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On-site Visits to Radiotherapy Centres: Medical Physics Procedures

Quality Assurance Team for Radiation Oncology (QUATRO)

IAEA
International Atomic Energy Agency

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FOREWORD

The IAEA has a long standing history of providing support and assistance for radiotherapy dosimetry audits in Member States, for educating and training radiotherapy professionals, and for reviewing the radiotherapy process in a variety of situations. Since 1969, and in collaboration with the World Health Organization (WHO), the IAEA has implemented a dosimetry audit service using mailed thermoluminescent dosimeters (TLD) to verify the calibration of radiotherapy beams in hospitals in Member States. The IAEA/WHO TLD service aims at improving the accuracy and consistency of clinical radiotherapy dosimetry worldwide. Detailed follow-up procedures have been implemented for correcting incorrect beam calibrations. When necessary, on-site visits by IAEA experts in radiotherapy physics are organized to identify and rectify dosimetry problems in hospitals.

The IAEA has also been requested to organize expert missions in response to problems found during the radiation treatment planning process. Assessment of the doses received by affected patients and a medical assessment were undertaken when appropriate.

Although vital for the radiotherapy process, accurate beam dosimetry and treatment planning alone cannot guarantee the successful treatment of a patient. The quality assurance (QA) of the entire radiotherapy process has to be taken into account. Hence, a new approach has been developed and named 'Quality Assurance Team for Radiation Oncology (QUATRO)'.

The principal aim of QUATRO is to review the radiotherapy process, including the organization, infrastructure, clinical and medical physics aspects of the radiotherapy services. It also includes reviewing the hospital's professional competence, with a view to quality improvement. The QUATRO methodology is described in the IAEA publication Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement.

QUATRO, in addition, offers assistance in the resolution of suspected or actual dose misadministrations (over and under-exposures) in radiotherapy. It includes the follow-up of inconsistent results detected with the IAEA/WHO TLD postal service and helps Member States at a very early stage in the problem-solving process, focusing on prevention of incidents or accidents in radiotherapy. The structure and systematic approach of QUATRO combined with its low-key problem-solving mode provide a complement to the operations of the IAEA Response and Assistance Network which deals with nuclear and radiological accidents and emergencies through the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

QUATRO involves audits both *pro-active*, i.e. comprehensive reviews of the radiotherapy practice, and *reactive*, i.e. focused investigations in response to suspected or actual incidents during radiotherapy.

This publication describes the audit technique for medical physics aspects of the operation of radiotherapy hospitals in Member States. The audit methodology was developed by a group of international experts through a series of IAEA consultants meetings conducted 1999–2005. The IAEA officers responsible for these meetings were J. Izewska for standardized procedures for resolving discrepancies in radiotherapy dosimetry and S. Vatnitskiy for the methodology for the auditing of clinical treatment planning. The IAEA officer responsible for this publication is J. Izewska of the Division of Human Health.

EDITORIAL NOTE

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PART I.

GENERAL GUIDELINES FOR RADIOTHERAPY AUDIT

1. INTRODUCTION

1.1. QUALITY ASSURANCE IN RADIOTHERAPY

Significant effort has been put into quality assurance (QA) in radiotherapy. It is generally understood that the aim of QA is to ensure high and continued quality in radiation treatment for all patients, in order to optimise clinical outcomes. The radiation treatment process is complicated and has many stages and many parameters, as well as requiring input from different professional groups. There is potential for error and uncertainty at every point, particularly at the many interfaces between different staff groups, between different stages and between different processes where information and data are passed back and forth. QA is necessary in all areas of radiotherapy and for all processes and procedures and various recommendations exist for comprehensive and consistent QA programmes, or quality systems, in radiotherapy and radiotherapy physics, e.g. [1–4].

This emphasis in QA has in part been to minimise the possibility of accidental exposure (in this report referred to as dose misadministration, to indicate situations where the treatment doses are substantially higher or lower than intended [5–6]). This is particularly important for radiotherapy as it is a potentially high-risk procedure. A significant underdose can cause failure to control the disease and a significant overdose increases the risk of damage to normal tissues. It should be noted that in radiotherapy underdoses are as important for the overall quality of treatment outcome as overdoses whereas, in a radiation protection context, only overdoses are generally considered to be of significance.

1.2. DISCREPANCIES IN RADIATION TREATMENT

Despite the widespread recommendations for QA, circumstances arise where discrepancies have been reported during radiation treatment or where the possibility of discrepancies may be indicated from measurement or observation of part of the radiotherapy process. For example, the IAEA and ICRP [5, 6] have analysed a series of accidental exposures during radiotherapy to draw lessons in methods of prevention of such occurrences. Other evaluations are reported in the literature from the results of *in vivo* dosimetry programmes or from audits of radiotherapy practice. Discrepancies between the delivered and intended treatment have been identified within the context of such QA activities and have therefore been rectified. These have been of various magnitudes below the level of accidental exposure, including ‘near misses’. Their causes have been catalogued to help others review their QA programmes. Examples include Essers and Mijnheer [7] *in vivo* dosimetry), Thwaites et al. [8], (dosimetry audit), Williams et al. [9] (chart review, planning calculations), but many others can be given.

In any wide-ranging analysis of such events a number of general observations can be made:

(a) Errors may occur at any stage and be made by any staff group.
(b) Besides direct causes of errors, there are a number of general contributing factors, including complacency, a lack of knowledge or experience, overconfidence, time pressures, lack of resources, lack of staff, failures in communication, etc.
(c) Most of the direct and contributing causes of discrepancies in radiation treatment are also compounded by the lack of an adequate QA programme or a failure in its application.
(d) Errors in any activity are always possible, including radiotherapy. However a comprehensive, systematic and consistently applied QA programme has the potential to minimise the number of occurrences and also to identify them at the earliest possible opportunity when they do occur, thereby also minimising their consequences in patient treatment.

1.3. QUALITY AUDIT

As part of a comprehensive approach to QA, the independent external audit is widely recognised as an effective method of checking that the quality of activities in an individual institution is suitable for achieving the required objectives. Quality audits can be of a wide range of types and levels, either reviewing the whole process or specific critical parts of it. Quality audits may be *proactive,* i.e. routine review of on-going procedures with the aim of improving the quality and preventing or minimizing the probability of errors and accidents, or they may be *reactive*, i.e., focused on response to a suspected or reported incident. Examples of proactive and reactive quality audits are the IAEA/WHO TLD mailed dose programme [10–11], and on-site review visits of radiotherapy institutions by IAEA experts, respectively. Quality audit testing and review can aid in providing advice on improvement, where appropriate.

1.4. PURPOSE AND STRUCTURE OF THIS PUBLICATION

A comprehensive review of the complete radiation treatment process is discussed in the IAEA 'Comprehensive audits of radiotherapy practices: a tool for quality improvement' [12]. The present technical report provides general as well as detailed guidelines for on-site visits to radiotherapy hospitals by IAEA experts, for the purposes of a quality audit, a specific review of dosimetry or treatment planning, and assessment of radiotherapy incidents. Part I of this publication gives general guidelines for on-site visits, to be read in conjunction with the detailed sets of procedures given in Parts II, III and IV, which correspond to external beam dosimetry visits (photon and electron beams), brachytherapy visits and visits for the review of the external beam treatment planning process, respectively. The procedures in this publication are limited to the medical physics part of the review and cover all steps from the request for review to final reporting and distribution of the lessons learned; however they do not extend to medical (radiation oncology) aspects. The medical aspects are reviewed in the QUATRO guidelines for comprehensive audit [12].

2. IAEA SUPPORT IN REVIEWING THE RADIOTHERAPY PROCESS IN HOSPITALS

The IAEA has a long history of providing support and assistance for dosimetry audit in radiotherapy, for education and support of radiotherapy professionals from developing countries, and for the review of the radiotherapy process in a variety of situations.

2.1. IAEA ACTIVITIES IN THE AUDIT AND REVIEW OF RADIOTHERAPY DOSIMETRY

Since 1969, together with the World Health Organization (WHO), the IAEA has undertaken postal TLD audits to verify the calibration of radiotherapy beams in developing countries. Detailed follow-up procedures for poor TLD results have been implemented since 1996. As part of these procedures, if observed discrepancies cannot be resolved by the local institution or the national experts, then on-site visits are offered by the IAEA to help to identify and rectify the problem. Such visits are made by an IAEA expert in radiotherapy physics and the IAEA has developed a standardized set of procedures to aid the expert during the visit (see [13] and Part II of this publication). Procedures carried out include a review of the dosimetry data and techniques, corrective measurements and ad hoc training. The reasons for the observed discrepancy are then traced, explained, corrected and reported.

2.2. IAEA ACTIVITIES IN THE REVIEW OF RADIOTHERAPY INCIDENTS

The IAEA has also been requested to provide experts for visits following observed problems in, or misadministration arising from, the treatment planning process, e.g. the incident in Panama [14]. In these cases a similar general approach has been taken. The reasons for any identified problems have been traced, explained, corrected and reported. In addition, an assessment of the doses incurred by affected patients and a medical assessment and evaluation of the group of affected patients has been

undertaken where appropriate. These examples of visits have highlighted the need for additional guidelines for the review process and to provide a structure for recommending the type and level of review, and also for additional procedures to aid the IAEA expert(s) carrying out the review visit.

2.3. IAEA ACTIVITIES IN A COMPREHENSIVE AUDIT OF RADIOTHERAPY PRACTICE

The IAEA, through its Technical Cooperation Programme, has received numerous requests from developing countries to perform a comprehensive audit to assess the whole radiotherapy process, i.e. the organization, infrastructure, and clinical and medical physics aspects of radiotherapy services. The objectives of a comprehensive audit are to review and evaluate the quality of all components of the practice of radiation therapy at the institution, including its professional competence, with a view to quality improvement. A multidisciplinary team comprising a radiation oncologist, medical physicist and radiotherapy technologist (RTT) carries out the audits. In response to the requests, the IAEA has prepared guidelines for IAEA audit teams to initiate, perform and report on such audits [12].

3. CLASSIFICATION OF ON-SITE VISITS BY IAEA EXPERTS TO REVIEW THE RADIOTHERAPY PROCESS

The different levels and types of on-site audits or review visits are summarized in Table 1 and described in detail in the following sections.

3.1. LEVELS OF REVIEW VISIT

Three levels of on-site review visits are envisaged:

Level A
A formal on-site visit to review the radiotherapy process of an institution by an IAEA expert team to investigate a reported dose misadministration.

A dose misadministration in this context is a deviation of the delivered dose by more than 25 % [6] from that intended, whether this is an overdose or an underdose. Under some circumstances a lower deviation may also be termed as a dose misadministration since a lower deviation may be considered by a given government to be a misadministration or may have had a serious impact on the patient's health. Examples of Level A review visits have been reported recently [14 – 16]. They were set up and carried out after formal requests by Member States had been submitted to the IAEA in terms of the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. It is to be expected that other similar requests to the IAEA will arise.

Level B
A general assistance on-site review of the radiotherapy process, or part of the radiotherapy process, in an institution by one or more IAEA experts.

The purpose of a Level B visit may be to assess QA systems and procedures, to provide advice and general assistance, or specifically for education and training. This may be in response to suspected or confirmed problems but not necessarily so. It may also be as part of the regular process in the IAEA Technical Cooperation Programme to strengthen QA in radiotherapy.

The situation with Level B visits is similar in approach to those IAEA on-site visits carried out by radiotherapy physics experts as part of the follow-up procedures established to support the mailed TLD dosimetry audit system [13].

Level C
Comprehensive audit of all components of radiotherapy practice at an institution or in a Member State to enhance the quality of the practice.

This level of audit is discussed in another IAEA publication [12] and is not addressed specifically in this report. However, many of the procedures in that report are also applicable here.

3.2. SCOPE OR TYPE OF REVIEW VISIT

On-site review visits may be directly related to certain types of problems in the radiotherapy process in which case the scope of the visit will be related to that part of the process. The main expected areas are:

(a) Problems with the radiotherapy beam or brachytherapy source calibration, or dosimetry parameters used to calculate the beam-on time, or in the performance of radiation treatment machines or related radiation treatment equipment including information systems.
(b) Problems in the treatment planning process, including the transfer of information from the treatment planning stage to the treatment delivery stage.
(c) Problems in medical procedures in the radiotherapy process.
(d) Problems may also occur in the treatment delivery process, but if they are systematic they will typically be linked to medical procedures, equipment, dosimetry, treatment planning or information transfer from treatment planning to treatment delivery and so will be covered by one or other of the above.

In addition, it may be that a request for an on-site visit arises from non-specific suspected or reported problems, which may overlap some or all of these various areas or where it may not be immediately clear which areas are involved.

Depending on the level of the problem involved and the route by which the review visit has been set up, problems in any of these areas may require review visits at either Level A or B (cf. Table 1).

4. COMPOSITION OF THE ON-SITE VISIT TEAM

The composition of the on-site visit team (Quality Assurance Team in Radiation Oncology, QUATRO) will depend on the scope, level and expected content of the review visit.

(a) In all cases, the team must include at least one radiotherapy physics expert who will have expertise matched to the expected scope and content of the visit, e.g. for problems with beam dosimetry an expert in radiotherapy dosimetry measurement and treatment machine quality control is required.

(b) Depending on the situation, the QUATRO team may require two radiotherapy physics experts. For example, for problems with clinical treatment planning, depending on the expected level and content of the visit, one physicist with specific expertise in treatment planning systems may be required and one with specific expertise in dose measurements and quality control on treatment machines. This may allow one physicist to carry out measurements on the treatment units while the other is investigating the treatment planning procedures and the data in the treatment planning system. It also allows a beneficial interaction between two radiotherapy physics experts in more complex investigation situations. Where possible, it would be useful for the radiotherapy physics expert with expertise in treatment planning systems to have previous knowledge of the same type of treatment planning system in use in the institutions to be visited.

(c) A radiation oncologist is essential in misadministration situations (Level A) as the medical consequences of patient doses need to be assessed independently and a medical evaluation of the affected patients is necessary. The expert team should also include a radiation oncologist when the magnitude of the expected discrepancy (Level B visits) could lead to a serious impact on patients.

(d) For audits to resolve problems identified by the mailed TLD system, depending on the outcome of the physicist's review, a radiation oncologist may be necessary to assess changes in the outcome of patient treatment or in dose prescription. The visit by the radiation oncologist may take place at a later date.

TABLE 1. SUMMARY OF ON-SITE VISITS

	Formal Level A			General assistance visit Level B				Comprehensive review Level C
Scope or type	Suspected or confirmed problem in beam (or source) calibration or performance of equipment	Suspected or confirmed problem in treatment planning process	Suspected or confirmed problem in medical procedures	Suspected or confirmed problem in beam (or source) calibration or performance of equipment	Suspected or confirmed problem in treatment planning process	Suspected or confirmed problem in medical procedures	Audit of medical physics procedures No pre-identified problems	Comprehensive audit of radiotherapy practice No pre-identified problems
Purpose	To investigate a notified misadministration			To assess QA systems and procedures, to provide advice or assistance, to provide education and training				To assess the quality of all components of radiotherapy practice
Composition of QUATRO team	1–2 medical physics experts, radiation oncologist, radiation protection physicist	1–2 medical physics experts, radiation oncologist, radiation protection physicist, other professionals as needed	1–2 medical physics experts, radiation oncologist, radiation protection physicist	1-2 medical physics experts, radiation oncologist, if needed to assess impact on patients	1–2 medical physics experts, radiation oncologist, if needed to assess impact on patients, other professionals as required	1–2 medical physics experts, radiation oncologist	1–2 medical physics experts	Radiation oncologist medical physics expert dosimetrist, radiation therapy technologist or engineer
Routes of request	Member State government			Institution or other bodies Results of expert missions TLD audits	Institution or other bodies Results of expert missions		Institution or other bodies As part of TC programme	From the oncology department From institution administration From national Ministry of Health
Guidance for experts	Parts I, II and III of this publication	Parts I and IV of this publication	Part I Detailed guidelines not available	Parts I, II and III of this publication	Parts I and IV of this publication	Part I Detailed guidelines not available	Parts I–IV of this publication	IAEA publication [12]*

*See Ref. [12].

(e) In addition, for treatment planning review visits, the mission team may include other experts representing some of the other professions involved in the treatment planning process. Depending on the circumstances surrounding the need for the visit the following persons may be needed:

  (i) A dosimetrist, depending on the nature of the problem;

  (ii) A radiotherapy technologist (RTT, therapy radiographer, radiation therapist), if it is felt necessary to investigate operational procedures on the simulator or CT scanner, or procedures involved directly in treatment delivery at the treatment unit;

  (iii) A radiation oncologist, if there is a need to assess clinical aspects of the treatment planning processes, such as prescription, volume outlining, etc.

(f) If the visit is organised through regulatory structures in the Member State and between the Member State and the IAEA (Level A), then it is necessary to include a radiation protection physicist in the team. However, in the event of general assistance visits (Level B) this should normally not be needed.

(g) In specific circumstances, it may be useful to include at least one radiotherapy physics expert from the IAEA staff. This has been shown to be valuable in previous visits investigating dose misadministrations or radiotherapy accidents [14–16].

5. ROUTES OF REQUEST TO THE IAEA FOR AN ON-SITE VISIT

Formal visits (Level A) must be formally requested by the Member State government via the appropriate channels by invoking the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency.

On-site Level A visits may arise from any of the above Level B visits, depending on the circumstances.

The general assistance visits (Level B) could be requested directly by the institution, a national professional group, a government body or other relevant organization.

On-site visits for investigation of discrepancies in dosimetry, treatment planning, problems with equipment or medical procedures, may be indicated from the results of any other type of on-site visit. Experts on general assistance missions may recommend a more focused investigation or review related to a specific problem that may need to be resolved in an institution.

Organizing on-site visits for resolving discrepancies in beam calibration, indicated by observed discrepancies in the mailed TLD audit results of an institution, will be suggested to the institution by the IAEA following the procedures already in place to support the mailed TLD programme.

Other on-site Level B visits may be part of the regular IAEA Technical Cooperation Programme aimed at strengthening QA in radiotherapy.

The requests for Level C audits are described in detail in the QUATRO guidelines for comprehensive audit [12].

6. PROCEDURES TO BE FOLLOWED BY IAEA EXPERTS DURING ON-SITE REVIEW VISITS

For on-site visits investigating problems with dosimetry practice, the appropriate procedures to be followed are those described in Part II (external beam therapy) or Part III (brachytherapy) of this publication. For on-site visits dealing with clinical treatment planning, the appropriate procedures to be followed are those described in Part IV.

This publication does not address on-site visits focusing on problems in medical procedures. The general procedures for review of radiation oncology practice are partially available in the QUATRO guidelines [12].

7. PREPARATION FOR, CARRYING OUT AND REPORTING ON-SITE REVIEW VISITS

7.1. THE PREPARATION FOR A VISIT

Careful structured preparation for the visit by the IAEA and by the expert(s) is required. This includes sending questionnaires to the institution, to be returned before the visit, sending other appropriate information beforehand to allow the institution to prepare for the visit and having the expert(s) review any information available about the institution. The various forms given in the appendices I–IV are intended to help experts in data collection and later in the reporting of the results of the visit.

The IAEA is in charge of the organization of the visit including the contacts with the expert(s) and the institution to be visited. The IAEA arranges for the on-site visit to the institution and for recruiting the expert(s), referring clearly to the request from the institution itself, from other requesting bodies or from any other indication, when the visit is a consequence of an assumed or proven radiotherapy misadministration. Upon confirmation from the institution, the IAEA contacts the expert(s) and provides him/her with a set of the data on the institution's radiotherapy and dosimetry equipment, and staff available (based on the IAEA directory of radiotherapy centres, DIRAC Appendices I.1–I.2, [17]). These data are confidential and cannot be distributed other than to the authorised individuals, i.e. the IAEA staff involved, the experts and the relevant WHO staff, when the mission results from discrepancies in the IAEA/WHO TLD audits. At this stage the arrangements are made for the practical aspects of the visit, including a request for the local staff to assist the expert. In addition, staff interview data collection forms (Appendices II.2, IV.5 and [12]) are made available to the expert prior to the on-site visit.

If information is missing regarding the detailed circumstances relating to the request for an on-site visit, the IAEA will request any additional necessary information from the institution. The IAEA will arrange to send questionnaires to the relevant staff members involved in the radiation therapy process at the institution. These questionnaires will need to be completed and returned to the IAEA promptly. The IAEA will forward the completed questionnaires to the expert(s) prior to the visit. By completing the questionnaires, some weaknesses in dosimetry, brachytherapy and treatment planning processes related to education, documentation and communication might be identified before the visit. Any ambiguity in the answers can be resolved, or additional information obtained, during the visit.

7.2. CONTENT AND STRUCTURE OF THE ON-SITE REVIEW VISIT

The aim of on-site review visits in the case of suspected or reported problems in the radiotherapy process, is primarily to verify that a problem exists or existed in the past. If a problem is confirmed, then the review must determine the time frame over which the problem existed, the magnitude of the problem, and all factors which contributed. The review should also help to provide solutions to avoid the same problems in the future.

It should be emphasized that the aim of the review is to carry out a fact-finding process intended to improve the quality of radiotherapy and retain as much confidentiality as possible. The data collected by QUATRO may include the fact that there is/was a deviation between the dose received by a patient or a group of patients versus that intended. These data may be involved in regulatory or legal processes but the team members may not give opinions, with respect to regulatory or legal actions, on the culpability of any of the staff member implicated in the propagation of the discrepancy.

Parts II to IV give procedures that the expert(s) can use as a guide in reviewing processes and procedures and obtaining data. These guidelines have been designed to enable the efficient resolution of any problems, including identification of possible contributing factors. However, the expert(s) must

be flexible in their approach and be prepared to modify the procedures to meet the specific circumstances at the time of the visit. The expert(s) must keep in mind that although there may be one primary failure there are usually other contributing factors. As many of these contributing factors as possible should be identified.

The detailed content of a review visit will depend on the circumstances giving rise to the visit and will follow the procedural frameworks in Parts II to IV of this publication. However, the general methods used in any such review visit will include:

(a) An entrance briefing to introduce the members of QUATRO and to inform the institution's various staff members of the objectives and the details of the audit.

(b) Assessing the infrastructure of the institution.

(c) Interviewing local staff. If a team of experts is involved then interview duties should be distributed by the appropriate QUATRO expert.

(d) Reviewing and evaluating operational and QA procedures and processes, including documentation, data and records. Attention should also be paid to any information or records on the education and training of the staff on the relevant procedures of the radiotherapy process, including the adequacy of the training done before implementing the use of new methods or equipment.

(e) Carrying out measurements and other practical tests of the performance of local systems and procedures, where appropriate and relevant.

(f) Investigating causes of observed problems and contributing factors.

(g) Reporting back to the local staff in an interactive exit briefing while maintaining as much confidentiality as possible. The briefing should present and explain the results and findings of the review, pointing out the causes of problems and contributing factors that were identified in the treatment and QA processes and procedures. When appropriate, the expert will emphasize that problems in radiotherapy are typically the result of the failure of multiple components in the QA system.

(h) Providing recommendations to correct the identified problems and avoid them in the future, and recommendations that could lead to improvement in the total treatment and quality assurance programme. Besides practical steps, this should always emphasise education, training and communication issues.

7.2.1. Interview with the institution's staff

The first step in the review process is to perform a series of interviews with the institution's staff. The purpose of these interviews is to assess the infrastructure of the department (equipment, staff, resources, training, etc.) and to determine the role of each staff member in the patient management and treatment process. The interviews should also be used to assess the level and quality of communication, with particular attention to the possibility that poor communication may contribute to any identified problems. Interviews are normally done individually with one or more IAEA expert(s) in attendance. Documentation of the interview must be completed by the IAEA expert(s). The staff to be interviewed will include:

(a) Medical radiation physicist(s) (radiotherapy physicist, medical physicist);
(b) Radiation oncologist(s);
(c) Representative from the administration (responsible for staffing, equipment purchases, etc.);
(d) Dosimetrist(s) when needed (in many systems there is no separate group of dosimetrists and these functions are carried out by medical physicists, medical physics assistants or technologists, radiation dosimetry technicians or therapy radiographers);
(e) Radiotherapy technologist(s) when needed (in some systems they are referred to as radiation therapists, therapy technologists, radiographers, radiation therapy technologists or radiotherapy nurses).

7.2.2. Assessment

7.2.2.1. Review of institution's quality assurance programme

The second main step is to review the QA programme of the institution. Based on the information gained in the interviews, the IAEA expert(s) will review written information on the quality control (QC) procedures and measurements. Original data are to be consulted whenever possible.

The goal of the review is twofold, firstly to gain a general impression of the QA programme at the institution and secondly to focus on those issues that are most likely to bear on reported or suspected problems. This review will typically include the following:

(a) The overall radiotherapy QA programme, focusing on those aspects that might be relevant to any actual or potential problems.

(b) The commissioning of QC data for imaging equipment, teletherapy machines and brachytherapy system(s). This should include a review of the original measurements obtained during commissioning, the source data for brachytherapy, and data selected to be the reference data set for periodic quality control measurements or calculations.

(c) The patient-specific QC checks, including independent verification of monitor units or treatment time, periodic checks of treatment records, *in vivo* dosimetry records, if available, and the treatment summary at the completion of the treatment.

(d) The reviews and calculations that the institution has performed to identify and resolve the reported problems.

(e) Current patient treatment records, to become acquainted with the institution's treatment techniques and dose calculation procedures.

7.2.2.2. Measurements

Any visit involving dosimetry and medical radiation physics investigations will require a series of measurements to be taken by the medical physics experts. Depending on the nature of the problem, the measurements will focus on various parts of the radiotherapy process. The relevant measurement procedures are addressed in Parts II–IV of this publication.

For comprehensive on-site audits of radiotherapy procedures, physics measurements constitute an integral part of the peer-review and the relevant procedures are described in the QUATRO guidelines for comprehensive reviews [12].

7.2.2.3. Review of patients' records

If the on-site visit is the result of a reported incident related to a dose misadministration to radiotherapy patients, appropriate records of all 'involved' or affected patients should be studied. Simulator, computer tomography (CT) and portal images, computerized treatment plans and daily treatment records should be reviewed. The expert(s) will usually determine on a case-by-case basis whether this review is to be carried out at the same time as the QA programme review discussed above, or immediately thereafter. Serious effort should be taken to identify all patients whose treatment was adversely affected by any reported or identified incident, and the actual dose received by these patients must be determined where possible. Each member of the expert team will focus on those areas of their specific expertise. The radiation oncologist in the expert team will arrange for a medical review of all affected patients. The institution will be advised of the necessity to inform affected patients (or their families). The local physicians will be given advice and support on how to manage the care of the affected patients.

For dosimetry errors exceeding 5% but not large enough to have obvious visible effects on the patient (such as those occurring from serious overexposures), the effects on the patient may be subtle. If the effects have persisted over a long time, the radiation oncologist may have adjusted prescriptions to compensate clinically (in principle, by increasing or decreasing the prescription). In these situations, the radiation oncologist expert must assess whether the institution has compensated clinically and advise the local physician on how to modify the prescription when the dosimetry error is corrected. If

there was no radiation oncologist on the audit team, the institution should be advised not to change the radiation's conditions until the effect on the patient prescription has been assessed. The IAEA may need to send a radiation oncologist to assist in this assessment.

7.2.3. Exit interview

At the end of the review process, the expert(s) must present the results of the on-site review to the institution's radiotherapy physicist(s) and others deemed appropriate by the expert(s), in the form of an exit interview, while maintaining as much confidentiality as possible. It is usually desirable for the local radiation oncologist and an appropriate administrator also to be present at this exit interview. The exit interview should cover the following points:

(a) The results of calculations, measurements, discrepancies identified and methods recommended to resolve them.

(b) The components of the total radiation therapy process that have been identified as failing in some fashion. The expert(s) should not focus only on the primary causes but also on all subsequent issues that may be expected to impact on patient treatment. The expert(s) will emphasize that accidents typically happen as the result of the failure of multiple components of the QA system.

(c) Discussion of what education or training might be helpful to stimulate improvement in all the components that failed. The whole review process will include an education and communication component.

(d) A list of recommendations that will help to correct and avoid any identified problem in the future, and recommendations that could lead to the improvement of the entire QA programme.

It is of the utmost importance that the radiotherapy personnel are able to understand the consequences of the observed discrepancies, how they affect patient treatment, and how the implementation of the expert's recommendations will impact on future treatments. The institution should be advised to verify all given recommendations through their own measurement or calculation, before implementing recommendations in the clinical practice. Ultimately, the responsibility for operation of the centre must rest with the local staff, not the IAEA experts.

The expert(s) will discuss with the radiation oncologist any changes recommended in the beam calibration, treatment planning, treatment machine operation, and patient treatment procedures as they may have an impact on the outcome of future patients' treatment. If appropriate, the expert(s) will discuss the ways that the institution reports the detected failures so that a similar problem will not occur at other institutions. Also, if appropriate, the expert(s) will discuss with the institution's staff ways to involve the manufacturer(s) in the identification and evaluation of any observed failure in their radiotherapy equipment.

7.2.4. Training

The various types or levels of on-site reviews will all have as one of their significant objectives the identification of the weaknesses in the radiotherapy QA processes, and methods to improve the quality of treatment and care for all subsequent radiotherapy patients at the institution. An important aspect of this is to provide training of the local staff. The training should emphasize quality assurance procedures to help individuals utilize their experience to notice and report any unusual circumstances. This is intended to improve the capability of the staff to identify errors before they impact on the patient's treatment. This educational process should be continuous, starting with the contacts before the expert's visit, through all the interviews, calculations, measurements and other actions during the visit, at the exit interview and ultimately in the final written report. These processes, the clinical dosimetry measurements and tests, as outlined in Parts II–IV, all have an important educational value for the institution's physicists and other staff involved in the daily treatment of patients.

7.3. CONFIDENTIALITY

All information related to an on-site review visit organised by the IAEA is confidential and may not be distributed to any individuals other than the IAEA staff involved, the appointed IAEA experts, relevant WHO staff (where appropriate), and the staff involved at the institution.

The institution will be advised to report misadministrations and other incidents of significant importance regarding the safety of the patients, to the relevant regulatory authority. It should be made clear that reporting these misadministrations and incidents is the responsibility of the institution and not the IAEA experts.

If relevant, experts will discuss ways by which the institution can report any identified problems so that other institutions can benefit from the experience and ensure that the same problem does not occur elsewhere. If the problem relates to equipment of any sort, the institution should attempt to involve the manufacturer to ensure rapid notification of potential problems to other users. In particular, the manufacturer should assess methods of improving the equipment, the instructions or whatever other aspect may have been identified as a cause of the dose misadministration or as a contributing factor. If the problem relates to a human error, consideration will be given to whether reporting this error serves any educational value. Any reports regarding human error are anonymous and have to be treated confidentially.

7.4. REPORTING

Typically the report resulting from an on-site review visit consists of two parts, a detailed report and its summary. The detailed report to the institution includes results of all the measurements, calculations and investigations. It contains explanations of all the expert(s) actions, recommendations, etc. The summary report, required for submission to the relevant national authority or other Member State government department, summarises the visit, its main findings and recommendations.

At the end of the visit, the expert(s) will present a preliminary report to the local physicist, the head of the radiotherapy department and, if appropriate, to the director of the hospital. The preliminary report will consist of the findings of the investigations undertaken during the visit. The report forms are included in the Appendices II–IV. Any records left at the institution will be clearly marked ‘Preliminary’.

In addition to the preliminary report, the expert will leave a signed and dated copy of the measurements, calculations, report of results and a copy of the TRS 398 dosimetry code of practice [18], if not available at the institution, for the local physicist. These data and information will provide the institution’s physicist with a set of independently measured reference data that can be used later to compare his/her own measurements for possible future dosimetry changes.

Following the completion of the on-site review visit, the experts will prepare an end-of-mission report to be sent to the IAEA. This end-of-mission report will contain the following data and information for further quality control and processing:

(a) The full on-site review visit’s report and its summary;
(b) Records of the tests and measurements undertaken by the expert;
(c) Results of any measurements;
(d) Results of benchmark cases and clinical dosimetry;
(e) Analysis of the results of the measurements;
(f) The expert’s explanation of the reason for the discrepancy;
(g) The impact of the discrepancy on patient treatments;
(h) Recommendations to the institution and the government;
(i) Recommendations to the IAEA.

PART II.

ON-SITE DOSIMETRY VISITS TO RADIOTHERAPY HOSPITALS

8. BACKGROUND FOR DOSIMETRY ON-SITE VISITS

Since 1969 the IAEA/WHO postal TLD audit service has verified the calibration of more than 6000 clinical photon beams at some 1500 radiotherapy hospitals. When the TLD result of a participating institution falls outside the acceptance limit of 5%, the institution is informed that there is a discrepancy and requested to try to identify the reasons why it occurred. The institution is then offered a second, follow-up TLD audit. If the deviation cannot be resolved by the local radiotherapy institution or the national SSDL, then an on-site visit is offered which, if accepted, will be made by an IAEA expert in clinical dosimetry. The on-site visit includes a review of the dosimetry data and techniques, corrective measurements and ad hoc training. The reasons for the discrepancy will then be traced, explained, corrected and reported. Until the discrepancies are resolved and changes have been implemented by the hospital to ensure that the discrepancies do not recur, the safe and effective delivery of radiation doses to patients may not be assured.

This part provides a standardized set of procedures for resolving discrepancies in dosimetry during on-site visits to radiotherapy hospitals by IAEA experts. The table below summarises the acceptance criteria to be applied by the IAEA experts for dosimetry and mechanical parameters of the hospital treatment units. If some of the parameters are outside the acceptance criteria, it will not be possible for an institution to ensure adequate quality of the dosimetry practices in radiotherapy. The criteria are based on analyses of clinical data and the measurement uncertainties for various dosimetry and mechanical parameters.

TABLE 2. PARAMETERS AND ACCEPTANCE CRITERIA FOR ON-SITE VISITS

Parameter	Criterion
Beam calibration	3%
Relative measurements (e.g. tray, wedge factors, %DD)	2%
Electron beam depth dose	3 mm
Brachytherapy source strength calibration	5%
Brachytherapy dose calculation	15%
Mechanical parameters	3 mm/2°

9. PREPARATION FOR A VISIT

The IAEA organizes the on-site visit following the procedures described in Part I of this publication. This publication and QUATRO guidelines for comprehensive audits [12] are made available to the expert prior to the visit.

The expert will be equipped with a standard instrumentation kit, which contains the following equipment:

(a) Electrometer;
(b) Two Farmer-type chambers and one plane-parallel ionization chamber along with calibration certificates;
(c) Triaxial cable;
(d) Digital barometer, thermometer (preferably 2 thermometers);
(e) Water phantom;
(f) Spirit level;
(g) Ruler;

(h) Calliper;
(i) Multimeter;
(j) Simple tools (screwdrivers), adaptor plug;
(k) Scotch tape;
(l) Seven verification films (pre-packed);
(m) Survey meter;
(n) Graph paper (millimetre scale);
(o) Spare batteries;
(p) Telescopic distance indicator for distance and isocentric checks;
(q) Stopwatch;
(r) Two TLD sets and a TLD holder along with the instruction and data sheets;
(s) If electrons are to be measured: a water phantom with provision for holding cylindrical and plane-parallel chambers and for varying the chamber position flexibly.

The dosimetry equipment is calibrated at the Dosimetry Laboratory of the IAEA and its calibration coefficients are traceable to BIPM. The Dosimetry Laboratory of the IAEA provides the quality assurance and maintenance of the expert's equipment. It is the expert's responsibility to complement this equipment with additional items which may be needed during the visit, such as a laptop and other items as appropriate.

In addition, the expert kit will contain copies of this publication, the QUATRO guidelines for comprehensive audit [12], TRS 398 [18], a CD-ROM with the dose calculation software and supporting data, and other documentation.

10. INTERVIEW OF THE INSTITUTION'S STAFF

It is essential that the expert interviews the appropriate staff from the local institution before any measurements are taken, using the interview data collection forms from Appendix II.2. The purpose of this interview is to understand the dosimetry practices of the institution, collect missing data, to compare the institution's dosimetry data with the standard data provided for the expert [19–21] and to gather details about the circumstances regarding the reported discrepancy or dose misadministration.

The expert will also review the patient treatment charts in order to understand the different radiotherapy techniques used in the institution. He/she will become familiar with the typical field sizes used for different treatments including the use of accessories such as blocks and wedges. This review is needed to ascertain that the necessary dosimetry data are available and that the test dose calculations done with the expert's assistance correspond to the typical treatments actually performed at the institution.

11. SAFETY AND MECHANICAL TESTS

11.1. SAFETY TESTS

Before conducting any tests on the treatment unit, the expert should conduct, as a minimum, the following safety tests to ensure the safety of working conditions:

(a) Door interlocking operation;
(b) Radiation light warning operation;
(c) Emergency on/off switches operation;
(d) Manual means to close the machine down;
(e) Exposure rate within the room when the treatment unit is in 'beam off' condition.

The expert must wear a personal radiation monitoring device and, if available, have a radiation survey meter with an active alarm option nearby.

11.2. MECHANICAL TESTS

The mechanical tests are designed to evaluate the geometrical accuracy and functionality of the treatment unit prior to the determination of the machine output under reference conditions. The confirmation of the geometrical integrity of the treatment unit is necessary to ensure proper set-up conditions for the calibration of the unit as well as the positioning of patients for daily treatments. To meet the IAEA acceptance criteria for the mechanical tests, the parameters measured or calculated by the expert and those used by the institution must agree within ±3 mm (2° for angle indicators). Any differences between the expert's measurements and the institution's values may provide the expert with additional information in determining the reason for the 2° discrepancy in the beam output measured with the TLDs or the reported dose misadministration. The minimum list and order of the mechanical tests to be performed by the expert is given below:

(a) **Collimator Axis of Rotation**. The mechanical axis of rotation of the collimator will be determined using the telescopic distance indicator or the institution's mechanical distance indicator if available.

(b) **Collimator Angle Indicator.** The collimator angle indicator will be evaluated at 90° intervals.

(c) **Gantry Axis of Rotation.** The mechanical axis of rotation of the gantry will be determined using the telescopic distance indicator (or the institution's mechanical distance indicator if available). This is accomplished by varying the gantry angles and placing the distance indicator as close as possible to the axis of rotation for each gantry angle, attempting to converge on the axis of rotation. A reference pointer will be used to follow the axis of rotation at each gantry angle. A distance from a fixed point on the treatment head (e.g. the bottom surface of the tray holder) to its centre will be measured and recorded.

(d) **Gantry Angle Indicator.** The gantry angle indicator will be evaluated at 90° intervals using a spirit level.

(e) **Field Size Indicator.** The field size indicator will be compared to the light field at the nominal treatment distance for three field sizes (5 cm × 5 cm, 10 cm × 10 cm, 20 cm × 20 cm) using the millimetre graph paper.

(f) **Light/Radiation Field Coincidence.** The light field and radiation field coincidence will be evaluated using film for a 10 cm × 10 cm field at the nominal treatment distance.

(g) **Lasers**. The congruence of the lateral lasers and the isocentre horizontal plane, 20 cm on either side of the isocentre, at the nominal treatment distance will be measured.

(h) **Optical Distance Indicator** (if available). The congruence of the optical distance indicator (ODI) and the mechanical isocentre will be measured. In addition, the ODI at –10 cm and +10 cm from the mechanical isocentre will also be measured. If the ODI is not available then the institution's mechanism for determining the source to skin distance will be verified by the expert.

(i) **Travel of Treatment Couch.** The congruence of the table indicators for vertical, lateral and longitudinal displacement with the measured displacement from isocentre, i.e. –10 cm and +10 cm, will be measured.

Once the above measurements have been taken and the comparisons made, the expert will discuss the findings with the institution's responsible physicist/personnel to correct any parameter found to be outside the acceptance criteria. The expert is encouraged to assist the institution staff in performing any additional mechanical tests needed to assess and correct any deviations found. Any parameter found outside the acceptance criteria may require the institution to alter its clinical treatments to account for the corrective actions taken by the institution's physicist or personnel. Once the expert confirms that the geometrical and functional integrity of the treatment unit is acceptable, he/she should proceed to make the dosimetry measurements outlined in the next section. If the integrity of the

treatment unit is not acceptable, the expert may wish to consider extending the visit to allow the personnel at the institution time to repair the treatment unit before making the dosimetry measurements. If the unit cannot be repaired, the expert is still encouraged to take as many measurements and collect as much data as possible to resolve the dosimetry problems.

12. DOSIMETRY EQUIPMENT COMPARISON

Before performing the beam output calibration, it is necessary for the expert to make the following comparisons:

(a) Comparison of the institution's and the expert's dosimetry systems;
(b) Comparison of the institution's and the expert's barometer and thermometer readings.

The aim of these comparisons is to verify the constancy of the local dosimetry system response, with reference to the calibration certificate and to identify possible systematic differences between the institution's and expert's beam output calibration.

If the standard local procedures involve the control measurements in a ^{90}Sr check source, these measurements must be taken prior to any other quality control tests and measurements. If the measured value is within 1% of the expected value, the result is considered acceptable. In the case of a larger deviation which cannot be explained, the local dosimetry system must be carefully checked for chamber leakage, loose cable connections, humidity influence, electrometer instability, etc.

The standard method for comparison of the institution's ionization chamber and electrometer with the expert's dosimetry system is to position both chambers in a water phantom, preferably in a box phantom, and compare their readings in a ^{60}Co beam. If the institution has an ionization chamber that will not fit in the box phantom, then it may be necessary to undertake the comparison in air, with both chambers having the appropriate build-up material (build-up caps). If no cobalt unit is available at the institution, the comparison will be undertaken on the accelerator with the lowest megavoltage photon beam energy available.

The two readings will be converted to the same physical quantity, i.e. air kerma or absorbed dose to water depending on the institution's dosimetry practice and compared, with an acceptance level of 2%. If the difference observed can account for the discrepancy that occurred in the TLD audit, it is necessary for the institution to request recalibration of their dosimetry system at the local SSDL, if there is one, or at the IAEA Dosimetry Laboratory.

For electron beams, the institution's ionization chamber and the expert's plane parallel chamber will be compared in the highest electron beam energy available, $R_{50} > 7$ g/cm^2 ($\bar{E}_0 > 16$ MeV) is recommended according to TRS 398 [18]. If any questions arise, the comparison will be made with both a cylindrical and a plane-parallel chamber.

The differences between the local and the expert's barometer and thermometer readings should be within 1.0% and 0.5°C, respectively.

13. DOSIMETRY CALIBRATIONS AND MEASUREMENTS

13.1. BEAM OUTPUT CALIBRATION

The local medical physicist will, under the scrutiny of the expert, calibrate the beam output according to the local institution's standard procedure. This procedure may include calibration in air, or in a water or plastic phantom at the reference depth (e.g. 5 cm or 10 cm) or at the depth of dose maximum, d_{max},. The expert will follow the whole procedure carefully, step by step and try to understand the local procedure completely. However, when an error is noticed, no remark should be made to the local physicists until he/she has completed the calibration procedure. The reason for this is that the expert

may better identify possible reasons for the TLD discrepancy that pertain to the local calibration procedure or set-up.

The expert will calibrate the beam output according to IAEA TRS 398 code of practice [18] and compare the measured output with the institution's specification. The calibration may be done using either:

(a) The water phantom from the expert's kit, or
(b) The water phantom used by the local institution.

In either case the measurements will be taken at the reference depth for a 10 cm × 10 cm field size at the nominal treatment distance, SSD or SAD, whichever method is used at the institution.

The shutter correction for cobalt units will be measured. In addition, the time indicated by the timer of the ^{60}Co unit and the time indicated by the stopwatch will be compared. The linearity of the treatment unit's timer will also be verified within the minimum and maximum treatment times used at the institution.

In the case of a linear accelerator, the monitor end effect will be measured, especially for older accelerator models. The ion recombination correction and polarity effect for the ionization chamber will be determined. The quality index for high-energy X ray beams will be measured according to TRS 398 [18] prior to the beam output calibration.

The electron beam calibration will be performed using the institution's standard cone (typically 10 cm × 10 cm or 15 cm × 15 cm) and a plane-parallel chamber at the reference depth, $z_{ref,}$ in the expert's water phantom with the variable depth device. The beam quality index, R_{50}, can be determined from the following process:

(a) Determine z_{max} by making measurements near the expected z_{max} (short exposures of 50 MU, estimated from institution's depth dose data or the electron standard data [19 – 21]);
(b) Determine $R_{50,ion}$ by interpolation between measurements at depths above and below the expected $R_{50,ion}$.

The Excel spreadsheet prepared by the IAEA for TRS 398 (and sent to the expert before the mission) is used by the expert for the calculation of the absorbed dose rate to water under the reference conditions.

A comparison of the beam output determined by the institution's physicist and by the IAEA expert will be made to identify any possible reasons for the discrepancy. If the local beam was not calibrated according to the TRS 398 code of practice, the expert must convert the local beam output value to that consistent with TRS 398 for reporting purposes. The difference between the two beam output measurements will be analysed carefully and discussed with the local physicists and other relevant staff.

As a quality control check of his/her beam output determination the expert will irradiate a set of TLDs provided by the IAEA and will demonstrate to the institution's staff the IAEA's standard TLD audit methodology.

13.2. ADDITIONAL MEASUREMENTS

The expert is encouraged to take a number of additional measurements designed to verify that the institution's use of basic clinical dosimetry data is appropriate. The extent of these additional measurements will depend on the mission time available to the expert. If a large water phantom is not available at the institution, the expert may consider making the appropriate adjustments to his/her water phantom to allow for measurements at a depth of 10 cm.

These additional measurements are suggested in order to provide a more complete assessment of the institution's clinical dosimetry practices (the standard data set may be used as a reference [19 – 21]).

For high energy photon beams:

(a) Verify the dose variation with field size and depth;
(b) Verify the institution's clinical wedge and tray transmission factors (if time does not allow for measurement of all wedges the expert will, as a minimum, verify the two wedges with the largest wedge angles used clinically);
(c) Verify the beam output for non-standard SSDs used clinically;
(d) Verify the dose at off-axis points for a wedged beam, where appropriate.

For electrons, the additional measurements will include:

(a) For the most commonly used cone/field size (and the largest cone/field size)
  (i) cone/field size ratios;
  (ii) output at an extended treatment distance (gap of 10 cm);
(b) Electron depth dose at z_{90} and z_{50};
(c) Any other measurements relevant to the discrepancies found.

If the differences between the expert's measured and the locally used clinical values exceed the criteria (3% for the beam output determination and 2% for the relative measurements), a detailed analysis and possibly additional measurements will be carried out in order to attempt to explain the differences.

14. CLINICAL DOSIMETRY

At this stage the expert will have confirmed the institution's basic dosimetry data and will have knowledge of the clinical techniques routinely used at the institution. His/her efforts will therefore focus on the clinical dosimetry data relevant to treatment planning.

14.1. BASIC DOSIMETRY DATA

The expert will review the beam data tables available (output factors, depth dose data, wedge and tray factors, off-axis factors, etc.), determine if the data are measured or based on published data, and obtain copies of appropriate data, if possible, to enable an independent review of the report by the IAEA staff.

The expert will confirm the validity of the basic beam dosimetry data used by the institution by comparison with standard data [19 – 21]. The expert will ascertain how the basic dosimetry data set is used by the treatment planning system (TPS) or the in-house software.

14.2. MONITOR UNITS / TIME SET CALCULATION

The expert will evaluate the institution's method used routinely to calculate the number of monitor units or time set for patient treatments. For this, the local physicist will be requested to determine monitor units or time set for the clinical dosimetry tests as described below. The expert will calculate the monitor units/time set for the same clinical dosimetry tests independently, using the output value that he/she has measured and the standard data supplied [19 – 21]. The expert's results will be compared with those determined by the institution. The detailed analysis of the differences in calculation, if any, must be undertaken.

For photon beams, the clinical dosimetry tests will be done for a water phantom irradiated with a single field. The institution will calculate monitor units or time set to deliver 2 Gy for the beam geometries as follows:

(a) Field size 10 cm × 10 cm, depth 5 cm, with and without the most commonly used wedge;
(b) Field size 10 cm × 10 cm, depth 10 cm;
(c) Field size 7 cm × 15 cm, depth 5 cm, with and without the most commonly used wedge;
(d) Field size 7 cm × 15 cm, depth 10 cm.

If blocks are used at the institution, the expert and the local physicist will calculate monitor units or time set for a typical blocked field used at the institution.

For electron beams the clinical dosimetry tests will be done for a water phantom treated with a single field. The institution will calculate monitor units to deliver 2 Gy for the beam geometries as follows:

(a) Standard cone/field size (10 cm × 10 cm or 15 cm × 15 cm) at z_{90};
(b) Largest cone/field size available at z_{90}.

The ion chamber measurements of the basic electron and photon dosimetry parameters as described in section 13.2 will be used to verify the clinical dosimetry tests and calculations as outlined above. This procedure will be discussed with the institution's physicist.

14.3. CHECK OF TREATMENT PLANNING SYSTEM

Resolution of any dosimetry discrepancies may require the expert to verify that the treatment planning system uses the basic dosimetry data appropriately. The expert will, as a minimum, perform a set of tests to verify the following parameters of the treatment planning system (TPS):

(a) Confirm that the field sizes on TPS printouts agree to within 2 mm with the input field sizes;
(b) Confirm that TPS depth dose data agree with measured data within 2%;
(c) Confirm the wedge isodose distributions agree with measured data within 2%.

PART III.

BRACHYTHERAPY ON-SITE VISITS

15. QUALITY ASSURANCE IN BRACHYTHERAPY

As with external beam radiotherapy, the objectives of brachytherapy are to ensure an accurate and safe dose delivery to a target volume while avoiding unnecessary dosage to surrounding healthy tissue. However, with external beam radiotherapy a larger volume of healthy tissue receives quite a significant dose compared to brachytherapy, where the healthy tissue located at a distance from the source receives very low doses. Brachytherapy is usually performed with remote afterloading equipment, for the safe transfer of sealed sources to and from the patient and for the protection of staff, although there are occasions when manual afterloading is used. Brachytherapy is practiced in many radiotherapy institutions. Often it is used for the application of a boost dose, in combination with or as an alternative to external beam therapy.

For safe and accurate dose delivery using brachytherapy many aspects need to be considered. The general safety aspects of the patient treatment and radiation protection of the personnel are important issues. In order to ensure the optimal treatment of patients much effort is required in the commissioning phase of new brachytherapy equipment and later during its clinical lifetime. The institution must therefore develop a proper QA programme for brachytherapy sources and equipment.

In 2000, the IAEA published its Report No. 17, 'Lessons learned from accidental exposures in radiotherapy' [5]. In this report, 92 accidents resulting in an incorrect dose to the patient were described. Although brachytherapy is applied only in, roughly speaking, 5% of all radiotherapy cases, 32 of the accidents reported in this booklet were related to the use of brachytherapy sources. Errors in the specification of the source activity, dose calculation or the quantities and units resulted in doses that were up to twice the prescribed dose. Some accidents were related to human mistakes: for example, the use of an incorrect source simply due to fading of the colour coding, poorly implanted sources and removal of the sources by the patient, or otherwise dislodged sources.

The overview of incidents given in IAEA Safety Report No. 17 [5] demonstrates clearly the need for a well-designed programme of quality assurance for brachytherapy. The goals to achieve should be consistency of the administration of each individual treatment, the realisation of the clinical prescription by the radiation oncologist, and the safe execution of the treatment with regard to the patient and to others who may be involved with, or exposed to, the sources during treatment. All three topics must be included in such a programme.

16. SCOPE OF BRACHYTHERAPY REVIEW VISITS

This part of the publication provides a general outline to be used for brachytherapy on-site review visits to institutions by the IAEA radiotherapy physics expert(s). These tasks include:

(a) Investigating and resolving reported discrepancies linked to brachytherapy processes; this may either be at the formal Level A or at the Level B of general assistance visits.
(b) Reviewing the institution's dosimetry and QA programme for brachytherapy (Level B), possibly as part of a Technical Cooperation Programme.

The brachytherapy review visits are built on the general guidelines for on-site visits as described in Part I and are intended to follow a similar structure. The procedures outlined in Part III of this publication will be followed, depending on the reasons for the review.

The brachytherapy review visit uses concepts and tests discussed in more detail in the IAEA TRS 430 'Commissioning and Quality Assurance of Computerized Planning Systems for Radiation Treatment of Cancer' [22], and the ESTRO Booklet No. 8: 'A Practical Guide to Quality Control of Brachytherapy Equipment' [23].

The various questions involved in the review of the treatment planning process are described in Part IV of this publication. These questions are not addressed separately in this Part III where treatment planning for brachytherapy is discussed. In general, it is assumed that the expert(s) will use this publication in conjunction with Part IV, if this is considered necessary in the frame of the visit, and with the other publications mentioned above.

17. GUIDELINES FOR A BRACHYTHERAPY REVIEW

An on-site visit to investigate and review brachytherapy can be part of a comprehensive review [12] but can also be initiated as a separate review arising out of incidents related to brachytherapy.

The following topics will be included in the on-site review by the expert through interviews and measurements:

(a) Operation and organisation of the brachytherapy process;
(b) Safety and physics parameters;
(c) Verification of the source strength;
(d) Verification of dose calculation procedures:
    (i) reconstruction of implant geometry;
    (ii) completion of brachytherapy benchmark cases.

During an on-site visit the expert will verify the brachytherapy procedures and the correct use of the following sources:

(a) ^{137}Cs, typically low dose rate (LDR);
(b) ^{192}Ir, as used in high dose rate (HDR), pulsed dose rate (PDR) and LDR techniques;
(c) ^{60}Co, HDR techniques.

It is noted that the physical forms of the sources may be significantly different from each other. The expert must be prepared to take measurements for the various possible physical forms of the brachytherapy sources he/she might encounter at the institution. These preparations may include obtaining catheters or well-type chamber inserts as appropriate.

Typical techniques of brachytherapy to be evaluated include: manual loading, manual afterloading and remotely controlled afterloading. The specific contents of a review are determined by the techniques and/or equipment available at and clinically used by the institution.

Remotely controlled afterloading systems may originate from different manufacturers or vendors. When there is more than one afterloader unit available at the institution, the expert will test each unit during the visit.

18. PREPARATION FOR THE REVIEW VISIT

The expert will be equipped with a brachytherapy instrumentation kit, relevant documents including chamber calibration certificates, the ESTRO Booklet 8 [23], IAEA-TECDOC 1274 [24], software and a series of data sheets to be used as reference data during the site visit (Appendix III). The expert will also be provided with a checklist describing tasks to be undertaken and various forms to assist in the review. The expert should review these forms before the visit.

The brachytherapy instrumentation kit consists of the following components as a minimum set:

(a) Well-type chamber, electrometer, barometer, thermometer;
(b) Inserts for the well-type chamber, suitable for insertion of the afterloader's catheters;
(c) Catheters to connect to the different types of afterloaders;
(d) A calliper and a ruler for measuring distances as anticipated by the expert (typically for less than 10 cm and for approximately 1 m);

(e) A Baltas-type phantom for geometric reconstruction checks;
(f) A personal dose/dose rate meter for radiation survey purposes;
(g) A pair of long forceps;
(h) A finger dosimeter for manual LDR source handling.

19. BRACHYTHERAPY TESTS AND MEASUREMENTS

19.1. SAFETY, PHYSICS PARAMETERS, OPERATION AND ORGANIZATION

19.1.1. Safety Tests

The expert will conduct the following safety tests on the afterloading unit prior to performing any other testing, in order to ensure safe working conditions:

(a) Door interlocking operation;
(b) Radiation light warning operation;
(c) Emergency on/off switches operation;
(d) Manual means to close the machine down;
(e) Exposure within the room with the afterloader in source 'safe' condition.

The expert will wear a personal radiation monitoring device and will use a radiation survey meter with an active alarm option.

19.1.2. Mechanical and functional tests

The mechanical tests are designed to evaluate the geometrical accuracy and functionality of the afterloading device unit prior to the determination of the source strength. The confirmation of the positional accuracy of the source in the catheter of the unit is necessary to ensure proper set-up conditions for the calibration as well as the safe dose delivery to patients during treatment. Acceptance criteria for the mechanical tests, the parameters measured or calculated by the expert and those used by the institution are described in the ESTRO booklet No. 8 [23]. The agreement criteria are 1 mm for the positional accuracy of the source in the catheter, 5% for source strength calibration, and 15% for brachytherapy dose calculations (see also Table 2).

The list of the mechanical and safety tests to be performed by the expert is given in Appendix III.2. This list is also used when interviewing the local physicist about the routine QC programme, and the frequency and action levels used. A description of how to perform the safety and physics tests can be found in the ESTRO booklet No. 8 [23], which describes the procedures for HDR/PDR, LDR, and manual brachytherapy.

Once these measurements have been taken and evaluated, the expert will discuss the findings with the institution's responsible physicist/personnel to correct any discrepancies. The expert is encouraged to assist the institution staff in performing additional measurements needed to assess and correct any deviations found. Any parameter found outside the acceptance criteria may require the institution to alter its clinical treatments to account for the corrective actions taken by the institution's physicist or personnel. Once the expert believes that the geometrical and functional integrity of the brachytherapy unit is acceptable, he/she should proceed to take the dosimetry measurements outlined in Appendix III.3. If the integrity of the afterloading unit is not acceptable, the expert may wish to extend the visit to allow the personnel at the institution to repair the equipment in a timely fashion before making the dosimetry measurements. If the equipment cannot be repaired, the expert is still encouraged to take as many measurements and collect as much data as possible, to resolve the problems.

19.1.3. Organization

The expert must become familiar with the institution's procedures and documentation used in brachytherapy treatments. These items include:

(a) Medical protocols;

(b) Physics protocols for commissioning and routine QC;
(c) Equipment documentation;
(d) Safety checks and personnel dosimetry records;
(e) Records of storage and waste disposal.

It is recommended that the expert observe a patient's brachytherapy procedure with the aim of ascertaining whether the benchmark cases are representative of the treatment of a patient. These observations will include imaging of the implant, creation of the treatment plan and transfer of treatment data to the treatment unit.

19.2. VERIFICATION OF THE SOURCE STRENGTH

The institution's physicist will measure, under the observation of the expert, the source strength calibration of at least one source from each group of nominal strengths according to the local institution's standard procedure. The expert will follow the local procedure carefully step by step and discuss any deficiencies with the institution's physicist.

The expert will receive a copy of the vendor's source strength certificate for each of the institution's sources.

The expert will then measure the source strength of a selection of brachytherapy sources according to IAEA-TECDOC-1274 [24] using a well-type ionization chamber. Inserts for the well-type chamber will be available to place the source(s) centrally in the chamber at or as near as possible to the most sensitive spot of the chamber. A worksheet is provided for the IAEA calibration measurements in Appendix III.3. The expert's chamber will be calibrated to have reference air kerma calibration coefficients for the various sources mentioned above. If for a given source type the reference air kerma calibration coefficient is not available, the expert will not perform a source strength measurement for that source type. The expert will compare his/her measured source strengths with the institution's clinical values.

If the institution's source strengths are specified in units other than the reference air kerma rate the expert will make the appropriate conversions from these units into the units of reference air kerma rate [25].

19.3. VERIFICATION OF BRACHYTHERAPY DOSE CALCULATION PROCEDURES

This section deals with the verification of brachytherapy dose calculation procedures including the reconstruction of the implant geometry and completion of brachytherapy benchmark cases.

19.3.1. Reconstruction of implant geometry

The standard procedure for the reconstruction of an implant will be checked at the institution. The expert will use a solid Baltas-type phantom to accomplish this test.

The institution's physicist will be asked to image the phantom as if it were a patient: i.e. with orthogonal or semi-orthogonal X rays, from a mobile X ray unit, C-arm X ray unit or simulator, or a CT scanner. The images will then be transferred to the treatment planning system using the institution's standard procedure. The institution's physicist will use the TPS software to reconstruct the points in the phantom and will print a list of their coordinates.

The expert will enter the set of coordinates onto an Excel spreadsheet, provided by the IAEA on a CD-ROM, which allows the calculation of the distances between the known coordinates of the phantom and the institution's coordinates for each point. Deviations are shown in the form of the mean deviation, standard deviation of the mean, a confidence level and a graphical representation. Printouts will be made of these results and given to the institution's physicist as part of the audit report. The possible origin of any deviations will be discussed with the institution's staff.

19.3.2. Brachytherapy benchmark cases

The institution's physicist will be asked to prepare a brachytherapy dose calculation according to the institution's standard calculation method used for patients, at a number of points along the transverse axis of a clinically used source. The configuration of this source arrangement and calculation points can be found in Appendix III.4.

The institution's staff will prepare a 2-D plot of the dose distribution around the single source in the plane of the source.

Taking into account the actual source strength, the expert will compare the results of the single source calculations with data from an along-and-away table typical for the specific source type [23].

A second benchmark case consisting of a two-source configuration will then be defined in the TPS. The sources are oriented parallel to each other at a typical distance of 2 cm apart. A dose of 10 Gy is prescribed at the 85% isodose line, with a 100% of the dose distribution normalization point in the centre of the configuration (see Appendix III.4.). Keyboard entry is preferred to avoid the possible influence of a reconstruction step.

The expert will discuss with the institution's physicist the two-source configuration calculated by the TPS and the conversion of the dose prescription into a treatment time. Any deviations will be discussed with the institution's staff.

PART IV.

ON-SITE VISITS FOR REVIEWING THE TREATMENT PLANNING PROCESS

20. QUALITY ASSURANCE IN TREATMENT PLANNING

In recent years, increased attention has been paid to QA of radiation treatment planning systems and procedures [22, 26 – . The treatment planning process is complicated and has many steps, with many interfaces between professional groups, between humans and machines and between machines and machines. Instructions and data cross these interfaces and are manipulated in complex ways. Human error can occur at any stage. Computer systems can introduce problems, due for example to inherent limitations in the algorithms, erroneous data input, software bugs, data corruption, or problems with hardware and peripheral devices. A review [5] has analysed direct causes and contributing factors of accidental exposures in radiotherapy and indicates that 30% of the incidents listed have causes directly related to the treatment planning process, coupled with failures in the overall QA. One such accident, which resulted in large patient overdoses, was recently reported [14] to have been a result of deficiencies in the treatment planning system and QA procedures.

Therefore an adequate level of QA, independent verification and quality audit are necessary for treatment planning as for other steps in the radiotherapy process. In particular, it may be noted that a similar safety philosophy of independent (redundant) checking should be applied to treatment planning calculations and processes as is recommended for all aspects of radiation treatments. Examples of these redundancies include:

(a) Dual monitor chambers, back-up timers, independent safety and interlocking systems, etc. in equipment design;
(b) Independent checking of beam calibration and external audit of beam dosimetry;
(c) The use of more than one measurement technique and the comparison of the sets of results in the measurements of beam characteristics;
(d) The comparison of input data to output at many levels in comparing the patient information in a computerised verification system;
(e) Independent checking of patient set-up parameters by more than one radiotherapy technologist;
(f) The use of *in vivo* dosimetry.

A comprehensive QA system for treatment planning should include checks of the integrity of hardware, software and data transfer. The QA programme should cover software upgrades, changing of peripheral devices, methods of data transfer and any modifications of beam data used for calculations. An important part of periodic QA are independent checks of monitor units (MU)/treatment time calculations. TRS 430 [22] discussed the immediate causes and contributing factors of a few accidental exposures, identifying those related to the treatment planning process from a more extensive list of accidents given in the IAEA Safety Series 17 [5]. From this discussion it was noted that an independent MU or treatment time check would have identified at least 60% of the incidents. It is also believed that such a MU verification procedure would have prevented the dose misadministration reported in the IAEA publication [14].

21. SCOPE OF REVIEWS OF TREATMENT PLANNING FOR EXTERNAL RADIOTHERAPY

This part provides a general outline and a set of procedures to be used for on-site review visits to radiotherapy hospitals by the IAEA radiotherapy physics expert(s) charged with:

(a) Investigating and resolving discrepancies linked to the treatment planning process. This may be either at the formal Level A or at the Level B of general assistance visit;
(b) Reviewing the hospital's approach to QA of the treatment planning process (Level B), possibly as part of a Technical Cooperation Programme.

This part builds on the general guidelines for on-site review visits (Part I) and is intended to provide the same structure to the investigations. It refers back to those procedures and expects part or all of those procedures also to be followed, depending on the exact circumstances of the review. It also uses some of the ideas and tests discussed in [22]. It is expected that the expert(s) will refer to Part II of this publication and to the QUATRO guidelines for comprehensive audits of radiotherapy practice [12].

This part outlines the content of the on-site review visit for treatment planning systems. Appendix IV gives more details on specific components of the review, e.g. forms, information sheets, checklists and reports.

21.1. STEPS IN THE TREATMENT PLANNING PROCESS

Many steps are involved in the treatment of a cancer patient with radiation therapy, which include the treatment planning process and the treatment delivery process. Figure 1 shows the various steps in the radiation treatment planning process. These steps involve the acquisition of the anatomical information, the delineation of the target volume(s) and organs at risk, the design of the beam arrangement, the dose calculation, the plan evaluation and the transfer of the plan to the treatment machine. All these steps will be reviewed by the IAEA's expert during the on-site visit.

For example, the questions to be answered are:

(a) Has the anatomical information been correctly transferred from the diagnostic equipment to the treatment planning system (TPS), and are these images / volumes distorted?
(b) Is the relative dose distribution calculated and displayed correctly?
(c) Are the dose prescription and dose normalisation consistent?
(d) Has the treatment plan been correctly transferred to the treatment machine?
(e) Is the actual dose delivered at the reference point in agreement with what can be derived from the MU / treatment time calculation?

In the following sections the handling of input and output of anatomical information in the TPS will be discussed, without however commenting on the quality of the diagnostic imaging. Furthermore, discussion of the institution's policy with respect to delineation of target volumes and organs at risk is beyond the scope of this publication. Other clinical aspects of the treatment planning process, such as the adequacy of dose/volume constraints of target volumes and organs at risk will not be dealt with in this publication either.

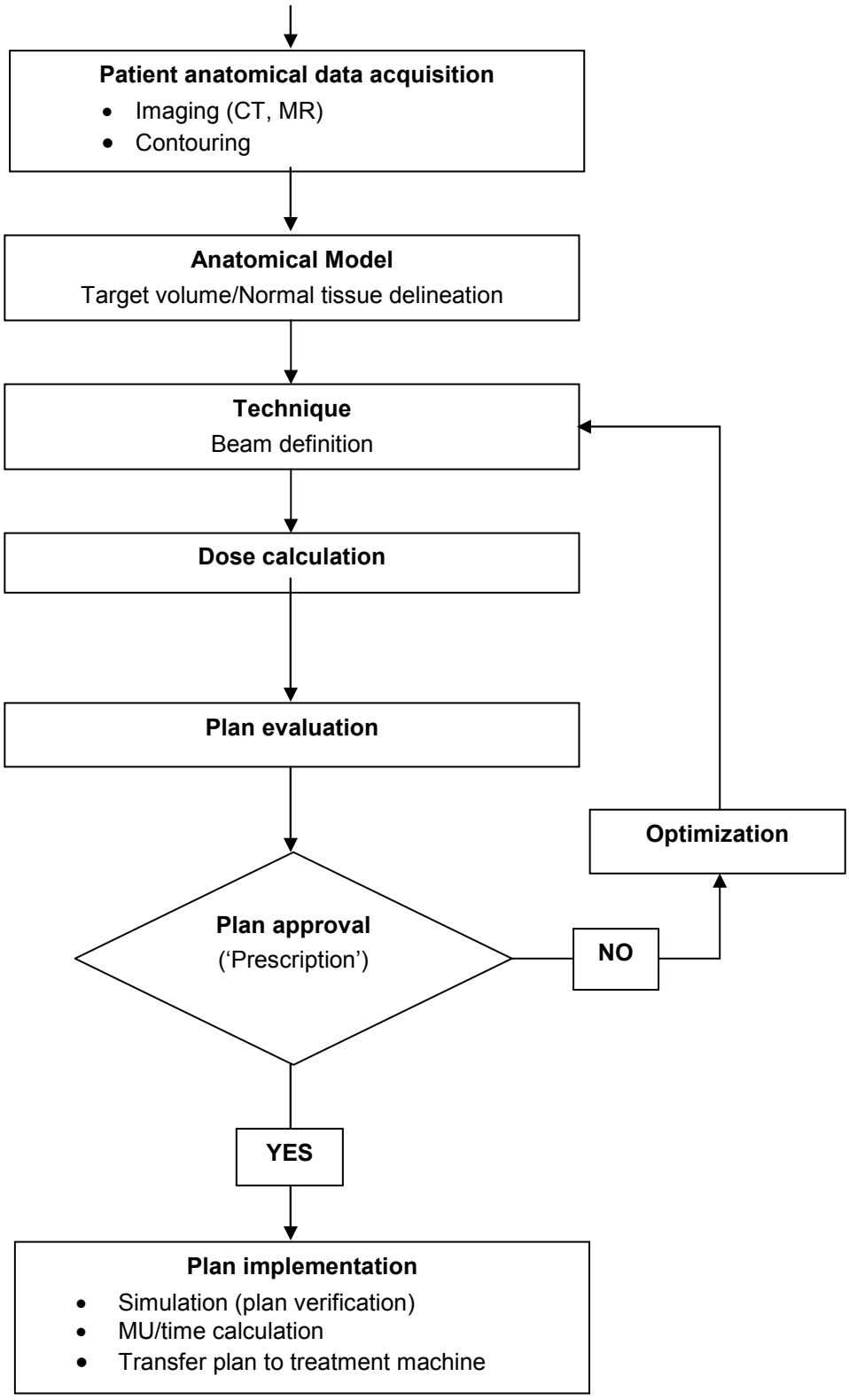


Figure 1. Steps in the radiation treatment planning process (reproduced from [22]).

21.2. ISSUES IN QA OF THE TREATMENT PLANNING

The major issues that relate to treatment planning errors have been summarized in the IAEA and ICRP publications [5 – 6]. Any QA programme of the treatment planning process should therefore include the following key elements:

(a) *Education*. These activities should not be restricted only to the technical aspects of the treatment planning process, i.e. knowledge of hardware and software, but should also include adequate professional training of the treatment planning team;

(b) *Verification.* Ideally, all steps involved in the treatment planning process should be verified separately. In some situations it is, however, more efficient to verify several steps at the same time, such as the independent MU/treatment time calculation, specific point measurements in a phantom for complex treatments or alterations due to changes in treatment prescription;

(c) *Documentation*. Inadequate documentation of treatment planning procedures or ambiguities in the actual treatment parameters of an individual patient can lead to errors;

(d) *Communication*. Inadequate communication by the treatment team in areas such as new treatments, procedures, equipment, complex treatment plans, changes in procedures or protocols, changes in the treatment plan of a specific patient or any unusual patient treatment response may result in deviations from the intended dose delivery.

22. PREPARATION FOR THE ON-SITE VISIT TO REVIEW THE TREATMENT PLANNING PROCESS

Prior to the visit, the set of benchmark cases as given in Section 23.3. will be sent to the institution. These benchmark cases will be completed by the institution, to be made available when the expert(s) arrive. It is essential that the treatment plans be prepared by the staff members who normally perform the patient treatment planning following the institution's procedures. These plans will be reviewed and approved by the institution's radiation oncologist and the medical physicist. The benchmark cases include:

(a) Three photon in-water-phantom cases;
(b) Four photon anatomical cases (pelvis, thorax, breast and head and neck);
(c) Four electron in-water-phantom cases.

The experts will be equipped with the standard instrumentation kit for on-site dosimetry visits as specified in Part II of this publication. A laptop with treatment planning software will be added to this kit. This software will include the Theraplan Plus TPS version 3.7 from MDS Nordion (2000), a photon beam database for treatment planning with ^{60}Co, 6 MV, 10 MV and 25 MV beams, pre-calculated dose distributions for the photon benchmark cases. Dose distributions as well as the MU/treatment time for the institution's specific radiotherapy beams will be calculated on the laptop during the on-site visit.

23. ON-SITE PROCEDURES FOR THE REVIEW OF THE TREATMENT PLANNING PROCESS

A general outline of the treatment planning on-site review visit is shown in Figure 2. In this figure the various review procedures and actions to be followed by the expert are represented by a flowchart.

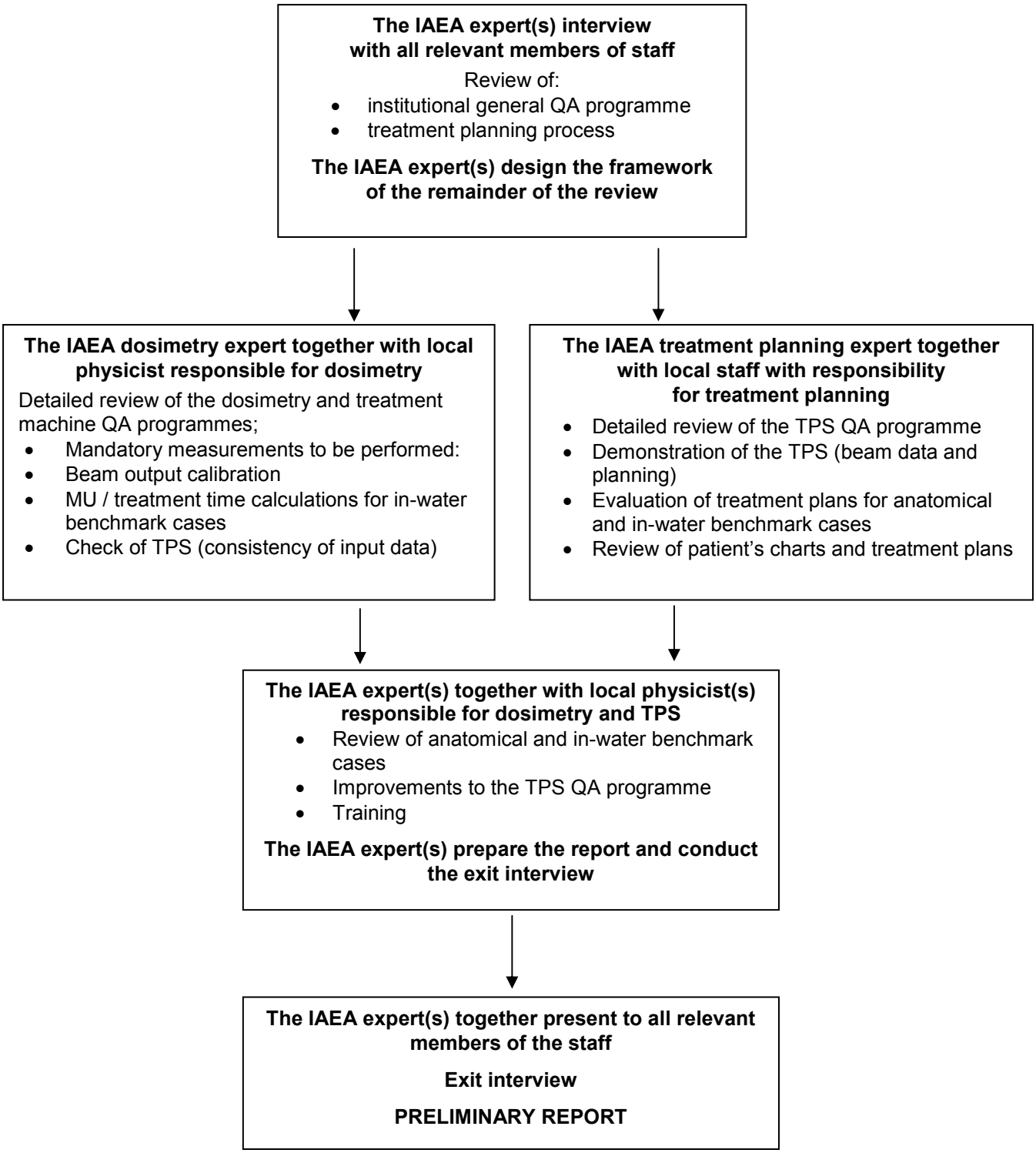


Figure 2. Outline of the on-site review of the treatment planning process.

23.1. REVIEW OF INSTITUTION'S TREATMENT PLANNING QUALITY ASSURANCE PROGRAMME

The review of the institution's QA procedures for the treatment planning process will include:

(a) The overall radiotherapy QA programme, focusing on those aspects that might bear on any actual or potential problems related to the treatment planning process;

(b) The commissioning and QA data for the TPS. This will include a review of the original beam data obtained during commissioning and beam data selected to be a reference data set for periodic quality control measurements or calculations;

(c) The patient-specific QA checks, including independent calculation of monitor units or time set for each treatment field, periodic checks of treatment records, and treatment summary at the completion of the treatment;

(d) The reviews and calculations that the institution has undertaken to identify and resolve any reported treatment planning problems.

The expert will also observe and discuss with the institution's treatment planning team the actual treatment planning procedures at the institution. This will be necessary to help the expert understand fully the details of the institution's treatment process.

Additional planning and measurements may be suggested during the visit. Measurements at the treatment unit will help not only to reveal errors in the treatment planning process but also to detect possible problems with the transfer of data from the TPS to the treatment machine or in the performance of that machine.

23.2. COMPARISON OF THE BEAM DATA

The expert(s) will compare the institution's tabulated basic beam dosimetry data with those generated by the institution's TPS, to ensure the consistency of the data for patient dose calculations. The expert(s) will also compare the institution's beam data (e.g. depth dose, output factors, off-axis data, wedge data) with the generic beam data [19 – 21], to search for possible discrepancies.

23.3. EVALUATION OF BENCHMARK IN-WATER CASES AND ANATOMICAL CASES

The purpose of the benchmark cases described in this part of the publication is twofold:

(a) To trace significant differences between the relative dose distributions calculated with the treatment planning system clinically applied by the institution, and the corresponding dose distributions calculated with the IAEA laptop TPS using generic beam data;

(b) To trace significant differences in MU/treatment time calculations made with the clinically applied programme and those determined with the IAEA laptop TPS.

To achieve this goal, a set of seven photon benchmark cases and four electron benchmark cases (if appropriate) will be sent to the institution prior to the site visit. The photon cases concern four typical treatments of tumours in the pelvis, lung, breast and head and neck areas using anatomical information ('the anatomical cases'), as well as three treatments simulated in a water phantom ('the in-water-phantom cases'). The institution should plan these eleven cases in the routine way. The information provided in the attached test set-ups should be used to design the various treatment plans. The electron cases are the four cases matching measurements made during the dosimetry review in Part II.

The following procedures are designed to provide a measured dose rate to compare against the institution's treatment planning calculation for the photon and electron in-water-phantom benchmark cases.

The institution's physicist will calibrate, under the observation of the expert, the beam output according to the institution's standard procedure. Next, the expert will undertake a beam output calibration as described in Section 13.1 of this publication. All measurements will be recorded on the DOSE MEASUREMENTS RECORD (Appendix II.3.3), and the final result on the BEAM OUTPUT REPORTING (Appendix II.3.4–II.3.5).

The next step will be the verification of the dose values calculated for the in-water benchmark cases (three photon and four electron cases) using the expert's water phantom and dosimetry system. Details of the set-up are given below. For each beam the expert's measured dose values will be compared with the corresponding values calculated by the institution's system. All measurements will be recorded on the DOSE MEASUREMENTS RECORD form (Appendix II.3.3), and the final result on the report form (Appendix IV.7).

A deviation between calculated and measured dose values might be caused by the validity of the basic beam data used by the institution in its dose calculation (either in the TPS or in the independent MU/treatment time calculation program). The evaluation of the in-water benchmark cases might therefore result in a number of follow-up measurements. These measurements may be focused on resolving possible differences in the beam data used in the TPS and the institution's commissioning beam data, or possible deviations between the data used in the MU/treatment time calculations and the institution's commissioning data. In addition, the expert's interview with some of the staff members, or any other observation of the expert(s), might reveal imperfections in the QA programme, which also might necessitate additional measurements. All additional measurements will be recorded in the DOSE MEASUREMENTS RECORD form (Appendix II.3.3).

The institution will have been asked to prepare treatment plans for four photon anatomical benchmark cases, and the expert(s) will have had these case results calculated on the IAEA laptop. The expert(s) results will be compared with those obtained by the institution. The plans will be evaluated considering the relative dose distributions, MU or treatment time calculations and any additional calculations done to explain observed differences.

If electron beam planning is available at the hospital the electron cases will be compared with measurements made at the time of the visit and must be available for comparison with the measurements while the measurements are being taken.

23.3.1. Photon in-water phantom benchmark cases

The goals of the following cases are:

(a) To create a patient model based on a set of 1 cm slices (in a 40 cm × 40 cm × 35 cm water phantom);
(b) To provide a calculation of the relative dose distributions for multiple beams with a given normalization;
(c) To verify the MU/treatment time calculations from the TPS through a manual check.

The treatment plans for the in-water-phantom cases should be prepared in the usual way the institution uses the respective treatment machines. The source-axis-distance (SAD) set up with a SAD of 100 cm should be used for the high-energy photon beams from medical linear accelerators or for ^{60}Co machines with the standard SAD = 100 cm. Fixed source-to-surface distance, the SSD set-up, should be used for other types of ^{60}Co units. To provide standardized comparisons of relative dose distributions at the same set of points in the phantom, the recommended field sizes for SAD = 100 cm should be scaled accordingly for test geometry at the selected SSD.

A limited number of points for the verification of the calculated dose distribution for each in-water-phantom case are determined from the analysis of dose distributions measured with the ionization chambers and radiographic films for ^{60}Co and different high-energy photon beams. Points are selected for the testing of as many parameters of the treatment planning system and dose calculation features as possible, based on the following:

(a) Points should be at different depths of the phantom with respect to the beam's entrance, to check the depth dose characteristics;

(b) Points should be at both sides of the central ray to check the symmetry of open profiles as well as the agreement between calculated and measured wedged profiles;

(c) Points should be located in areas where the dose distribution is relatively flat, i.e. areas with a small dose gradient.

The recommended number of points will require about 2 hours of measurement time to complete all three in-water-phantom cases in linac beams; a similar time might be spent for measurements at the ^{60}Co machine with appropriate source activity (time of the measurements may be longer for a machine with a low activity source).

The coordinate system which is used to indicate the positions of the selected points, is illustrated in Figure 3. For each in-water-phantom case, the origin of the coordinate system is located at the position of the normalization point. Dose calculation will be verified in the XZ-plane (transverse plane) through the isocentre, thus at Y=0. The dose distribution of the first and second case (described below) has to be symmetric with respect to the z-axis. It should be established that this is fulfilled by the calculated distribution prior to comparison with the measured one.

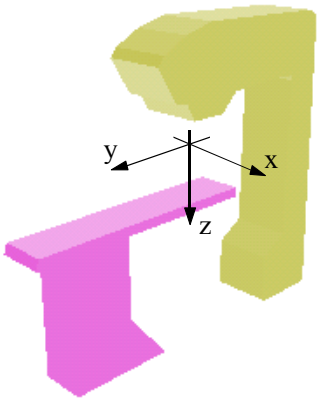


Figure 3: Coordinate system used for describing the position of the measurement points. For each case, the system's origin is located at the normalization point.

23.3.1.1. Photon in-water-phantom case #1

The first case is the application of two oblique incident beams, intended to simulate schematically the treatment of a head and neck site. The following set-up should be used: two beams with 45-degree beam incidence (with angles of 45° and 315° on the scale defined by the International Electrotechnical Commission (IEC) standard [13]), having field sizes of 8 cm × 10 cm at SAD = 100 cm and 45º wedges, are irradiating the top of the water phantom. The MU/treatment time set should be calculated to deliver 1 Gy by each field at a point located at 5 cm depth in the phantom. A diagram of the set-up of this test is shown in Figure 4.

(a) Create a water phantom with dimensions 40 cm × 40 cm × 35 cm with a slice thickness of 1 cm;

(b) Select two beams with standard SAD set-up (SAD = 100 cm) using the following parameters:

Beam angle (1) 45°	Beam angle (2) 315°
Field Size (1):	Field Size (2):
8 W cm × 10 cm	8 W cm × 10 cm
Depth (1): 5 cm	Depth (2): 5 cm
Wedge (1) angle: 45 º	Wedge (2) angle: 45 º

(c) If the SSD set-up is used and the field size at the surface is used as input data in TPS for treatments with SSD set-up, the recommended field sizes should be scaled to provide analysis of dose distributions in the same geometry for high-energy photon beams and the ^{60}Co beam. The values for SSD = 80 cm are given below:

Beam angle (1) 45°	Beam angle (2) 315°
Field Size (1):	Field Size (2):
7.4 W cm × 9.2 cm	7.4 W cm × 9.2 cm
Depth (1): 5 cm	Depth (2): 5 cm
Wedge (1) angle: 45 ^{o}	Wedge (2) angle: 45 ^{o}

(d) Calculate the MU/treatment time to deliver 1 Gy per field at a depth of 5 cm;

(e) The dose distribution should be verified in the XZ-plane (transverse plane) through the isocentre, thus at Y = 0. Check that the calculated dose distribution is symmetric with respect to the vertical axis of the phantom for the two-beam combination; fill in data for relative doses at selected points in the form (Appendix IV.7).

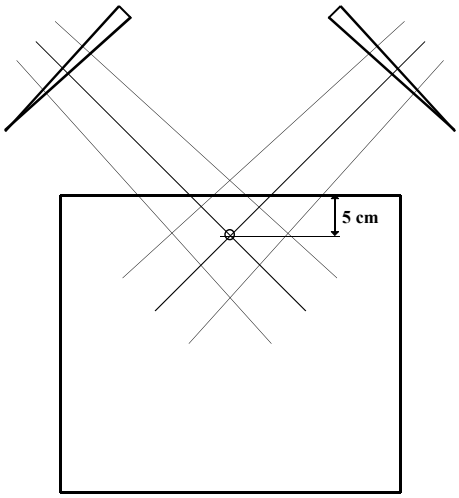


Figure 4. Geometry for in-water-phantom dosimetry case #1: simulation of a head & neck case. The beam set up consists of two oblique-wedged fields. The depth of the dose specification point is 5 cm.

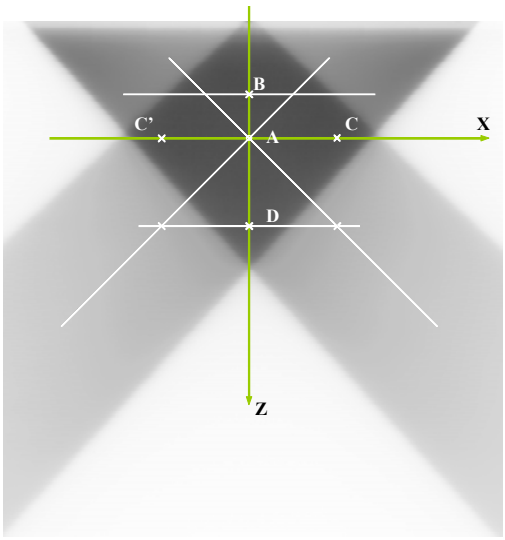


Figure 5. Dose distribution and selected points for dose verification for the first in-water-phantom case. The radiographic film was exposed in a 10 MV beam set up for case #1.

Table 3. presents the coordinates of the points for the verification of the calculated dose distribution for in-water-phantom case #1. Data are given for the SAD set-up at SAD = 100 cm and for the SSD set-up at SSD = 80 cm.

TABLE 3. A SET OF POINTS FOR THE VERIFICATION OF CALCULATED DOSE DISTRIBUTIONS: IN-WATER-PHANTOM TEST CASE #1.

	SAD = 100 cm		SSD = 80 cm	
Label	X (mm)	Z (mm)	X (mm)	Z (mm)
A	0	0	0	0
B	0	-20	0	-20
C	40	0	30	0
C’	-40	0	-30	0
D	0	40	0	30

23.3.1.2. Photon in-water-phantom dosimetry case #2.

The second in-water case is where three fields, which might be considered to simulate schematically the treatment of a pelvic tumour, are applied. The following set-up should be used: one open anterior-posterior beam and two lateral fields having a 30º wedge. The intersection of the three beams is located in the middle of the phantom. Monitor units or time set should be calculated to deliver 1 Gy by the anterior field and 0.5 Gy by each of the two lateral fields to the beam intersection point (ICRU dose specification point). Figure 6 shows the set-up for this treatment for which the photon beam with the highest energy available in the institution should be applied.

(a) Create a water phantom with dimensions 40 cm × 40cm × 35 cm with a slice thickness of 1 cm.

(b) Select three beams with standard SAD set-up using the following parameters:

Beam angle (1) 0°	Beam angle (2) 90°	Beam angle (3) 270°
Field Size (1):	Field Size (2):	Field Size (3):
12 W cm × 18 cm	10 W cm × 18 cm	10 W cm x 18 cm
Depth (1): 12 cm	Depth (2): 15 cm	Depth (3): 15 cm
Open field	Wedge (1) angle: 30 ^{o}	Wedge (2) angle: 30 ^{o}

(c) If only a ^{60}Co beam is available at the institution, the SSD set-up may be used, and the field size at the surface is used as input data in the TPS for treatments with SSD set-up. The recommended field sizes should be scaled. The values for SSD = 80 cm are given below:

Beam angle (1) 0°	Beam angle (2) 90°	Beam angle (3) 270°
Field Size (1):	Field Size (2):	Field Size (3):
10.4 W cm × 15.7 cm	8.0 W cm × 14.4 cm	8.0 W cm × 14.4 cm
Depth (1): 12 cm	Depth (2): 20 cm	Depth (3): 20 cm
Open field	Wedge (1) angle: 30 ^{o}	Wedge (2) angle: 30 ^{o}

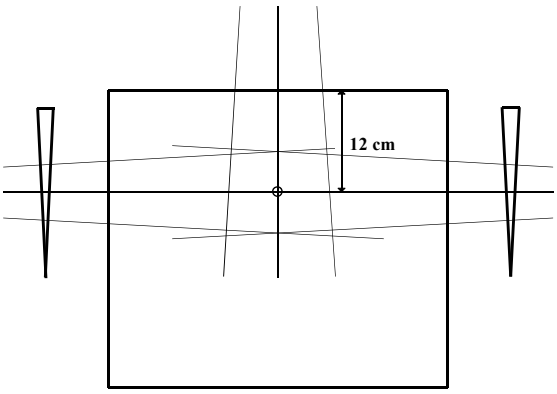


Figure 6. Geometry for in-water-phantom case #2: simulation of the treatment of a pelvic tumour. The beam set-up consists of an open anterior-posterior field and two wedged lateral fields. The depth of the dose specification point is 12 cm.

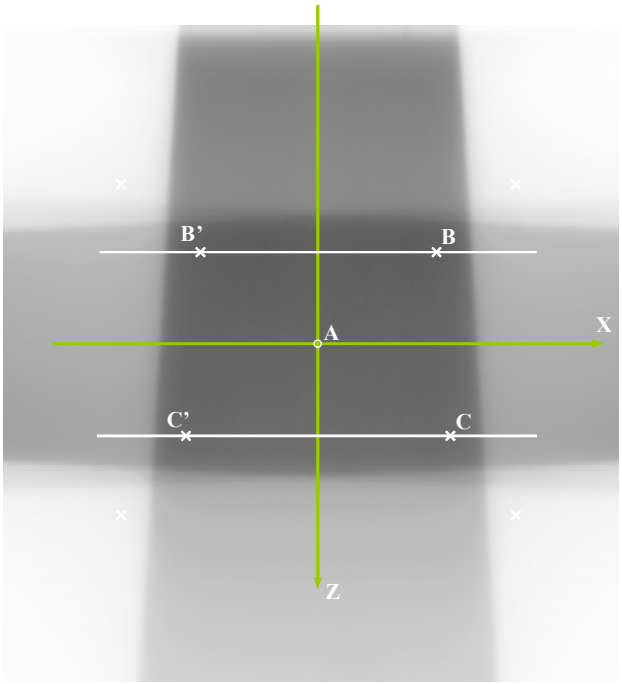


Figure 7. Dose distribution and selected points for dose verification for the second in-water-phantom case. The dose distribution has been obtained by film measurement in a 10 MV beam set-up.

(d) Calculate the dose distribution with weighting 2:1:1;

(e) Calculate the MU/treatment time to deliver 2 Gy to the isocentre (1 Gy per anterior field and 0.5 Gy per each lateral field);

(f) The dose distribution should be verified in the XZ plane (transverse plane) through the isocentre, thus at Y = 0. Check that the calculated dose distribution is symmetric with respect to the vertical axis of the phantom for the three-beam combination; fill in data for relative doses at selected points.

Figure 7 shows a radiographic film image and the location of the selected points for dose verification for the in-water-phantom dosimetry case #2. Table 4 presents the coordinates of the points for the verification of the calculated dose distribution for in-water phantom test case #2. Data are given for the linac set-up at SAD = 100 cm and for the ^{60}Co unit (SSD = 80 cm).

TABLE 4. A SET OF POINTS FOR THE VERIFICATION OF CALCULATED DOSE DISTRIBUTIONS: IN-WATER-PHANTOM CASE #2

	SAD = 100 cm (Y = 0 mm)		SSD = 80 cm (Y= 0 mm)	
Label	X (mm)	Z (mm)	X (mm)	Z (mm)
A	0	0	0	0
B	45	-35	35	-25
B’	-45	-35	-35	-25
C	50	35	40	25
C’	-50	35	-40	25

23.3.1.3. Photon in-water-phantom dosimetry case #3

The third in-water phantom test case is designed to confirm a blocked beam situation. A phantom is irradiated with a field of 20 cm × 20 cm in which one shielding block is positioned in the corner of the field, covering a square area with sides of 8 cm. Monitor units or time set should be calculated to deliver 1 Gy at a depth of 10 cm both for the open and shielded situation. A diagram of the set-up of this test is shown in Figure 8. The institution has to choose the energy of the photon beam.

(a) Create a water phantom with dimensions 40 cm × 40 cm × 35 cm with a slice thickness of 1 cm.

(b) Select a beam with the standard SAD set-up using the following parameters:

Beam angle: 0°	Block dimensions:
Field Size: 20 cm × 20 cm Depth: 10 cm	The shielded area: square, size 8 cm

(c) If the SSD set-up is used, and the field size at the surface is used as input data in the TPS for treatments with the SSD set-up and the recommended field sizes should be scaled. The values for SSD = 80 cm are given below.

Beam angle: 0°	Block dimensions:
Field Size: 17.8 cm × 17.8 cm Depth: 10 cm	The shielded area: square, size 8 cm

(d) Calculate the dose distribution for the open and blocked field using the standard SSD set-up.

(e) Calculate the MU/treatment time to deliver 1 Gy at a depth of 10 cm for the open and blocked field

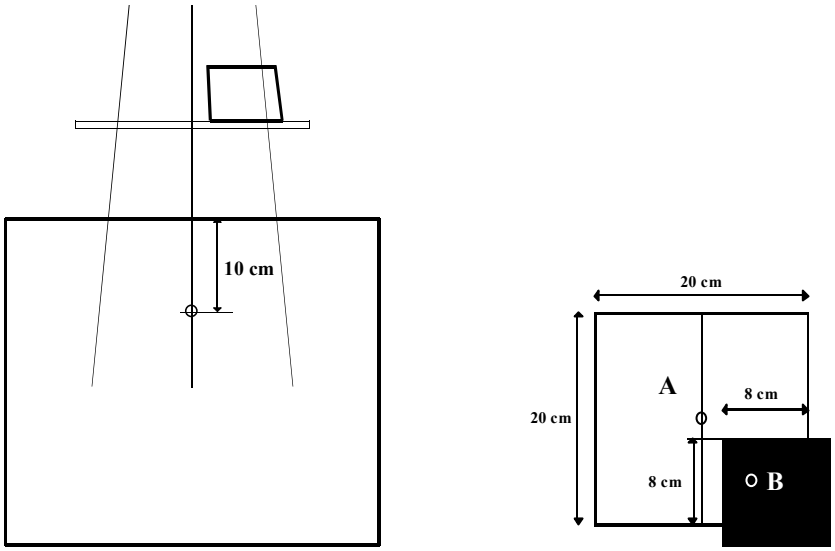


Figure 8. Geometry for in-water-phantom case #3. Left: Blocked beam treatment. One block is partly covering one quadrant of the square field. Upper right: Beam's-eye view (BEV). At the depth of the dose specification, the size of the blocked area is 8 cm × 8 cm.

Table 5 presents the coordinates of the points for the verification of the calculated dose distribution for in-water-phantom test case #3. Data are given for the set-up at SAD = 100 cm and for the ^{60}Co unit (SSD = 80 cm).

TABLE 5. A SET OF POINTS FOR THE VERIFICATION OF CALCULATED DOSE DISTRIBUTIONS: IN-WATER PHANTOM TEST CASE #3

	SAD = 100 cm (Y = 100 mm)		SSD=80 cm (Y = 100 mm)	
Label	X (mm)	Z (mm)	X (mm)	Z (mm)
A	0	0	0	0
B	60	60	60	60

23.3.2. Photon anatomical cases

Four transversal cross sections will be distributed through the central part of the target volume of typical patients. The anatomical data indicated in these slices are the outer contour of the patient, the planning target volume (PTV) and some organs at risk, with their specific density. The beam directions, field sizes and points at which the dose should be calculated are indicated. It is assumed that the patient has a cylindrical geometry, i.e. has the same dimensions in other transversal slices outside the plane of planning. The four cross-sections are indicated in Figures 9–12. These cross-sections will be given to the institutions on a 1:1 scale and should be entered in the planning system using a digitizer.

The prescribed dose to the isocentre is 2 Gy for all anatomical cases and the set-up information is summarized in Tables 6–10. Anatomical case #1 for pelvis irradiation has an additional table for the four-beam set-up with a ^{60}Co treatment machine, as the use of four beams is more common with these machines.

Treatment plans calculated for the set-ups listed below are stored in the IAEA laptop TPS and can be used for comparison purposes. As in the case of the in-water phantom cases, the SAD set-up and corresponding field sizes are listed for the high-energy photon beams from medical linear accelerators. The SSD set-up (SSD = 80 cm) corresponds to the geometry of the plans for anatomical tests for a ^{60}Co treatment machine.

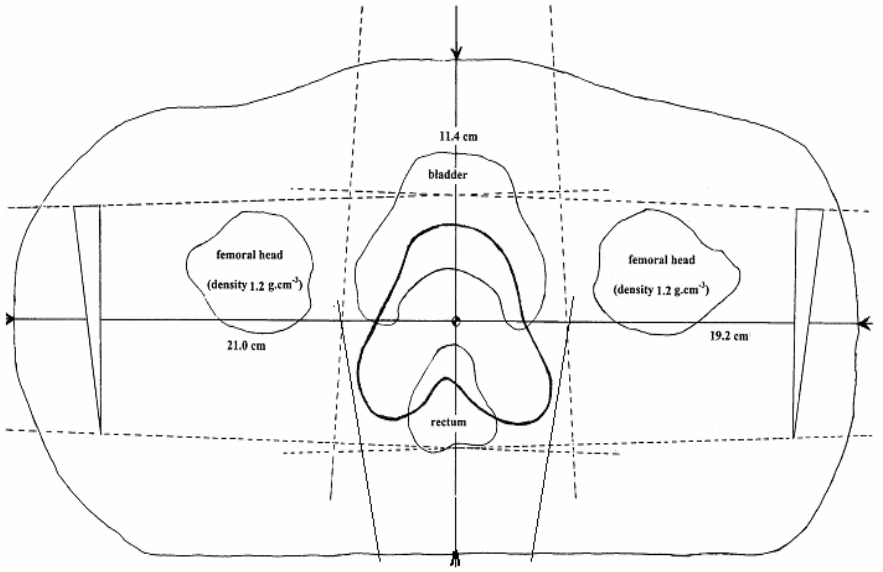


Figure 9. Transversal cross-sections through the central part of the target volume for the first anatomical case (pelvis). Fourth posterior field (depth 12.0 cm) may be used for additional four-beam set-up with ^{60}Co treatment machine, as the use of four beams is more common with these machines.

TABLE 6. ANATOMICAL CASE #1 – PELVIS (3 BEAMS)

Anatomical Case #1 – Pelvis (3 beams) Beam weighting 2:1:1			
Position of normalization point:			
x = 0.00, y = 0.00, z = 0.00			
Set-up: SSD	3 beams		
Radiation quality:	^{60}Co		
Beam label	AP	RL	LL
Gantry angle [deg]	0	270	90
Beam width [cm]	9.0	9.0	9.0
Beam length [cm]	9.0	9.0	9.0
Wedge type [deg]	—	30	30
Set-up: SAD	3 beams		
Radiation quality:	Linac		
Beam label	AP	RL	LL
Gantry angle [deg]	0	270	90
Beam width [cm]	11.0	11.0	11.0
Beam length [cm]	9.0	9.0	9.0
Wedge type [deg]	—	30	30

TABLE 7. ANATOMICAL CASE #1 – PELVIS – ADDITIONAL (4 BEAMS)

Anatomical Case #1 – Pelvis – additional (4 beams) (Beam weighting 1:1:1:1)				
Position of normalization point:				
x = 0.00, y = 0.00, z = 0.00				
Set-up: SSD	4 beams			
Radiation quality:	^{60}Co			
Beam label	AP	RL	LL	PA
Gantry angle [deg]	0	270	90	180
Beam width [cm]	9.5	9.0	9.0	10.5
Beam length [cm]	9.0	9.0	9.0	9.0
Wedge type [deg]	—	—	—	—
Set-up: SAD	4 beams			
Radiation quality:	Linac			
Beam label	AP	RL	LL	PA
Gantry angle [deg]	0	270	90	180
Beam width [cm]	11.0	11.0	11.0	11.0
Beam length [cm]	9.0	9.0	9.0	9.0
Wedge type [deg]	—	—	—	—

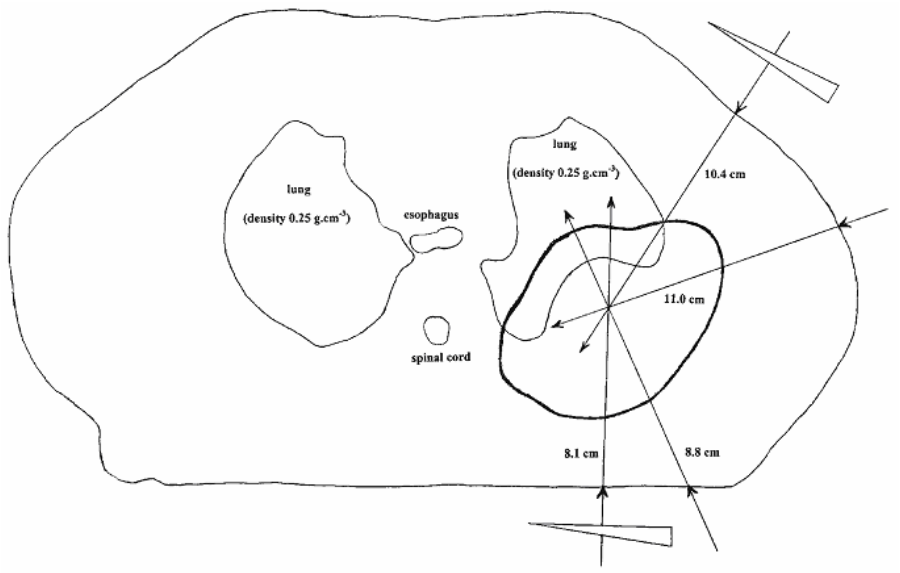


Figure 10. Transversal cross-sections through the central part of the target volume for the second anatomical case (lung).

TABLE 8. ANATOMICAL CASE #2 – LUNG

Anatomical Case #2 – Lung (Beam weighting 1:1:1:1)				
Position of normalization point: x = 8.00, y = 0.00, z = 0.00				
Set-up:	4 beams			
Radiation quality:	^{60}Co			
Beam label	LAO 35	LAO 70	LPO	PA
Gantry angle [deg]	35	70	155	180
Beam width [cm]	8.3	8.5	11.5	10.6
Beam length [cm]	11.6	11.6	11.6	11.6
Wedge type [deg]	45	—	—	30
Set-up:	4 beams			
Radiation quality:	Linac			
Beam label	LAO 35	LAO 70	LPO	PA
Gantry angle [deg]	35	70	155	180
Beam width [cm]	9.2	9.5	12.5	11.5
Beam length [cm]	11.6	11.6	11.6	11.6
Wedge type [deg]	30	—	—	30

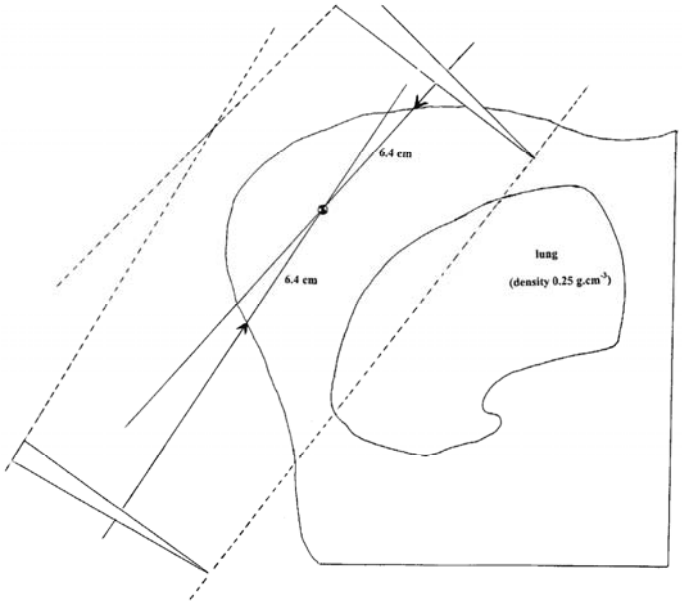


Figure 11. Transversal cross-sections through the central part of the target volume for the third anatomical case (breast).

TABLE 9. ANATOMICAL CASE #3 – BREAST

Anatomical Case #3 – Breast Beam weighting 1:1		
Position of normalization point:		
x = –6.00, y = 0.00, z = 6.00		
Set-up: SSD		
Radiation quality:	^{60}Co	
Beam label	RPO	LAO
Gantry angle [deg]	214	41
Beam width [cm]	10.0	10.0
Beam length [cm]	20.0	20.0
Wedge type [deg]	15	15
Set-up: SAD		
Radiation quality:	Linac 6 MV	
Beam label	RPO	LAO
Gantry angle [deg]	214	41
Beam width [cm]	12.6	12.6
Beam length [cm]	21.0	21.0
Wedge type [deg]	15	15

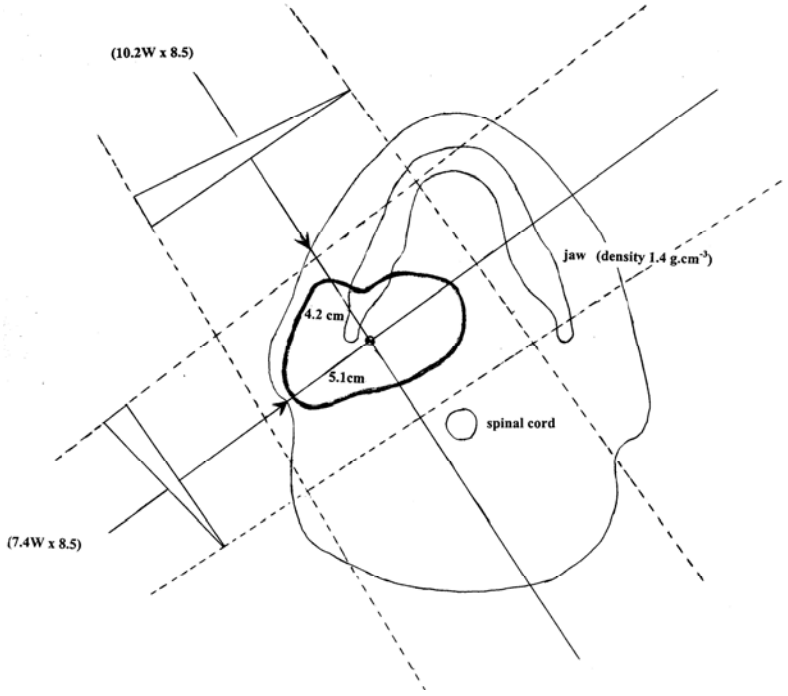


Figure 12. Transversal cross-sections through the central part of the target volume for the fourth anatomical case (head & neck).

TABLE 10. ANATOMICAL CASE #4 – HEAD & NECK

Anatomical Case #4 – Head & Neck Beam weighting 1:1		
Position of normalization point:		
x= –0.0 y = 0.00, z = 0.00		
Set-up: SSD		
Radiation quality:	^{60}Co	
Beam label	RAO	RPO
Gantry angle [deg]	325	250
Beam width [cm]	9.5	6.5
Beam length [cm]	8.5	8.5
Wedge type [deg]	45	45
Set-up: SAD		
Radiation quality:	Linac 6 MV	
Beam label	RAO	RPO
Gantry angle [deg]	325	250
Beam width [cm]	9.0	6.5
Beam length [cm]	8.5	8.5
Wedge type [deg]	45	60

23.3.3. Electron in-water-phantom benchmark cases

The goal of the following electron in-water-phantom cases is to verify the MU calculations from the TPS or a manual calculation against the measurements taken by the expert.

The treatment plans or manual calculations for the electron in-water phantom cases should be prepared in the usual way the institution uses the respective treatment machines. The time required to perform the verification measurements (as described in sections 13.2 and 14.2) is approximately 3 hours.

(a) Square beam under normal conditions:

(i) Use the 15 cm × 15 cm cone, at the standard treatment distance;
(ii) Choose the electron energy most frequently used in the institution's treatments;
(iii) With the treatment planning system:
— Generate an isodose distribution along a major axis including the central axis;
— Identify the depth of maximum dose, and the depth of 80% and 50% of the maximum dose (z_{max}, $z_{80,}$ and z_{50});
— Calculate the MU set to deliver 2 Gy at z_{max};
— Calculate the MU set to deliver 2 Gy at z_{90}.

(b) Cone ratio test under normal conditions:
(i) Use the institution's 10 cm × 10 cm cone at the standard treatment distance;
(ii) Use the same energy as used in case (a) above;
(iii) With the treatment planning system:
— Generate an isodose distribution along a major axis including the central axis;
— Identify the depth of maximum dose, and the depth of 80% and 50% of the maximum dose (zmax, z80, and z50);
— Calculate the MU set to deliver 2 Gy at zmax;
— Calculate the MU set to deliver 2 Gy at z90.

(c) Extended distance test:
(i) Use the 15 cm × 15 cm cone, at the standard treatment distance plus 10 cm (i.e. a 10 cm gap);
(ii) Use the same energy as used in case (a) above;
(iii) With the treatment planning system:
— Generate an isodose distribution along a major axis including the central axis;
— Identify the depth of maximum dose, and the depth of 80% and 50% of the maximum dose (zmax, z80, and z50);
— Calculate the MU set to deliver 2 Gy at zmax;
— Calculate the MU set to deliver 2 Gy at z90.

(d) Triangular-shaped field:
(i) Use the 10 cm × 10 cm cone, at the standard treatment distance;
(ii) Use the same energy as used in case (a) above;
(iii) Block one half of the field from along the diagonal (see Figure 13);
(iv) With the treatment planning system:
— Generate an isodose distribution in the plane passing through the irradiated corner perpendicular to the block (see Figure 13);
— Generate a beam's-eye view isodose distribution at zmax;
— Identify the depth of maximum dose, and the depth of 80% and 50% of the maximum dose (zmax, z80, and z50) in the centre of the treated beam;
— Calculate the MU set to deliver 2 Gy at zmax in the centre of the treated beam;
— Calculate the MU set to deliver 2 Gy at z90 in the centre of the treated beam.

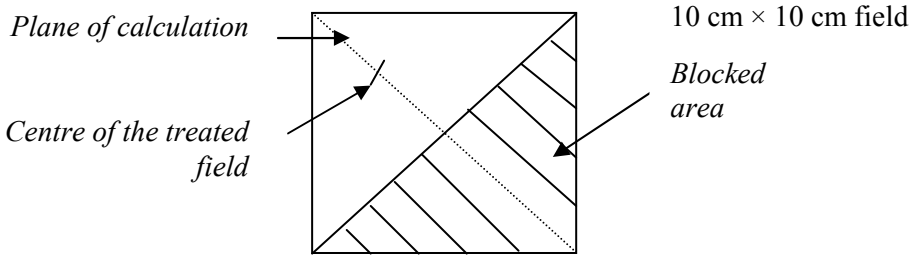


Figure 13. Geometry of triangular-shaped field.

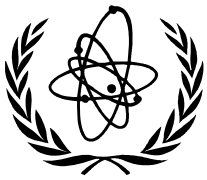
23.4. REVIEW THE RECORDS OF ALL ‘INVOLVED’ OR AFFECTED PATIENTS

If the on-site visit is due to a reported misadministration related to the treatment planning, where appropriate, the records of all ‘involved’ or affected patients should be studied. Simulator and portal images, computerized treatment plans and daily treatment records should be reviewed. The expert(s) will usually determine on a case-by-case basis, whether this review is to be carried out at the same time as the QA programme review discussed above, or following it. Serious effort should be expended to identify all patients who were adversely affected by any reported or identified incident, and the actual dose received by those patients should be determined.

Appendix I

FORMS FOR PART I

I.1. DIRAC QUESTIONNAIRE



INTERNATIONAL ATOMIC ENERGY AGENCY

WORLD HEALTH ORGANIZATION

International Directory of Radiotherapy Centres (DIRAC)

GENERAL INSTRUCTIONS FOR COMPLETING THE QUESTIONNAIRE:

Please enter data **separately** for each therapy unit or type of brachytherapy source on pages 2 and 3 of this form. **Photocopies should be used for additional units**.

Please fill in the questionnaire using capital letters or by typing. All questions must be answered. Where answers are not known or questions are not relevant to a particular machine, please indicate by writing **N/A** on the form.

II. ORGANIZATION OR INSTITUTION PROFILE

1. NAME: _____

2. ADDRESS: _____

_____

_____

City/Postal Zone: _____ Country: _____

Tel. No.: _____ Fax No.: _____

e-mail: _____

II. RESPONDENT'S PROFILE

1. NAME: _____

2. POSITION: _____

3. DEPARTMENT: _____

4. SIGNATURE AND DATE: _____

This form is to be returned by fax or mail as soon as possible to the following address:

Project DIRAC
Dosimetry and Medical Radiation Physics Section
Division of Human Health
International Atomic Energy Agency
P. O. Box 100
Wagramer Strasse 5
A-1400 Vienna, AUSTRIA

Fax: +43 1 26007 21662

For contact or answers:
Phone: +43 1 2600 21664
e-mail: DOSIMETRY@IAEA.ORG

EQUIPMENT FOR EXTERNAL BEAM RADIOTHERAPY	
Type of Machine	☐ Radionuclide Teletherapy ☐ X ray generator ☐ Clinical accelerator (electrons, photons) ☐ Other: _____
Make & Model (e.g. Gammatron 3, Siemens, Germany)	Model: _____ Manufacturer: _____
Machine Use	☐ Patient Treatment ☐ Research
Location of Machine (building, room, etc)	
Date of Installation:	yyyy/mm/dd: _____
Operational Status	☐ Operational ☐ Temporarily inoperable (e.g. awaiting repair, under construction, etc) ☐ Non-operational (e.g. decommissioned, source removed, etc)
Type of Radiation:	☐ X rays only ☐ ^{60}Co ☐ X rays + Electrons ☐ Other:

For accelerators/x ray generators only

Maximum energy: Photons: ☐ MV or ☐ kV Electrons or other: MeV

For Radionuclide units only

Maximum loading capacity of the unit (apparent activity)	_____ ☐ TBq or ☐ Ci		
Current source strength and date	_____ ☐ TBq or ☐ Ci	yyyy/mm/dd:	_____
Output in air, date of measurement	_____ ☐ Gy/min or ☐ RHM	yyyy/mm/dd:	_____
SSD and field size	Distance:_____cm	_____ cm x _____ cm	

Remarks or comments	

Please enter data **separately** for each therapy unit. **Photocopies must be used for additional units.**

EQUIPMENT FOR BRACHYTHERAPY	
Isotope	☐ Cs-137 ☐ Ra-226 ☐ Ir-192 ☐ Other: _____
Stored activity or source strength (select units. For short-lived isotopes, i.e. ^{192}Ir, give max. activity to be stored). On date:	☐ MBq ☐ mCi ☐ Ci ☐ μ Gy h^{-1}@1m ☐ mg-Ra eq ☐ Other: _____ yyyy/mm/dd: _____
Sources used for	☐ Patient Treatment ☐ Research
If patient treatment, applications are	☐ Intracavitary ☐ Interstitial ☐ Other: _____ ☐ Manual ☐ Manual afterloading ☐ Remote afterloading
Type of sources:	☐ Tube ☐ Mini-cylinder ☐ Train of sources ☐ Needle ☐ Pellet ☐ Eye applicator ☐ Wire ☐ Seed ☐ Other: _____
Operational Status	☐ Operational ☐ Temporarily inoperable (e.g. awaiting repair, under construction, etc) ☐ Non-operational (e.g. decommissioned, sources removed, etc)
For Remote Afterloader only:	
Make & Model	Model: _____ Manufacturer: _____
Mode of operation	☐ LDR (0.4-2 Gy/h approx.) ☐ MDR (2-12 Gy/h approx.) ☐ HDR (>12Gy/h)
Location of Machine (building, room, etc)	
Date of Installation:	yyyy/mm/dd: _____
Remarks or comments	

Please enter data **separately** for each brachytherapy unit. **Photocopies must be used for additional units.**

Equipment and Staff strength		
Equipment	Make & Model (remarks if any)	Date of last calibration or installation yyyy/mm/dd
Dosimetry: ☐ Reference thimble ionization chamber(s) ☐ Plane-parallel ionization chamber(s) ☐ Well-type ionization chamber ☐ Electrometer(s) ☐ Others	_____ _____ _____ _____	_____ _____ _____ _____
Monitoring Instruments ☐ Survey meter ☐ Pocket Dosimeters ☐ Others	_____ _____	_____ _____
Beam Analyzer System ☐ Manual ☐ Computer assisted	_____	_____
Treatment Planning ☐ Manual ☐ Computerized	_____	_____ _____
Radiographic Facility: ☐ Simulator ☐ CT ☐ Others	_____ _____	_____ _____ _____

STAFF STRENGTH

No. of Radiation Oncologists: _____ No. of Medical Physicists: _____ No. of RT technicians (radiographers, technologists, dosimetrists, etc): _____

Approximate No. of patients treated per year with:	Teletherapy & Brachytherapy: _____	Teletherapy alone: _____	Brachytherapy alone: _____

Please use **photocopies if necessary**.

I.2. INSTITUTION CONTACT LIST

This appendix is intended to provide the IAEA and its expert(s) with information concerning the staff, equipment and procedures at the institution to be visited.

Organization or Institution:

_____

Address

_____

_____

_____

Radiation Oncologist

Name: _____

Position: _____

Medical Radiation Physicist

Name: _____

Position: _____

Department Administrator

Name: _____

Position: _____

Dosimetrist (when needed)

Name: _____

Position: _____

Radiographer/Radiotherapy Technologist (when needed)

Name: _____

Position: _____

I.3. ON-SITE VISIT EXPERT CHECKLIST OF ACTIVITIES

Tick each item, when check completed, indicate N/A if not applicable

Interviews with personnel

- ☐ Medical Physicist
- ☐ Radiation Oncologist
- ☐ Department Administrator
- ☐ Dosimetrist (when needed)
- ☐ Radiotherapy Technologist (when needed)

Review institution's Quality Assurance Programme

- ☐ Commissioning and QA data for the treatment planning system
  - ☐ Original beam data obtained during commissioning
  - ☐ Periodic quality assurance measurements or calculations
- ☐ Overall QA Programme; focus on aspects that might bear on reported problems
- ☐ QA of individual patient treatments (including monitor/time set
  - ☐ Initiation of treatment
  - ☐ Periodic checks
  - ☐ Treatment summary

Review and compare any measurements taken and/or calculations done by the institution to resolve the present situation.

- ☐ Measurements: _____
- Comments: _____
- ☐ Calculations: _____
- Comments: _____

Evaluate anatomical benchmark cases

- ☐ Complete cases with IAEA software
- ☐ Compare with institution's cases
- ☐ Special calculations done
- Comments: _____
  _____

Evaluate institution's dosimetry data

- ☐ Obtain and compare institution's tabular data with the TPS data
  - ☐ Depth dose data
  - ☐ Field size dependence
  - ☐ Off-axis data
  - ☐ Wedges
- ☐ Compare institution's data with the IAEA 'generic' data
- Comments: _____
  _____

Confirm institution's dosimetry data by ionization chamber measurements

- ☐ Output under reference conditions
- ☐ In-water benchmark cases
  - ☐ Measured
  - ☐ Compared with institution's data
- ☐ Special measurements taken _____
- ☐ Comments: _____

Other measurements:

- ☐ Institution's data are sufficiently close to 'generic' data, no measurements made to verify relative dosimetry data
- ☐ Additional measurements taken
  - ☐ Field size dependence
  - ☐ Depth dose
  - ☐ Off-axis factors
  - ☐ Wedge factors

Identify and review dosimetry for any 'involved' patients

- ☐ Identify all 'involved' patients
- ☐ Review dosimetry on all such patients

Exit Interview

- ☐ Interviews held
- ☐ Interview form completed

Education efforts

- ☐ All recommendations explained to physicist clearly
- ☐ Clinical implications of recommended changes discussed and explained clearly to
  - ☐ Physicist
  - ☐ Oncologist
  - ☐ Dosimetrists and radiotherapy technologists (when needed)
  - ☐ Management

Important information copied and presented to institution (sign/initial and date all)

- ☐ Expert's measurement data and report
- ☐ Expert's calculations
- ☐ Expert's benchmark cases
- ☐ Exit interview form
- ☐ Recommendations

End-of-Mission report

- ☐ Draft prepared, presented to IAEA _____
- ☐ Final report prepared, signed and submitted _____

I.4. END-OF-MISSION REPORT EXPERT'S CHECKLIST

☐ Draft prepared, circulated to expert team Date: ___/____/____

☐ Final report prepared, signed, submitted to the IAEA Date: ___/____/____

Report content checklist

- ☐ Institution name, mission dates, expert(s) involved.
- ☐ Reason for on-site visit, nature of request, scope of visit.
- ☐ The methods used in the visit, how problems were investigated.
- ☐ Information passed in the exit interview (see appendix IV.7, expert's checklist for exit interview).
- ☐ Information passed to and left with the institution:
  - ☐ Calculations, measurements (signed and dated)
  - ☐ All identified causes of and contributing factors to any observed problems
  - ☐ The inter-relationships between the various causes and factors

Recommendations made to the institution

- ☐ Prevention of the identified problems in the future
- ☐ Improvement of the QA programme
- ☐ Any education and training requirements identified
- ☐ Any structure, resource or communication requirements identified

Explanations of the reasons for the recommendations

- ☐ Explanation of the consequences of the recommendations, particularly where they demand a change of data or procedures, or where they impact on the outcome of patient treatment.
- ☐ A strong recommendation that changes should not be implemented on the basis of the IAEA expert(s) recommendations alone. They should only be introduced after the institution has determined that the given recommendations are necessary, justified and acceptable. The implementation of the recommendations should be planned carefully with the proper training of the institution's personnel.
- ☐ Methods of reporting the findings and disseminating any lessons drawn more widely where appropriate:
  - ☐ Report to the equipment manufacturers
  - ☐ Report to other users of similar equipment
  - ☐ General report to the radiotherapy and the medical physics community
  - ☐ Feedback to the IAEA on the content and conduct of the visit
  - ☐ Recommendations which might be useful for expert(s) on any future visits

Appendix II

FORMS FOR PART II

II.1. A TYPICAL ON-SITE DOSIMETRY REVIEW VISIT

As a consequence of the request to the IAEA or because of a persisting TLD deviation, the IAEA will conduct an on-site review at this radiotherapy centre. In general this visit will attempt to trace the origin of the TLD deviation or other discrepancy in radiotherapy dosimetry. This review will be undertaken by expert(s) sent by the IAEA. The information contained in this publication is intended to help to organize the visit efficiently and to minimize the disturbances it might cause in the routine work of the visited institution.

The review begins typically with an interview of the physicist (and other appropriate staff) to determine clinical calculation techniques and to provide other relevant information. This interview usually lasts one to two hours. The experts will then review individual treatment records of several patients presently under treatment, to familiarize themselves with treatment techniques and to verify that the dosimetry data being reviewed are those used routinely in the clinic.

The measurements will be taken at the end of the day, without need to interrupt patient treatment. Safety and mechanical checks will be done on the treatment units. In addition, the local ionization chamber, barometer and thermometer will be compared with the IAEA expert's equipment. Subsequently the local physicist will be asked to proceed with the calibration of the beam following the usual methodology. The local calibration will be followed immediately by the expert's measurements, following the IAEA TRS 398 Code of Practice. The local staff will be requested to calculate the treatment time to deliver a dose of 2 Gy in a number of simple clinical set-ups, involving different field sizes, depths and wedges. These calculations will be verified by the expert, using ionization chamber measurements. Finally, the expert will check some clinical dosimetry data (PDDs, output factors, wedge transmission factors, etc.) that is routinely used in the clinic. On the last day of the visit the local staff will be asked to irradiate TLDs according to the standard IAEA procedure.

The expert will work 5-6 hours each evening and efforts to adjust the working schedule of the local personnel accordingly will be necessary.

On the last day an exit interview will be held where the expert(s) will present a detailed report to the physicist, radiation oncologist and other interested parties. This will encompass a discussion of the results of the measurements and any questions or problems encountered in the patient chart or dosimetry reviews. Where appropriate, the expert will also tender preliminary recommendations for dosimetry changes to help the institution to improve the situation.

The first draft of the expert(s) report detailing the results of the measurements will be given to the physicist during the exit interview. After the visit all calculations will be rechecked carefully and a final report will then be sent to the physicist and radiation oncologist.

A few points need to be emphasized:

(a) This on-site review is at the request by the radiotherapy centre or as a consequence of a persisting deviation observed in the mailed TLD dosimetry.
(b) There is no need to reschedule patients; before starting the measurements on the therapy units the expert will wait until all patients have been treated.
(c) A physicist or another staff knowledgeable in calibration and treatment techniques, will need to stay with the expert during the measurement sessions to answer any questions and to run the machines.
(d) The dosimetry system used for calibration must be available for comparison with the expert's system and for beam calibration according to the usual methodology. The expert will also perform barometer and thermometer comparisons.
(e) Copies of the records need to be made available at the first interview meeting. These must include the following data:
(f) The calibration certificate of the local dosimetry system;

(g) For each megavoltage unit, photon beams:
(h) Output as a function of field size;
(i) Central-axis depth dose data such as PDD, TMR, TAR, etc.;
(j) Wedge isodose distributions for 10 cm × 10 cm fields, or maximum width × 10 cm long if maximum width is less than 10 cm;
(k) Clinically-used tray and wedge transmission factors.
(l) For each megavoltage unit, electron beams:
(m) Cone ratios;
(n) Central axis depth dose data;

— Extended treatment distance data (virtual source distance or VSD, gap correction, etc.).

The IAEA requests the cooperation of the local staff in helping to explain the observed TLD discrepancy and in maintaining high quality radiotherapy standards.

II.2. STAFF INTERVIEW DATA COLLECTION FORMS

II.2.1. Instrumentation

1. INSTITUTION: _____ Date:___/___/___

Expert: _____

Physicists interviewed: _____

2. DOSIMETER SYSTEM USED FOR CALIBRATION

Chamber 1 model: _____ Serial No. _____

Electrometer model _____ Serial No. _____

Electrometer settings _____

Calibration coefficient _____

Last calibrated by: _____ Date: ___/___/___

Chamber 2 model: _____ Serial No. _____

Electrometer model: _____ Serial No. _____

Electrometer settings: _____

Calibration coefficient: _____

Last calibrated by: _____ Date: ___/___/___

3. CONSTANCY CHECKS

How is the sensitivity of your dosimeter systems monitored?

☐ ^{60}Co irradiator ☐ ^{90}Sr ☐ Other

Do you apply a decay correction? ☐ Yes ☐ No

If yes, what was the half-life value used? _____

How frequently is this check done? _____

Do you use the constancy check readings to correct the calibration? ☐ Yes ☐ No

When was leakage last checked? _____

4. TEMPERATURE AND PRESSURE

Type of barometer: ☐ mercury ☐ aneroid ☐ other _____

If mercury, is temperature correction applied? ☐ Yes ☐ No

If mercury, is gravity correction applied? ☐ Yes ☐ No

Is barometer accuracy verified periodically? ☐ Yes ☐ No

Describe method: _____

Type of thermometer: ☐ mercury ☐ alcohol ☐ thermocouple ☐ other

II.2.2. ^{60}Co unit data

1. INSTITUTION: _____ Machine: _____

Manufacturer: _____ Model: _____

Date machine brought into clinical use: ___/___/___

Date present source installed: ___/___/___

Isocentric? ☐ Yes ☐ No if yes, SAD _____ cm

Nominal treatment distance: _____ cm

Source diameter: _____ cm

2. ACCESSORIES

Wedges available: Manual? ☐ Yes ☐ No

If manual, fixed position?: ☐ Yes ☐ No

Internal? ☐ Yes ☐ No

List of wedges: _____

Other accessories available: Blocks? ☐ Yes ☐ No

Method of fixation: _____

Source to tray distance: _____

Size of blocks used: _____

3. BEAM OUTPUT DETERMINATION

Dosimetry protocol: _____

Set-up: ___ cm x ___ cm, ___ cm ☐ SSD or ☐ SAD Trimmers: ___ cm

Ionization chamber measurements: ☐ in air ☐ in phantom

Gantry angle: _____ º

Source to chamber distance: ___ cm

Depth of ☐ chamber's centre: ___ cm or ☐ effective point of measurement: ___ cm

Phantom: material _____ density _____ g/cm^3

Time set: ☐ minutes and seconds or ☐ hundredths of a minute

Shutter correction: _____ ☐ seconds or ☐ hundredths of a minute

Net time: ☐ greater or ☐ less than set time

Used during: ☐ output calibration ☐ patient treatment ☐ TLD irradiation

FACTORS USED TO CALCULATE ABSORBED DOSE RATE (Gy/min) FROM DOSIMETER READING (give equation, define all factors and give numerical values; if a standard form is used, attach a copy. If a 'consolidated factor' is used (i.e. if all correction factors are included in one unique factor), attach copy of its calculation.)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

4. DOSE SPECIFICATION INFORMATION

Reference beam output as stated for the clinical data:

☐ Water ☐ Other _____

☐ dmax

at _____ cm ☐ SAD ☐ SSD

Comment if necessary _____

_____

_____

5. QUALITY ASSURANCE INFORMATION

How often is the calibration done? _____

How often is dose rate updated for decay? _____

What method of decay calculation is used? _____

Distance from isocentre to the reference point on machine: _____

Reference point: _____

Distance to isocentre: _____ cm

How is this distance determined? _____

How is treatment distance determined for patients?

☐ Using ODI ☐ Using lasers ☐ Other _____

How often are ODI and lasers compared with the mechanical indicator? _____

Who is responsible for QA checks following machine repair/maintenance? _____

II.2.3. Accelerator data (photons)

1. INSTITUTION: _____ Machine: _____

Manufacturer: _____ Model: _____

Date machine brought into clinical use: ___/___/___

Nominal treatment distance: ____ cm

Photon energies available: _____ MV

Method of specifying beam quality: _____

Quality index: _____

Other: _____

2. OUTPUT DETERMINATION

Dosimetry protocol: _____

Set-up: ____ cm x ___ cm, ____ cm ☐ SSD or ☐ SAD

Ionization measurements: ☐ in air ☐ in phantom

Gantry angle: ___ °

Source to chamber distance: ____ cm

Depth of ☐ chamber's centre: ___ cm or ☐ effective point of measurement: ___ cm

Phantom material: _____ density: _____ g/cm^3

FACTORS USED TO CALCULATE ABSORBED DOSE RATE (Gy/mu) FROM DOSIMETER READING (give equation, define all factors and give numerical values; attach extra sheet if necessary; attach detailed calculation from most recent annual calibration.)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

3. DOSE SPECIFICATION INFORMATION

Reference beam output as stated for the clinical data:

☐ Water ☐ Other medium: _____

☐ d_{max} ☐ Other depth: _____

At _____ cm ☐ SAD ☐ SSD

Comment, if necessary: _____

_____

_____

4. QUALITY ASSURANCE INFORMATION

How often is the calibration done? _____

How often is beam output checked? _____

Method: _____

Is the output readjusted? ☐ Yes ☐ No

What are the criteria for readjusting the output?

☐ >2% ☐ >3% ☐ >5% ☐ Other _____

If output is allowed to float, what are the criteria for adjusting the monitor set for the patient?

☐ >2% ☐ >3% ☐ >5% ☐ Other _____

Distance from isocentre to reference point on machine:

Reference point: _____

Distance to isocentre: _____ cm

How is this distance determined? _____

How is treatment distance determined for patients? _____

☐ Using ODI ☐ Using lasers ☐ Other _____

How often are ODI and lasers compared with a mechanical indicator? _____

Who is responsible for QA checks following machine repair/maintenance? _____

II.2.4. Accelerator data (electrons)

1. INSTITUTION _____ Machine: _____

Manufacturer: _____ Model: _____

Date machine brought into clinical use: ___/___/___

Nominal treatment distance: _____ cm

Electron energies available: ___/___/___/___/___/___/___/___/ nominal MeV

Method of specifying beam quality: _____

Quality index (R_{50}): ___/___/___/___/___/___/___/___/ cm

Measurement depth: ___/___/___/___/___/___/___/___/ cm

2. OUTPUT DETERMINATION

Dosimetry protocol: _____

Set-up: ____ cm x ___ cm cone/field at _____ cm SSD

Ionization measurements: ☐ in air ☐ in phantom

Phantom material: ☐ H_2O ☐ Other material Density: _____ g/cm^3

Gantry angle: ____ °

FACTORS USED TO CALCULATE ABSORBED DOSE RATE (Gy/mu) FROM DOSIMETER READING (give equation, define all factors and give numerical values; attach extra sheet if necessary. Attach detailed calculation from most recent annual calibration.)

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

3. DOSE SPECIFICATION INFORMATION

Reference beam output as stated for the clinical data:

☐ Water ☐ Other, specify: _____

☐ d_{max} ☐ Other depth, specify: _____

at _____ cm ☐ SAD ☐ SSD

Comment if necessary: _____

_____

_____

4. QUALITY ASSURANCE INFORMATION

How often is the calibration verified? _____

How often is beam output checked? _____

Method: _____

Is the output readjusted? ☐ Yes ☐ No

What are the criteria for readjusting the output?

☐ >2% ☐ >3% ☐ >5% ☐ Other _____

If output is allowed to float, what are the criteria for adjusting the monitor set for the patient?

☐ >2% ☐ >3% ☐ >5% ☐ Other _____

Distance from isocentre to reference point on machine:

Reference point: _____

Distance to isocentre: _____ cm

How is this distance determined? _____

How is treatment distance determined for patients? _____

☐ Using ODI ☐ Using lasers ☐ Other

How often are ODI and lasers compared with the mechanical indicator?

_____

II.2.5. Clinical dosimetry

1. TREATMENT TECHNIQUES USED

Photons

Fixed SSD? Yes ☐ No ☐ If yes: ____ % of total number of treatments

Isocentric? Yes ☐ No ☐ If yes: ____ % of total number of treatments

Special techniques? Yes ☐ No ☐ Description: _____

Electrons

Fixed SSD? Yes ☐ No ☐ If yes: ____ % of total number of treatments

Extended distances? Yes ☐ No ☐ If yes: ____ typical distance

Special techniques: Yes ☐ No ☐ Description: _____

2. METHOD OF MONITOR UNIT / MINUTES SET CALCULATION

Photons:	Electrons:
☐ Treatment Planning System	☐ Treatment Planning System
☐ In-house software	☐ In-house software
☐ Manual calculation	☐ Manual calculation
☐ Other: _____	☐ Other _____

Comments, if any _____

_____

3. BASIC DOSIMETRY DATA FOR PHOTONS

Depth dose tables? Yes ☐ No ☐

Comments: _____

_____

TPR or TMR tables? Yes ☐ No ☐

Comments: _____

_____

Equivalent square tables? Yes ☐ No ☐

Comments: _____

_____

Beam output variation with field size? Yes ☐ No ☐

Comments: _____

_____

Wedge transmission factors? Yes ☐ No ☐

Comments: _____

_____

Tray transmission factors? Yes ☐ No ☐

Comments: _____

_____

4. DOSE PRESCRIPTION FOR PATIENTS

☐ d_{max}

☐ Isocentre

☐ Depth of target volume

☐ Other: _____

5. BASIC DOSIMETRY DATA FOR ELECTRONS

Depth dose data tables? Yes ☐ No ☐

Comments: _____

_____

Equivalent square tables? Yes ☐ No ☐

Comments: _____

_____

Electron cone ratios? Yes ☐ No ☐

Comments: _____

_____

For small field sizes, how is beam output determined?

☐ Measurement ☐ Other, specify: _____

For treatments at distances other than the nominal distance, how is the dose rate determined?

☐ Inverse square correction ☐ Nominal SSD ☐ Virtual Source Distance

☐ Other, specify: _____

6. DOSE PRESCRIPTION FOR PATIENTS

☐ d_{max}

☐ Other, specify: _____

II.2.6. TLD discrepancy interview record

Institution: _____ Date ___/___/___

Expert: _____

Treatment unit: _____

Physicist Interviewed: _____

Any changes in dosimetry practices since TLD irradiation? Yes ☐ No ☐

Possibilities, if yes

New physicist: _____

Qualifications: _____

Do routine checks show any change or trend? Yes ☐ No ☐ _____

Has ^{60}Co source changed? Yes ☐ No ☐ _____

Major servicing of therapy unit? Yes ☐ No ☐ _____

Any operating problems with therapy unit? Yes ☐ No ☐ _____

Any problems with dosimetry system
(e.g. chamber, electrometer, cables, etc.) ? Yes ☐ No ☐

How was TLD set up? Isocentric ☐ Fixed SSD ☐

Distance set to water surface: _____

Was water set to the top of the TLD holder? Yes ☐ No ☐

Distance set with:

☐ laser ☐ optical distance indicator ☐ mechanical distance indicator

Field size used _____ at a source distance of _____ cm

Who irradiated TLDs? _____

Is it possible that an incorrect energy was set? Yes ☐ No ☐

Is it possible that an incorrect time / monitor unit was set? Yes ☐ No ☐

NOTE: In order to look for the possibility of error ask the physicist to set up the TLD holder as was done for the TLD irradiation,

Other comments: _____

_____

_____

_____

_____

Was output measured prior to irradiating TLDs? Yes ☐ No ☐

If yes, does the dose delivered to TLDs reflect this? Yes ☐ No ☐

TLD history

Is this the first TLD audit? Yes ☐ No ☐

How do the recent results relate to prior TLD audits for this beam? _____

_____

_____

_____

How do the TLD results relate with other beams checked in the same centre? _____

_____

_____

_____

_____

Other comments: _____

_____

_____

_____

_____

II.3. MEASUREMENT RECORDS AND FORMS FOR DOSIMETRY

II.3.1. Safety and mechanical measurements

Institution: _____ Date ___/___/___

Expert: _____

Treatment unit: _____

Physicist Interviewed: _____

1. SAFETY DEVICES

Door interlock installed?	Yes ☐	No ☐
Door interlock operational?	Yes ☐	No ☐
Radiation warning light installed?	Yes ☐	No ☐
Radiation warning light operational?	Yes ☐	No ☐
Emergency switches installed?	Yes ☐	No ☐
Emergency switches operational?	Yes ☐	No ☐
Manual means to close the machine down?	Yes ☐	No ☐
Measured exposure at the machine console within the room in beam-on condition:	_____ μSv/h	
Maximum measured exposure (at 1 m from source) within the room in beam-off condition:	_____ μSv/h	

2. MECHANICAL TESTS (acceptance level 3 mm for all measurements)

Collimator rotation possible?	Yes ☐	No ☐
Collimator angle indicator acceptable?	Yes ☐	No ☐
Gantry rotation possible?	Yes ☐	No ☐
Gantry angle indicator acceptable?	Yes ☐	No ☐
Distance from isocentre to bottom surface of tray holder:	_____ cm	
Diameter of mechanical isocentre:	_____ mm	
Field size adjustable?	Yes ☐	No ☐
Deviation from indicated value:	_____ mm	
Light field available?	Yes ☐	No ☐

Congruence of light/radiation field:	_____ mm
Lasers available?	Yes ☐ No ☐
Deviation of laser:	_____ mm
Optical distance indicator available?	Yes ☐ No ☐
Deviation at isocentre:	_____ mm
Deviation at +10 cm:	_____ mm
Deviation at –10 cm:	_____ mm
Mechanical distance indicator (MDI) available?	Yes ☐ No ☐
If yes, agreement between MDI and isocentre:	_____ mm
Is there a dedicated fixed treatment couch?	Yes ☐ No ☐
Table top movements; scale available?	Yes ☐ No ☐
Vertical movements, deviation at –10 cm:	_____ mm
Vertical movements, deviation at +10 cm:	_____ mm
Lateral movements, deviation at –10 cm:	_____ mm
Lateral movements, deviation at +10 cm:	_____ mm
Longitudinal movements, deviation at –10 cm:	_____ mm
Longitudinal movements, deviation at +10 cm:	_____ mm
Fulfils the mechanical requirement? (if No, comment below)	Yes ☐ No ☐

3. COMMENTS: _____

_____

_____

_____

_____

_____

II.3.2. Dosimetry equipment comparison

Institution: _____ Date ___/___/___

Expert: _____

Treatment unit: _____

Physicist Interviewed: _____

1. BAROMETER AND THERMOMETER COMPARISON

Acceptance criteria: temperature 0.5°C, pressure 1%

	Unit	Expert	Institution	Expert/Inst.	Within criteria?
Pressure:	_____	_____	_____	_____	Yes ☐ No ☐
Temperature:	_____	_____	_____	_____	Yes ☐ No ☐

Comments: _____

_____

_____

_____

2. CONSTANCY CHECK OF THE LOCAL DOSIMETRY SYSTEM

Institution expected reading: _____

Expert reading: _____ within 2% Yes ☐ No ☐

3. ION CHAMBER COMPARISON

☐ In air (^{60}Co beam)

☐ In water (expert's phantom)

☐ In water (institution's phantom, 5 cm depth)

Other: _____

4. CALIBRATION COEFFICIENTS

Reported institution's chamber calibration coefficient

☐ N_X _____ ☐ N_K _____ ☐ $N_{D,w}$ _____

Reference temperature: _____ Reference pressure: _____

Expert chamber calibration coefficient

☐ N_K _____ ☐ $N_{D,w}$ _____

T = 20°C, p. = 101.3 kPa

Calculate the calibration coefficient for the institution's chamber

_____

_____

_____

II.3.3. Dose measurement record (photons and electrons)

Date: _____ Time: _____ Institution: _____ Therapy Unit: _____

IAEA Expert: _____

Electrometer: _____ Serial # _____

Chamber #1: _____ Serial #: _____ N_K _____ $N_{D,w}$ _____

Chamber #2: _____ Serial #: _____ N_K _____ $N_{D,w}$ _____

Electrometer range: _____ Reference temperature and pressure: 20°C, 101.3 kPa (760 mm Hg)

Irradiation Conditions Phantom, Chamber, Gantry, SSD/SAD, etc.	Dist. (cm)	Field Size (cm × cm)	Depth (cm)	Temp. Press.	Irrad. Time	Elect. Scale	Reading (M)	Mean reading $\bar{M}$	Notes Bias voltage, wedge, tray, etc.

II.3.4. Photon beam output reporting form

Expert: _____ Date: ___/___/___

Institution: _____

Treatment unit: _____ Photon Energy: _____ MV

Institution's staff: _____

1. INITIAL DOSE RATE MEASUREMENT BY THE INSTITUTION'S STAFF

Conditions: field 10 cm × 10 cm, at ___ cm, ☐ SSD ☐ SAD depth = ___ cm

Date: _____ Dose rate: _____

Taken according to TRS 277 ☐ TRS 398 ☐ other ☐

Dose rate converted to TRS 398

2. DOSE RATE MEASUREMENT BY THE IAEA EXPERT (TRS 398)

Conditions: field 10 cm × 10 cm, at ___ cm, ☐ SSD ☐ SAD depth = ____ cm

Date: _____ Dose rate: _____

Ratio (Expert/Institution) Value: _____

Ratio within the 3% criterion? ☐ Yes ☐ No

Reason for the deviation, if any:

_____

_____

_____

_____

3. FINAL DOSE RATE MEASUREMENT BY THE INSTITUTION'S STAFF

Expert: Institution: Expert/Institution:

_____ _____ _____

4. COMMENTS: _____

_____

_____

_____

_____

_____

II.3.5. Electron beam output reporting form

Institution: _____ Date: ___/___/___

Expert: _____

Treatment unit: _____ Electron energy: _____ MeV

Institution's staff: _____

1. INITIAL DOSE RATE MEASUREMENT BY THE INSTITUTION'S STAFF

Conditions: cone/field ____ cm × _____ cm, SSD = ____ cm, depth = ___ cm

Date: _____ Dose rate _____

Taken according to TRS 277 ☐ TRS 381 ☐ TRS 398 ☐ other ☐

Dose rate converted to TRS 398: _____

2. DOSE RATE MEASUREMENT BY THE IAEA EXPERT (TRS 398)

Conditions: cone/field ____ cm × ____ cm, SSD = ____ cm, depth = ____ cm

Date: _____ Dose rate: _____

Ratio (Expert/Institution): _____

Ratio within the 3% criterion? ☐ Yes ☐ No

Reason for the deviation, if any _____

_____

_____

_____

3. FINAL DOSE RATE MEASUREMENT BY THE INSTITUTION'S STAFF

Expert:	Institution:	Expert/Institution:
_____	_____	_____

Comments: _____

_____

_____

_____

_____

_____

II.3.6. Clinical Dosimetry test #____

Institution: _____ Date: ___/___/___

Expert: _____

Treatment unit: _____

Institution's staff: _____

Test for: ☐ photons ☐ electrons _____

_____

Photons: _____ MV

SSD ☐ SAD ☐ _____ cm

Field Size: _____ cm × _____ cm

Depth: _____ cm

Wedge? ☐ Yes ☐ No

If yes, wedge angle: _____ ; reference (in-house designation) _____

Electrons: _____ MeV

SSD _____ cm

Cone/Field Size: _____ cm × _____ cm

Depth: _____ cm

Monitor units / time to deliver 2 Gy at the depth of interest

Expert's calculation	Institution's calculation	Expert's measurements
_____	_____	_____
_____	_____	_____
_____	_____	_____

Expert's calculation: _____

_____

_____

Comments on the results: _____

_____

_____

_____

_____

II.4. TEMPLATE OF THE REPORT ON A DOSIMETRY REVIEW VISIT TO A RADIOTHERAPY HOSPITAL

REPORT

ON A DOSIMETRY REVIEW VISIT

TO A RADIOTHERAPY HOSPITAL

Institution visited: _____

_____

_____

Mission dates: _____

Expert: _____

Signature: _____

Restricted

1. EXPERT'S REVIEW OF THE INSTITUTION'S DOSIMETRY PRACTICES

The dosimetry review on-site visit organized by the International Atomic Energy Agency is the result of a persisting discrepancy which occurred in the IAEA/WHO TLD postal dose audit programme at the radiotherapy hospital. The visit was conducted by an expert recruited by the IAEA to resolve the TLD discrepancy and to assist the institution in clinical dosimetry practices. The expert used the IAEA dosimetry protocol for the calibration of high energy photon beams recommended in the Technical Reports Series (TRS) No. 398 [1] published by the IAEA. The expert refers to IAEA-TECDOC-1040 [2] and the Basic Safety Standards [3] for safety, mechanical and other quality assurance measurements.

The results of the IAEA expert's review of the institution's dosimetry practices resulted in a set of recommendations aimed at the improvement of the radiotherapy standards at the institution. The resulting changes should not be implemented on the basis of the IAEA expert's recommendations alone. They should be introduced only after the institution has determined that these changes are necessary, justified and acceptable. Their implementation should be carefully planned with the proper training of the institution's personnel. The details of the expert's measurements and calculations forms are attached to this report.

2. INSTITUTION'S RADIATION AND TREATMENT PLANNING EQUIPMENT

The _____ treatment unit, with a _____ nominal photon energy, began clinical use in _____. The nominal treatment distance is _____ cm. If the unit uses ^{60}Co, the source was last replaced on _____.

The institution's treatment planning system is a _____ manufactured by _____. The software version at the time of the IAEA expert's visit was _____.

3. DOSIMETRY SYSTEM COMPARISON

3.1. Barometer and thermometer comparison

	Expert	Institution	Expert/Institution
Pressure (kPA)	_____	_____	_____
Temperature (°C)	_____	_____	_____
P_{TP}	_____	_____	_____

The institution's readings of pressure were obtained using a _____ barometer. The institution's readings of temperatures was obtained using a _____ thermometer.

3.2. Dosimetry system comparison

A comparison of the institution's dosimetry system with the expert's dosimetry system was made by sequential irradiation at the centre of a _____ cm × _____ cm field in the _____ beam of the _____ treatment unit at _____ cm ☐ SSD ☐ SAD in _____ ☐ air ☐ water. For the measurement in water, the depth of measurement was _____ g/cm^2 at the expert's water phantom.

Expert's coefficient (Gy/scale unit)	Institution's factor (Gy/scale unit)	Expert/Institution
_____	_____	_____

The reference temperature and pressure are: 20°C and 101.3 kPA, respectively.

3. RESULTS OF DOSIMETRY PARAMETERS MEASUREMENTS

3.1. ^{60}Co gamma rays

Treatment unit: _____

Beam output

The absorbed dose rate to water at _____cm depth in full phantom, at ____ cm ☐ SSD ☐ SAD, gantry vertical on the date _____

Field Size (cm × cm)	Expert (Gy/min)	Institution (Gy/min)	Expert/Inst.
10 × 10	_____	_____	_____

The expert determined the shutter correction to be _____ min. The institution's measured one is _____ min.

Output factors

The output variation with a field size at a depth of d_{max} = 0.5 cm at ____ cm ☐ SSD ☐ SAD in a full-scatter phantom used by the expert as a reference data set, are derived from the standard data provided by the IAEA.

Field Size (cm × cm)	Expert Output factor	Institution Output factor	Expert/Inst.
5 × 5	_____	_____	_____
10 × 10	_____	_____	_____
15 × 15	_____	_____	_____
20 × 20	_____	_____	_____

Depth dose data

The institution uses its own measured ☐ or published ☐ central axis depth dose data from _____. The expert uses the depth dose data from the BJR-25 [4] in reporting absorbed dose for ^{60}Co units or specific standard data from _____ depending on the make/model of the treatment unit.

Depth (cm × cm)	Expert %DD	Institution %DD	Expert/Inst.
5 cm × 5 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____
20	_____	_____	_____
10 cm × 10 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____

Depth (cm × cm)	Expert %DD	Institution %DD	Expert/Inst.
20	_____	_____	_____
20 cm × 20 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____
20	_____	_____	_____

Wedge and tray transmission

Wedge and tray transmission for a 10 cm × 10 cm field at 5 cm depth in water, unless otherwise indicated, _____ cm, ☐ SSD ☐ SAD.

Description	Expert	Institution	Expert/Inst.
_____ tray	_____	_____	_____
_____ tray	_____	_____	_____
_____ tray	_____	_____	_____

Wedges field, depth	Expert	Institution	Expert/Inst.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Additional measurements

Dose rates for a 10 cm × 10 cm field at _____cm depth in water for the following non-standard SSDs.

SSD	Depth (cm)	Expert (cGy/min)	Institution (cGy/min)	Expert /Inst.
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Wedge profile measurements

Wedge profile measurements were taken in the expert's NE 2528 water phantom at ____ cm ☐ SSD ☐ SAD at a 5 cm depth, 2 cm toward the heel and toe of the wedge with respect to the central axis.

Description	Expert*	Institution*	Expert/Inst.
towards heel	_____	_____	_____
towards toe	_____	_____	_____

*indicated ratios are the ratios of the values off-axis to the value on the central axis.

Safety and mechanical measurements
The results of safety and mechanical measurements are in the attachment _____.

Clinical dosimetry measurements
The results of clinical dosimetry measurements are in the attachment _____.

3.2. High-energy X rays from a linear accelerator

Treatment unit: _____

Beam quality: _____

Beam output
The absorbed dose rate to water at _____cm depth in full phantom, at ____ cm ☐ SSD ☐ SAD as measured with the mechanical distance indicator, gantry vertical.

Field Size (cm × cm)	Expert (Gy/MU)	Institution (Gy/MU)	Expert/Inst.
10 × 10	_____	_____	_____

Output factors
The output variation with field size at a depth of d_{max} ____ cm at ____ cm ☐ SSD ☐ SAD in a full-scatter phantom used by the expert as a reference data set, is derived from the standard data provided by the IAEA.

Field Size (cm × cm)	Expert Output factor	Institution Output factor	Expert/Inst.
5 × 5	_____	_____	_____
10 × 10	_____	_____	_____
15 × 15	_____	_____	_____
20 × 20	_____	_____	_____

Depth dose data
The institution uses its own measured ☐ or published ☐ central axis depth dose data from _____. The expert uses the depth dose data from the BJR-25 [4] in reporting absorbed dose for ^{60}Co units or specific standard data from _____ depending on the make/model of the treatment unit.

Depth (cm × cm)	Expert %DD	Institution %DD	Expert/Inst.
5 cm × 5 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____
20	_____	_____	_____
10 cm × 10 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____
20	_____	_____	_____
20 cm × 20 cm			
5	_____	_____	_____
10	_____	_____	_____
15	_____	_____	_____
20	_____	_____	_____

Wedge and tray transmission

Wedge and tray transmission for a 10 cm × 10 cm field at 5 cm depth in water, unless otherwise indicated, _____ cm, ☐ SSD ☐ SAD.

Description	Expert	Institution	Expert/Inst.
_____ tray	_____	_____	_____
_____ tray	_____	_____	_____
_____ tray	_____	_____	_____

Wedges field, depth	Expert	Institution	Expert/Inst.
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Additional measurements
Dose rates for a 10 cm × 10 cm field at _____cm depth in water for the following non-standard SSDs;

SSD	Depth (cm)	Expert (Gy/MU)	Institution (Gy/MU)	Expert /Inst.
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Wedge profile measurement
Wedge profile measurements were taken in the expert's NE 2528 water phantom at ____ cm ☐ SSD ☐ SAD at a 5 cm depth, 2 cm towards the heel and toe of the wedge with respect to the central axis.

Description	Expert*	Institution*	Expert/Inst.
towards heel	_____	_____	_____
towards toe	_____	_____	_____

*indicated ratios are the ratios of the values off-axis to the value on the central axis.

Safety and mechanical measurements
The results of safety and mechanical measurements are detailed in the attachment
_____

Clinical dosimetry measurements
The results of clinical dosimetry measurements are detailed in the attachment
_____

3.3. High-energy electrons from a linear accelerator

Treatment unit _____

Beam output
Absorbed dose to water per monitor unit at the reference depth (z_{ref}) in water phantom at ____ cm SSD, ___ cm × ___ cm field size.

Nominal Energy (MeV)	R_{50} (cm)	Z_{ref} (cm)	Expert (cGy/MU)	Institution (cGy/MU)	Expert/Inst.
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Cone ratios (CR)

The output variation with cone size at a depth of z_{max} at ____ cm SSD in a full scatter water phantom used by the expert normalized to the institution's reference cone size.

Nominal Energy (MeV)	Field Size (cm × cm)	z_{max} (cm)	Expert* CR	Institution CR	Expert/Inst.
________	___________	________	—	(1.000)	—
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________
_________	___________	________	—	(1.000)	—
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________
_________	___________	________	—	(1.000)	—
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________
	___________	________	________	________	________

*This value was measured at an extended SSD of 110 cm. The institution's cone ratio was obtained by applying an inverse-square correction, $\{(VSD+\_\_\_\_\_)/(VSD+\_\_\_\_\_+\_\_\_\_\_)\}^2$, to the CR using its own virtual source distance data (VSD =_____ cm).

Depth dose data

Determination of the depths of 90% and 50% doses on the central axis, ____ cm SSD, ___ cm × ___ cm cone size. The institution's depth dose data were obtained from (source of institution's depth dose data)

____

Nominal Energy (MeV)	%DD	Expert* Depth (cm)	Institution Depth (cm)	Expert – Inst. (cm)
_________	90%	______	______	______
	50%	______	______	______
_________	90%	______	______	______
	50%	______	______	______

_____	90%	_____	_____	_____
	50%	_____	_____	_____
_____	90%	_____	_____	_____
	50%	_____	_____	_____
_____	90%	_____	_____	_____
	50%	_____	_____	_____
_____	90%	_____	_____	_____
	50%	_____	_____	_____

* Interpolated or extrapolated values.

Clinical dosimetry measurements
The results of the clinical dosimetry measurements are in the attachment _____

4. FINAL REMARKS

Analysis of discrepancies

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Recommendations

It is recommended that the institution:

_____
_____
_____
_____
_____
_____

_____

_____

_____

_____

NOTE: The recommendations made by the IAEA expert may influence the treatment of patients. If the recommendations are implemented, the following will be the impact on patient treatments.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

5. REFERENCES TO THE EXPERT'S REPORT

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Radiotherapy: an International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water, Technical Reports Series No. 398, IAEA, Vienna (2000).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Design and Implementation of a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA-TECDOC-1040, IAEA, Vienna (1998).

[3] FAO/IAEA/ILO/OECD(NEA)/PAHO/WHO, International Basic Safety Standards for protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[4] BRITISH INSTITUTE OF RADIOLOGY, Central Axis Depth Dose Data Use in Radiotherapy, Brit. J. Radiol. Supplement No. 25, The British Institute of Radiology, London (1996).

Appendix III

FORMS FOR PART III

III.1. INFORMATION FORM 'A TYPICAL ON-SITE REVIEW VISIT FOR BRACHYTHERAPY'

The aim of the on-site visit is twofold: firstly to trace the origin of any deviations in the treatment planning process and to assist the staff of the institution to correct them; secondly to assist the review and improvement of the overall brachytherapy treatment process and its QA. The on-site visit by the IAEA expert includes a review of the source calibrations as well as the treatment planning process. The information contained here is intended to help the institution to organise the visit efficiently and to minimise the disturbance that it might cause in the routine work of the radiotherapy department.

This on-site visit focuses on brachytherapy treatment and procedures, but will also include some dosimetry measurements and QA tests of the dose delivery systems. The different steps of the on-site visit are presented in a proposed time sequence; the expert(s) may however modify the sequence of events to meet the needs of the particular circumstances.

The visit typically begins with the completion of questionnaires and a series of interviews of some of the staff involved in the treatment planning process:

(a) Medical physicist(s) (radiotherapy physicist(s))
(b) Radiation oncologist(s)
(c) Dosimetrist(s) when needed (in many institutions there is no separate group of dosimetrists and these functions are carried out by medical physicists, medical physics technicians or technologists, radiation dosimetry technicians or therapy radiographers.)

The purpose of these questionnaires and interviews is to determine the role of each staff member in patient management and treatment, and in the QA process and, in particular, to determine the role of those staff involved in the steps in the brachytherapy treatment process where discrepancies occurred. The interviews will help to amplify any reported problems and the role of communication between the involved staff. These interviews usually last from 30 min. to two hours per person.

The next step is to conduct a series of safety, mechanical and functionality tests and to identify those issues that are most likely to bear on any reported or suspected problems. For safety reasons these tests will be undertaken prior to any other tests or measurements that the expert might perform. The institution's documented QA procedures should be available for review by the expert.

The staff at the institution will be asked to demonstrate the routine use of the brachytherapy afterloaders or manual loading of sources as well as the planning for any patients involved in the review. The manuals for the afterloader units and the relevant source certificate(s) should be available as well as documentation of the routine local procedures for the use of the afterloaders.

The staff at the institution will be asked to make available a sample from or all of the brachytherapy sources used by the institution to treat patients. The expert(s) will make source strength calibrations and compare these values with the institution's calibration data and with the data stored in the TPS, in order to assure the consistency of the data throughout the department. The expert will also review the institution's procedure for calibrating source strengths and comment as appropriate.

The expert(s) will then review individual treatment plans and records of several patients under treatment, to familiarise themselves with the treatment techniques and the treatment plans used routinely in the clinic. If the visit is a result of a reported treatment planning problem, treatment plans and records of any patients involved will be analysed in detail.

The expert will verify the institution's dose calculation procedures including the reconstruction of the implant dosimetry and the basic dose calculation steps. The standard procedure of the implant reconstruction will be reviewed using a special phantom and software that the expert will bring to the institution. The basic dose calculations will be reviewed by asking the staff at the institution to prepare different source configurations and to develop dose distributions. The expert(s) will review them and

compare the dose distributions and MU/treatment time calculations with those obtained by manual calculation using the algorithms and dosimetry parameters found in the AAPM Task Group 43 report.

An objective of this on-site visit is to identify any weaknesses in the total brachytherapy treatment process, and to help to improve the quality of patient treatment and care. An educational process regarding quality of the whole brachytherapy treatment process will start with the initial contacts and continue throughout the visit. At the end of the visit, the expert(s) will present the results of the review. The medical physicist as well as the radiation oncologist and an appropriate administrator should be present at the exit interview. The exit interview will not only present the results but also focus on the QA programme, education and training. Finally, before they leave the expert(s) will provide the institution with a signed copy of measurement and calculation results, a list of preliminary recommendations, and other information of interest.

Some points to be emphasized for brachytherapy:

(a) There is no need to reschedule patients for treatment. The measurements of the treatment units will be taken at times when patients are not being treated.
(b) The expert(s) will bring all equipment needed for the measurements.
(c) At least one member of the institution's staff knowledgeable in brachytherapy (implant reconstruction, planning procedures and source strength determination) needs to remain with the expert(s) during the test session of the treatment units in order to answer questions and operate the unit.

III.2. PROCEDURES FOR QUALITY CONTROL OF THE AFTERLOADING EQUIPMENT

The following tables show items that are part of a regular QC programme for brachytherapy systems. Forms III.1 – III.3 include tests for HDR/PDR equipment, LDR/MDR equipment and manual afterloading systems, respectively.

Forms III.1 – III.3 should be prepared by the local physicist before the on-site visit takes place. For each afterloading system a corresponding table should be used. The local physicist should complete the last 2 columns indicating test frequency and action level whenever applicable. The first column is reserved for the expert, to be completed during the on-site visit while performing the tests of the equipment. Each test should be marked as completed when done and found to be in order.

APPENDIX III

FORM III. 1. FREQUENCIES AND TOLERANCES OF QUALITY CONTROL TESTS FOR HDR/PDR AFTERLOADING EQUIPMENT.

Description of the items	Checked by the expert during on-site visit	Part of the regular QC programme of the local physicist	
Safety systems	(tick if checked)	Test frequency	——
Warning lights	☐		
Room monitor	☐		
Communication equipment	☐		
Emergency stop	☐		
Treatment interrupt	☐		
Door interlock	☐		
Power loss	☐		
Applicator and catheter attachment	☐		
Obstructed catheter	☐		
Integrity of transfer tubes and applicators	☐		
Timer termination	☐		
Contamination test	☐		
Leakage radiation	☐		
Emergency equipment (forceps, emergency safe, survey meter)	☐		
Practising emergency procedures	☐		
Hand-crank functioning	☐		
Hand-held monitor	☐		
Protection device, such as movable shield	☐		
Physics parameters		Test frequency	Action level
Source calibration	☐		
Source position	☐		
Length of treatment tubes	☐		
Irradiation timer	☐		
Date, time and source strength in treatment unit	☐		
Transit time effect	☐		

Note: The expert's column will be ticked if the test is done during the on-site visit and the result is satisfactory.
Test frequencies can be indicated by the local physicist as: daily, 3M- quarterly; 6M- biannual; A- annual; SE- source exchange.
Action levels can be indicated as % or mm depending on the item

General comments of the expert with regard to QC of HDR/PDR equipment:

_____

_____

_____

FORM III. 2. FREQUENCIES AND TOLERANCES OF QUALITY CONTROL TESTS FOR LDR/MDR AFTERLOADING EQUIPMENT.

Description of the items	Checked by the expert during on-site visit	Part of the regular QC programme of the local physicist	
Safety systems	(tick if checked)	Test frequency	——
Warning lights	☐		
Room monitor, battery back-up and wall-mounted	☐		
Communication equipment	☐		
Emergency stop	☐		
Treatment interrupt	☐		
Door interlock	☐		
Power loss	☐		
Air pressure loss	☐		
Applicator and catheter attachment	☐		
Obstructed catheter	☐		
Integrity of transfer tubes and applicators	☐		
Timer termination	☐		
Leakage radiation	☐		
Contamination test applicators	☐		
Emergency equipment (forceps, emergency safe, survey meter)	☐		
Practising emergency procedures	☐		
Hand-held monitor	☐		
Protection device, such as movable shield	☐		
Physics parameters		Test frequency	Action level
Source calibration, mean of batch	☐		
Source calibration, individual source; decay	☐		
Linear uniformity	☐		
Source position, source length	☐		
Irradiation timer	☐		
Date, time and source strength in treatment unit	☐		

Note: The expert's column will be ticked if the test is done during the on-site visit and the result is satisfactory.
Test frequencies can be indicated by the local physicist as: daily, 3M- quarterly; 6M- biannual; A- annual; SE- source exchange.
Action levels can be indicated as % or mm depending on the item.

General comments of the expert with regard to QC of LDR/MDR equipment:

_____

_____

APPENDIX III

FORM III. 3. FREQUENCIES AND TOLERANCES OF QUALITY CONTROL TESTS FOR MANUAL AFTERLOADING.

Description of the items	Checked by the expert during on-site visit	Part of the regular QC programme of the local physicist	
Safety systems	(tick if checked)	Test frequency	—
Room monitor	☐		
Source preparation area survey	☐		
Obstructed applicator	☐		
Integrity of transfer tubes and applicators	☐		
Leakage radiation	☐		
Contamination test applicators	☐		
Emergency equipment (forceps, emergency safe, survey meter)	☐		
Practising emergency procedures	☐		
Source inventory	☐		
Protection device, such as movable shield	☐		
Physics parameters		Test frequency	Action level
Source calibration, decay calculation	☐		
Linear uniformity, source length	☐		
Source identification	☐		

Note: The expert's column will be ticked if the test is done during the on-site visit and the result is satisfactory.
Test frequencies can be indicated by the local physicist as: daily, 3M- quarterly; 6M- biannual; A- annual; SE- source exchange.
Action levels can be indicated as % or mm, depending on the item.

General comments of the expert with regard to QC of manual afterloading:

_____

_____

_____

_____

III.3. WORKSHEET FOR EXPERT'S WELL-TYPE CHAMBER MEASUREMENT

1. SPECIFICATION OF AFTERLOADING DEVICE

Afterloading device, description (vendor, type):
_____

Source strength stated on certificate of source vendor:
_____

Date_____ time_____ in units_____

Afterloader source-nuclide and strength:
_____

Date_____ time_____ in units_____

Date of source installation: _____

Institution's clinical source strength is derived from:

☐ certificate value

☐ certificate value, if in agreement with own measurement within _____%

☐ own measurement

Comments: _____
_____

2. EXPERT'S MEASUREMENT SYSTEM

Well-type chamber, model _____, serial No.: _____

Electrometer, model _____, serial No.: _____

PSDL/SSDL calibration date: _____/_____/_____

Calibration coefficient for combination of measurement system and source type: _____

Length of catheter used to transfer source from afterloader to chamber: _____mm

Type of catheter (vendor_____; diameter_____; material _____)

Position of source in catheter for calibration measurement: _____mm or dwell position _____

3. THERMOMETER AND BAROMETER COMPARISON

The expert will allow the measurement system to equilibrate to the room temperature for at least 1 hour before starting the measurement. The expert's measurement system is an open-type well chamber requiring pressure and temperature correction.

Acceptance limits: temperature 0.5°C, pressure 1%

	Unit	Expert	Institution	Expert/Inst.		
Pressure	_____	_____	_____	_____	Yes ☐	No ☐
Temperature	_____	_____	_____	_____	Yes ☐	No ☐

Comments: _____
_____
_____
_____

Readings

Dwell position	Reading
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____

Irradiation time per dwell position _____

(typically 10-15 seconds for HDR sources, or up to a few minutes for LDR sources)

$$K_R = M_u \, k_{Tp} \, k_{recom} \, N_{K_R} \, N_{elec}$$

where:

K_R — reference air kerma rate

M_u — electrometer scale unit reading, corrected for transit time (if applicable, see below)

k_{Tp} — correction factor for temperature and air pressure

k_{recom} — correction factor for recombination effect. Caveat: to be measured according to IAEA TECDOC 1274.

N_{K_R} — calibration coefficient for the air kerma rate

N_{elec} — correction factor for use of the electrometer. Caveat: $\mathrm{N_{elec}}$ equals unity in case $\mathrm{N_{K_R}}$ is given for the combination of the well-type chamber and electrometer.

The expert is cautioned that a correction factor may be required to account for catheter-wall absorption, specific to the conditions found at the institution.

Note that, dependent on a number of factors, the transit time correction may have to be determined for the local situation by taking measurements of different duration. The

$$f_{tr}(t) = 1 - \frac{M_{t0}}{M_t(t)}$$

correction factor can be derived from:

where t is the dwell time, M_{t0} is the electrometer reading at $t = 0$ (zero dwell time, only dose contribution during source transport) and M_t is the electrometer reading for dwell time t. The value for $t = 0$, M_{t0}, is determined for the specific geometry by programming dwell times in the range of 5 to 120 seconds and then extrapolating to $t = 0$.

Source strength

Source type	Units	Expert	Institution	Expert/Inst.

General comments of the expert with regard to source strength measurement:

_____

_____

_____

III.4. VALIDATION OF THE DOSE CALCULATION PROCEDURES IN BRACHYTHERAPY

The two benchmark cases illustrated in Figure III.1 are to be used to compare brachytherapy dose / dose rate calculations of the TPS (or the calculations of the local physicist) with a manual calculation by the expert.

III.4.1. Two cases of brachytherapy dose / dose rate calculations

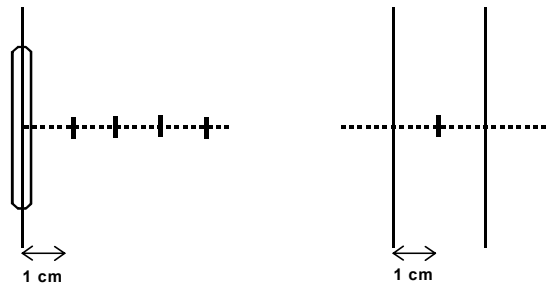


Figure III. 1. Schematic of the dose points for source arrangements (a) a single source, (b) two parallel sources.

Two examples of defining dose points for comparing the dose (or dose rate) calculation at the institution with a manual calculation. The source arrangement in *(a)* represents a single source in water. The source arrangement in *(b)* represents 2 sources in parallel, spaced 2 cm apart with a calculation point at the centre of the configuration, one cm from each source.

Required calculations

CASE #1

A source typical for the treatments in the institution should be selected. The dose rates at points along and away from the source in the transversal direction at every cm up to a distance of 10 cm should be calculated.

FORM FOR CASE #1 (SINGLE SOURCE IN WATER)

Source description: nuclide_____

Source description: type_____ length_____

Source description: strength_____ in units_____

Distance of calculation point along transverse axis (in cm)	Dose rate (expert)	Dose rate (institution)	Expert/Inst
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____
6	_____	_____	_____
7	_____	_____	_____
8	_____	_____	_____
9	_____	_____	_____
10	_____	_____	_____

CASE #2

Two sources typical for the treatments in the institution should be selected. At the specified point between the 2 sources (see Figure III.1.) the dose rate (100%) should be calculated. The treatment time for a prescribed dose of 1000 cGy at the 85% isodose line should be calculated.

If a treatment planning system is used, keyboard entry of source position is preferred to avoid possible influence of reconstruction on outcome.

FORM FOR CASE #2 (TWO SOURCES)

For a dose prescription of 1000 cGy at the 85% isodoseline, calculate the treatment time for the 2nd configuration of the figure

Source description: nuclide_____

Source description: type_____ length_____

Source description: strength_____ in units_____

	Expert	Institution	Expert/Inst
Dose rate at the centre point of the 2 sources contributing (= 100%)	_____	_____	_____
Treatment time for a dose of 1000 cGy at the 85% isodoseline	_____	_____	_____

III.4.2. Guidance for procedural checks for treatment planning in brachytherapy.

The following tables provide a number of tasks regarding commissioning and quality control of treatment planning with brachytherapy. The expert should check which of the following tasks is covered in the normal operating procedure of the institution. Comments by the expert should be given at the end of section III.4.2.

TABLE III. 1. PHYSICIST'S TASKS WITH REGARD TO SOURCE DATA.

Task	Material	Frequency
Source data (nuclide, type, numbers, construction details, strength, decay, TG-43 data, dose rate tables)	Literature, documentation of the system, information from the vendors, benchmarking of data	Initially (for all sources available) and with new sources
Integrity of data	Printed data of library sources; to be kept in a logbook	Initially and with each software update, annually
Sources with short half-lives	Double checking by a second person of the input of the source strength	At each delivery

TABLE III. 2. BASIC DOSE CALCULATIONS.

Item	Material	Frequency
Source decay	Check the basic calculations with well-known source decay	Initially and with each source type (nuclide)
Decay during treatment correction Yes/No?	Calculate the treatment duration in two cases, with the source strength differing by a factor 10; the correction is not included if the treatment duration differs by a factor of 10 exactly	Initially and with software updates
Point dose calculation	Identify relevant dose points around the source for which a dose rate table is available, compare results, tolerance level is at 2%, analyse in detail if deviations are > 5%	Initially and with software updates, for each source type
Source selection	Check that the system performs the source selection from the library correctly	Initially and with software updates, for selected source types
Check dose distribution calculated by TPS against atlas	Pre-calculated atlas of dose distributions, archive the calculated distributions in a logbook	Initially and with software updates
Check dose distribution calculated by TPS of multiple source geometries	Pre-calculated dose distributions, archive the calculated distributions in a logbook	Initially and with software updates
Source manipulations	Check consistency of outcome of point dose calculations after consecutive source transformations (rotations and translations)	Initially and with software updates
Inhomogeneity, shielding	Check dose distribution of sources near an interface, e.g. near the surface, check dose distribution of sources with applicator shielding enabled (if possible compare with measured data)	Initially and with software updates, if applicable

TABLE III. 3. CALCULATION OF STANDARD DOSE DISTRIBUTIONS.

Item	Material	Frequency
Creation of an 'atlas'	Define standard geometries, e.g. for single catheter applicators of different lengths; the (pre-) calculated dose distributions should be kept in a logbook	For relevant types of applications check for selected geometries with each new software release
Multiple source geometries	Define a few typical sets of well described (keyboard entry) source applications; rectangular and triangular implants according to the 'Paris' dosimetry system are suitable for the purpose, calculate the distributions and archive in a logbook	For relevant types of applications check for selected geometries with each new software release

TABLE III. 4. DOCUMENTATION AND DATA TRANSFER.

Item	Material	Frequency
Output completeness, consistency	Confirm that prints and plots are complete with patient ID, dates, use of quantities and units, all treatment data included, information on algorithm used (version), relevant corrections applied, dose prescription, dose to points	Initially and with software updates
Transfer of data	Confirm that data are properly transferred to the afterloader, prints from the afterloader must correspond with planned data, check for decay calculation, test delay between planned and actual treatment (decay included?)	Initially and with software updates
Interrupts	Check registry of emergency brake-off and unintended interrupts	Initially and with software updates

General comments of the expert with regard to dose calculation and treatment planning for brachytherapy:

_____

_____

_____

_____

_____

_____

III.5. WORKSHEET ON THE GEOMETRIC RECONSTRUCTION TECHNIQUES

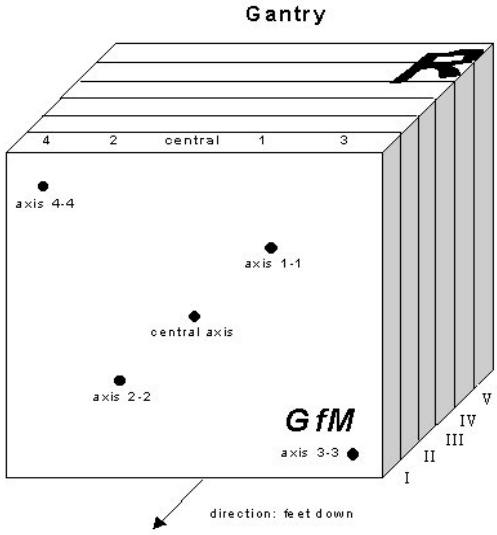


Figure III.2. The Baltas type phantom, to check the geometric reconstruction technique(s) in the institution.

General procedure

(a) The phantom is placed on the table as if it were a patient.
(b) The phantom is then imaged following normal institution procedures, e.g. orthogonal X rays are taken.
(c) The images are then used for input in the TPS, e.g. by digitizing.
(d) The individual marker points (25 in total) are marked and the TPS reconstructed coordinates are then recorded in TABLE III.5.
(e) The coordinates are transferred to an Excel spreadsheet on the expert's laptop for analysis.
(f) Use copies of TABLE III.5, if more than one reconstruction technique is to be tested.

TABLE III.5. REGISTRATION OF THE COORDINATES OF THE MARKER POINTS.

Analysis of the reconstruction of the Baltas phantom points
Reconstruction method #
Measured co-ordinates, all in **mm**
Items to be completed
Phantom ID nr: #

Central	X	Y	Z
1			
2			
3			
4			
5			

Axis 1-1	X	Y	Z
1			
2			
3			
4			
5			

Axis 2-2	X	Y	Z
1			
2			
3			
4			
5			

Axis 3-3	X	Y	Z
1			
2			
3			
4			
5			

Axis 4-4	X	Y	Z
1			
2			
3			
4			
5			

Code centre	
Hospital Name	
Department	
Address	
ZIP code	
City	
Country	
Physicist	
Telephone	
Date	
Localisation equipment type manufactured	
TP System used version	
Reconstruction method	
Reconstruction angles (if used)	
Magnification factor (if used)	
Radiographic facility	

Summary of results*	**in mm**
mean deviation	
standard deviation	
minimum deviation	
maximum deviation	
confidence limit	

* Results can be classified by using the mean deviation and the confidence limit, Δ, defined as (Δ = abs (mean) + 2 standard deviation):

(a) Within the optimal level, when the mean deviation is ≤ 0.5 mm and when Δ ≤ 1.0 mm;
(b) Outside the optimal level and within the tolerance level, when the mean deviation is > 0.5 mm and ≤ 1.0 mm; or when Δ > 1.0 mm and ≤ 2.0 mm;
(c) Outside the tolerance level, when the mean deviation is > 1.0 mm; or when Δ > 2.0 mm;
(d) In the emergency level, when the mean deviation is > 2.0 mm; or when Δ > 3.0 mm.

General comments of the expert with regard to the reconstruction techniques:

_____

_____

_____

_____

_____

III.6. REPORT ON A BRACHYTHERAPY REVIEW VISIT TO A RADIOTHERAPY HOSPITAL

REPORT

ON A BRACHYTHERAPY REVIEW VISIT
TO A RADIOTHERAPY HOSPITAL

Institution visited: _____

_____

_____

Mission dates: _____

Expert: _____

Signature: _____

Restricted

APPENDIX III

1. EXPERT REVIEW OF THE INSTITUTION'S BRACHYTHERAPY PRACTICES

The dosimetry review on-site visit organized by the International Atomic Energy Agency (IAEA) was the result of a request from the Member State or the institution. The visit was conducted by an expert(s) recruited by the IAEA to assist in the evaluation of the brachytherapy programme and to advise on quality assurance and clinical dosimetry practices. The expert uses the IAEA dosimetry protocol for the calibration photon sources used in brachytherapy recommended in the Technical Reports Series TRS No. 1274 [1] published by the IAEA. Another publication, IAEA-TECDOC-1040 [2], describes the general design and implementation of a radiotherapy programme. The expert refers furthermore to the Basic Safety Standards [3] for safety, mechanical and other quality assurance measurements, and to the ESTRO recommendations for quality control of brachytherapy equipment published in ESTRO Booklet 8 [4]. For evaluation of the brachytherapy treatment planning procedures, the suggestions of IAEA Technical Report Series TRS 430, [5] and ESTRO Booklet 8 [4] are used.

The results of the IAEA expert's review of the institution's brachytherapy procedures yielded a set of recommendations aimed at the improvement of the radiotherapy standards at the institution. The resulting changes should not be implemented on the basis of the IAEA expert's recommendations alone. They should be introduced only after the institution has determined that these changes are necessary, justified and acceptable. Their implementation should be carefully planned with the proper training of the institution's personnel. The details of the expert's measurements and calculations are included in this report as attachments.

Contents of the report of the brachytherapy review:

(a) Institution's afterloading and treatment planning equipment
(b) Safety and mechanical measurements (for different types of equipment)
(c) Validation of the brachytherapy dose calculation procedures
(d) Clinical dosimetry measurements (source strength verification)
(e) Geometric reconstruction techniques

2. INSTITUTION'S AFTERLOADING AND TREATMENT PLANNING EQUIPMENT

The following equipment for brachytherapy was available at the institution during the expert's on-site visit for evaluation.

HDR /PDR afterloading equipment

The (type/vendor)_____ afterloading unit with a (nominal source strength)_____$\mu Gy \cdot h^{-1} \cdot m^2$ (isotope) _____source began clinical use in _____.

LDR /MDR afterloading equipment

The (type/vendor) _____ afterloading unit with (total nominal source strength)_____$\mu Gy \cdot h^{-1} \cdot m^2$ (isotope) _____source(s) began clinical use in _____.

Manual afterloading

The (system or technique description)_____ with (typical nominal source strength)_____$\mu Gy \cdot h^{-1} \cdot m^2$ (isotope) _____source(s) began clinical use in _____.

The institution's treatment planning system is a _____ manufactured by _____.

The software version at the time of the IAEA expert's visit was _____.

The institution's reconstruction technique for implants makes use of (describe X ray or other imaging modality; use of reconstruction box; reconstruction method, e.g. (semi-) orthogonal, variable angle, stereo shift, other) _____

_____

_____

3. SAFETY AND MECHANICAL MEASUREMENTS (HDR/PDR)

HDR /PDR afterloading equipment

A check of the safety systems of the HDR/PDR afterloading equipment and facilities was done by the expert for the items listed in (the upper part of) FORM III. 1. The results of the check were:

☐ Satisfactory for all safety items

☐ Not satisfactory; the expert's comments: _____

_____

_____

A check of the physics parameters of the HDR/PDR afterloading equipment was done by the expert for the items listed in (the lower part of) FORM III. 1. The results of the check were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments: : _____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the test frequency of the safety systems and the physics parameters (FORM III. 1) were:

☐ Satisfactory for all items

☐ Not satisfactory; the expert's comments:_____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the action levels used for the physics parameters (FORM III. 1, lower part) were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments:_____

_____

_____

4. SAFETY AND MECHANICAL MEASUREMENTS (LDR/MDR)

LDR /MDR afterloading equipment

A check of the safety systems of the LDR/MDR afterloading equipment and facilities was done by the expert for the items listed in (the upper part of) FORM III. 2. The results of the check were:

☐ Satisfactory for all safety items

☐ Not satisfactory; the expert's comments:_____

_____

_____

A check of the physics parameters of the LDR/MDR afterloading equipment was done by the expert for the items listed in (the lower part of) FORM III. 2. The results of the check were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments: _____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the test frequency of the safety systems and the physics parameters (FORM III. 2) were:

☐ Satisfactory for all items

☐ Not satisfactory; the expert's comments: _____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the action levels used for the physics parameters (FORM III. 2, lower part) were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments:_____

_____

_____

5. SAFETY AND MECHANICAL MEASUREMENTS (MANUAL)

Manual afterloading

A check of the safety systems of the manual afterloading equipment and facilities was done by the expert for the items listed in (the upper part of) FORM III. 3. The results of the check were:

☐ Satisfactory for all safety items

☐ Not satisfactory; the expert's comments:_____

_____

_____

A check of the physics parameters of the manual afterloading systems was done by the expert for the items listed in (the lower part of) FORM III. 3. The results of the check were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments: _____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the test frequency of the safety systems and the physics parameters (FORM III. 3) were:

☐ Satisfactory for all items

☐ Not satisfactory; the expert's comments:_____

_____

_____

According to the interview of the local physicist and the inspection of the logbook of the equipment, the action levels used for the physics parameters (FORM III. 3, lower part) were:

☐ Satisfactory for all physics items

☐ Not satisfactory; the expert's comments:_____
_____
_____

6. CLINICAL DOSIMETRY MEASUREMENTS (SOURCE STRENGTH VERIFICATION)

During the on-site visit a dosimetric check was done by the expert, of a source calibration of which the result was compared with the result of the experiments of the local physicist and the data used clinically. The check regards the following equipment and source:

Afterloading unit (type/vendor) _____ with source (isotope)_____

with a (nominal source strength) _____ $\mu Gy \cdot h^{-1} \cdot m^2$

Barometer and thermometer comparison

A comparison of the expert's and institution's readings of air pressure and temperature was made. This comparison was found to be:

☐ Satisfactory

☐ Not satisfactory:_____
_____
_____

Source strength verification

The institution's source verification system consists of a _____ chamber with _____ electrometer. The calibration coefficient for converting the reading to reference air kerma rate is _____, obtained from ☐ PSDL, ☐ SSDL on the following date ____/_____/_____.

A comparison of the institution's clinical source strength with the expert's measured source strength was made by irradiation at the centre position of the expert's well-type chamber for a _____ source in the _____ afterloading equipment. The expert's well-type calibration coefficient was assigned at the IAEA SSDL on the following date ___/_____/_____.

The results of the source strength* comparisons are as follows:

Expert	Institution	Expert/Inst
_____	_____	_____
_	__	__
_____	_____	_____
_	__	__
_____	_____	_____
_	__	__
_____	_____	_____
_	__	__

* Units of reference air kerma rate, $\mu Gy \cdot h^{-1} \cdot m^2$.

A copy of the vendor's source certificate is attached to this report.

General comments of the expert with regard to source strength measurement: _____
_____
_____

7. VALIDATION OF THE BRACHYTHERAPY DOSE CALCULATION PROCEDURES

A check of the calculation procedures was done by the expert, based on two brachytherapy benchmark cases described in Appendix III.4.1. The results of the comparisons were:

☐ Satisfactory;

☐ Not satisfactory the expert's comments:_____
_____
_____

With regard to commissioning and quality control of treatment planning with brachytherapy, the expert took notice of the procedures in the institution guided by the tables in Appendix III.4.2.

☐ Satisfactory:

☐ Not satisfactory: the expert's comments: _____
_____
_____

8. GEOMETRIC RECONSTRUCTION TECHNIQUES

The geometric reconstruction technique(s) used clinically for patient treatment were verified by the expert.

The verification was conducted for the following equipment and technique(s):

X ray equipment (or other imaging modality): _____

Reconstruction technique: _____

Reconstruction box used? (Yes ☐ No ☐); if yes, type: _____

Summary of the reconstruction analysis	in mm
Mean deviation	_____
Standard deviation of the mean	_____
Minimum deviation	_____
Maximum deviation	_____
Confidence limit, Δ	_____

A graphical representation of the results is attached as a scatter diagram of the absolute value of the deviations vs. distance. The results were

☐ Satisfactory

☐ Not satisfactory; the expert's comments: _____
_____
_____

9. FINAL REMARKS

Analysis of discrepancies

Recommendations

It is recommended that the institution:

NOTE: The recommendations made by the IAEA expert may influence the treatment of patients. If the recommendations are implemented, the following will be the impact on patient treatments.

10. REFERENCES TO THE EXPERT'S REPORT

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Photon and Beta Ray Sources Used in Brachytherapy: Guidelines on Standardized Procedures at Secondary Standards Dosimetry Laboratories (SSDLs) and Hospitals, IAEA-TECDOC-1274, IAEA, Vienna (2002).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Design and Implementation of a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA-TECDOC-1040, IAEA, Vienna (1998).

[3] FAO/IAEA/ILO/OECD(NEA)/PAHO/WHO, International Basic Safety Standards for protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[4] EUROPEAN SOCIETY OF THERAUPEUTICAL RADIOLOGY AND ONCOLOGY, A practical guide to quality control of brachytherapy equipment, Booklet 8, ESTRO, Brussels (2004).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning and Quality Assurance of Computerized Treatment Planning Systems for Radiation Treatment of Cancer, Technical Reports Series No. 430, IAEA, Vienna (2004).

Appendix IV

FORMS FOR PART IV

IV.1. A TYPICAL ON-SITE VISIT FOR TREATMENT PLANNING

The aim of the on-site visit is twofold: firstly to trace the origin of any deviations in the treatment planning process and to assist the staff of the institution to correct them; secondly to assist in reviewing and improving the overall treatment planning process and its QA. The on-site visit by the IAEA experts includes the review of the beam calibrations as well as the treatment planning process. The visit will be planned so that one of the experts will deal mainly with the treatment planning and the other with dose measurements and QA of the treatment machine. The information contained here is intended to help the institution to organise the visit efficiently and to minimise the disturbance that it might cause to the routine work of the radiotherapy department.

This on-site visit will focus on the treatment planning system and procedures but it will also include some dosimetry measurements and QA tests of the dose delivery. The different steps of the on-site visit are presented in a proposed time sequence; however the expert(s) may modify the sequence of events to meet the needs of the particular circumstances.

The visit typically begins with a series of interviews of some of the staff involved in the treatment planning process:

(a) Medical physicist(s) (radiotherapy physicist(s));

(b) Radiation oncologist(s);

(c) Representative from the administration (responsible for staffing, equipment purchases, etc.);

(d) Dosimetrist(s) as needed (in many institutions there is no separate group of dosimetrists and those functions are carried out by medical physicists, medical physics technicians or technologists, radiation dosimetry technicians or therapy radiographers);

(e) Radiotherapy technologist(s) as needed (in some systems these are referred to as radiation therapists, therapy technologists, radiographers, radiation therapy technologists or radiotherapy nurses).

The purpose of these interviews is to determine the role of each staff member in patient management and treatment, in the QA process and, in particular, the role of those staff involved in the steps of the treatment planning process where discrepancies occurred. The interviews will help to amplify any reported problems and the role of communication between the involved staff. These interviews usually last from 30 min. to two hours per person.

The next step is the review of the QA programme of the treatment planning process and the identifying of those issues that are most likely to bear on any reported or suspected problems. The documented QA procedures should be available and the following issues will be reviewed:

(a) Overall radiotherapy QA programme at the institution;

(b) QA programme of the TPS;

(c) Patient-specific QA programme.

The staff at the institution will be asked to demonstrate the routine use of the local TPS and particularly the planning of the treatment of any patients involved in the review. The manuals for the TPS should be available as well as documentation of the routine local procedures for the use of the TPS.

The expert(s) will compare the institution’s tabulated dosimetry data with the data stored in the TPS, in order to verify the consistency of the data throughout the department. These data will also be compared with generic data provided by the IAEA.

The experts will then review individual treatment plans and records for several patients under treatment to familiarise themselves with the treatment techniques and the treatment plans used routinely in the clinic. If the visit is the result of a reported treatment planning problem, the treatment plans and records of any patients involved will be analysed in detail.

The anatomical benchmark cases presented to the institution are to be completed prior to the expert(s) visit. The expert(s) will review them and compare the dose distributions and MU/treatment time calculations with those obtained on the IAEA laptop system. The dose distributions calculated on the IAEA laptop are based on generic beam data selected for the purposes of these comparisons; these would not therefore be expected to be exactly the same as the institution's data.

The expert(s) will take measurements on the treatment unit(s), for at least the three in-water benchmark cases. Measurements will also be taken evaluating basic dosimetry performance including output calibration, beam quality and other parameters if necessary. Results of the benchmark measurements will be compared with the cases planned at the institution. The following data for each treatment unit should be available:

(a) Output as a function of field size
(b) Central axis depth dose data such as PDD, TPR, TMR, etc.
(c) Clinically used tray, wedge and block transmission factors
(d) Beam profiles.

One objective of this on-site visit is to identify any weaknesses in the total treatment planning process, and to help to improve the quality of patient treatment and care. An educational process regarding quality of the whole treatment planning process will start with the initial contacts and continue throughout the visit. At the end of the visit the expert(s) will present the results of the review. The medical physicist as well as the radiation oncologist and an appropriate administrator should be present at the exit interview. The exit interview will not only present the results but also focus on the QA programme, education and training. Finally, before they leave, the expert(s) will provide the institution with a signed copy of the measurement and calculation results, a list of preliminary recommendations, and other information of interest.

Points to be emphasized for treatment planning

(a) There is no need to reschedule patients for treatment. The measurements on the therapy units will be taken during the evening after the patients have been treated
(b) The expert(s) will bring all equipment needed for the measurements.
(c) At least one member of the institution's staff knowledgeable in the TPS (planning procedure and beam data configuration) needs to remain with the expert(s) during the test session of the system in order to answer any questions and to operate the system. Also, at least one member of the institution's staff knowledgeable in the treatment machines will be required during any work by the expert(s) on the treatment machines.
(d) The TPS will be partly used during the visit of the experts. Planning on the system may therefore be disturbed for some of the time during the visits of the experts.

IV.2. INSTITUTION QUESTIONNAIRE FOR TREATMENT PLANNING

1. TREATMENT PLANNING EQUIPMENT

1.1. Primary Treatment Planning Computer: (Computerized Treatment Planning System)

Manufacturer: _____ Date installed: ___/____/____

Model: _____

Original Software Version: _____

Acceptance testing done? _____ Date of acceptance: ___/____/____

Commissioning done? _____ Date: ___/____/____

Photons

☐ Institution's measured data

☐ Data provided by: _____

Commissioning data available? ☐ Yes ☐ No

Latest Software Version: _____ Date installed: ____/____/____

Verification of update performed? ☐ Yes ☐ No

Verification data available? ☐ Yes ☐ No

Maximum capabilities of the system:

☐ IMRT ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

Electrons

☐ Institution's measured data

☐ Data provided by: _____

Commissioning data available? ☐ Yes ☐ No

Latest Software Version: _____ Date installed: ____/____/____

Verification of update performed? ☐ Yes ☐ No

Verification data available? ☐ Yes ☐ No

Maximum capabilities of the system: ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

1.2. Secondary Treatment Planning Computer

Manufacturer: _____ Date Installed: ___/____/____

Model: _____

Original Software Version: _____

Acceptance testing done? _____ Date of acceptance: ___/____/____

Commissioning done: _____ Date: ___/____/____

Photons

☐ Institution's measured data

☐ Data provided by: _____

Commissioning data available? ☐ Yes ☐ No

Latest Software Version: _____ Date installed: ____/____/____

Update verified? ☐ Yes ☐ No

Verification data available? ☐ Yes ☐ No

Maximum capabilities of the system:

☐ IMRT ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

Electrons

☐ Institution's measured data

☐ Data provided by: _____

Commissioning data available? ☐ Yes ☐ No

Latest Software Version: _____ Date installed: ____/____/____

Update verified? ☐ Yes ☐ No

Verification data available? ☐ Yes ☐ No

Maximum capabilities of the system: ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

2. INDEPENDENT MONITOR (TIME) SET CALCULATOR

Photons

☐ Commercial software on desktop or laptop

Supplier's name: _____

Software version: _____ Date installed: ____/____/____

Source of dosimetry data:

☐ Institution's measured data

☐ Data provided by: _____

Maximum capabilities of the system:

☐ 2-D ☐ 1-D Comment: _____

_____

☐ Locally written software on desktop or laptop

Software package (e.g. Excel spreadsheet): _____

Developed by: _____ Date ____/____/____

Source of dosimetry data

☐ Institution's measured data:

☐ Data provided by: _____

Describe algorithm (define all symbols used):

_____

_____

_____

☐ Manual calculation:

Source of dosimetry data

☐ Institution's measured data:

☐ Data provided by: _____

Describe equation used (define all symbols used):

_____

_____

_____

Other:

_____

_____

_____

Electrons

☐ Commercial software on desktop or laptop

Supplier's name _____

Software version: _____ Date installed: ____/____/____

Source of dosimetry data

☐ Institution's measured data

☐ Data provided by: _____

Maximum capabilities of the system:

☐ 2-D ☐ 1-D Comment: _____

_____

☐ Locally written software on desktop or laptop

Software package (e.g. Excel spreadsheet) _____

Developed by _____ Date ____/____/____

Source of dosimetry data

☐ Institution's measured data:

☐ Data provided by: _____

Describe algorithm (define all symbols used):

_____

_____

_____

☐ Manual calculation:

Source of dosimetry data

☐ Institution's measured data

☐ Data provided by: _____

Describe equation used (define all symbols used):

_____

_____

_____

Other:

_____

_____

_____

3. IMAGING EQUIPMENT (PATIENT CONTOURING)

CT Scanner

Manufacturer: _____ Date installed: ___/____/____

Model: _____

Software Version: _____

Are CT images used in the TPS? ☐ Yes ☐ No

How are images transferred to the TPS?

☐ Hard copy images transferred.

☐ Transferred on disk

☐ Transferred electronically

☐ DICOM

☐ Other: _____

MRI Scanner

Manufacturer: _____ Date installed: ___/____/____

Model: _____

Software Version: _____

Are MR images used in the Treatment Planning System? ☐ Yes ☐ No

How are images transferred to the TPS?

☐ Hard copy images transferred.

☐ Transferred on disk

☐ Transferred electronically

☐ DICOM

☐ Other: _____

4. PATIENT ANATOMY INPUT INTO TPS

Patient skin contour is entered into TPS by:

☐ Digitizing from hardcopy of CT or MRI images

☐ Outlined electronically with screen cursor, from CT or MRI images

☐ Auto-contouring with TPS software

☐ Only in the central plane

☐ In multiple planes: typical slice thickness, ____cm; typical slice spacing: _____cm

☐ Who does the outlining? _____

Internal structures are entered into TPS by:

☐ Digitizing from hardcopy of CT or MRI images

☐ Outlined electronically with screen cursor, from CT or MRI images

☐ Auto-contouring with TPS software

☐ Only in the central plane

☐ In multiple planes: typical slice thickness, ____cm; typical slice spacing: _____cm

☐ Who does the outlining? _____

5. DEMOGRAPHICS OF TREATMENT PLANNING

5.1. Photons

IMRT

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

3-D Conformal

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

2.5-D

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

2-D

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

Manual calculations

Treatment sites planned: _____

Number of patients planned this way? _____ per annum: _____% Treatments

5.2. Electrons

3-D Conformal:

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

2.5-D

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? ____ per annum: _____% Treatments

2-D

Treatment sites planned: _____

Treatment Planning System used ☐ Primary ☐ Secondary

Number of patients planned this way? _____ per annum: _____% Treatments

2.4. Manual calculations

Treatment sites planned: _____

Number of patients planned this way? ____ per annum: _____% Treatments

6. QUALITY ASSURANCE PROCEDURES

Annual QA procedures are undertaken? ☐ Yes ☐ No

(attach list and reports)

Periodical QA procedures are undertaken? ☐ Yes ☐ No

(attach list and reports)

Patient-specific QA checks are undertaken? ☐ Yes ☐ No

An independent calculation check of MU/treatment time for each treatment field is done? ☐ Yes ☐ No

By _____

An independent check of the overall treatment plan is done? ☐ Yes ☐ No

By _____

Is patient treatment reviewed periodically? ☐ Yes ☐ No

By _____

Frequency: _____

Treatment Summary is performed? ☐ Yes ☐ No

By _____

Simulation and/or portal images are used? ☐ Yes ☐ No

By _____

Frequency: _____

Simulation and portal images are reviewed? ☐ Yes ☐ No

By _____

Frequency: _____

Patients are seen by the physician:

☐ every day ☐ every week

☐ whenever plans or fields are changed

☐ other: _____

7. FOR COMPLEX TREATMENT PLANS (E.G. IMAGE GUIDED TREATMENTS)

Transverse images are obtained by:

☐ CT ☐ MR ☐ PET ☐ PET/CT

Person outlining targets: _____

Person preparing the plan: _____

Person approving the plan: _____

MU/treatment time is determined by:

☐ Primary TPS ☐ Secondary TPS ☐ Independent MU calculator

☐ Other: _____

MU/treatment time calculations are verified by

☐ Primary TPS ☐ Secondary TPS ☐ Independent MU calculator

☐ Other: _____

8. TREATMENT PLANNING EQUIPMENT MAINTENANCE

Who undertakes maintenance on the:

Primary TPS? _____

Secondary TPS? _____

Other treatment planning devices? _____

CT? _____

MRI? _____

Who is responsible for QA checks following repairs?

_____

9. COMMENTS

_____

_____

Questionnaire completed by:

Name (print): _____

Position: _____

Signature: _____ Date ____/____/____

IV.3. QUESTIONNAIRE FOR PHOTON BENCHMARK CASES

1. PHOTON IN–WATER PHANTOM CASE #1 (TWO OBLIQUE FIELDS)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance: SSD _____ cm or SAD _____ cm

Wedge angle: _____ degrees (45° recommended)

Wedge transmission (under treatment conditions): _____

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Fields 1 and 2: _____

2. PHOTON IN-WATER PHANTOM CASE #2 (THREE FIELDS)

Radiation therapy unit: _____

Energy photon beam:_____MV Beam quality index: _____

Treatment distance AP–PA field: SSD _____cm or SAD _____ cm

Treatment distance lateral fields: SSD _____cm or SAD _____ cm

Wedge angle: _____degrees (30° recommended)

Wedge factor (under treatment conditions): _____

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

AP–PA field: _____

Lateral fields: _____

3. PHOTON IN–WATER PHANTOM CASE #3 (BLOCKED FIELD)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance: SSD _____cm

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No)

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Open field and shielded field: _____

4. PHOTON ANATOMICAL CASE #1: PELVIS (THREE-FIELD TECHNIQUE)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance AP–PA field: SSD _____cm or SAD _____cm

Treatment distance left lateral field: SSD _____cm or SAD _____cm

Treatment distance right lateral field: SSD _____cm or SAD _____cm

Wedges:

Left lateral field: wedge angle: _____degrees

Wedge transmission (under treatment conditions): _____

Number of fractions wedge used: _____

Right lateral field: wedge angle: _____degrees

Wedge transmission (under treatment conditions): _____

Number of fractions wedge used: _____

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

AP–PA field: _____

Left lateral field: _____

Right lateral field: _____

5. PHOTON ANATOMICAL CASE #2: LUNG (FOUR-FIELD TECHNIQUE)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance field 1: SSD _____cm or SAD _____cm

Treatment distance field 2: SSD _____cm or SAD _____cm

Treatment distance field 3: SSD _____cm or SAD _____cm

Treatment distance field 4: SSD _____cm or SAD _____cm

Wedges:

Field 1: wedge angle: _____degrees

Wedge transmission (under treatment conditions):_____

Number of fractions wedge used: _____

Field 4: wedge angle: _____degrees

Wedge transmission (under treatment conditions):_____

Number of fractions wedge used: _____

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Field 1: _____

Field 2: _____

Field 3: _____

Field 4: _____

6. PHOTON ANATOMICAL CASE #3: BREAST (TWO TANGENTIAL FIELDS)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance anterior-medial field: SSD _____cm or SAD _____cm

Treatment distance posterior-lateral field: SSD _____cm or SAD _____cm

Wedges:

Field 1: wedge angle: _____degrees

Wedge transmission (under treatment conditions):_____

Number of fractions wedge used: _____

Field 2: wedge angle: _____ degrees

Wedge transmission (under treatment conditions):_____

Number of fractions wedge used: _____.

Tangential fields are used with:

Half-beam block_____

Asymmetric jaws_____

None_____

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Anterior-medial field: _____

Posterior-lateral field: _____

7. PHOTON ANATOMICAL CASE #4: HEAD AND NECK (TWO-FIELD OBLIQUE INCIDENT TECHNIQUE)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index: _____

Treatment distance field 1: SSD _____cm or SAD _____cm

Treatment distance field 2: SSD _____cm or SAD _____cm

Wedges:

Field 1: wedge angle :_____degrees

Wedge transmission (under treatment conditions): _____

Number of fractions wedge used: _____

Field 2: wedge angle: _____degrees

Wedge transmission (under treatment conditions): _____

Number of fractions wedge used: _____.

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU/treatment time: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Anterior-oblique field: _____

Posterior-oblique field: _____

IV.4. QUESTIONNAIRE FOR ELECTRON BENCHMARK CASES

1. ELECTRON IN–WATER PHANTOM CASE #1 (SQUARE BEAM)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index (R_{50}): _____

Treatment distance: SSD _____cm Cone/field size _____cm × _____ cm

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU calculation: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or the complete calculation):

Depth of maximum dose: _____cm

Depth of 80% dose: _____cm

Depth of 50% dose: _____cm

MU calculation (give data provided by the TPS or the manual calculation):

2 Gy at z_{max} _____ MU

2 Gy at z_{90} _____ MU

2. ELECTRON IN–WATER PHANTOM CASE #2 (CONE RATIO)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index (R_{50}): _____

Treatment distance: SSD _____cm Cone/field size _____cm × _____ cm

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU calculation: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or complete calculations)

Depth of maximum dose: _____cm

Depth of 80% dose: _____cm

Depth of 50% dose: _____cm

MU calculation (give data provided by the TPS or the manual calculation):

2 Gy at z_{max} _____ MU

2 Gy at z_{90} _____ MU

3. ELECTRON IN–WATER PHANTOM CASE #3 (EXTENDED DISTANCE)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index (R_{50}): _____

Extended treatment distance: SSD _____cm Cone/field size _____cm × _____ cm

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU calculation: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or complete calculations)

Depth of maximum dose: _____cm

Depth of 80% dose: _____cm

Depth of 50% dose: _____cm

MU calculation (give data provided by the TPS or the manual calculation):

2 Gy at z_{max} _____ MU

2 Gy at z_{90} _____ MU

4. ELECTRON IN–WATER PHANTOM CASE #4 (TRIANGULAR SHAPED FIELD)

Radiation therapy unit: _____

Energy photon beam: _____MV Beam quality index (R_{50}): _____

Treatment distance: SSD _____cm Cone/field size _____cm × _____ cm

Hard copy of the treatment plan available? ☐ Yes ☐ No

(Attach a copy of the 2-D plan)

MU calculation: Calculated by the TPS? ☐ Yes ☐ No

☐ Other method (give equation): _____

_____

Definition of parameters: _____

_____

_____

MU/treatment time (give data provided by the TPS or complete calculations)

Depth of maximum dose: _____cm

Depth of 80% dose: _____cm

Depth of 50% dose: _____cm

MU calculation at the centre of the treated field: give data provided by the TPS or the manual calculation

2 Gy at z_{max} _____ MU

2 Gy at z_{90} _____ MU

IV.5. INTERVIEW FORMS FOR TREATMENT PLANNING

1. INTERVIEW FORMS FOR TREATMENT PLANNING

Pre-interview activities

Review questionnaires completed by the institution:

☐ Appendix III.2. Institutional questionnaires (this report).

Various questionnaires from Appendix II (as needed):

☐ Appendix II.2.1. Instrumentation

☐ Appendix II.2.2 ^{60}Co unit data

☐ Appendices II.2.3. – II.2.4. Accelerator data (photons and electrons)

☐ Appendices II.2.5. (clinical dosimetry).

2. INTERVIEW WITH RADIATION ONCOLOGIST

Demographics

Name: _____ Date _____/_____/_____

Institution: _____ _____

Time spent at the facility (hrs per week): _____

Number of patients treated: _____ per annum, _____ per day

Percentage of patients treated with curative intent per annum: _____%

Other treatment facilities serviced: _____

Discuss philosophy of dose prescription: (GTV, CTV, PTV, prescribe to point or periphery? ICRU 50 / 62, etc.)_____
_____

If the visit is the result of the reported misadministration (if not, proceed to next item):

Does this radiation oncologist prescribe the dose differently for the patients in question?

_____

Did this radiation oncologist notice unusual clinical results on the patients in question?

_____

When? _____

What was this radiation oncologist's role in the discovery of this situation?

_____

Was the situation discussed within the department, institution (detail discussions)?

_____

_____

For complex treatments, what is the role of this radiation oncologist in the treatment planning process (drawing targets, working with dosimetrist during planning, approving plan, etc.)?

_____

_____

Detail communications with the rest of the staff (physicist, dosimetrist, radiotherapy technologists, management)

_____

_____

The relationship of this radiation oncologist with management (To whom does he/she report? What is the administrative chain of command? Could this have played a role in the present situation?)

_____

3. INTERVIEW WITH MEDICAL PHYSICIST RESPONSIBLE FOR DOSIMETRY MEASUREMENTS AND QUALITY CONTROL.

Name: _____ Date _____/_____/_____

Institution: _____

Time spent at the facility in question (hrs): _____

Other treatment facilities serviced: _____

If the visit is the result of the reported misadministration (if not, proceed to next item):

What was this medical physicist's role in the discovery of this situation? _____

_____

Detail any special measurements taken with respect to this situation:

_____

_____

_____

_____

Detail the discussions within the department, institution concerning the situation:

_____

_____

_____

With complex treatments, what was this physicist's role, if any, in the treatment planning process (redundant calculations, independent MU/treatment time calculations, measurements to verify calculations, etc.)?

_____

_____

Detail communications with the rest of the staff (radiation oncologist, other physicist(s), dosimetrist, radiotherapy technologists, and management)

_____

_____

This physicist's relationship with management: (To whom does he/she report? What is the administrative chain of command? Could this have played a role in the present situation?)

_____

_____

4. INTERVIEW WITH MEDICAL PHYSICIST WITH RESPONSIBILITY FOR TREATMENT PLANNING

Name: _____ Date _____/_____/_____

Institution: _____

Time spent at the facility in question (hrs)? _____

Other treatment facilities serviced?_____

If the visit is a result of the reported misadministration (if not, proceed to next item):

What was this medical physicist's role in the discovery of this situation?

_____

_____

Detail the discussions within the department, institution.

_____

_____

What level of treatment planning is there and which treatment planning system is used for:

Single appositional field? _____

Parallel opposed treatment? _____

Four-fields box? _____

Wedges? _____

Asymmetric jaws? _____

Irregular fields? _____

3-D Conformal? _____

IMRT? _____

Electrons? _____

Describe the role of various imaging modalities (CT, MR, PET) in treatment planning:

What modalities were used? _____

How were data transferred to the TPS? _____

Who outlined various patient contours (skin, internal organs)? _____

Repair of relevant equipment? _____

Detail QA done after various imaging equipment has been repaired: _____

_____

How are treatment plans verified: (redundant calculations, independent MU/treatment time calculation, measurements to verify calculations, etc.)? _____

_____

Who performs these verifications?_____

_____

Detail communications with the rest of the staff: (radiation oncologist, other physicist(s), dosimetrist, radiotherapy technologists, management) _____

_____

This physicist's relationship with management: (To whom does he/she report? What is the administrative chain of command? Could this have played a role in the present situation?)

_____

_____

Describe the original data taken during commissioning of the TPS:

_____

_____

Describe what measurements are taken and calculations done when a new software version is installed. _____

_____

Describe the steps taken to verify that the treatment plans are correct (redundant checks)

_____

_____

Describe the process for redundant checks of the monitor set (either MU or time):

_____

_____

Describe any *in vivo* dosimetry performed on patients.

_____

_____

IV.6. EXIT INTERVIEW CHECKLIST FOR TREATMENT PLANNING

Tick each item when completed, (indicate N/A if not applicable)

Institutional Staff Present

- ☐ Medical physicist
- ☐ Radiation oncologist
- ☐ Department administrator
- ☐ Dosimetrist (when needed)
- ☐ Radiotherapy technologist (when needed)

Validation of institution's dosimetry data by ionization chamber measurements and tests

- ☐ Measurements taken and checks performed
- ☐ Safety and mechanical tests
- ☐ Dosimetry equipment comparison
- ☐ Dosimetry calibration of therapy unit
- ☐ Clinical dosimetry (photons and electron)
  - ☐ MU/treatment time calculations
  - ☐ Check of TPS

Validation of institution's photon beam data (tabulated and entered in TPS)

- ☐ Tabular beam data with computer beam data compared
  - ☐ Depth dose data
  - ☐ Output factors
  - ☐ Off-axis data
  - ☐ Wedge factors
  - ☐ Institution's data compared to 'generic' data.

Validation of institution's electron beam data

- ☐ Institution's beam data compared
  - ☐ Depth dose data
  - ☐ Cone ratio (output factors)
  - ☐ Institution's data compared to 'generic' data.

Results of the in-water photon benchmark cases

- ☐ Two oblique fields
- ☐ Three-field treatment
- ☐ Blocked field

Results of the anatomical benchmark cases (photons)

- ☐ Pelvic
- ☐ Thorax
- ☐ Breast
- ☐ Head and neck

Results obtained from other special cases

- ☐ Type of cases: _____
- ☐ Measurements compared with institution's data
- ☐ Comments: _____

Results of the electron in-water benchmark cases

- ☐ Standard square field: _____
- ☐ Small field: _____
- ☐ Extended SSD: _____
- ☐ Triangular field: _____

Review of the treatment planning for any 'involved' patients.

- ☐ All 'involved' patients identified
- ☐ All treatment plans for such patients reviewed

Comments on the actions taken by the institution to resolve the present problem.

- ☐ Measurements

Comments: _____

- ☐ Calculations

Comments: _____

- ☐ Other actions

Comments: _____

Comments on institution's QA Programme

- ☐ Commissioning and QA data for the treatment planning system
  - ☐ Beam data obtained during commissioning
  - ☐ Periodic QA measurements or calculations
- ☐ Overall QA programme
- ☐ QA of individual patient treatments, [including MU/treatment time checks]
  - ☐ Individual patient checks
  - ☐ Periodic checks
  - ☐ Treatment summary

Education efforts

- ☐ All recommendations explained to physicist
- ☐ Clinical implications of recommended changes explained clearly to:
  - ☐ Physicist?
  - ☐ Oncologist
  - ☐ Dosimetrists and radiotherapy technologists (when needed)?
- ☐ All recommendations explained to management?

IV.7. REPORT ON A TREATMENT PLANNING REVIEW VISIT TO A RADIOTHERAPY HOSPITAL

REPORT

ON A TREATMENT PLANNING REVIEW VISIT

TO A RADIOTHERAPY HOSPITAL

Institution visited: _____

_____

_____

Mission dates: _____

Expert: _____

Signature: _____

Restricted

1. EXPERT'S REVIEW OF THE INSTITUTION'S TREATMENT PLANNING PROCEDURES

The treatment planning review on-site visit organized by the International Atomic Energy Agency (IAEA) was the result of a request from the Member State or the institution. The visit was conducted by an expert(s) recruited by the IAEA to assist in the evaluation of the treatment planning process and to advise on quality assurance and clinical practices. The expert used the IAEA dosimetry protocols for the calibration of photon and electron beams, Technical Reports Series (TRS) No. 398 [1] published by the IAEA. Another publication, IAEA-TECDOC-1040 [2], describes the general design and implementation of a radiotherapy programme. For evaluation of the treatment planning procedures, the guidelines of IAEA Technical Report Series TRS 430 [3] were used.

The results of the IAEA expert's review of the institution's treatment planning procedures yielded a set of recommendations aimed at improving the radiotherapy standards in the institution. The resulting changes should not be implemented on the basis of the IAEA expert's recommendations alone. They should be introduced only after the institution has determined that these changes are necessary, justified and acceptable. Their implementation should be carefully planned with the proper training of the institution's personnel. The details of the expert's measurements and calculations are included in this report as attachments.

Contents of the report on the treatment planning review visit:

(a) Institution's treatment planning equipment
(b) The treatment planning system in clinical practice, responsibilities, maintenance
(c) Report on the in-water photon benchmark cases
(d) Report on the photon anatomical cases
(e) Report on the in-water electron benchmark cases
(f) Final remarks

2. INSTITUTION'S TREATMENT PLANNING EQUIPMENT

The following equipment for treatment planning was available at the institution for evaluation during the expert's on-site visit.

TP system

Primary Treatment Planning Computer (Computerized Treatment Planning System)
Manufacturer: _____ Date installed: ___/____/____

Model: _____

Original Software Version:
_____

Capability of the software: ☐ IMRT ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

A secondary Treatment Planning Computer is available at the institution

Manufacturer: _____Date installed: ___/____/____

Model: _____

Original Software Version: _____

Capability of the software: ☐ IMRT ☐ 3-D conformal ☐ 2.5-D ☐ 2-D

Implementation of the beam data in the TPS

The implementation of the photon beam data in the TPS was checked by the expert.

☐ Institution's measured data was used; these data were available to the expert.

☐ If not, comment: _____

_____

The implementation of the electron beam data in the TPS was checked by the expert.

☐ Institution's measured data was used; these data were available to the expert.

☐ If not, comment: _____

_____

Independent monitor (time) set calculator

For independent calculation of the monitor units or treatment time for photon and electron treatments, another system is available to the institution, based on:

☐ Commercial software on desktop or laptop

☐ Locally written software

☐ Tabular data, own measurements

☐ Data from elsewhere

☐ None or other:_____

_____

Comments: _____

_____

_____

Imaging equipment

Imaging equipment for treatment planning is available to the institution.

☐ CT scanning

☐ MRI scanning

☐ PET scanning

☐ PET/CT scanning

☐ Other, specify: _____

_____

Comments: _____

_____

_____

Image transfer

Images are transferred to the TPS as:

☐ Hard copy images

☐ On disk

☐ Electronically

☐ DICOM

☐ Other, specify: _____

_____

Comments: _____

_____

3. THE TREATMENT PLANNING SYSTEM IN CLINICAL PRACTICE, RESPONSIBILITIES, MAINTENANCE

Responsibility for contouring

According to the interviewee, patient outer contouring in the TPS is generally performed by the:

☐ Radiation oncologist

☐ Medical physicist

☐ Other, (e.g. radiation technologist) specify: _____

According to the interviewee, tumour and internal organ contouring in the TPS is generally performed by the

☐ Radiation oncologist

☐ Medical physicist

☐ Other, (e.g. radiation technologist) specify: _____

Comments: _____

_____

_____

Treatment planning system quality assurance procedures

Quality assurance procedures regarding the treatment planning process were discussed during the interview.

The result of the observations about the periodical QA procedures was:

☐ Satisfactory

☐ Not satisfactory; the expert's comments: _____

_____

_____

The result of the observations about the patient-specific QA checks was:

☐ Satisfactory

☐ Not satisfactory; the expert's comments: _____

Maintenance of the system

Maintenance of the treatment planning system was discussed during the interview.

The result of the observations on regular preventive and corrective maintenance procedures was:

☐ Satisfactory

☐ Not satisfactory; the expert's comments: _____

_____

_____

4. REPORT ON THE IN-WATER PHOTON BENCHMARK CASES

Expert: _____ Date:___/___/___

Institution: _____

Treatment unit: _____

Institution's staff: _____

Describe reference conditions for output (1 MU = 1 cGy; Dose rate/min with ^{60}Co beam at date of calculation of the cases)

^{60}Co Dose rate: _____ _____ cGy/min on date ____/____/____

Beam output

The absorbed dose rate to water at _____cm depth, for a field of _____ cm × _____cm in a water phantom, at ____ cm☐ SSD☐ SAD, gantry vertical on the date _____.

The institution calibrated according to: ☐ TRS 277, ☐ TRS 398. The institution value listed below is the dose rate converted to TRS 398. The expert's calibration was according to TRS 398.

Field size (cm × cm)	Expert calculations (cGy/min or MU)	Institution calculations (cGy/min or MU)	Expert/Inst.
10 × 10	_____	_____	_____

Comments: _____

_____

_____

In-water photon benchmark case #1
(2 oblique fields, if SAD set-up was used)

Beam energy: _____MV/ ^{60}Co SAD: _____cm

Field size (1): 8 W cm × 10 cm Field size (2): 8 W cm × 10 cm

Beam angle (1): 45° Beam angle (2): 315°

Wedge (1) angle: 45° Wedge (2) angle: 45°

Wedge angle : 45° Reference ('in-house' designation): _____

Monitor units / time to deliver 1 Gy per field at a depth of 5 cm

	Expert's calculations	Institution's calculations	Expert's measurements
Beam 1	_____	_____	_____
	–	–	–
Beam 2	_____	_____	_____
	–	–	–

Institution's calculation: _____

_____

_____

Expert's calculation: _____

_____

_____

Relative doses at selected points

Point	Institution's calculations	Expert's measurements	Expert/Institution ratio
A	_____	_____	_____
B	_____	_____	_____
C	_____	_____	_____
C'	_____	_____	_____

Comments on the results: _____

_____

_____

_____

_____

In-water photon benchmark case #1
(2 oblique fields, if SSD set-up was used)

Beam energy: _____MV/ ^{60}Co SSD: _____ cm

Field size (1): 7.4 W cm × 9.2 cm Field size (2): 7.4 W cm × 9.2 cm

Beam angle (1): 45° Beam angle (2): 315°

Wedge (1) angle: 45° Wedge (2) angle: 45°

Wedge angle : 45° Reference ('in-house' designation): _____

MU / time to deliver 1 Gy per field at a depth of 5 cm

	Expert's calculations	Institution's calculations	Expert's measurements
Beam 1	_____	_____	_____
Beam 2	_____	_____	_____

Institution's calculation: _____

_____

_____

Expert's calculation: _____

_____

_____

Relative doses at selected points

Point	Institution's calculations	Expert's measurements	Expert/Institution
A	_____	_____	_____

B	_____	_____	_____
C	_____	_____	_____
C'	_____	_____	_____

Comments on the results: _____

_____

_____

_____

_____

In-water photon benchmark case #2
(three fields technique, if SAD set-up was used)

Beam energy: _____ MV/ ^{60}Co SSD: _____ cm

Beam angle (1): 0°	Beam angle (2): 90°	Beam angle (3): 270°
Field size (1): 12 W cm × 18 cm	Field size (2): 10 W cm × 18 cm	Field size (3): 10 W cm ×18 cm
Depth (1): 12 cm	Depth (2): 20 cm	Depth (3): 20 cm
Open field	Wedge (1) angle: 30 ^{o}	Wedge (2) angle: 30 ^{o}

Wedge angle: 30 ^{o} reference (in-house designation) _____

Monitor units / time to deliver 1 Gy per posterior field and 0.5 Gy per each lateral beam at the depth of interest

	Expert's calculations	Institution's calculations	Expert's measurements
Beam 1	_____	_____	_____
Beam 2	_____	_____	_____
Beam 3	_____	_____	_____

Institution's calculation: _____

_____

_____

_____

Expert's calculation: _____

_____

_____

_____

Comments on the results: _____

_____

_____

Case #2 continued (if SAD set-up was used)

RELATIVE DOSES IN SELECTED POINTS

Point	Institution's calculation	Expert's measurements	Expert/Institution
A	_____	_____	_____
B	_____	_____	_____
B'	_____	_____	_____
C	_____	_____	_____
C'	_____	_____	_____

Comments on the results: _____

_____

_____

_____

_____

In-water photon benchmark case #2

(Three fields technique, if SSD set-up was used)

Beam energy: _____MV/ ^{60}Co SSD: _____ cm

Beam angle (1): 0°	Beam angle (2): 90°	Beam angle (3): 270°
Field size (1): 10.4 W cm × 15.7 cm	Field size (2): 8 W cm × 14.4 cm	Field size (3): 8 W cm × 14.4 cm
Depth (1): 12 cm	Depth (2): 20 cm different font size!	Depth (3): 20 cm Different font size!
Open field	Wedge (1) angle: 30°	Wedge (2) angle: 30°
Wedge angle: 30°	reference (in-house designation): _____	

Monitor units / time to deliver 1 Gy per posterior field and 0.5 Gy per each lateral beam at the depth of interest

	Expert's calculations	Institution's calculations	Expert's measurements
Beam 1	_____	_____	_____
Beam 2	_____	_____	_____
Beam 3	_____	_____	_____

Institution's calculation: _____

_____

_____

_____

_____

Expert's calculations: _____

_____

_____

_____

_____

Comments on the results: _____

_____

_____

Case #2 continued (if SSD set-up was used)

Relative doses at selected points

Point	Institution's calculations	Expert's measurements	Expert/Institution
A	_____	_____	_____
B	_____	_____	_____
B'	_____	_____	_____
C	_____	_____	_____
C'	_____	_____	_____

Comments on the results: _____

_____

_____

_____

_____

In-water photon benchmark dosimetry case #3 (blocked field)

Beam energy: _____ MV/^{60}Co

SAD ☐ SSD ☐ _____cm Depth: 10 cm

Field size (1): 20 cm × 20 cm

Beam angle (1): 0° Block dimensions: the size of shielded area: square, side of 8 cm

Monitor units / time to deliver 2 Gy at a depth of 10 cm for blocked and open field

	Expert's calculations	Institution's calculations	Expert's measurements
Beam 1	_____	_____	_____

Institution's calculations: _____

_____

_____

Expert's calculations: _____

_____

_____

Comments on the results: _____

_____

_____

Relative doses in selected points

Point	Institution's calculations	Expert's measurements	Expert/Institution
A	_____	_____	_____
	_	_	_
B	_____	_____	_____
	_	_	_

Comments on the results: _____

_____

_____

5. REPORT ON THE PHOTON ANATOMICAL CASES

The expert reviewed the institution's calculations of tumour dose delivery for four anatomical benchmark cases. The comparison of monitor units / treatment time between the expert and the institution is given below. In addition a visual comparison of the relative dose distributions generated by the expert and by the institution was performed by the expert.

Anatomical case	Treatment machine (beam energy)	Expert/Institution
Pelvis	_____ (_____MV)	_____
Lung	_____ (_____MV)	_____
Breast	_____ (_____MV)	_____
Head & neck	_____ (_____MV)	_____

Details of the specific anatomical cases are listed in the photon questionnaire for benchmark cases reference. The dose distributions for these anatomical cases were generated by the institution using its _____ TPS. The expert generated dose distributions using the IAEA laptop with the Theraplan-Plus software.

Comments by the expert: _____

_____

_____

The expert also reviewed several patient treatment records in order to become acquainted with the institution's treatment techniques and treatment planning procedures as well as establishing the consistency between TPS dosimetry data and the dosimetry data provided to the expert.

Comments by the expert: _____

_____

_____

6. REPORT ON THE IN-WATER ELECTRON BENCHMARK CASES

Expert: _____ Date:___/___/___

Institution: _____

Treatment unit: _____ Beam energy : _____ MeV

Institution's staff: _____

Beam Output

Absorbed dose-to-water per monitor unit at the depth of maximum dose (z_{max}) in the water phantom at ____ cm SSD, ___ cm × ___ cm field size.

The institution performed its calibration according to:

☐ TRS 277 ☐ TRS 381 ☐ TRS 398

The institution value listed below is the dose rate converted to TRS 398. The expert's calibration was performed according to TRS 398.

Nominal Energy (MeV)	R_{50} (cm)	Z_{ref} (cm)	Expert (cGy/MU)	Institution (cGy/MU)	Expert/Institution
_____	_____	_____	_____	_____	_____

Comments:_____

_____

_____

In-water electron benchmark case #1
(square field)

Field/cone size: __ cm × __ cm SSD _____ cm

Depth of interest	Expert's depth (cm)	Institution's depth (cm)	Expert – Institution (cm)
z_{max}	_____	_____	_____
z_{90}	_____	_____	_____
z_{50}	_____	_____	_____

Dose verification at the depth of interest

	Institution MU to deliver 2 Gy	Expert's measured dose (Gy)	Institution's calculated dose (Gy)	Expert/Institution
z_{max}	_____	_____	_____	_____
z_{90}	_____	_____	_____	_____

Comments on dose distribution: _____

_____

_____

_____

_____

Comments on discrepancies: _____

_____

_____

_____

In-water electron benchmark case #2
(cone ratio)

Field/cone size: __ cm × __ cm SSD _____ cm

Depth of interest	Expert's depth (cm)	Institution's depth (cm)	Expert – Institution (cm)
z_{max}	_____	_____	_____
z_{90}	_____	_____	_____
z_{50}	_____	_____	_____

Dose verification at the depth of interest

	Inst. MU to deliver 2 Gy	Expert's measured dose (Gy)	Institution's calculated dose (Gy)	Expert/Inst.
z_{max}	_____	_____	_____	_____
z_{90}	_____	_____	_____	_____

Comments on dose distribution: _____

_____

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Comments on discrepancies: _____

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In-water electron benchmark case #3 (extended SSD)

Field/cone size: __ cm × __ cm SSD _____ cm

Depth of interest	Expert's depth (cm)	Institution's depth (cm)	Expert – Institution (cm)
z_{max}	_____	_____	_____
z_{90}	_____	_____	_____
z_{50}	_____	_____	_____

Dose verification at the depth of interest

	Inst. MU to deliver 2 Gy	Expert's measured dose (Gy)	Institution's calculated dose (Gy)	Expert/Inst.
z_{max}	_____	_____	_____	_____
z_{90}	_____	_____	_____	_____

Comments on dose distribution: _____

_____

_____

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Comments on discrepancies: _____

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In-water electron benchmark case #4 (triangular shaped field)

Field/cone size: __ cm × __ cm SSD _____ cm

Depth of interest	Expert's depth (cm)	Institution's depth (cm)	Expert – Institution (cm)
z_{max}	_____	_____	_____
z_{90}	_____	_____	_____
z_{50}	_____	_____	_____

Dose verification at the depth of interest

	Inst. MU to deliver 2 Gy	Expert's measured dose (Gy)	Institution's calculated dose (Gy)	Expert/Institution
z_{max}	_____	_____	_____	_____
	–	–	–	–
z_{90}	_____	_____	_____	_____
	–	–	–	–

Comments on dose distribution: _____

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Comments on discrepancies: _____

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7. FINAL REMARKS

Analysis of discrepancies

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Recommendations

It is recommended that the institution:

NOTE: The recommendations made by the IAEA expert may influence the treatment of patients. If the recommendations are implemented, the following will be the impact on patient treatments.

8. REFERENCES TO THE EXPERT'S REPORT

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water, Technical Reports Series No. 398, IAEA, Vienna (2000).

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, Design and Implementation of a Radiotherapy Programme: Clinical, Medical Physics, Radiation Protection and Safety Aspects, IAEA-TECDOC-1040, IAEA, Vienna (1998).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning and Quality Assurance of Computerized Treatment Planning Systems for Radiation Treatment of Cancer, Technical Reports Series No. 430, IAEA, Vienna (2004).

REFERENCES

[1] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Report of AAPM TG 40, Comprehensive QA for radiation oncology, Med. Phys. 21 (1994) 581–618.

[2] EUROPEAN SOCIETY OF THERAPEUTICAL RADIOLOGY AND ONCOLOGY, Quality assurance in radiotherapy, Radioth. Oncol. **35** (1995) 61–73.

[3] EUROPEAN SOCIETY OF THERAPEUTICAL RADIOLOGY AND ONCOLOGY, Practical guidelines for the implementation of a quality system in radiotherapy, ESTRO Physics for Clinical Radiotherapy Booklet No. 4, ESTRO, Brussels (1998).

[4] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, Physics aspects of quality control in radiotherapy, IPEM, York, (1998).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY, Lessons Learned from Accidental Exposures in Radiotherapy, Safety Report Series No. 17, IAEA, Vienna (2000).

[6] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Prevention of Accidental Exposures to Patients Undergoing Radiation Therapy, ICRP report 86, Annals of the ICRP **30** (2000).

[7] ESSERS, M., MIJNHEER, B. J., In vivo dosimetry during external beam radiotherapy, Int. J. Radiat. Oncol. Biol. Phys. **43** (1999) 245–259.

[8] THWAITES, D.I., WILLIAMS, J.R., AIRD, E.G.A., KLEVENHAGEN, S.C., WILLIAMS, P.C., A dosimetric intercomparison of megavoltage photon beams in UK radiotherapy centres, Phys. Med. Biol. **37** (1992) 445–461.

[9] WILLIAMS, J.R., BRADNAM, M.S., MCCURROCH, G.M., DEEHAN, C., JOHNSTON, S., A system for the quality audit of treatment dose delivery in radiotherapy, Radioth. Oncol. **20** (1991) 197–202.

[10] IZEWSKA, J., ANDREO, P., The IAEA/WHO TLD postal programme for radiotherapy hospitals, Radioth. Oncol. **34** (2000) 65–72.

[11] IZEWSKA, J., ANDREO, P., VATNITSKY, S., SHORTT, K.R., The IAEA/WHO TLD postal dose quality audits for radiotherapy: a perspective of dosimetry practices at hospitals in developing countries, Radioth. Oncol. **69** (2003) 91–97.

[12] INTERNATIONAL ATOMIC ENERGY AGENCY, Comprehensive Audits of Radiotherapy Practices: A Tool for Quality Improvement, Quality Assurance Team for Radiation Oncology (QUATRO). IAEA, *in press.*

[13] INTERNATIONAL ATOMIC ENERGY AGENCY, Standardized Quality Audit Procedures for On-site Dosimetry Visits to Radiotherapy Hospitals, SSDL Newsletter No. 46, IAEA, Vienna (2002).

[14] INTERNATIONAL ATOMIC ENERGY AGENCY, Investigation of an Accidental Exposure of Radiotherapy Patients in Panama, IAEA, Vienna (2001).

[15] INTERNATIONAL ATOMIC ENERGY AGENCY, Accidental Overexposure of Radiotherapy Patients in San José, Costa Rica, IAEA, Vienna (1998).

[16] INTERNATIONAL ATOMIC ENERGY AGENCY, Accidental Overexposure of Radiotherapy Patients in Białystok, IAEA, Vienna (2004).

[17] INTERNATIONAL ATOMIC ENERGY AGENCY, Directory of Radiotherapy Centres (DIRAC), http://www-naweb.iaea.org/nahu/dirac/default.shtm.

[18] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Radiotherapy: an International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water, Technical Reports Series No. 398, IAEA, Vienna (2000).

[19] BRITISH INSTITUTE OF RADIOLOGY, Central Axis Depth Dose Data Use in Radiotherapy, Brit. J. Radiol. Supplement No. 25, British Institute of Radiology, London (1996).

[20] FOLLOWILL, D., DAVIS, D., IBBOTT, G., Comparison of Electron Beam Characteristics from Multiple Accelerators. Int. J. Radiat. Oncol. Biol. Phys. **59** (2004) 905–910.

[21] TAILOR, R.C., FOLLOWILL, D.S., HERNANDEZ, N., IBBOTT, G.I., HANSON, W.F., Predictability of electron cone ratios with respect to linac make and model, Journal of Applied Clinical Medical Physics, **4**, 2 (2003) 173–178.

[22] INTERNATIONAL ATOMIC ENERGY AGENCY, Commissioning and Quality Assurance of Computerized Treatment Planning Systems for Radiation Treatment of Cancer, Technical Reports Series No. 430, IAEA, Vienna (2004).
[23] EUROPEAN SOCIETY OF THERAPEUTICAL RADIOLOGY AND ONCOLOGY, A practical guide to quality control of brachytherapy equipment, ESTRO Booklet 8, Brussels (2004).
[24] INTERNATIONAL ATOMIC ENERGY AGENCY, Calibration of Photon and Beta Ray Sources Used in Brachytherapy: Guidelines on Standardized Procedures at Secondary Standards Dosimetry Laboratories (SSDLs) and Hospitals, IAEA-TECDOC-1274, IAEA, Vienna (2002).
[25] DUTREIX, A., MARINELLO, G., WAMBERSIE, A., Dosimétrie en Curiethérapie, Masson, Paris (1982).
[26] VAN DYK, J. et al., Commissioning and quality assurance of treatment planning computers, Int. J. Radiat. Oncol. Biol. Phys. **26** (1993) 261–273.
[27] MILLER, D. W., BLOCH, P. H., CUNNINGHAM, J. R., Radiation treatment planning dosimetry verification, AAPM Report Number 55, American Institute of Physics, New York (1995).
[28] AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE, Report of AAPM TG 53, Quality assurance for clinical radiation treatment planning, Med. Phys **25** (1998) 1773–1829.
[29] INSTITUTE OF PHYSICS AND ENGINEERING IN MEDICINE, A guide to commissioning and quality control of treatment planning systems, IPEM Report 68, York (1996).
[30] NETHERLANDS COMMISSION ON RADIATION DOSIMETRY, Quality assurance of 3-D treatment planning systems, NCS (2002).
[31] EUROPEAN SOCIETY OF THERAPEUTICAL RADIOLOGY AND ONCOLOGY, Quality Assurance of treatment planning systems, ESTRO Booklet 7, Brussels (2004).
[32] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Radiotherapy Equipment – Coordinates, Movements and Scales, IEC 61217, Geneva (2002).

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