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Quality Assurance of External Beam Therapy Units

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Introduction

Every patients with cancer deserves to receive the best possible management to achieve cure, long-term tumor control or palliation.

For some tumors and normal tissues, the dose response curves may be very steep in the therapeutic dose range. In addition, the prescribed dose to the tumor is usually constrained by the tolerance of the surrounding normal tissue. The ICRU has recommended that the dose be delivered to within 5% of the prescribed dose. This is a very stringent requirement, considering the uncertainties in equipment calibration, treatment planning, and patient setup.

For a radiation oncology a QA program is essentially a set of policies and procedures to maintain the quality of patient care. QA of radiotherapy equipment is primarily an ongoing evaluation of functional performance characteristics. Functional performance of RT equipment can change suddenly due to electronic malfunction, component failure or mechanical breakdown, or can change slowly due to deterioration and aging of the components. Uncertainties associated with RT equipment tend to be of a systematic nature. Systematic uncertainties maintain their magnitude over a period of time, and should therefore be controllable. QA measurements should be performed periodically on all RT equipments, including the dosimetry and other QA measurement devices, and there should be regular preventive maintenance monitoring and correction of the performance of the therapy machines and measurement devices.

Acceptance Test

Unless there is a written set of specifications, the customer should go along with the vendor's acceptance test procedures. These procedures are set up by the company to demonstrate that the product meets the specifications contained in its brochures and satisfies the legal requirements of the equipment safety. If there is a set of bid specifications, the specifications and criteria contained in the purchase contract are satisfied when performing all the tests in accordance with the company's procedure manual.

The institution's physicist is responsible to acceptance testing of a radiotherapy

unit.

Radiation Survey

The radiation survey of the treatment facility is evaluated to ensure that during the testing of the machine the exposure levels outside the room will not be exceed permissible limits. After completion of the installation, a formal radiation protection survey is carried out, including the measurement of head leakage, area survey, and test of interlocks, warning lights, and emergency switches.

Mechanical Specification

In symmetric mode a pair of photon jaws should move symmetrically about the rotation axis. It should be tested that the collimator rotation axis. gantry rotation axis and couch rotation axis pass through a sphere of the specified radius. The collimator should rotate around an axis normal to the plane of collimator bearing. The X-ray and electron sources should both be located on the collimator axis. Due to heavy weight, the gantry frame may flex during rotation. The horizontal shift of table top for the vertical motion should be tested.

If radiation sources are not on the collimator axis and/or the collimator axis does not cross the gantry axis, the radiation isocenter would not coincide with the mechanical isocenter. Radiation isocenter should be tested for rotation of each pair of collimator jaws, gantry rotation and couch rotation.

Light field and X-ray field should coincide in both alignment and size. The coincidence of two kind of fields in size should be tested for two different field sizes. Optical distance indicator (ODI) should be tested at SAD and SAD$\pm$20cm.

Field size and jaw position indicator should be tested for both several field sizes and several jaw positions at SAD. Collimator position and gantry position should be tested at the cardinal angles. All laser beams should pass the isocenter.

Radiation Specification

Radiation specifications will be checked by a set of instruments and equipment such as ionization chambers, water phantoms, computers and electrometers. Before the acceptance tests and QA tests are performed, this instrumentation must itselt be subjected to quality assurance tests to insure its proper functioning.

Two kind of important energies of an electron beam are the most probable energy and mean energy at surface. The practical range is the parameter of

choice determining the most probable energy. The mean energy at the surface is related to the depth of 50% of D_{max}. The flatness, symmetry and uniformity index of the electron beam should meet the specification. They should be measured at D_{max} or at some fixed depth. The flatness and symmetry should be measured in the inplane, crossplane and diagonal directions.

The specification of a depth dose at a specific depth is the most practical method of specifying a beam quality. Flatness and symmetry should be checked for the maximum field size at least at 2 depths: 10 cm depth and d_{max}. Linearity of monitor chambers should be checked as a function of dose rate and for special operating conditions such as TBI, TSEI and arc rotation. Lomg term stability check of the chambers is important.

Commissioning

A linear accelerator cannot be used for patient treatments until it has been calibrated and all the beam data and parameters for teatment planning have been obtained. These data are then input into a treatment planning computer in accordance with the software requirements. The computer-generated dose distributions are checked against measured data and/or manually calculated distributions. After all the necessary beam data have been acquired and adopted to the treatment-planning system, the machine can be commissioned for clinical use.

Commissioning of a linear accelerator is the responsibility of the medical physicist. It includes a several kind of data: dose per MU, central axis depth dose distribution, dose profiles in transverse, longitudinal and diagonal directions, isodose distribution, output and field-size factors, off-axis factors, verification of inverse square ratio for photon, TPR, wedge factor, tray factor, virtual SSD's and effective SSD's of electron beams, buildup dose, beam data input to RTPS, special dosimetry such as TBI, SRS, IORT, TSEI, etc.

Development of QA Program

A periodic QA program is designed to maintain the system into its acceptable performance standards. The QA program should be based on a throughout investigation for baseline standards at the time of the acceptance and commissioning of the equipment for clinical use. The QA program must be designed so that significant changes in machine performance receive prompt

attention and investigation to determine the cause of the malfunction.

The type and frequency of tests depend primarily on the probability of occurrence of a particular performance error, its clinical impact, and the time required for performing the test. The guiding principle is to follow national or international standards if they exist. If formal standards do not exist, the institution should design its own program by consulting relevant literature, manufacturer's manuals and other equipment users. Moreover, a QA program should be reviewed in a regular basis to incorporate ideas from new protocols, user's own experience and the experience of others, and appropriately modified to accommodate newly developed techniques or accessaries.

It should be noted that testing is distributed among daily, weekly, monthly and annual tests. IEC recommends weekly tests but AAPM does not. Daily tests include those which could seriously affect patient positioning and the registration of the radiation field and target volume, patient dose and safely. Monthly tests include more refined testing of parameters which will either have a smaller impact on the patient or have a lower likelihood of changing over a month. The annual full calibration should include output calibration, central axis depth dose curves, beam profiles at selected depths and field sizes, output factors, wedge factors and other parameters that are not covered in the tests on a more frequent basis.

The tolerance values for dosimetric, geometric, and mechanical parameters are intended to make it possible to achieve an overall dosimetric uncertainty of ± 5% and an overall spatial uncertainty of ±5 mm. These uncertainties are generally perceived as clinically acceptable and technically achievable.

QA of Co-60 Teletherapy Unit

QA of Co-60 teletherapy should be similar to that of a linear accelerator. Full calibration of Co-60 unit is required: a) before the first medical use of the unit; b) whenever spotcheck measurements differ by more than 5% from the output at the last full calibration, corrected for radioactive decay; c) following replacement of the source or relocation of the unit; d) following repairs that could affect the source exposure assembly; and e) at intervals not exceeding 1 year. The full calibration checks include a) output being within ±3% for the range of field sizes and distances used clinically; b) coincidence of radiation and light fields; c) uniformity of radiation field and its dependence on the orientation of the radiation field; d) timer constancy and linearity over the range of the use; e) on-off error; and f) accuracy of all distance measuring and localization devices.