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3-D Planning for gynecological tumors (cervix uteri): Procedure description

KEYWORDS: Cervix Neoplasms; Radiotherapy Planning Computer-Assisted

Treatment of carcinoma of the cervix uteri is a complex issue conditioned by numerous factors: clinical stage of the disease, patient's age, performance status, coincidental diseases, etc. The choice of therapy procedures is certainly influenced by following prognostic factors:
- Clinical tumor volume
- Histopathological type of tumor
- Status of pelvic and retroperitoneum lymph nodes
- Proliferation of tumor into lymphovascular system
- Depth of stomal infiltration of the tumor into cervix
- Condition of surgical margins
- Degree of tumor cells differentiation (histological and nuclear grade)
- Inadequate surgery (simple hysterectomy)
- Time interval between operation and commencement of radiotherapy
- Total duration of radiotherapy

The use of high-resolution imaging techniques (CT, MR, and PET) and improved computer technology have made possible the construction of efficient computer systems for radiotherapy planning (TPS) and creation of virtual simulation concept - 3-D planning of conformal radiotherapy.
3-D planning is based on the series of referent CT cross-sections whose 3-D reconstruction provides anatomic model of virtual patient and makes possible:
- More complex observation of the spatial relations between tumor and its surroundings
- More accurate three-dimensional definition of the tumor and distribution of radiation dose that corresponds to the shape of tumor volume

3-D planning involves individual modeling of the radiation field shape and the application of radiation beams with different angles of direction with central axes that are not in the same plane - the use of non-coplanar beams.
3-D planning isodose surfaces that correspond to the high-dose radiation are maximally adjusted to the shape of the targeted volume.
Radiation oncologist and physicist make an objective assessment and compare all relevant therapeutic parameters until they obtain the plan that best suits therapy requirements:
HOMOGENOUS RADIATION OF TUMOR VOLUME WITH DEFINED RADIATION DOSE (dose homogeneity interval within PTV +7%-5%) WITH MAXIMAL SALVAGE OF SURROUNDING NORMAL ORGANS AND MINIMAL OCCURRENCE OF POST-IRRADIATION COMPLICATIONS ALONG WITH LOCOREGIONAL DISEASE CONTROL

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STANDARD PROCEDURES IN 3-D PLANNING

- Positioning and immobilization,
- CT imaging (for planning purposes).
- Defining of targeted volume contours and risk organs.
- Radiotherapy planning

Radiation beams simulation (BEV, DRR)
Modeling of radiation filed shape (MLC)
Radiation dose prescription
Display of distribution dose volume (DVH)
- Verified simulation (EPID - Electronic Portal Imaging Device)
- Radiation

POSITIONING AND IMMOBILIZATION

Positioning of patient for therapy and defining of referent positioning points are important procedures in 3-D planning. Positioning should provide comfortability for the patient and reproducibility of the position. The efficacy of conformal radiotherapy greatly depends on the immobilization of the patient.
After the preliminary preparation of the patient, which includes barium contrast application per os and cervix marking off (by a gauze saturated with contrast medium) we perform pre-simulation procedure. It involves following: the patient is lying down on the table in supine position with her arms crossed over her chest; markers are placed on anterior and lateral pelvic walls or positioning is directly done on the flat table of the CT. In therapy position, we also adjust the position of marking points on the body surface of the patient by means of lasers that are fixed on the ceiling and lateral CT walls with same geometric angles.

IMAGING FOR RADIOTHERAPY PLANNING

After positioning and immobilization of the patient a series of 5 mm CT cross-sections of region of interest (ROI) is done in therapy position and referent CT cross-section is marked on the patient's skin.

DEFINING OF TARGETED VOLUME CONTOURS AND RISK ORGANS

Referent volumes are defined according to the ICRU-50 guidelines (Figure 1).

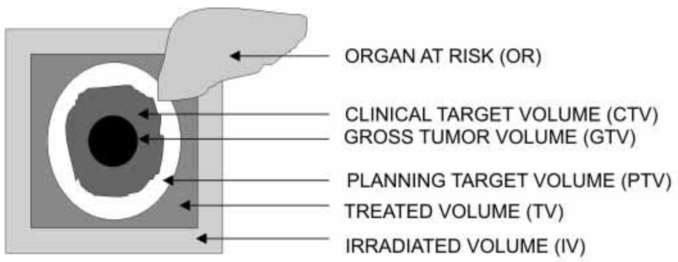

Figure 1. Scheme of the referent volumes according to the ICRU-50 guidelines

- GTV - clinically or by imaging methods visible part of the tumor with macroscopically visible metastases in lymph nodes.
- CTV=GTV + the zone of microscopic spreading of the tumor

CTV1 - the zone of subclinical spreading around the primary tumor
CTV2 - the zone of subclinical spreading around regional lymph nodes
- PTV=CTV + the margin defined by geometrical error due to:
- Difference in daily positioning (interfractional error)
- Tumor movement during radiation caused by physiological parameters (breathing amplitudes, intestinal peristalsis, the level of bladder and rectum

contents (intrafractional error)
- Variations in size, shape, and position of CTV during radiotherapy

Precision in the outline of the contours is the most important task of the radiation oncologist. It takes a lot of time, great clinical experience, and high resolution of the imaging equipment.

CTV/carcinoma of the cervix uteri
- GTV + vagina (which part?) + bilateral parameters + corpus uteri with adnexa + regional lymph nodes (which level?)

Vagina
-Without macroscopically visible lesions (2 cm below cervix uteri): anterior part of the vagina
- Macroscopically visible lesions in anterior third part: half of the vagina
- Macroscopically visible lesions below the third part: whole vagina

Regional lymph nodes
- If negative, the external iliac level (Level 1) must be included
- If positive, one level above positive lymph nodes should also be included
- Inguinal lymph nodes should be included if the lower part of the vagina is infiltrated
- Para-aortic field should be included when lymph nodes are positive

CTV/ carcinoma of the cervix uteri/ - RECOMMENDATIONS

Radiation volume must include: whole uterus, bilateral parameters, presacral, internal and external iliac lymph nodes, uterosacral ligaments and other paracervical tissues, even in case they are not completely invaded (Morris et al., 2004)
- PTV=CTV + uniform margin of 15 mm, (TD 45Gy/25 fr)
- In case of subdosing of parametrial infiltrates a boost (PTV2)-10-12 Gy/5-6 fr should be applied
- Optimal median pelvic dose (including brachytherapy) should be 64 Gy (not < 56 Gy)

RADIOTHERAPY PLANNING

Basic steps in radiotherapy planning are:
- Simulation of radiation beams
- Modeling of radiation field shape
- Radiation dose prescription
- Display of distribution dose volume

Simulation of radiation beams

Simulation of the position, shape, and geometry in relation to the targeted volume is done by means of BEV (beam eye view) (Figure 2).

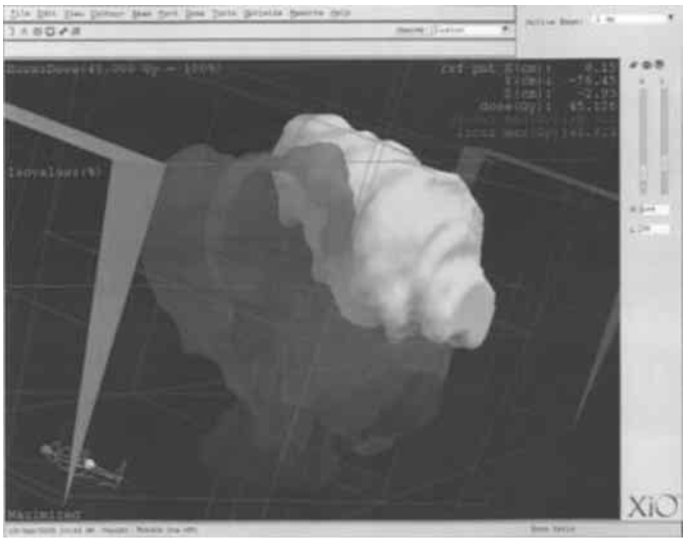

Figure 2. Position of the beams relative to volumes of intereset

Modeling of radiation field shape

DRR (digitally reconstructed radiography) - serves as a matrix on which the shape of the radiation filed is being modeled by Multi Leaf Collimator (MLC) (Figure 3).

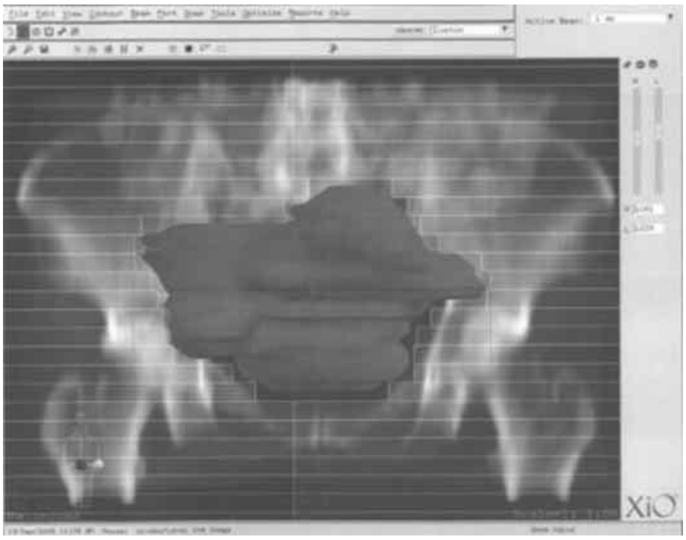

Figure 3. Digitally reconstructed radiography of the beam shaped by MLC's on the figure, planning target volume could be seen

Dose prescription

It se done on the isocenter or 95% of isodose surface which incorporates the whole targeted volume

Display of distribution dose volume

It is obtained by means of distribution dose volume (DVH) and is used in the analysis of the therapy plan parameters. It shows the relation of the volume three-dimensionally defined structures (on y axis) and radiation dose applied to this volume (on x axis) (Figure 4).

Figure 4. Dose volume histogram of the plan, with the main volumes displayed and the doses they get

VERIFIED SIMULATION (DRR-EPID)

After repositioning of the patient according to geometrical parameters of RT plan and overlapping of the isocenters of radiation beams and isocenters of the therapy machine we perform the final marking (tattoo) on the patient's skin (Figure 5).

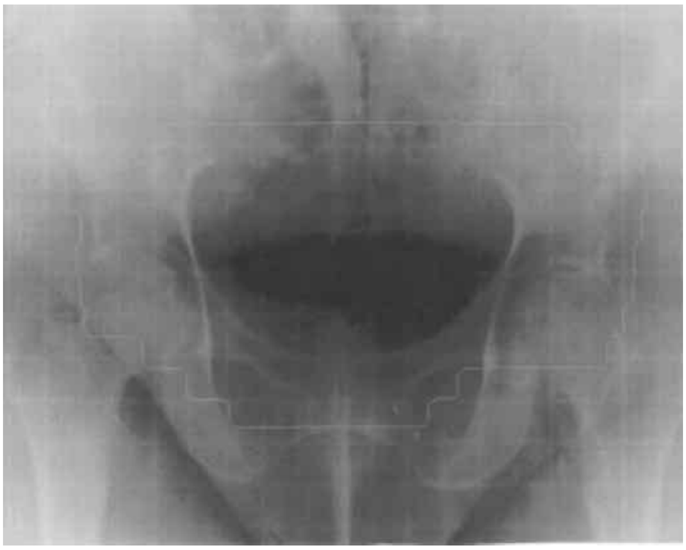

Figure 5. Verification image done by means of EPID

CONCLUSION

- 3-D conformal radiotherapy provides more accurate three-dimensional definition of the tumor and distribution of radiation dose that corresponds to the shape of tumor volume.
- 3-D conformal radiotherapy provides accuracy in the dose application and dose escalation to the targeted volume.
- Efficacy of the treatment greatly depends on the immobilization of the patient.
- Precision in the outline of the contours is the most important task of the oncology radiologist. It takes a lot of time, great clinical experience, and high-resolution imaging equipment.
- 3-D provides maximal approach to the basic aim of the radiotherapy.
- 3-D conformal radiotherapy significantly reduces to dosing of normal tissues; yet, a great caution is still necessary because any erroneous demarcation of pelvic, inguinal or para-aortal lymph nodes always results in the appearance of locoregional diseases

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