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Quality Assurance in LINAC-based Stereotactic Radiosurgery

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INTRODUCTION

In 1980's, a technique to convert a standard linear accelerator for stereotactic radiosurg ery was developed at several radiation cancer centers as an alternative to the commerciall y available Gamma Knife. Since radiosurgery requires accurate localization and mechani cal alignment of LINAC, it is desirable to conform the whole procedures of radiosurgery following quality assurance protocal. This protocal include an intensive quality assuranc e program to encompass all aspects of dose calibration and mechanical integrity of the tr eatment unit, the treatment planning process, and treatment delivery.

The recent linear accelerator has accurate and stable mechanical alignment, excellent be am stability during gantry rotation. It is modified for stereotactic radiosurgery by mounti ng an auxiliary collimator to the collimator face plate. This secondary collimator mini mizes penumbra and allows circular radiation beams. The more important mechanical a ccuracy is related with table rotation.

The need for high geometric and dosimetric accuracy in radiosurgery requires a special radiosurgical quality assurance program that goes beyond those QA procedures generally applied to routine radiation therapy. One important consideration is that a treatment ma chine used for stereotactic radiosurgery must be initially aligned with great accuracy. Th e programs developed at several institutes are similar each other, and generally includes checking of accuracy of LINAC and stereotactic localization system, cross checking of th e radiosurgery planning, and quality assurance check list of the treatment delivery proced ure. This paper gives a review of QA program in detail currently in use.

Check Items in QA of LINAC Radiosurgery

1. Mechanical Check of LINAC and Auxiliary System

The linear accelerator should undergo mechanical QA tests for normal radiation therapy. This include the machine alignment, laser lights, etc.

1) Auxiliary collimator

The stereotactic radiosurgery procedure uses circular collimator with diameters less than 35mm. The central axis of the radiation field, as defined by the auxiliary co llimator must fall within the 1 mm diameter sphere . Coincidence of the central a xis of the small circular radiation field with the mechanical rotational collimator axi s could be tested using a modified jaw symmetry test.

2) Mechanical alignment

Special attention must be paid to the basic alignment of the machine prior to its use for stereotactic radiosurgery. Every 6 months an accurate mechanical pointer test should be performed to determine the diameter of the sphere less than 1mm encompassing the intersection of the three axes (gantry, turntable, collimator). The error range must be within this value for all stationary field configurations covering the range of motions used for treatment delivery. To verify the mechanical accuracy the multiple film exposure tungsten ball test is performed.

3) Laser alignment

During patient set-up for stereotactic radiosurgery, positioning laser beams are used as a secondary set-up verification. All lasers are tested, including spot size, prior to the treatment delivery and are adjusted to converge within 1.0 mm to the isocenter.

4) Safety of patient support assembly

Special concern for radiosurgery is the safety condition of the mechanical components and anti-collision devices. The patient head is attached to the floor standard or table while the patient body rests on the couch top. It is therefore necessary to check routinely the integrity of all mechanical and electrical components of the patient support assembly.

2. Dosimetric Check

1) Stability of beam spot

A stable beam spot is essential to preserve the geometric integrity of the stereotactic treatment system. A beam spot camera is used to monitor the stability for different gantry angles. The beam spot camera is mounted to the gantry face with a ready pack film attached to the end. This test is performed every six months.

2) Arc therapy test

Since the radiosurgery technique require non-coplanar arcs to deliver a high dose single fraction, the accuracy of the MU/degree must be checked prior to treatment to ensure the performance of the machine arc mode. If the arc mode is in error by more than 2% an electronic adjustment is made.

3) Basic beam data

The basic beam data set obtained include a set of TMR's and OAR's which covered the full extent of field sizes and depths available. Both TMR and OAR measurements are primarily made with an proper detector for small field, which might be a diode or a small volume ion chamber. The validity of diode or small ion chamber throughout the range could be crossed checked with TLD and film dosimetry.

TMR and Collimator size output factor measurements are performed every month to make sure the photon energy, and the OAR spot checks are also routinely made.

3. Localization QA

Two primary methods of localization are angiographic and CT. MR localization is being used by some institutions, even with unreasonable distortion error. The standard angiographic and CT localizer are used. In conjunction with the phantom base multiple targets are set up and localized. An error analysis on these targets is carried out. Since the entire accuracy of the procedure depends upon localization plates, the testing of the device should be an integral part of the procedure. In order to verify the accuracy of the Angiographic and CT or MR, several phantoms (both Rando and solid water) with multiple targets of known size are loaded, and localized with Angiography and CT. The location and size of the targets are computed with localization software. The geometry of the angio and CT localizer can be checked by the system. The potential warping or damage of the ring over time should be checked.

4. Treatment planning

The treatment planning is performed upon reformatted CT images, both for beam placement and dose evaluation. The dose planning programs are checked in several ways. The computations are verified by hand at selected points in a phantom. Single arcs are performed and film and TLD measurements are taken. The computed and measured data are then compared. Once agreement for single, relatively simple, arcs are verified then multiple arcs are checked. Routinely, a simple spherical phantom with film is used to obtain individual planes of the 3-D dose distribution. Transaxail, sagittal, and coronal planes are checked. These checks could be also repeated using TLD's placed in a spherical phantom. Both relative and absolute dosimetries are verified. To recheck the absolute dose values a diode or small ion chamber could be used inside a spherical or solid water phantom. Finally, set-up sheets and treatment delivery documentation should be prepared.

5. Pre-treatment set-up verification

The isocenter coordinates for the frame coordinate system are determined from the localization software. Any deviation that exceeds a pre-determined value of isocenter for each gantry/table position requires a repeat of the test to eliminate possible errors caused by incorrect settings on the target positioner. If the repeat target ball test shows a consistent error, the base line mechanical pointer test which normally performed every 6 months, is to be repeated to determine the exact cause of the misalignment.

6. Patient set-up

Once the mechanical alignment of the linear accelerator has been verified, the patient is placed in treatment position. Before treatment is delivered, three final checks of the set-up are performed. The first check is to ensure that the position of the head ring has not changed, the second is to conform that the target center is located at mech

anical isocenter and the third is to verify the depth from the skull surface to the isoce nter.

7. Treatment delivery

Because linear accelerators have limitations regarding the number of monitor units th at can be delivered per degree, calculations are done to determine how many partial ar cs, or sweeps of the gantry will be necessary to deliver the total calculated minitor un its over the planned number of degrees for each arc rotation and the number of monit or units to be delivered in each sweep. Documentation of the start/stop angles and m onitor unit delivered for each partial arc is crucial. Close observation of the patient t hroughout treatment delivery is also crucial

8. Quality assurance checklist

Each item is signed by the person completing the step. The completed checklist, al ong with the beam alignment film and all documentation of treatment is filed in the tr eatment record.

CONCLUSION

Stereotactic radiosurgery using a linear accelerator can be delivered with confidence onl y after an extensive quality assurance program has been completed for each phase of the procedure. This includes the comprehensive testing of the linear accelerator, auxiliary c ollimator, target-isocenter coincidence. During treatment planning the result of each step are cross checked by at least one independent procedure. Each step of quality assurance procedures should be carried out without variation.

REFERENCES

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