Seven-Field IMRT Treatment Plan for Carcinoma of the Prostate

Four risk objects - the rectum, bladder and right and left femurs - have been contoured.

A dose wash showing 95%, 50% and 30% isodose lines is superimposed.

- Real-time verification of IMRT dose-distributions.
- Integrated dose-distributions.
- Quick checkout of each patient treatment.
- Commissions brain, breast, and prostate IMRT systems with site-specific anthropomorphic phantoms.
The IMRT Phantom is a 25-cm diameter cylinder, 30 cm long, molded of dry water. It has 15 ducts, 1.1 cm in diameter, parallel to the longitudinal axis, and passing completely through the phantom. These accommodate dry-water rods with molded-in recesses to receive diodes and their cables. The diodes are located at the midpoints of the rods, so they can be moved to any position along the length of the cylinder by sliding the rods. Rod lengths are tolerated closely, so the positions of the diodes can be determined accurately by measurement of rod protrusions from the ends of the cylinder.

The phantom is mounted on a polycarbonate base with rollers for positioning the set of diodes at any angle relative to the base. The front dial provides accurate, repeatable angular settings. These mechanical features permit the constellation of dosimetry points to take unlimited forms and positions relative to couch and gantry.
IMRT PHANTOM DOSIMETRY

The complex dose distributions produced by IMRT must be measured in real time for pre-treatment checkout and adjustment. However, measurements must also provide integrated dose data. Since both functions should be performed in the same test treatment, dosimetric modalities such as TLD's, film and Bang gel are not suitable.

Both real-time and integrated dose distributions can be obtained by using the Sun Nuclear In-Vivo Dosimetry System, (IVD) with ISORAD-p diodes.

The Sun Nuclear IVD™ (Model 1131) is a sixteen-channel dosimeter designed to read dose data from diode detectors. The sixteen channels are organized in a very compact design that contains all operational electronics. This unit remains in the treatment room at all times. A single cable delivers all measurement data from the treatment room to the PC interface in the control area. The interface for the IVD™ is a Windows software application that runs on Windows 95 and higher. The software is both intuitive and flexible, and quickly organizes the real time dose data from all sixteen channels.

PHANTOM-BASED IMRT DEVELOPMENT

- CT Scan the phantom
- Define PTV and RO volumes
- Define inverse planning input parameters
- Obtain and evaluate results

- Translate fluences to leaf motions
- Position the phantom
- Delivery
- Data Acquisition Analysis
IMRT VERIFICATION
Intensity profiles for each patient are determined in an inverse planning process as a function of gantry and couch position. These patient-specific profiles are applied in turn to the phantom by performing a forward calculation through a CT scan of the phantom. The same profiles are then translated into a series of leaf positions, using a leaf-sequencing algorithm, and are delivered to the phantom in either a step-and-shoot or a dynamic manner. Dose is measured in the phantom at the points where the diodes are positioned. Measured dose at each point is compared to that computed in the forward calculation. If the dose at any point or set of points exceeds a specified tolerance, the delivery is subdivided into smaller segments (e.g., individual beams) to help identify errors in the procedure.

COMMISSIONING IMRT SYSTEMS
Unlimited constellations of dosimetry points are available in the cylindrical IMRT Phantom. However, the shape of this phantom differs from the shapes of patients, and it is molded in a homogeneous material whereas patients have heterogeneous tissues. Therefore, the dose distribution obtained with the cylindrical phantom is an approximation. A heterogeneous, site-specific anthropomorphic phantom is required to establish patient / phantom correspondence.

The precise treatment plan for a patient will nearly always be different from that of the anthropomorphic phantom. However, the processes involved in the development and commissioning of treatment plans are similar. Essentially, if an optimal treatment is developed for the phantom, the same methodology will be applicable to the patient.

TLD-INSTRUMENTED SITE-SPECIFIC ANTHROPOMORPHIC PHANTOMS
Dose-distribution data for commissioning IMRT require a closely-spaced, multi-plane array of dosimeters. Since real-time data are not required for commissioning, TLD dosimeters can be used. They have many advantages over other dosimetric modalities, including small size tissue equivalents, and simplified mechanical packaging, while providing high-precision dose data.

General purpose, whole-body phantoms are not optimal for acquisition of the required data. Rather, phantoms designed to yield comprehensive data to fully evaluate IMRT for particular sites have many advantages. Such phantoms are currently available (October, 2001) for breast, brain and prostate. Phantoms for other sites are being developed.

TLD Rod
1-mm diameter
x 3-mm long
PHANTOM RENTALS

Site-specific phantoms are designed for commissioning IMRT, and the use of each is limited to its site. Usually, one or two test treatments are delivered to the site-specific phantom, which then has no further use except for possible rechecking at long intervals. Consequently, the cost / benefit ratios of such phantoms are not favorable.

RSD has established a short-term rental basis for the site-specific phantoms that brings the cost / benefit ratio to a very acceptable level. The rentals take into account the situation of radiation therapy departments with respect to the use of TLD rods that are 1-mm in diameter and 3-mm long. These rods have been standardized for use in all site-specific phantoms.

For institutions with TLD readers and the standard rods, phantoms are fitted with TLD holders for all regions of interest. For institutions using different TLD rods or chips, the standard rods can be supplied by RSD as part of the rental base. For institutions that do not have basic TLD equipment, a complete dosimetry service is available.

DOSMETRY SERVICES

The dosimetry process begins with the dispatch of a set of data charts to the treatment facility for designation of the instrumented areas for each plane. The data charts are then returned to RSD for TLD loading. All holes in the dosimetry grids are filled with either TLD holders or TLD holders with TLDs, and, for areas that do not require dosimetry, with blank pins or rods. The blank pins are differentiated from those with TLDs by red coloring.

TLDs display fading effects for both pre- and post-irradiation as functions of time from annealing to irradiation and from irradiation to reading. Correction factors that deal simultaneously with both pre- and post-irradiation fading are available to maintain precision. It is important for the treatment facility to report the time and date of irradiation to RSD when dosimetry services are ordered.

All TLDs furnished by RSD have been cycled several times, both to eliminate those few that do not have close repeatability and to group the others in 1% intervals to maintain a high degree of accuracy of dose-distribution data.

Although the TLDs are calibrated by reference to precision ion-chambers, the calibrations are repeated for the users' facilities. This is done by sending out a group of TLD rods packaged in a holding tray to be irradiated by the user to 300 cGy. The tray also provides build-up.

The dose reading at each point is recorded on the data charts, so that isodose curves may be drawn by the using facility.

The correction factors for fading are valid for periods of more than 10 days. Hence, shipments of phantoms to and from the using facility can be made by surface or air freight without diminution of accuracy.
THE BRAIN PHANTOM

Although this phantom was developed for stereotactic radiotherapy, it is equally applicable to IMRT. The phantom utilizes dosimetric cylinders 44 mm in diameter, built up of 7 dry-water disks, 3-mm thick with 1-mm thick spacers between the disks. The central disk and the disks immediately superior to and inferior to the target disks hold 25 TLD rods each. Two locations are provided in the cranial vault, representing two different relationships of the dosimetric cylinder to the skull and soft tissues of the brain. (A dummy cylinder is provided so that test treatments can be delivered separately to each cylinder).

The Stereotactic Head Phantom

Typical Data Chart

THE BREAST/THORAX PHANTOM

Commissioning IMRT with site-specific phantoms requires that the Breast / Thorax Phantom be based upon the use of the RSD Treatment Brassiere to provide optimal shapes and repeatable locations of the breasts relative to the thorax. Since the Treatment Brassiere is now in use in hundreds of treatment centers, this commissioning phantom is realistic. The left breast is chosen to be the ipsilateral breast because dose-distributions in the region of the heart are critical.

A 2-cm x 2-cm grid of TLDs is located in transverse planes, spaced 2-cm apart. The TLD rods are inserted into 5-mm nylon rods, cross-drilled at 2-cm intervals.

The Breast / Thorax Phantom

Typical Data Chart
THE PROSTATE PHANTOM

This phantom is based upon CT scans of an average male and includes the organ cluster of prostate, seminal vesicles, bladder and rectum. Each organ is radio-equivalent to the organs of an average patient.

Mechanical considerations in the positioning of TLD rods have led to 2-cm thick slices. The dosimetry plane is located between the superior and inferior surfaces of each slice. This is accomplished by the use of 2-cm long tissue-equivalent TLD rod holders that are cross-drilled at their centers to receive the TLD rods.
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<td>RS-1200</td>
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<td>Stereotactic Head Phantom Loaded With Holders for TLD rods (1-mm diameter x 3-mm long).</td>
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