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Quality assurance in dynamic conformal radiotherapy at Aichi Cancer Center Hospital

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Definition and classification of the CRT (conformal radiotherapy)

Until 1980 the 'conformal radiotherapy' had meant the 'dynamic conformal radiotherapy developed by Prof. Takahashi,S. in 1960'. Recently it is definition has been more and more expanding and the 'conformal radiotherapy' could be defined as follows: radiotherapy technique to conform the high dose region to the target volume as precisely as possible, while keeping the dose to the neighboring healthy tissues as low as possible. From this broad definition, it is clear that in near future this technique will become a standard technique for the patients irradiated with curative intent.

The conformal radiotherapy can be classified as follows:

(A) Coplanar conformal radiotherapy
- A-1 Conformal static field radiotherapy
  - (a) using multi-leaf collimator (MLC)
  - (b) without multi-leaf collimator (for example, customized shielding block)
- A-2 Dynamic conformal radiotherapy (DCRT)
  - (a) using multi-leaf collimator---'Conformation RT by Takahashi,S.'
  - (b) without multi-leaf collimator (for example, 'Tomotherapy')

(B) Non-coplanar conformal radiotherapy
- B-1 Conformal static field radiotherapy
  - (a) using multi-leaf collimator
  - (b) without multi-leaf collimator
- B-2 Dynamic conformal radiotherapy
  - (a) using multi-leaf collimator
  - (b) without multileaf collimator

Aims of the conformal radiotherapy

There are two main aims in the conformal radiotherapy; (1) the protection of the surrounding normal tissues, and (2) the improvement of the local control rate. Usually the first aim can be more easily obtained than the second one, because the incidence rate of radiation injury often increases very quickly according to the increase of the given dose. From 1980 through 1987, 47 patients with maxillary cancer were treated using DCRT combined with 'hollow-out' technique. In 5 year survivors, the radiation injury of the affected-side eye decreased significantly from 87% to 30% compared with the conventionally irradiated 106 cases from 1971 through 1977, because of the precise protection of the lens using the 'hollow-out' technique.

In order to obtain the better local control rate, the dose-escalation to the target region is

indispensable. In 'dose-escalation' study, the total systemization of each device for conformal radiotherapy and its 'quality assurance' are very important to obtain the better results without any increase of the late radiation injury of the surrounding normal tissues.

Systemization of the conformal radiotherapy --- ACCROS (Aichi Cancer Center Radiation Oncology System)

In order to apply our conformal technique to each patient as precisely as possible, the integrated system of computer-controlled conformation radiotherapy was accomplished in February 1992. We call this system "ACCROS". This system consists of a radiotherapy-oriented CT-device, a simulator, a MR-device, a radiotherapy planning system (FOCUS), two computer-controlled linear accelerators with multi-leaf collimator, a cobalt machine and a radiotherapy-oriented PACS. Nine work stations with the image display terminals are equipped almost every room in our department. These equipments are linked together by a local-area-network (LAN) controlled by two host-computers. Quality assurance in conformal radiotherapy, for dosimetry and mechanical alignment of the treatment unit, has always been recognized as an important part of radiotherapy physics. The QA program for conformal treatment under computer control is carried out on a conformal radiotherapy unit in addition to the routine dosimetry and mechanical checks.

Quality assurance of each component in ACCROS

In order to preserve the good quality assurance of our ACCROS system, it is very important to check the quality-assurance of each device and each process.

(1) QA of the radiotherapy-oriented CT device and the simulator:

The simulator and radiotherapy-oriented CT device are routinely used to decide the target region in the patient's body. The patient is placed on the simulator couch in the same position as is adopted in radiotherapy, and the fixing device is made. In order to estimate the position and the shape of the three dimensional target region in the body from the skin surface of the patient, three standard lines (median, left and right) are marked on the skin surface of the patient using the three laser-beam localizers. The couch of the simulator is also used to that of the radiotherapy-oriented CT-device. The couch is slowly turned for 90° , and the CT-images are taken at 1cm interval. The treatment planning CT should be acquired with the patient in the same position, immobilization device, and conditions, as he will be for treatment. The mechanical accuracy of the simulator, the three localizers, the couch and the CT-device should be periodically tested.

(2) QA of the 3D- treatment planning system:

(2-1) The serial CT-images taken therapy-oriented CT-device are sent on line to the 3D-treatment planning computer (FOCUS). The contour of the gross target volume (GTV) and clinical target volume (CTV) are drawn by the Radiation Oncologist on the

CT-image one by one. If necessary, the MR-images are superimposed to the DT-images to decide the target region more precisely. In spite of the development of new diagnostic technologies such as CT, MR and PET, the clinical decision of the target volume remains one of the most inaccurate process in radiotherapy.

(2-2) The tasks required for adequate quality assurance on computer dose planning systems can be broken down into three distinct areas; (a) the algorithm verification, deals with the accuracy, precision, and limitations of the algorithm, as well as the implementation of the software for isodose planning calculation and display, (b) the equipment (input digitizers, output plotters, screen recorders (both hardcopy and film), and printers), and (c) treatment planning data-sets given by the radiation physicist at each hospital.

The precision and accuracy required for the 3D treatment planning process exceeds accepted tolerances generally found in 2D treatment planning. Systematic testing of the hardware and software used in the 3D treatment planning process, careful review of each patient's treatment plan, and careful review of the physical implementation of the treatment plan are very important.

(3) Computer-controlled medical accelerators for conformal RT:

Acceptance testing for a computer-controlled linear accelerator should include all of the tests performed on conventional therapy machines plus additional tests to verify proper operation of hardware, software, communications for the conformal techniques. For example, in the multi-leaf collimator system for the conformal technique, the leaf settings for each field are sent to the treatment machine, which drives the leaves via a controller system. The leaf settings may be obtained by two different methods. First, computer software and hardware is provided with which the user can digitize a portal shape drawn on a simulation film. In addition, most 3D-CRT planning systems provide the ability to configure MLC shaped fields using beam's eye view display obtained by the serial CT-images. In both cases, rigorous QA is essential when MLC is clinically implemented. Imaging checks using the electronic portal imaging devices (EPID) for all MLC portals should be performed periodically.

(4) Electronic portal imaging devices (EPID) for verification:

The accurate treatment planning in the CRT should be followed by accurate set-up of the treatment field. The skin marks do not always coincide with the deep-seated target region of the patient's body due to the shift of the skin surface in daily treatment. For the daily check of skin marks the EPID is very useful. In our clinical experiences the difference between skin marks and internal standard marks was more than ± 2 mm in almost one third of the patients. From these experiences the simple type of X-ray simulator was also installed in the treatment room to coincide the skin marks with the definite standard points in the body in 1992. By the correction of the skin marks two or three times per week using the simple type of simulator in the treatment room, the frequency of cases with difference of more than ± 2 mm between two marks decreased from 49% to 17% in head and neck region, from 47 % to 7 % in thoracal region and 35% to

17% in abdominal region, respectively.

Conclusion

The contemporary outline of the comprehensive quality assurance (QA) program for our ACCROS (Aichi Cancer Center Radiation Oncology System) is demonstrated. New techniques and software will continually require new methodologies for proper testing. The medical physicist must be aware of such changes and include them in a QA program if the program is to remain useful.

Monthly QA checks of MLC

(a) testing of MLC settings versus light field versus radiation field
for selected gantry and collimator angles
(b) network testing
(c) check of active patient files
(d) interlock checks
(e) interleaf leakage testing, testing penumbra dependence on leaf position