Planning Optimization of Conformal Radiotherapy Techniques for Meningioma Brain Tumors

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Abstract

In modern radiotherapy (RT) techniques (conformal), the optimum dose distribution can be achieved by covering the target volume with certain isodose line (e.g. 95%), aiming to cover this volume with the clinical prescribed dose. Recent linear accelerators are provided with multileaf collimators (MLCs) to configure the shape of the radiation field with the treated volume in any direction. To gain the same results in conventional radiotherapy, tedious work is necessary in mould room to make the required shielding blocks. The aim of this study is to evaluate the conformal radiotherapy techniques with different field arrangements in comparison with the conventional field arrangement in order to deliver a higher dose to the target volume than conventionally given, in other words to rise the dose, while sparing surround healthy tissues. A three dimensional treatment planning system (3D-TPS) will be used for dose calculations and data analysis to choose the optimal dose distributions. In order to deliver a high conformal dose distribution, multileaf collimators and accurate patient/phantom positioning is essential.

Key Words: Radiotherapy – Multileaf collimator – Three dimensional treatment planning system.

Introduction

IN radiotherapy, the goal of treatment planning is to spare the critical structures while delivering the complete prescription dose to the target volume [1], in which the determination of treatment parameters optimal in the management of a patient’s disease is involved, these parameters include target volume, dose-limiting structures, treatment volume, dose prescription, and dose fractionation, dose distribution, positioning of the patient, treatment machine settings, and adjuvant therapies [2], but this process has to be repeated several times since by changing input parameters such as field shape, beam energy, beam weights, compensators and beam blocks, respectively better treatment plans evolve. The degree of optimization achieved in the final result depends on the time available and the skill of the radio therapeutic team [3]. Recent advances in planning and delivery of radiotherapy including three dimensional conformal radiotherapy, intensity modulated radiotherapy, allow dose escalation with more precise localization of the maximum dose region and maximum sparing of normal brain [4]. In patients treated with conventional radiotherapy, the primary obstacles to achieving the maximum possible therapeutic advantage are the uncertainties in the true extent of the disease, inadequate knowledge of the exact shapes and locations of normal structures, the lack of optimal tools for efficient planning and delivery of radiation therapy and limitations of existing methods of producing desirable radiation dose distributions. These limitations result in the incorporation of large safety margins to reduce the risk of local relapse. So, the tumor dose often has to be maintained at suboptimal levels to prevent unacceptable normal tissue complications which lead to a higher probability of local failures [5]. Today, conformal radiotherapy is widely used in the management of cancers, especially meningiomas. Conformal radiotherapy is a new irradiation technique made possible by technological improvements, especially progress in imaging and 3D dosimetry by conforming the volume irradiated as closely as possible to the clinical anatomical target volume. Conformal radiotherapy is designed to deliver a higher dose to the tumor volume, while more effectively sparing the adjacent tissues from the adverse effects of irradiation [6]. The aim of most conformal radiotherapy is to achieve a high-dose treatment volume restricted to be within the planning target volume. To achieve this, the application of multileaf collimators [MLCs] has become of a great importance to make radiotherapy more efficient [7]. For several
years now, the computer-controlled multi-leaf collimator [MLC] has been used for conformal radiotherapy as a replacement for metal alloy blocks [8].

**Material and Methods**

The study was carried out at Clinical Oncology & Nuclear Medicine Department, Mansoura University Hospitals, Egypt.

High energy linear accelerator LA, computed tomography CT, simulator, Elekta Precise three dimensional treatment planning System 3D-TPS, and dosimetry equipments will be used in this study on 25 meningioma patients. We carry out the following steps conventionally (without using MLC), and conformally (with using MLC) on each patient:

**Patient positioning and immobilization (Treatment Simulation and Setup):** For a patient set-up on simulator device, markers (lead wires) are placed on the skin at the medial and lateral borders, in a transverse treatment plane in the lesion or away from it. The patient is marked so that the set-up can be reproduced for treatment, using an isocentre reference point on stable skin. The couch height will be set using this reference point, and then the couch moved laterally for a measured distance x cm.

**Imaging data:** With CT-Scan we will obtain a CT data set of the region to be treated or region of interest [ROI], with a suitable slice spacing (0.3cm), serial number of transverse cuts along the lesion and extending an extra area above and below the lesion in order to see the normal tissues (OARs). these images will be received by the three dimensional treatment planning system 3DTPS through a net cable, whose software will translate the image number into the electron density, and then collect and load the transverse cuts conforming the sagittal, coronal views, and 3D image.

**Anatomy delineation:** The radiation oncologist delineates the GTV, CTV, and PTV [9], on every CT slice shows tumor mass and organs at risk around the target. In this work we delineate 12 organs at risk (right and left eyes, optic nerves, and orbits, optic chiasma, brain stem, spinal canal, spinal cord, brain, and normal brain tissue).

**Dose specification (Prescription):** Brain tumors are often treated by 200cGy per fraction along 30 fractions, and five ones daily per week.

**Trying treatment techniques:** Photon beam radiotherapy is carried out with a variety of field sizes under a constant SSD = 100cm for all beams, with photon beam of 6MV energy. There are several techniques of using external beam therapy to treat meningiomas. These techniques are: Stationary or fixed techniques, and dynamic techniques.

A- The stationary techniques: Include the use of from one beam to several beams: Two fields, three fields, four fields (box, or diamond)... 

**Using wedge filters:** Wedge Pairs Technique: Wedged fields are often used in pairs (wedge pairs), the two beams aimed at a structure at right angles with wedges, with the insertion of 45° wedges with their heels toward each other, the dose uniformity over the tumor is markedly improved. N.B. The pink color outer the PTV represents the 95% dose wash and the discrete yellow lines represent the used beams.

**Three fields’ technique:** This technique can reduce the relative dose to superficial tissues while maintaining a high central dose in the tumor. The three fields may be open, wedged, or two wedged and one open. Figs. (1,2) show the effect of an open three-fields plan (two laterals, G. A. 90°, and 270° and one anterior G. A. 0°) on the isodose distribution in the conventional and conformal technologies respectively, in the treatment of the patient with Middle Meningiothelial Meningioma, 42 years aged.

![Fig. (1): A conventional technique (three open fields, two laterals, and one anterior).](image1)

![Fig. (2): A conformal technique (three open fields, two laterals, and one anterior), with the use of MLC.](image2)
Figs. (3,4) show the effect of a three beams technique (two parallel opposed wedged fields, G.A. 237°, and 31°, and one open right lateral oblique, G.A. 304°), on the isodose distribution in the conventional and conformal technologies respectively, in the treatment of the patient with Transitional Meningioma, 53 years aged.

![Fig. (3): A conventional technique (three fields, two parallel opposed wedged fields, and one open lateral oblique).](image3)

Fig. (4): A conformal technique (three fields, two parallel opposed wedged fields, and one open lateral oblique), with the use of MLC.

Four-field technique: Using two sets of parallel opposed fields, four fields at right angles aimed at the same center, resulting isodose distribution is box-like, or diamond-like. This configuration of beams lowers the dose at the sides of the patient.

The input of coronal beams: The use of one or more coronal beams alone, or in a combination with one or more direct beams, with wedges or not. Figs. (5,6) show the effect of a three beams technique (Right, and left lateral wedged fields, G.A. 270°, and 90°, and one coronal open, G.A. 40°, couch A. 270°), on the isodose distribution in the conventional and conformal technologies respectively, in the treatment of the patient with Meningiothelial Meningioma with some typical features, 28 years aged.

B- The dynamic techniques:

Arc technique: This technique produce a relatively concentrated region of high dose near the isocentre, but also irradiate a greater amount of normal tissue. Figs. (7,8) show the effect of three arcs (right, G.A. starts at 203°, stops at 300°, left, G.A. starts at 30°, stops at 164°, and anterior, G.A. starts at 284°, stops at 60°), on the isodose distribution in the conventional and conformal technologies respectively, in the treatment of the patient with Frontal Transitional Meningioma, 48 years aged.

![Fig. (5): A conventional technique, a three beams technique, (Right, left lateral wedged fields, and one coronal open).](image5)

Fig. (6): A conformal technique, a three beams technique (Right, left lateral wedged fields and one coronal open), with the use of MLC.

Fig. (7): A conventional technique of three arcs (right, left, and anterior fields).
Rotational technique is the same as arc technique, but the beam is turned-on during one only rotation around 360 of the gantry.

And finally, using a combination between stationary and dynamic techniques.

**Dose calculation:** A dose computation algorithm, calculates the dose distribution, and dose statistics (maximum, minimum, and mean doses), through the defined 3D volume.

**Plans evaluation:** Using plan evaluation tools (isodose display, DVH, and dose statistics).

**Plan documentation:** At the end of dose calculation process, we obtain the data sheet, which represents a report about the beams, and technique used.

**Plan implementation and verification:** In order to verify different treatment techniques, we will apply it on the Alderson Rando phantom to know if it is applicable on the patient and treatment machine or not, then the treatment technique which is applicable and acceptable by the oncologist will be applied on the patient, and the patient will be irradiated by linear accelerator with the typical set-up as that on CT, and Simulator, with thermoplastic mask, and head-rest for immobilization purposes.

**Results and Discussion**

The setup margin (SM) is added to take into account all uncertainties in patient-beam positioning [10-12]. From a realistic standpoint, the goal of CTV-to-PTV margins is to compensate for the variability of treatment setup and internal organ motion. However, with improved methods of target localization, specifically with the advent of image guided radiotherapy [IGRT], the concept of PTV continues to be evaluated [13-17]. The goal was to deliver >95% of the prescribed dose to >95% of the PTV [18-20].

By comparing statistically between the volumes covered by 95% isodose level in the conformal and conventional technologies, we found that the mean dose difference is highly significant ($p < 0.005$), for most sites at risk, for normal brain tissue ($p=0.000$), optic chiasma ($p=0.001$), brain stem ($p=0.000$), Rt. eye ($p=0.000$), Rt. optic N. ($p=0.000$), Rt. orbit ($p=0.000$), Lt. orbit ($p=0.005$), and the mean dose difference is significant ($p<0.05$), for Lt. eye ($p=0.008$), Lt. optic N. ($p=0.01$), spinal canal ($p=0.03$), spinal cord ($p=0.04$), but there is no difference for the target itself, GTV ($p=0.4$), and PTV ($p=0.04$), and a higher dose [MUs] being given to the tumor in the conformal technology ($p<0.05$), for beam1 ($p=0.01$), for beam2 ($p=0.001$), for beam3 ($p=0.002$). From our study, conformal radiotherapy widely replaced by conventional radiotherapy in the treatment of brain meningiomas. Our study emphasizes that the three dimensional conformal radiotherapy treatment planning [3DCRT]; increases the dose on the target, and decreases the dose on normal tissues as possible. In other words, increase the tumor control probability, and decrease the normal tissue complication probabilities [21,22], by the use of MLC which permits increasing of field size around the PTV, and tightening the dose around the target, so decreases the deposition of radiation in normal tissues around the target and OARs.

From the previous study, as the number of beams increased, the isodose levels become tighter on the target, on the other hand, as the number of fields increased, the treatment process will be a time consuming, loaded on the linac machine, and very expensive if we used irregular shaping beams, and accordingly the entrance and exit of beams were also controlled, then the number of beams used was limited, since all normal tissues around the target and OARs must be kept in the safe side to apply the rule of treatment stated that “increase the dose on the target and decrease the dose on normal tissues as possible as we can”.

Figs. (9,10) show the optimum technique used in frontal transitional meningioma which is the three fields (two parallel opposed wedged Rt., and Lt., G. A. 270º, and 90º, and one anterior open, G. A. 0º, couch A. 0º), as in the patient aged, 48 years, or instead of the direct anterior open field, we use one coronal anterior open (G. A. 40º, couch A. 270º), as in the patient aged, 28 years. The arc technique (Rt. arc starts at G. A. 222º, stops at G. A. 304º, Lt. arc starts at G. A. 43º, stops at G. A. 160º), as in the above patient, will give nearly the same results, but increase the dose on normal brain tissue. The use of wedge pair technique (G. A.
322°, and 44°), as in the first patient, increases the maximum dose in the GTV, PTV, brain, normal brain tissue, optic chiasma, brain stem, Rt. eye, Rt. optic nerve, and Rt. orbit up to 106%, 107%, 107%, 107%, 106%, 82%, 103%, 100% and 103% respectively, and raise the minimum dose also of the optic chiasma to 35%, then the mean dose to 65% of the prescribed dose. If we try the three arc fields (Rt. arc starts at G. A. 203°, stops at G. A. 300°, Lt. arc starts at G. A. 30°, stops at G. A. 164°, anterior arc starts at G. A. 284°, stops at G. A. 60°), as in the first patient, the maximum dose increases on the structures GTV, PTV, brain, normal brain tissue, optic chiasma, brain stem, Rt. eye, Lt. eye, Rt. optic nerve, Lt. optic nerve, Rt. orbit, Lt. orbit, up to 106%, 106%, 106%, 106%, 91%, 84%, 102%, 101%, 100%, 100%, 102%, and 101% respectively, then higher the mean dose up to 101 %, 100%, 35%, 31%, 81%, 23%, 60%, 47%, 71%, 71%, 61%, and 50% respectively, the minimum dose also raised on the optic chiasma up to 63%.

Figs. (11,12) show the optimum technique used in occipital transitional meningioma which is the three fields (two parallel opposed anterior, and posterior oblique wedged, G. A. 3 1°, 237°, and one Rt. oblique open, G. A. 304°), as in the patient, aged, 53 years, in this technique we safe the optic chiasma as it is possible, but the brain stem is included in the target, thus it must be covered by 95% at least of the prescribed dose. The use of two wedge technique (G. A. 312°, and 0°), although it decreases the mean dose on nearly all organs at risk, but it higher the dose on the optic chiasma, minimum up to 95%, maximum up to 100%, and mean up to 98% of the prescribed dose. If we also try the three fields technique (two parallel opposed wedged Rt., and Lt., G. A. 270°, 90°, and one anterior open, G. A. 0°, couch A. 0°), it also decreases the mean dose on Rt. orbit to 10%, but it higher the dose on the optic chiasma, minimum up to 95%, maximum up to 99%, and mean up to 99% of the prescribed dose.

Figs. (13,14) show the optimum technique used in midline (basal) meningiothelial meningioma which is the three fields (two parallel opposed wedged Rt., and Lt., G. A. 270°, 90°, and one coronal anterior open, G. A. 30°, couch A. 270°), as in the patient aged, 42 years, optic chiasma is included in the target, thus it must be covered by 95% at least of the prescribed dose. The use of the three fields (two wedged, G. A. 312°, 56°, and one coronal open, G. A. 36°), gives nearly the same results, but raise the maximum dose on the GTV, PTV, brain, normal brain tissue, Rt. eye, Lt. eye, Rt. optic nerve, Lt. optic nerve, Rt. orbit, Lt. orbit up to 107%, 107%, 107%, 107%, 103%, 103%, 104%, 105%, 104%, and 104% respectively. The use of wedge pair technique (G. A. 316°, and 53°), makes a general increase in the maximum dose in all structures, GTV, PTV, brain, normal brain tissue, optic chiasma, Rt. eye, Lt. eye, Rt. optic nerve, Lt. optic nerve, Rt. orbit, Lt. orbit, up to 104%, 107%, 108%, 107%, 105%, 104%, 104%, 106%, 106%, 106%, and 106% respectively.

Fig. (9): 95% isodose distribution (in transverse view) and the data sheet, for conventional and conformal techniques respectively from the left to right.
Fig. (10): 95% isodose distribution (in sagittal view) and the DVH (dose volume histogram), for conventional and conformal techniques respectively from the left to right.

Fig. (11): 95% isodose distribution (in transverse view) and the data sheet, for conventional and conformal techniques respectively from the left to right.
Fig. (12): 95% isodose distribution (in sagittal view) and the DVH (dose volume histogram), for conventional and conformal techniques respectively from the left to right.

Fig. (13): 95% isodose distribution (in transverse view) and the data sheet, for conventional and conformal techniques respectively from the left to right.
Fig. (14): 95% isodose distribution (in sagittal view) and the DVH (dose volume histogram), for conventional and conformal techniques respectively from the left to right.

**Conclusion:**

In conformal radiotherapy CRT, the use of multi-leaf collimator (MLC), will permit the increase of field size around the PTV and reduce irradiated normal tissues, while the PTV is shaped in three dimensions around the CTV exactly, so the MLC will conform the shape of the tumor, so reduce the total volume of tissue irradiated, then the tissue damage is reduced, a higher dose can be given to the tumor, so that increasing the chance of cure to fewer long-term complications (more tumor control, and less normal tissue complication probabilities). In the treatment of Meningioma brain tumor, the optimum technique used is the three fields (two parallel opposed wedged Rt., and Lt., G. A. 270°, 90°, and one anterior open, direct or coronal), with frontal transitional Meningioma, or middle Meningiothelial Meningioma. The three fields (two parallel opposed anterior, and posterior oblique wedged, and one lateral oblique open), is the best with occipital transitional Meningioma.

**References**


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sion In Non-Small-Cell Lung Cancer For Three-
Dimensional Conformal Radiotherapy Planning”. Int. J.
Radiation Oncology Biol. Phys., Vol. 48, No. 4, pp. 1015-

13- ALLEN M.C., GREGORY F., QUANG L., PAUL J.D.,
JULIAN P., and JAMES A.P.: “Evaluation Of The Planning
Target Volume In The Treatment Of Head And Neck
Cancer With Intensity-Modulated Radiotherapy: What Is
The Appropriate Expansion Margin In The Setting Of

14- SUZUKI M., NISHIMURA Y. and NAKATSU K.: “Analysis of interfractional set-up errors and intrafractional
organ motions during IMRT for head and neck tumors to
define an appropriate planning target volume (PTV)- and
planning organs at risk volume (PRV)-margins”. Radiother.

of patient setup fidelity and intrafraction motion using

16- VAANDERING A., LEE J.A. and RENARD L.: “Evaluation of MVCT protocols for brain and head and

protocols in the treatment of head and neck cancer”. Int.

18- ALONGI F., FIORINO C. and COZZARINI C.: “IMRT significantly reduces acute toxicity of whole-pelvis irra-
diation in patients treated with post-operative adjuvant

19- PERNA L., ALONGI F. and FIORINO C.: “Predictors of acute bowel toxicity in patients treated with IMRT whole
pelvis irradiation after prostatectomy”. Radiother. Oncol.,

20- AMAURY P., CÉCILE L-P., ANNE N., IVALDO F., ELENA R., JANE B., DIMITRI L., NICO-
LAS D-S., JEAN B. and SYLVIE B.: “IMRT or conformal
radiotherapy for adjuvant treatment of retroperitoneal

21- SENAN S., RUYSSCHER D. and GIRAUD P.: “Literature-
based recommendations for treatment planning and exe-
cution in high-dose radiotherapy for lung cancer”. Radio-

22- ZHENG-FEI Z., MIN F., KAI-LIANG W., KUAI-LE Z.,
HUAN-JUN Y., GUI-YUAN C., GUO-LIANG J., LI-
JUAN W., SEN Z. and XIAO-LONG F.: “A phase II trial of accelerated hypofractionated three-dimensional con-
formal radiation therapy in locally advanced non-small
cell lung cancer”. Radiotherapy and Oncology, 98: 304-
308, 2011.