Step 6: TLD and film 2D profile quality audit for small photon MLC shaped field sizes

Please irradiate the TLDs and films during the period:

__________________________
__________________________

and return them to the address given in the covering letter. Timely response will improve the accuracy of your results. Should the TLDs and films arrive late, please irradiate them as soon as possible but no later than one month after their receipt. If you are unable to carry out the irradiation, please RETURN the TLD and film set, marking it "UNEXPOSED".

GENERAL INSTRUCTIONS

Two TLDs are supplied for irradiation. One additional TLD has a white mark and must not be irradiated; it is used to record environmental influences during transport and storage. The red capsule is only for use in imaging the phantom.

Two cassettes are supplied containing radiochromic film for irradiation. These cassettes should not be opened to maintain the film positioning and to avoid excessive exposure to UV light.

1. The phantom will need to be CT-scanned, images exported to the TPS and monitor units calculated as if for a patient to deliver 2 Gy to the TLD and 8 Gy to the film at 10 cm depth.
2. Irradiate the TLDs and films as instructed in the Technical Instruction (part B, C and D) as if they were inside a patient. Ensure that the treatment unit is functioning properly. Each TLD and film will be identified with irradiation conditions used (use labels or similar).
3. It is recommended to irradiate all TLDs and films in the same session. If this is not possible, please provide the irradiation dates for each TLD and film.
4. After the TLD and film irradiations, measure the beam output in the reference conditions (part E).
5. Fill in the Data Sheet. An evaluation of the TLD and film results are only possible if these forms are complete.
6. Return TLDs, films and Data Sheet to the [DAN] within ONE WEEK after the irradiation.

SPECIAL NOTE: Please protect the TLD capsules and radiochromic film cassettes from accidental irradiation, heat (e.g. sunshine), and excessive humidity during storage. Do not store TLDs and films in a place where accidental exposure to radiation could occur.

CONFIDENTIALITY: The TLD and film results of individual centres are kept confidential by the [DAN] staff and will not be disseminated without the written permission of the participating radiotherapy centre. The statistical distribution of the results may be reported anonymously to the relevant authorities or published.

The phantom, TLD and film equipment sent to you represents a significant investment in cost, time and effort to the [DAN]. Failure to return the TLDs and films may be reported to your local authorities.
A. Aim of the TLD and 2D profile quality audit for small photon MLC shaped field sizes

The purpose of this TLD and film audit is to check the dose and dose distribution profile calculations performed by the treatment planning system (TPS) for small photon MLC shaped fields as used for patient treatments. Increasingly complex treatments require more sophisticated dose measuring and modeling techniques that consider not only the magnitude of the dose but the shape and localization of the dose profile delivered using MLC shaped field sizes. This is particularly relevant for stereotactic and intensity modulated radiation therapy (IMRT) in order to make optimal use of the capabilities of more complex equipment. An independent experimental verification of the 2D dose profiles calculated by treatment planning systems using film dosimetry is an important step in the improvement of quality assurance in radiotherapy and therefore an important extension of the [DAN] programme.

The absorbed dose to water at a 10 cm depth in a solid phantom for a 2 cm x 5 cm field will be checked using TLDs. The 2D dose profiles (in-plane and cross-plane) normalized to the central axis dose for a 2 cm x 5 cm and 2 cm x 2 cm MLC shaped field will be verified using radiochromic film. A solid phantom composed of polystyrene will be used for this quality audit.

You are requested to calculate the number of monitor units required to irradiate the TLDs and films at a depth of 10 cm to the specified dose, according to the TPS used in your clinical practice for patients. The TLD measured absorbed doses and film measured dose profiles will be compared to the dose calculations from your TPS for the MLC shaped field sizes at the location of the TLDs and films.

B. Preparation of the solid phantom configuration for imaging and TPS dose calculations

To perform this quality audit, it is necessary to use the solid polystyrene phantom provided by the [DAN]. This phantom has an overall dimension of 15 cm x 15 cm x 15 cm and can include one of two 2 cm slabs, one that can accommodate a TLD or the imaging red capsule on the central axis and the other a film in a plane at 10 cm depth. There is also 5 cm of phantom beyond the dosimeters for adequate scatter conditions.

1. The solid polystyrene phantom configuration for imaging is shown below in FIG. 1. Prior to irradiation of the dosimeters, the solid phantom should be imaged with a CT. For the imaging procedure, the solid phantom will be configured with the slab containing the ‘red imaging’ capsule which is to remove the effect of the air cavity. (This ‘red imaging’ TLD will have to be removed prior to irradiating the audit TLD and should be saved in case the phantom has to be imaged again.)

2. The phantom’s CT images will be exported to the TPS.

3. A treatment plan with a single 2 cm x 5 cm field will be generated to deliver 2 Gy to the location of the TLD on the central axis at a physical depth of 10 cm. A second and third treatment plan will also be generated for 2 cm x 5 cm and 2 cm x 2 cm MLC shaped fields, respectively, to deliver 8 Gy to the location of the film plane on the central axis at a physical depth of 10 cm. The plan can be generated either using an SSD or SAD technique as long as the TLD and film irradiation setup is consistent with the plan. The photon beam energy (less than 12 MV) most often used clinically should be used.

4. Obtain the number of monitor units to deliver a dose of 2 Gy and 8 Gy to water at the centre of the TLD capsule and film plane, respectively, according to the procedure used in your daily practice for patient treatments.
C. Irradiation of the TLD capsules

1. Assemble the solid phantom configuration as illustrated below in FIG. 2.
2. Insert a TLD into the TLD slab.
3. Before irradiation, recheck whether the alignment, field size and distance are correct.
4. Irradiate the phantom with the number of monitor units as calculated above by the TPS to deliver 2 Gy to the TLD.
5. Remove the TLD from the phantom and label appropriately.
6. Repeat steps 1 to 5 for the second TLD.

TLD Irradiation
Deliver 2 Gy to a TLD placed at 10 cm physical depth in a homogeneous polystyrene solid phantom (FIG. 2); MLC shaped field size 2 cm x 5 cm at the distance from the source used in the treatment plan above. The longitudinal axis of the TLD must be placed parallel to the long dimension of the MLC field.

D. Irradiation of radiochromic films

1. Assemble the solid phantom configuration and setup in relation to the linac as illustrated below in FIG. 3. The 2 cm
slab containing the TLD insert must be replaced with the 2 cm film slab.

2. Insert the film cassette for the 2 cm x 5 cm field into the film slab. The long dimension of the film cassette must be parallel to the long dimension of the MLC shaped field.

3. Before irradiation, recheck whether the alignment, field size and distance are correct.

4. Irradiate the phantom with the number of monitor units as calculated above by the TPS.

5. Remove the film cassette from the phantom.

6. Insert the film cassette for the 2 cm x 2 cm field into the film slab keeping the same orientation of the phantom in relation to the linac and the same orientation of the collimator.

7. Repeat steps 3 to 5 for the second film cassette irradiation for the 2 cm x 2 cm MLC shaped field size.

**Film Irradiation #1 (2 cm x 5 cm MLC shaped field)**

Deliver 8 Gy to the film placed at 10 cm physical depth in a homogeneous polystyrene solid phantom (FIG. 3); MLC shaped field size 2 cm x 5 cm at the distance from the source used in the treatment plan above. The long dimension of the film cassette must be placed parallel to the long dimension of the MLC field.

**FIG. 3. The solid polystyrene phantom showing the irradiation of the film with a 2 cm x 5 cm MLC shaped field.**

**Film Irradiation #2 (2 cm x 2 cm MLC shaped field)**

Deliver 8 Gy to the film placed at 10 cm physical depth in a homogeneous polystyrene solid phantom (FIG. 4); MLC shaped field size 2 cm x 2 cm at the distance from the source used in the treatment plan above. The long dimension of the film cassette must be kept in the same orientation of the phantom in relation to the linac.
FIG. 4. The solid polystyrene phantom showing the irradiation of the film with a 2 cm x 2 cm MLC shaped field.

E. Absorbed dose measurements with an ionization chamber

Determine experimentally the absorbed dose to water in reference conditions for the radiation beam used for the TLD measurements above according to your usual dosimetry code of practice (dosimetry protocol) and complete the data sheet.

F. Treatment planning system dose profile calculations

The local hospital is required to generate in-plane and cross-plane dose profiles for the 2 cm x 5 cm and 2 cm x 2 cm MLC shaped fields at 10 cm depth under the same conditions used to irradiate the films. The dose profiles must have a 1 mm resolution to generate a smooth curve in the low dose region, penumbra and central high dose regions. Data should be provided for 2 cm beyond the edge of the field in each direction. These dose values along with the position with respect to the central axis should be provided in an Excel spreadsheet for comparison to the film measurements.
FILM HANDLING INSTRUCTIONS FOR DANs
Step 6: TLD and film 2D profile quality audit for small photon MLC shaped field sizes

GENERAL GUIDANCE

1. Radiochromic film (EBT2) will be provided to each of the DANs. The [DAN] will designate an institution to be the Film Measurement Center (FMC). The FMC will store, prepare, load film cassettes, ship, receive and analyze the radiochromic films.

2. Radiochromic film and loaded film cassettes should be stored in such a manner as to avoid accidental irradiation, heat (e.g. sunshine), exposure to UV light and excessive humidity. The film should be kept in a dark location.

3. Radiochromic film must not be handled with bare hands. Cotton gloves must be worn when touching the film. In addition the film should not be folded or damaged mechanically, as that will cause artifacts to appear when scanning irradiated films.

4. Further detailed information can be found in the AAPM’s task group report 55, entitled “Radiochromic Film Dosimetry”.

TECHNICAL GUIDANCE

Radiochromic film preparation procedures:

1. The FMC should note the batch of the film being used and to not mix batches if at all possible.

2. The film needed for the 2D dosimetry quality audit for small MLC shaped photon field sizes will be cut by the FMC from a full sheet of radiochromic EBT2 film as shown in FIG.1. The film can be cut with a very sharp pair of scissors or other sharp cutting device (a 1 mm strip along the cut line will not be usable for dosimetry purposes). Any individual handling the film must wear cotton gloves.

3. Once the film has been cut it must be stored in a black envelope until it is used. A small piece of film from the bottom of the full sheet as indicated in FIG.1 will be retained for a background reading to be used with each set of two films sent for measurement.

4. The radiochromic film will be positioned into the 2 phantom film cassettes by the FMC, as shown in FIG. 2. The film will be placed against the positioning lip and the top of the cassette will then be placed over the film, applying pressure to the cover such that the pins can mark the film and hold it in place.
5. The film will be held in position by positioning pins located in each polystyrene film cassette as shown in FIG. 2. The pin marks on the film will also serve to orient the film and locate the central axis on the film.

6. Once the film is positioned within the polystyrene film cassette, the film cassette, a black envelope containing the background piece of film and remaining polystyrene slabs will be sent to the local hospital who will carefully assemble the solid phantom prior to irradiation according to the instructions provided.

7. When the films return from the local hospital, the cassettes will be unloaded, handled and stored in the same manner indicated above until they are analyzed. The film storage envelopes must be labelled accordingly.
TLD and FILM POSTAL DOSE QUALITY AUDIT FOR X-Ray BEAMS

DATA SHEET

Step 6: TLD and film 2D profile quality audit for small photon MLC shaped field sizes

It is of great importance for the TLD and film evaluation that the information requested below be completed. Please complete Part II if additional absorbed dose to water was made by ionization chamber measurements.

Individuals responsible:
Radiation oncologist: ...........................................................
/position/

Medical physicist: ...........................................................
/position/

Name of institution: ...........................................................

Address: ...........................................................................

Telephone number: ...........................................................

Fax number: ....................................................................

E-mail: ............................................................................

Form completed by:
Name: ............................................................................

Position: Medical physicist [ ] Radiation oncologist [ ] Technician [ ]

on the day:  ____  ____  ____
day  month  year

Irradiation performed by:
Name: ............................................................................

Position: Medical physicist [ ] Radiation oncologist [ ] Technician [ ]

Previous participation in an external audit or intercomparison for this beam

No [ ]

Yes [ ] Date: ............................................................

Please also give information on participation in any other audit: ..................................................
PART I. FOR HOSPITAL STAFF (PHYSICIST, ONCOLOGIST, TECHNICIAN)

I.1 Specifications of the treatment unit

The treatment unit used for this audit is of the type

/manufacturer/ /model/ /serial number/ /production year/

Installed in the year ........................................................................................................................................

The manufacturer’s stated beam energy is .................................................................

The beam is □ with □ without the flattening filter and is commissioned as □ standard □ SRS □ SRT beam.

The beam quality is characterized by one of the following:

□ D20/D10 = ..................... (10 cm x 10 cm at SSD = 1 m)
□ TPR 20/10 = ..................... (10 cm x 10 cm at a constant source detector distance of ........... cm)
□ other ................................conditions: ..............................................................

I.2 Beam output used for patient treatment planning

Treatment Planning System used is: ............................................................. Software version: ............... 

The reference absorbed dose to water per monitor unit which is used for treatment planning for patients in daily routine is: ......................... Gy/MU.

It refers to a depth of ............. cm in water for a ............. cm x ............. cm field size at:

SSD = ............cm fixed source surface distance

SSD = ............cm fixed source detector distance

OR

SSD = ............cm fixed source to centre of the TLD distance (isocentric set-up)

I.3 Irradiation of the TLD capsules and films

(see section B, C and D of the instruction sheet)

The TLD capsules were irradiated at:

SSD = ............cm fixed source surface distance

SSD = ............cm fixed source detector distance

OR

SAD = ............cm fixed source to centre of the TLD distance (isocentric set-up)

NOTE: Please provide the [DAN] with a printout copy of the treatment plan summary including the monitor unit calculation and isodose distribution showing the isodose line going through the center of the TLD(s) or films for each treatment plan generated.
SOLID POLYSTYRENE PHANTOM IRRADIATIONS

**TLD Irradiation:** TLDs were irradiated using a 2 cm x 5 cm field, with an absorbed dose rate of ............ cGy/MU at the 10 cm irradiation depth.

- **TLD Irradiation #1:** ............ MU, D = ............ Gy
- **TLD Irradiation #2:** ............ MU, D = ............ Gy

**Film Irradiation #1:** Film was each irradiated using a 2 cm x 5 cm field, with an absorbed dose rate of ................. cGy/MU at the 10 cm irradiation depth. Collimator angle was ............

- **Film Irradiation #1:** ............ MU, D = ............ Gy

**Film Irradiation #2:** Film was each irradiated using a 2 cm x 2 cm field, with an absorbed dose rate of ................. cGy/MU at the 10 cm irradiation depth. Collimator angle was ............

- **Film Irradiation #2:** ............ MU, D = ............ Gy

For each of the film irradiation treatment plans, the in-plane and cross-plane dose profiles with a 1 mm resolution, including the low dose regions, penumbra and central high dose region, will be provided in an Excel spreadsheet as a table of normalized dose values and position with respect to CAX to the [DAN] for comparison to the film measured dose profiles. Data should be provided for 2 cm beyond the edge of the field in each direction.
PART II. ADDITIONAL REQUEST FOR MEDICAL PHYSICISTS

DETERMINATION OF THE ABSORBED DOSE TO WATER BY IONIZATION CHAMBER IN REFERENCE CONDITIONS

Measurements were performed by

/name/ /position/
on the following day: |__|__| |__|__|__|__|
day month year

The absorbed dose rate to water in this beam was determined by using a dosimeter system composed of
an ionization chamber and an electrometer

/manufacturer/ /model/

The Co-60 calibration coefficient of the dosimeter system (ionization chamber together with electrometer) was:

.................... R/scale unit (exposure calibration factor N\text{\text{\text{\text{\text{\text{X}}}}}})
or .................... Gy/scale unit (air kerma calibration factor N_{\text{K}})
or .................... Gy/scale unit (absorbed dose to water calibration factor N_{D,w})

The above stated calibration coefficient was determined by the following laboratory/manufacturer

on the following date .............. and refers to a temperature of ...............°C and a pressure [units] of ...........

The absorbed dose to water in this beam was measured under the following conditions:

phantom: water □ other □ please specify material: .................

field size............ cm x ............ cm

distance:

SSD = ............. OR SAD = .............

(SSD set-up) (Isocentric set-up)

the measurement depth was ............ cm to

☐ the geometrical centre

☐ P_{\text{eff}}

Please give your measurement results:

Monitor units.................................................................MU
Average electrometer reading .................................... scale units
Temperature..............................................................°C
Pressure [units]........................................................... [........]
Electrometer scale......................................................
Polarizing voltage ......................................................
The absorbed dose rate to water in this beam was determined by the following code of practice (dosimetry protocol):

Please give a detailed explanation of your procedure to determine the dose at the position of the centre of the TLD #1a and 1b based on the measurement described above. Please provide all factors you have used:

The resulting dose rate in reference conditions is: ............................................cGy/MU.
### RESULTS OF TLD MEASUREMENTS FOR HIGH-ENERGY PHOTONS

<table>
<thead>
<tr>
<th>Beam</th>
<th>Radiation unit</th>
<th>Field size (cm x cm)</th>
<th>TPS</th>
<th>User stated dose [Gy]</th>
<th>DAN (measured) dose [Gy]*</th>
<th>DAN mean dose [Gy]</th>
<th>% deviation relative** to DAN mean dose</th>
<th>DAN mean dose to User stated dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 MV</td>
<td>Name of the Radiation Unit</td>
<td>2 x 5</td>
<td>Name of the TPS</td>
<td>2.00</td>
<td>1.93</td>
<td>1.95</td>
<td>2.6</td>
<td>0.97</td>
</tr>
</tbody>
</table>

* The uncertainty in the TLD measurement of the dose is ±x.% (1 standard deviation); this does not include the uncertainty intrinsic to the dosimetry protocol (see IAEA TRS-398).

** % deviation relative to DAN measured dose = 100 x (User stated dose - DAN mean measured dose)/ DAN mean measured dose. A relative deviation with negative (positive) sign indicates that the user estimates lower (higher) dose than what is measured; a patient would therefore receive higher (lower) dose than what is intended by the factor given in the last column.

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**IMPORTANT NOTICE:** This information is provided only as an independent verification of beam output and NOT as a machine calibration, nor as an alternative to frequent calibrations by a qualified physicist. **IT DOES NOT CONSTITUTE A STATEMENT WITH REGARD TO THE QUALITY OF RADIOTHERAPY TREATMENTS.**
STEP 6 - TLD AND FILM 2D PROFILE QUALITY AUDIT FOR SMALL PHOTON MLC SHAPED FIELD SIZES

Institution: Institution Name
Address: Institution Address
Country: Country Name
TPS: TPS Model
Radiation unit: Name of the Radiation Unit
Beam: xx MV
Field size: yy cm x yy cm
Films irradiated by: Family Name
Date of irradiation: yyyy-mm-dd
Evaluation: yyyy-mm-dd

RESULTS OF COMPARISONS BETWEEN TPS AND FILM PROFILES FOR HIGH-ENERGY PHOTONS

<table>
<thead>
<tr>
<th>Rel. Dose</th>
<th>TPS field size [mm]</th>
<th>Film field size [mm]</th>
<th>Film-TPS [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>14.9</td>
<td>15.7</td>
<td>0.9</td>
</tr>
<tr>
<td>50%</td>
<td>19.8</td>
<td>19.1</td>
<td>-0.7</td>
</tr>
<tr>
<td>20%</td>
<td>25.3</td>
<td>23.3</td>
<td>-2.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rel. Dose</th>
<th>TPS field size [mm]</th>
<th>Film field size [mm]</th>
<th>Film-TPS [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>15.8</td>
<td>16.7</td>
<td>0.9</td>
</tr>
<tr>
<td>50%</td>
<td>20.4</td>
<td>20.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>20%</td>
<td>25.3</td>
<td>24.4</td>
<td>-0.9</td>
</tr>
</tbody>
</table>

Date: yyyy-mm-dd
Signature

[Graphs of In-plane and Cross-plane profiles]
RESULTS OF COMPARISONS BETWEEN TPS AND FILM PROFILES FOR HIGH-ENERGY PHOTONS

<table>
<thead>
<tr>
<th>Rel. Dose</th>
<th>TPS field size [mm]</th>
<th>Film field size [mm]</th>
<th>Film-TPS [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>44.9</td>
<td>46.2</td>
<td>1.3</td>
</tr>
<tr>
<td>50%</td>
<td>49.6</td>
<td>49.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>20%</td>
<td>54.5</td>
<td>52.7</td>
<td>-1.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rel. Dose</th>
<th>TPS field size [mm]</th>
<th>Film field size [mm]</th>
<th>Film-TPS [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>80%</td>
<td>16.1</td>
<td>17.3</td>
<td>1.2</td>
</tr>
<tr>
<td>50%</td>
<td>20.4</td>
<td>20.0</td>
<td>-0.4</td>
</tr>
<tr>
<td>20%</td>
<td>24.8</td>
<td>24.0</td>
<td>-0.8</td>
</tr>
</tbody>
</table>

Date: yyyy-mm-dd

Signature