Effect of Perturbation of Dose Distribution at the Lung-Tumor Tissue Interface by changes in Density

Deepti Narla, M.C. Schell (PhD), R.L. Ruo, W. O'Dell (PhD), P.C. Murdock

University of Rochester

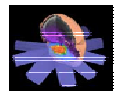
MOTIVATION

Novalis Treatment Planning System does not account for the perturbation of electron fluence due to the tissue density changes at the lung and tumor interface. We want to study the impact of this heterogeneity in dose delivered to the tumor.

INTRODUCTION

Stereotactic Radiosurgery

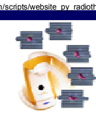
Stereotactic Radiosurgery is a procedure of directing an x-ray beam at the tumor from different angles. The beam is shaped by a collimator to mirror the image of the tumor for each of the different angles. Stereotactic radiosurgery is a non-invasive procedure. Through this procedure one is able to give a high dose to the tumor as well as protect the surrounding tissue.



Picture taken from: http://www.brainlab.com/scripts/website_py_radiotherapy.asp

Novalis Treatment Planning System

Using the Novalis Treatment Planning System (TPS), one contours the tumor and important organs and the TPS configures the beam to give high dose to the tumor while protecting the surrounding tissue.

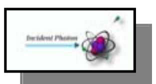


Picture taken from:

Photon interaction

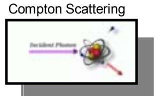
Photons interact with the individual atoms of an irradiated body by the photoelectric effect, Compton scattering and pair production.

Photoelectric Effect



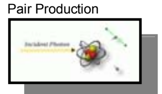
The energy of the incoming photon is transmitted to the electron of an atom of the irradiated body. Some of the energy is lost to overcome the binding energy of the electron.

Compton Scattering



The energy of the incoming photon is only partially transmitted to the electron of an atom of irradiated body. The reduced energy photon is deflected.

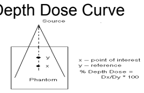
Pair Production

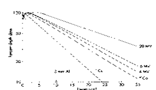


When the incoming photon interacts with the electron close to the nucleus, a positive (positron) and negative electron are produced.

Pictures taken from: http://www.cnde.iastate.edu/ncce/RT_CC/Sec.2.5/Sec.2.5.html

Percent Depth Dose Curve





(Hendee 186)

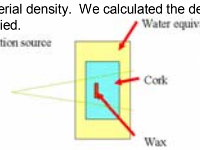
The depth-dose curve gives the relative dose versus depth along the central axis in a phantom.. The phantom used in taking these measurements simulates the patient set up. The percent depth dose is equal to the ratio of dose at a particular depth over dose at a reference depth. The reference depth is usually taken at the depth where maximum dose occurs. These measurements are taken along the central axis of the beam.

METHODS

First, we tested to see if the penumbra decreased with material density. We calculated the density of balsa and pine and irradiated these materials. Then, the Dose profile was studied.

Phantom Study:

We constructed a representative phantom of lung lesion irradiation as shown to the right. A CT scan was done and a simple treatment plan was devised using Novalis treatment planning system by BrainLAB. Then, the phantom was irradiated and the depth-dose curve was analyzed. The curves were smoothed out using Savitsky-Golay filter so that the general trend in the data can be visualized better. The phantom was irradiated with and without the wax to allow us to compare the dose at the interface.



Material Used	Represents
Water equivalent plastic	Chest Wall
Cork	Lung tissue
Wax 20mm	Tumor 10mm

Savitsky Golay filter : $Y(I)=(-3*Y(I-2)+12*Y(I-1)+17*Y(I) +12*Y(I+1) -3*Y(I+2))/35$

REFERENCE

Hendee, William R. and Geoffrey S. Ibbott. *Radiation Therapy Physics.* St. Louis: Mosby-Year Book, Inc., 1973.

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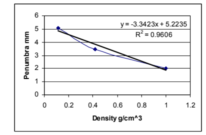
RESULTS

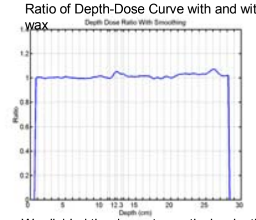
Penumbra Vs. Density

The graph shows that the penumbra decreases linearly with increasing density.

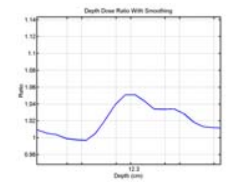


Phantom Study

Ratio of Depth-Dose Curve with and without the wax

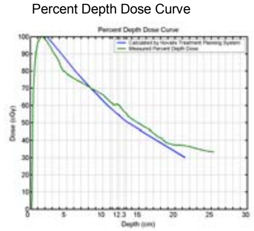


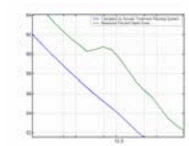
Zoomed in at the cork and wax interface



We divided the dose at a particular depth with the wax with dose at the same depth without the wax to see how the dose is affected at the interface. From the graph we can see that there is an increase in dose at the interface. We found the increase to be about 5%.

Percent Depth Dose Curve





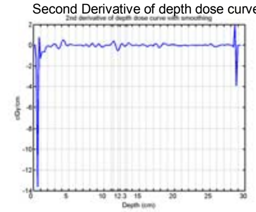
Zoomed in at the cork and wax interface

Depth (cm)	Abs Difference (%)
3.0	4.5
5.0	7.5
7.0	2.8
9.0	1.5
11.0	3.4
12.3	6.0
13.0	4.9
15.0	3.7
17.0	3.1
19.0	2.4
21.0	6.0

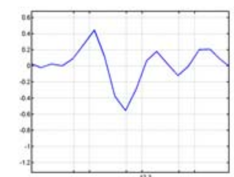
Table shows the absolute difference between the percent depth dose of measured vs the calculated (TPS)

The graph (left) shows the percent depth dose that was measured as well as the one calculated by the Novalis Treatment Planning System. The graph to the right is zoomed in at the interface between the cork and the wax. From this graph, one can see that in the Novalis Treatment planning System the dose is inversely proportional to depth-squared once the max dose is reached. However, in the measured percent depth dose, there is an increase in the dose at the interface.

Second Derivative of depth dose curve



Zoomed in at the cork and wax interface



The second derivative of the depth dose curve gives information about the photon fluence. From the graph to the right, one can see that fluence has decreased in the tumor. This decrease in fluence is due to the increase in density which cause more attenuation.

CONCLUSION

When different densities were radiated, we found that penumbra decreases linearly with density. In a lower density materials, the electrons are able to travel farther before they are attenuated. Therefore, we know that the beam spreading occurs because of the difference in densities. Then, we studied how the perturbation of electron fluence due to the change in electron density effects dose administered to the tumor. The tumor has a higher density than the surrounding lung tissue. After analyzing the data, we found that a dose build up occurs at the interface between the tumor and tissue. There is an 5% increase of dose at the interface. We compared this percent depth dose curve with the one computed by the Novalis Treatment Planning system. We found that the average difference between the two curves is 4.164% while at the lung –tumor interface the difference is 6% (+/-3%). The data we obtained will be analyzed by other TPS to gain a more clear understanding about how the dose deposition is affected by the lung-tumor interface. This experiment will be simulated in the future by a Monte Carlo analysis. Current TPS do not take into account the perturbation of electron fluence caused by difference in densities at the interface resulting in an underestimation of dose to the tumor by 6 to 8%.

ACKNOWLEDGEMENT

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