the re-evaluation of:
 - k_{wall} and k_{an} (including the BIPM standard);
 - W_{air} values and uncertainties;
 - Stopping power ratios;
 - Type B uncertainties related to Monte Carlo methods, taking account of the underlying interaction coefficients.

Session 4: Meeting the Needs

During Session 4 the WHO clearly presented the dramatic increase that is likely in the number of cancer patients in developing countries within the foreseeable future. Since nuclear technology in the form of radiotherapy will remain central for the treatment of cancer in both developed and developing countries within the same time frame, the symposium felt that:

16. Organisations engaged in assisting countries to develop and implement cancer control strategies should be proactive in order to address their current and future needs for cancer treatment.

It is clear that cobalt teletherapy and brachytherapy source trains will be the mainstays of radiotherapy for most developing countries for the foreseeable future. To support these therapies, the symposium felt that:

17. Appropriate staffing — medical, technical, nursing and scientific — is crucial for treatments to be effective.
18. Treatment equipment must be accompanied by the appropriate techniques for diagnosis, tumour localization and staging, immobilization, shielding, treatment simulation and planning, clinical dosimetry (including displays), treatment verification and follow-up.
19. Appropriate dosimetry equipment must be made available for equipment commissioning and continuing quality control.

With regard to therapy and supporting diagnostic equipment, the symposium felt that a number of issues could be addressed. There were particular concerns raised during the final discussion session that low dose rate brachytherapy equipment was no longer being produced, whereas this was considered by some radiation oncologists to be better or less expensive than high dose rate brachytherapy. Consequently, the symposium recommended that:

20. The equipment industry should be encouraged to recommence the production of low dose rate brachytherapy equipment and also to strive to make high dose rate brachytherapy equipment more affordable.
21. The equipment industry should be made aware of the future needs of the Member States regarding the increasing demands for cancer services.

While collaboration between industry and government was seen as useful for developing countries, concern was expressed that voluntary organizations often donated equipment without taking account of the consequent needs. Understanding that this is the domain of the WHO and PAHO, the symposium felt that:

22. WHO advice that provides guidance to organizations donating technologies to the developing countries should be disseminated widely.
23. Supporting guidance covering all factors required to implement such radiation technologies for safe and effective diagnosis and therapy should be developed.

Where the necessary infrastructure and expertise for maintaining linacs are missing, cobalt therapy may be much safer and more reliable for patients than linacs. Hence the symposium felt that:

24. Manufacturers should be encouraged to continue the production of cobalt therapy units.

The current lack of properly trained radiotherapy personnel is as serious as the lack of equipment in many developing — and indeed in some developed — Member States. It was noted that optimizing the use of existing equipment through the proper use of personnel could sometimes be more cost effective than simply adding new equipment. In view of the current lack of and future need for trained personnel and in order to increase awareness of this need among organisations such as the IAEA, WHO, PAHO, European Commission (EC),

International Society for Radiation Oncology (ISRO), European Federation of Organisations for Medical Physics (EFOMP), European Society for Therapeutic Radiology and Oncology (ESTRO) and International Organisation for Medical Physics (IOMP), the symposium recommended that:

25. Training programmes should be implemented on a large scale for professional staff working in radiotherapy, not just to follow the basic curricula but also to comply with a requirement for continuing professional development.
26. National or regional centres of excellence for training should be developed and supported in co-operation with international organizations.

Sessions 5, 6 and 8b: Dosimetry Protocols and Comparisons

The symposium felt very strongly that radiotherapy dosimetry within a given country should be consistent. To achieve this, ideally the same dosimetry protocol should be used in all radiotherapy centres of that particular country. Keeping in mind that some countries have developed their own national dosimetry protocol (e.g. TG 51¹ in the United States of America), for those countries that prefer to use TRS 398 the symposium recommended that:

27. TRS 398 should be adopted initially at the national level in collaboration with the national scientific societies and the SSDLs.
28. Training and education on TRS 398 should be encouraged prior to its implementation.
29. The differences from existing protocols expected with the practical implementation of TRS 398 should be disseminated.
30. The necessary changes in quality assurance procedures should be assessed before the adoption of TRS 398.
31. Both TRS 398 and the code of practice previously adhered to should be used in parallel for a short time and differences between the codes of practice outside those expected should be explained.
32. A specific date should be chosen for the adoption of the new code of practice by all hospitals in the country.
33. Independent dosimetry checks in co-operation with peers should be encouraged.
34. External audits should be performed, if available.
35. The practical aspects of the adoption of TRS 398 for kilovoltage X-rays should be studied and a pilot study should be encouraged for the adoption of the kilovoltage code of practice in the clinic.

It is recognized that several PSDLs and many SSDLs do not have their own accelerators for calibrating secondary standards for clinics. It has been suggested that the SSDLs could use hospital equipment (out of normal operating hours) for this purpose. However, the setting up of a facility for calibration takes time and the uncertainties associated with setting up may be larger than the uncertainties associated with using a protocol's calculated values. Consequently, the symposium recommended that:

36. A feasibility study (including the assessment of uncertainties) should be carried out in order that SSDLs can disseminate experimentally determined $N_{D,w}$ calibrations — traceable to PSDLs — to radiotherapy centres for both megavoltage photon and electron beams.

¹ AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, AAPM's TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams, Med. Phys. **26** (1999) 1847–1870.

Further recommendations concerning the dissemination of dosimetry protocols were that:

37. PSDLs should be encouraged to measure k_Q factors, which should be compiled in a single document.
38. Clinical electron dosimetry (at the hospital level) should be based, in order of preference, on:
 - Ionization chamber calibrations in electron beams based on a standard traceable to a PSDL; or
 - Cross-calibration in an electron beam against a ^{60}Co calibrated reference chamber, or, if no other option is possible;
 - Direct ^{60}Co calibrations.

Sessions 7 and 8a: Dosimetry Issues for Diagnostic Radiology

A large number of quantities have been used for dosimetry measurements in diagnostic radiology, in particular for dosimetry in computed tomography. This has caused considerable confusion, so it was strongly recommended that:

39. The quantities used for these purposes should be harmonized.
40. New codes of practice for dosimetry in diagnostic radiology should use the quantities agreed.
41. The determination of diagnostic reference levels, a process in which image quality also needs to be assessed, should use the quantities agreed.

Some SSDLs have established or are in the process of establishing calibration services for dosimetry in diagnostic radiology. The number of laboratories that can provide these services is not sufficient to meet national needs. The symposium recommended that:

42. SSDLs should develop calibration services for dosimetry in diagnostic radiology in order to be able to cover their national needs.
43. A set of recommendations should be developed to provide an interim approach to traceability for countries with no access to an SSDL undertaking the calibration of diagnostic dosimeters.

The symposium noted that computed tomography could deliver significant doses to the patient, although these doses were not always simple to assess, and that interventional radiology had caused irreversible skin damage to some patients. The discussions provoked the recommendations that:

44. Appropriate methods for quality assurance and quality control in digital and interventional radiology should be developed urgently.
45. New dosimetry methods should be developed to meet the needs of current and future X ray diagnostic methods.
46. Dosimetry audits to check the performance of calibration laboratories and of end users should be developed and implemented for these diagnostic radiology techniques.

It was further noted that new skills need to be acquired by those performing diagnostic radiology measurements. Consequently, the symposium recommended that:

47. Education and training programmes should be developed for physicists and technical staff working in clinical diagnostic radiology.

Session 9: Nuclear Medicine Dosimetry

During Session 9 a number of concerns were expressed about the state of radionuclide measurements and patient dosimetry in nuclear medicine. The use of unsealed sources for radiotherapy is increasing, but there does not seem to be a concerted effort to improve the quality of the therapies, although standardization is becoming increasingly important, especially in view of multi-national trials. The symposium summarized the concerns by making the recommendations that:

48. Clinical radioactivity measurements should be traceable to national or international activity standards in each country in which nuclear medicine is practised.
49. PSDLs should be encouraged to focus on establishing reliable procedures for measuring low energy gamma emitters, beta emitters, low energy electron emitters and alpha emitters.
50. Quality assurance/quality control programmes should be established and implemented, particularly for quantitative dosimetry analyses in nuclear medicine; guidance for such programmes should be developed.

With reference to patient dosimetry, the symposium recommended that:

51. The use of current dosimetry models should continue with the collection of adequate data to obtain good dose estimates, using as many patient specific modifications as possible.
52. The dissemination of better dosimetric models, particularly those based on patient images in a voxel format, should be encouraged in order that internal dose calculations can be more accurate and detailed and able to provide better correlations between calculated dose and observed effect.
53. Comparison programmes for the quantification of radioactivity should be established, especially for in-phantom measurement and for the calculation of organ doses from multiple image sets.
54. The development of standardized and well documented software programs for traditional dose calculation methods, and for implementing newer, voxel based methods, should be encouraged.

Finally, in Session 9, the symposium recommended that:

55. A standardized code of practice for simple and for more complicated dosimetry calculations should be developed.

Sessions 10 and 12a: Brachytherapy

Although brachytherapy has been practised for decades, it is a many faceted area in which, the dosimetry is not always clear nor always practised well. The symposium considered that the time had come to take definite steps to improve the situation. Consequently, it was recommended that:

56. PSDLs should establish dosimetry standards for brachytherapy sources that SSDLs then disseminate using an internationally agreed method.

57. Dosimetry comparisons between PSDLs and SSDLs should be developed and implemented.
58. Dosimetry audits for clinical end users should be developed and implemented.
59. Research efforts should be focused on dosimetry standards based on absorbed dose to water for photon emitting brachytherapy sources.
60. Beta dosimetry for brachytherapy should be improved, in particular for $^{106}\text{Ru}/^{106}\text{Rh}$ sources.
61. Quality assurance programmes for brachytherapy dosimetry should be developed and implemented.
62. Education and training programmes should be developed for SSDL staff and for clinical personnel.

Sessions 11 and 12b: Radiotherapy Dosimetry Audits

Quality assurance and quality audit of a number of areas in the radiotherapy process were covered in Sessions 11 and 12b, which resulted in a large number of recommendations. In particular, to set the scene, the symposium felt that:

63. Radiotherapy at levels 1 (basic) and 2 (advanced) should be strengthened through education and training, equipment provision and expert support, while at level 3 (developmental) it should be advanced through research programmes.

The symposium strongly expressed the view that quality assurance and quality audits are a very effective way to ensure the correct delivery of the radiation dose to the patient and to enable the therapeutic outcome to be assessed in a consistent manner. Consequently, it was recommended that:

64. Quality assurance programmes for radiotherapy equipment, dosimetry and processes should be promoted, implemented and strengthened in order to ensure accurate, reproducible dose delivery to each radiotherapy patient.
65. Quality assurance programmes should cover the medical aspects of radiotherapy as well as the physics and technical aspects.
66. Audits should be encouraged for all levels of radiotherapy.

The many facets of the auditing of dosimetry were considered, and the symposium recommended that:

67. Dosimetry audit should be included within the scope of clinical audit, as assured dosimetry is required to enable assured clinical practice.
68. An external audit should be available to all radiotherapy centres for all clinically used external beam treatment units, as recommended internationally (e.g. in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources² and the EC Medical Exposure Directive 97/43/Euratom³).

² FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

³ EUROPEAN UNION, Council Directive 97/43/Euratom of 30 June 1997, Health Protection of Individuals against the Dangers of Ionizing Radiation in Relation to Medical Exposure (Repealing Directive

69. The level of external audit should be appropriate to the level of the radiotherapy department and of the national expertise (see also Recommendation 73).
70. As a minimum external audit for radiotherapy beam dosimetry, each beam dose output should be measured independently of the institution's procedures, for example using a mailed thermoluminescent dosimeter from an external laboratory, at least once every two years.

It was agreed that nationally adopted quality assurance programmes provide consistency for radiotherapy practice, and consequently the symposium recommended that:

71. The development of national quality assurance programmes should be encouraged and supported, especially in developing countries.
72. National programmes should include guidelines on quality assurance procedures for radiotherapy centres and also for audit networks or audit systems at the national level.
73. National audit systems for radiotherapy dosimetry should be operated by qualified groups involving co-operation between SSDLs and clinical medical physicists.

The symposium understood that complex radiotherapy techniques require a significantly increased effort for their safe and effective implementation and use. Consequently, it was recommended that:

74. The development of quality assurance recommendations and programmes should be promoted for complex treatment situations (e.g. total body irradiation, stereotactic radiosurgery and intensity modulated radiotherapy).

A range of audit tools has been developed by several audit programmes, including that successfully run by the IAEA, for dosimetry audit. Postal dose audits based on thermoluminescence dosimetry are widely used and well established. However, it was noted that other systems (e.g. alanine) are being considered at the research level. The symposium recommended that:

75. Support should be given, through research programmes, to the development and evaluation of audit methodologies suitable for the various radiotherapy levels.

Appreciating the particular importance of audit when used to assure the dosimetry of patients from multiple countries participating in co-operative clinical trials, the symposium recommended that:

76. Activities in quality audit should be co-ordinated internationally and different audit systems should be compared.

Session 13: Proton and Hadron Dosimetry

The symposium noted that the number of treatment facilities using proton beams and heavier ion beams (mostly ^{12}C) was growing, with 24 currently operational and another 20 planned worldwide over the next five years. There is still a divergence of opinion internationally and even nationally about the dosimetry methods to use for these therapy beams. However, the results presented indicate that the adoption of TRS 398 would provide a coherent approach.

Consequently, the symposium felt that the dosimetry of these beams should be in keeping with conventional radiotherapy beam dosimetry and recommended that:

77. Proton and heavier ion beam dosimetry should be based on absorbed dose to water standards.
78. Comparisons based on absorbed dose to water calibrations should be organized between centres.

For ion dosimetry, the symposium felt that considerable research was still needed to improve knowledge on basic physics data for dosimetry, and consequently recommended that:

79. Research projects on ion dosimetry techniques should be supported.

Session 14: Developments in Clinical Radiotherapy Dosimetry

At the clinical level two areas of concern were discussed, dose measurements and dose calculations. The practicalities of dosimetry systems were evidently a problem and the symposium recommended that:

80. Industry should be encouraged to develop affordable systems for practical use in quality assurance and dosimetry (e.g. tissue equivalent materials, easy to use phantoms and equipment that is robust and reliable).
81. Gel dosimetry methodology should be developed to evaluate its potential for routine use in radiotherapy centres.
82. In vivo dosimetry should be promoted, including its use in developing countries.
83. Alternative methods of clinical dosimetry should be tested and compared with traditional techniques.

With regard to dose calculations, the symposium recommended that:

84. Advanced computing methods for dose calculation should be encouraged where appropriate expertise is available.
85. Guidelines should be developed on which quality assurance tests of treatment planning systems should be performed by manufacturers, user groups and individual users.

Recognizing that errors in treatment monitor units and treatment time calculations have caused accidents, the symposium also recommended that:

86. All radiotherapy institutions should implement an independent monitor unit or time calculation protocol for each patient.

Session 15: Symposium Conclusions and Recommendations

Some additional discussion points were raised during the round-up session. In particular, concern was expressed on the lack of understanding of the role of the medical physicist, specifically regarding dosimetry for the patient. The symposium recommended that:

87. During the training of administrators, the different roles of professionals working in radiotherapy should be clearly identified.

88. National, regional and international professional societies such as the IOMP should be encouraged to work together to register the profession of medical physicist with the International Labour Organization.
89. Medical physicists should involve themselves in the education and training of clinical practitioners.

Views were also exchanged on the lack of medical physics staff currently available and the need for more staff in the future. Evidence of the lack of staff currently employed, even in developed countries, can be seen in the report commissioned by a United Kingdom government department on the need for nuclear skills (<http://www.dti.gov.uk/energy/nuclear/skills/nsg.shtml>). The symposium recommended that:

90. National, regional and international professional societies should work towards promoting the profession of medical physics to university undergraduates.

Conclusion

In conclusion, the symposium was greatly appreciated by all participants and each felt personally involved with the recommendations. The view was expressed that the time interval since the last symposium had been too long. Recognising the importance of recent changes in the field of medical radiation dosimetry and notwithstanding the heavy organizational burden on any organisation willing to host future such meetings, it was recommended that:

91. A further dosimetry symposium should be held in six years' time (2008).

Discussion

Tony Aalbers –I was very astonished to learn that the calibration service of NPL, for which the uncertainty budget has to be declared on the primary standard. It was reported that NPL promised to give an uncertainty budget about the standard so maybe ...

Simon Duane – I think that statement just referred to (the) calorimeter but the context was in water calorimetry ... our primary standard ...

Tony Aalbers –What have you reported now? Was this the outcome of the Symposium or the meeting in June?

Frank Pernicka – Recommendations were done during the symposium, specifically at the end of the symposium. Actions that resulted from the recommendations were discussed during the action plan meeting in June this year. In the next step, actions will be reviewed by all parties and they will be submitted to the Board of Governors, probably this November. If they are approved then it will make things much easier for us and we believe also for other organisations. Because the Agency is one of the major players in the application of ionizing radiation in health care in many, specially developing, countries, these actions can support various activities in primary laboratories, in secondary standards laboratories, in hospitals etc. These institutions can then refer to the document. So that's (the) philosophy behind it.

Malcolm McEwen – Maybe (I) can just clarify about the actions. We put actions in, not to be taken as exclusive, but as specific examples of what (actions) might be taken. The introductory text for the action plan will say something along the lines that "Other organisations are invited to review this plan and make whatever contributions they feel appropriate ..." So it's just giving some ideas of what (actions) might be taken, and

some of the people at the meeting in June agreed to sign up for certain actions. But they're not exclusive and they're not things that anyone's actually committing to that the IAEA's going to come back in 2008 and say "Why is NPL not ..."

Frank Pernicka – We do not have that power!

David Webb – Frank, I'd like to go back to your comment on the recommendation regarding the CMCs and ... if the SSDLs should submit their CMCs. I guess that those depend upon rules that are set by the Joint Committee of the Regional Metrology Organisations and the BIPM (JCRB). There's a meeting coming up to be held at the BIPM at the end of September for the ionizing radiation CMCs. Is the IAEA going to make a specific representation to that meeting based on that recommendation, because that would be the way to go, I believe.

Frank Pernicka – I believe that we will try to participate, yes. The person responsible for the SSDL network in our Section is my colleague Ahmed Meghziene. He has some ideas how to proceed and we have been discussing it. Until now I haven't heard any specific information about participation in a meeting at the BIPM, but I'm almost sure that Ken is involved in these activities. I don't know anything specific.

David Webb – I think the idea is to discuss (in fact to review) and approve the CMCs, to go forward. I think there's a deadline at the end of the year, but I believe also that there are some problems with the CMCs in so far as the rules have excluded various contributions which may be also referring to some of the calibration capabilities of some of the SSDLs. I know we have a little bit of a problem in Australia because we have an SSDL up in ANSTO, but of course they are traceable back to us, so those issues perhaps need to be discussed at this meeting also ... but the sort of SSDLs that you are referring to are in developing countries I suspect.

Frank Pernicka – I know that we will discuss it because most of these SSDLs are traceable to us. They cannot afford to be traceable to PSDLs, which is the same problem.

Tony Aalbers – I had the impression that the September meeting is not really (directed) to SSDLs or whatever, but just to harmonise some of the problems between the regional metrology organisations at the moment. But it's only the PSDLs at the moment, as far as I know.

David Webb – That's right, but that's why I think that the IAEA perhaps should make a representation to that meeting. Otherwise the issue would be overlooked.

Tony Aalbers – I'm not aware of that, I don't know.