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Quality Assurance (QA) in Brachytherapy

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The quality assurance (QA) is important and necessary in brachytherapy as well in external beam radiotherapy. However, comprehensive QA in brachytherapy has not been established until a recent date because it contains not only source strength calibration but integrity of sources and applicators, localization of source position, treatment planning, delivery process, and radiation protection. Brachytherapy differs from external beam radiotherapy in that the treatment planning is more difficult and the dose specification is less precise due to the high dose gradient within patients' target volume.

Recently, use of artificially produced radionuclides which have suitable characteristics for brachytherapy is rapidly increasing. Moreover, advanced remote controlled afterloading system that consists of the equipments with new technology has been developed and increasingly used in many institutions. Therefore, it requires practical and effective QA for maintaining the integrity and accuracy of techniques and devices to execute the treatment in brachytherapy.

The QA procedures in brachytherapy depend on the equipments and personnel which can be dedicated to brachytherapy in each institution. To develop an adequate brachytherapy treatment delivery system, the procedures and endpoints of each treatment step must be clearly identified and QA process should be established in each step having its own checklists, instructions and documentations. This QA involves numerous routine checks covering source integrity and the calibration and measurement of radiation dose rates. It is important that control checks can be carried out regularly and with a minimum of inconvenience.

1. Calibration of sources

The source strength should be calibrated in each institution independently and verified with the values provided by the source supplier. The calibration of sources is traceable to national or international standards. The

methods of calibration are classified into two categories according to the source strength (dose rate).

Low dose rate (LDR) source. The strength of LDR sources should be calibrated by intercomparison with a standard source. The calibration is usually carried out with a well type ionization chamber (reentrant chamber) which is known as isotope calibrator. The response of well type chambers depends on the source position in the well, the energy of source nuclides and the shape of the source. Correction factors must be determined for these effects for a given instrument and the type of sources to be calibrated. The standard source of the same radionuclide and construction should be calibrated to be traceable to national standard. For short lived source, a properly calibrated standard source is determined and another long lived source is selected to transfer the calibration as a reference source.

High dose rate (HDR) source. HDR sources are used in most remote afterloading systems. There are two procedures for the calibration of HDR sources. One is the same method that is used in the calibration of LDR sources. However, the well ionization chambers for LDR source calibration may not be used for HDR sources due to the low collection efficiency and high signal current. Well ionization chambers specifically designed for HDR are now commercially available. The other one is open-air calibration using thimble ionization chamber. In the open-air calibration, the ionization chamber and source/applicator should be fixed rigidly with a calibration jig to minimize errors and uncertainties during the measurement. A buildup cap is necessary to attain electron equilibrium and to stop the secondary electron from source. Calibration factors traceable to national standard of both well and thimble chamber should be determined for the source nuclide.

2. Source description

The dose distribution of around an encapsulated source is strongly affected by the radiation characteristics of source nuclide and source encapsulation. The following informations should be obtained and checked with the sources and applicators.

Source construction. The information about source constructions such as physical and chemical form, physical length and diameter, encapsulation, material of capsule should be supplied by the manufacturer. Some of these may be checked by the user using physical measurement, radiography and visual inspection.

Source uniformity and symmetry. All sources should be checked for the loading of radioactive material within the source capsule. For some sources

the distribution of activity may not be uniform and the active length may not be centrally located along the source. This check is carried out using an autoradiography and transmission x-ray.

Source identification. Sources which have same radionuclide and capsule shape must be distinguished correctly. A simple and reliable system is necessary for source inventory and verification of source strength. Color coding and color thread are common method to identify the source, but care must be taken for fading and disconnection.

Applicator. The QA tests of applicator may be divided into functions and structures. The integrity of structures such as location of internal shield, the transformationins of shape, cracks and corrosions can be checked by visual inspection and orthogonal radiograph. Functions such as source position, coincidence of dummy and active source should also be checked.

3. Localization

The accuracy of source localization system in brachytherapy should be checked to assure that locations of sources and tissues are obtained accurately to estimate the dose and dose distribution. Equipments to take images for localization are simulator, C-arm x-ray system or CT. The digitizer used for entry of positions should be checked to assure the function and scaling accuracy. The QA of these equipments is carried out according to the procedures for external beam radiotherapy.

4. Dose calculation algorithms

There are several algorithms in brachytherapy dose calculation. The accuracy of the dose distribution heavily depends on the model employed in the planning system and in particular depends on the user's input data. The result of dose calculation should be correct and clinically acceptable. The QA of calculation algorithms is divided into (1) source data set, (2) source positioning and reconstruction, and (3) dose calculations.

The user should verify that the source data set for the sources in use are correct and any files in planning system have not been changed irregularly. The source positioning and reconstruction are checked by using reference films of sources in a phantom to reconstruct the source positions. When newly acquired films of sources in a standard phantom are used, the test for alignment of imaging system can be checked. The dose distribution around a single line source or seed should be checked against manual calculations, published reference data, or measured data if available. Special attention should be taken to the unit of source strength, oblique filtration of cap-

sule wall and tissue attenuation.

5. Remote afterloading system

Recent remote afterloading systems consist of equipments using high technology and require the skilled operation. To maintain the functions of a remote afterloading unit QA programs similar to external beam radiation therapy equipments are necessary. However, the wide range of remote afterloding unit functions prevents the formulation of unified QA program. The most test procedures are usually indicated in the manuals supplied by the manufacturer. The QA program specific to the unit of each user should be developed.

The QA tests may be divided into (1) functional performance of the unit, (2) radiation safety features, (3) source calibration and description, and (4) dose calculation. Functional tests contain checks with temporal, positional and dose delivery accuracy. The QA tests for (3) and (4) can be achieved using the same procedures for conventional brachytherapy.

6. Present status of QA in radiotherapy in Japan

In Japan, there is no regulatory QA control for radiation oncology except radiation protection. The guidelines or standards for QA are proposed by some academic organizations such as Japanese Society for Therapeutic Radiology and Oncology (JASTRO), Japanese Association of Radiological Physics (JARP), and Japan Radiological Society (JRS). Several protocols for external beam therapy have been published in the past and are in preparation for brachytherapy. The physical QA in radiotherapy is still not practicing sufficiently in Japan. The major reason is the lack of medical physicists who work in the department of radiotherapy.

However, the dose calibration system of radiotherapy equipments that is organized by JRS is working well. Usually, ionization chambers used to measure the output of radiotherapy equipment are calibrated at a JRS Dose Standard Center. Fourteen Centers are settled in regional area of Japan. Each Center has regional standard that has a calibration traceable to national standard of Electo-technical Laboratory. The total number of chambers calibrated in all Centers a year is about 400. It means the most part of main institutions that are carrying out radiotherapy request their measurement equipments to calibrate once a year.