# Intercomparison study of superposition and pencil beam algorithms used in intensity modulated radiation therapy

**Presented by**

## Maha Kamal Eldin Mahmoud

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## APROVAL SHEET FOR SUMISSION

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**Name of candidate: Maha Kamal Eldin Mahmoud**

**This thesis has been approved for submission by the supervisors:**

**1- Prof. Dr.Nader A. Elsherbini.**

**Signature:**

**2- Dr. Wael M. Elshemey.**

**Signature:**

**Prof. Dr. Osiris W.Guirguis**

**Chairman of Biophysics Department**
**Faculty of Science- Cairo University**

# Acknowledgement

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Now I am sure that I am a lucky person not only because I finished my thesis in time I decided, but also because my God entered all these great people in my life. May God bless them all.

## Contents

# Abstract

## Abstract:

In radiotherapy department, the medical physicist may have several choices for the selection of treatment planning system and treatment algorithms. Knowing that there is no single treatment planning system or planning algorithm that provides the best possible performance in all treatment situations, one has to evaluate the performance of available combinations of planning systems and algorithms for each specific case. For such purpose the present study examines the performance of two planning systems (Xio and Eclipse) employing three planning algorithms (superposition algorithm on Xio and pencil beam & AAA algorithms on Eclipse) for head and prostate cases. The parameters of evaluation included dose distribution, dose volume histogram, monitor units, number of segments and quality assurance parameters. Results show that for head case the AAA algorithm gives the lowest dose to large number of risk structures. It also exhibits the lowest number of segments and monitor units. For prostate case both AAA and pencil beam algorithms give the lowest dose for most of the risk structures. The AAA algorithm produces the lowest number of segments and monitor units. For head and prostate cases, the quality assurance measurements in homogeneous phantom for Xio and Eclipse planning systems show that for both systems there are good agreement between measured and calculated dose distributions. For almost all fields the maximum variation did not exceed 4%. The dose measurements using TLD in heterogeneous phantom revealed that in head case the Eclipse planning system (employing pencil beam algorithm) overestimates the dose. In prostate case the Xio planning system (employing superposition algorithm) overestimates the dose wile the Eclipse planning system (employing pencil beam algorithm) underestimates the dose.

# Introduction

## Introduction:

The aims of radical radiotherapy are to deliver a homogeneous radiation dose to a tumor target while minimizing the dose to surrounding normal tissues. In this way the maximum number of tumor cells can be eradicated with the minimum risk of normal tissue injury. Conventional external beam radiotherapy using a small number of rectangular or simply shaped beams partly achieves these goals, but for many tumor sites this radical radiotherapy treatment leads to irradiation of unnecessarily large volumes of normal tissue.

Conformal radiotherapy aims to minimize the volume of normal tissue irradiated by shaping the dose distribution to tightly conform to the shape of the tumor reducing the dose to surrounding normal tissues. Adequate immobilization of the target and improved three-dimensional imaging, enable a higher degree of certainty of target localization which permits the use of narrower margins around the target.

Three-dimensional conformal radiotherapy (3DCRT) entails direction of multiple beams conformed to the shape of the target from each beam's eye view (BEV). In this type of radiotherapy treatment, three-dimensional dose distributions are calculated by a treatment-planning computer with dosimetric algorithms. Radiotherapy planning studies have confirmed that 3DCRT reduces the volume of normal-tissue within the high-dose volume compared to conventional and is very helpful in cancer treatment. Randomized clinical trials have demonstrated a clinically significant reduction of late radiation side effects as in patients with prostate cancer treated with 3DCRT compared to conventional radiotherapy, and at other tumor sites in non-randomized comparisons. Dose escalation within acceptable rates of normal tissue complications is a further challenge for 3DCRT. Non-randomized clinical studies in prostate cancer have suggested that dose escalation with conformal therapy improves tumor control, and several randomized clinical studies are underway.

Over the past 10 years, intensity-modulated radiation therapy (IMRT) has been the subject of considerable research and development effort. Intensity Modulated Radiation Therapy (IMRT) is the state of the art technology for radiotherapy treatment of cancer patients. Radiation is delivered from a linear accelerator that can move around the patient body, which is immobilized on the "couch". Modern equipment using multileaf collimators makes very accurate delivery of radiation to the tumor possible while at the same time protecting any organs at risk from radiation. A multileaf collimator uses metal leaves that can move into the radiation field to block out certain areas of radiation across the beam.

This means that IMRT adds the modulation possibility to 3DCRT (i.e. combines the geometrical and flounce shaping).

When choosing a plan for any individual patient, the radiation therapy planner has to determine beam directions, intensity profiles (i.e. the varying intensity across the beam head made possible by multileaf collimation) with the goals of a high (tumouricidal) dose in the tumor, and low dose in normal tissue and organs at risk. In addition, the chosen intensity profiles have to be realized through a number of reconfigurations of the multileaf collimator (the collimator sequence). In the case of step and shoot collimators, these involve irradiating with a given position of leaves, then stopping and reconfiguring the leaves for a new "shot" of radiation. Thus the problem of choosing a sequence of leaf-positions to have a short treatment time arises.

IMRT is now being implemented in many centers worldwide. In spite of its potential to improve target coverage and normal tissue sparing, implementation and commissioning of IMRT remain labor-intensive, and the choice of planning system is a crucial component that may, in some circumstances, substantially impact the time and effort required.

# Literature Review

# 1. Literature review:

## 1.1 Main features of Intensity Modulated Radiation:

Intensity modulated radiotherapy (IMRT) is a major development in the delivery of radiation therapy that has the potential to improve patient outcome by reducing morbidity or increasing local tumor control. The complexity of IMRT techniques demands a high level of quality control both in the operation of the equipment and in the delivery of treatment to individual patients, **Williams, P C (2003)**.

‘‘Beam modulation’’, ‘‘variable fluences’’, and a variety of other phrases mean the same thing as no official body has standardized the language. The acronym ‘‘IMRT’’ has entered our language (about 1996) without anyone being able to recall its first use. Certainly no-one has come forward to claim ownership, **Webb, S (2003)**.

Intensity-modulated radiotherapy (IMRT) is one of the most important advances in oncology in the past decade. Improvements in both computer technology and imaging techniques have enabled the rapid development of this exciting treatment modality. For many tumors there is a clear relationship between radiation dose and the probability of tumor control, but the tumor dose is often limited by the radiation tolerance of surrounding structures. By conforming more precisely to the selected target, IMRT may allow more normal tissue to be spared than with other techniques. This provides the possibility of both reducing late toxicity and increasing the delivered dose which could lead to improved tumor control and survival.

IMRT has two key additional features compared to conformal radiotherapy:

1. Non-uniform intensity of the radiation beams.
2. Computerized inverse planning.

Variable radiation intensity is generated across each beam, in contrast to the uniform intensity used in other radiotherapy techniques. Each beam is subdivided into hundreds of beamlets, each with an individual intensity level, enabling a very complex pattern to be constructed. The use of several beams can build up a highly conformal dose distribution, allowing precise shaping to a curved target and thus further sparing of the normal tissues, **Taylor, A & Powell, M E B (2004)**.

## 1.2 Advantages and disadvantage of IMRT:

IMRT adds the modulation possibility to conformal radiotherapy, i.e. combines geometrical and fluence shaping (Figure 1.1), **Webb, S (2003)**.

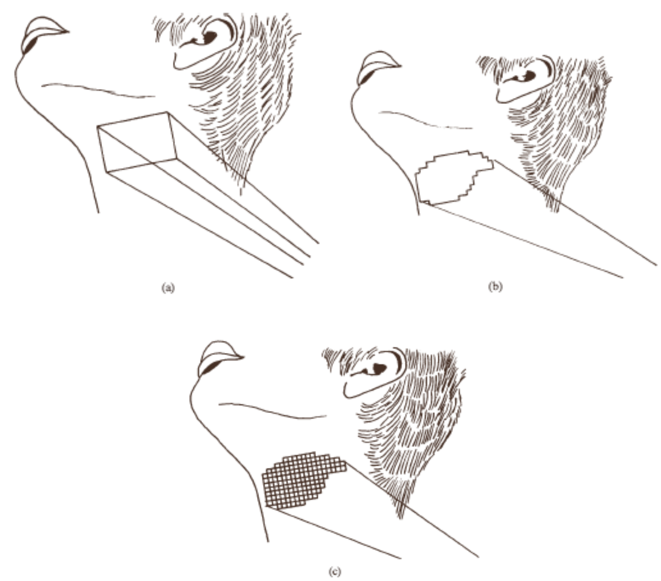


Figure (1.1) Illustrating the key differences between (a) conventional radiotherapy, (b) conformal radiotherapy (CFRT) without intensity-modulation and (c) CFRT with intensity modulation (IMRT). For almost a century, radiotherapy could only be delivered using rectangularly-shaped fields with additional blocks and wedges (conventional radiotherapy). With the advent of the multileaf collimator (MLC) more convenient geometric field shaping could be engineered (CFRT). The most advanced form of CFRT is now IMRT whereby not only is the field geometrically shaped but the intensity is varied pixel-by-pixel within the shaped field. This is especially useful when the target volume has a concavity in its surface and/or closely besides organs-at-risk, e.g. as shown here in the head-and-neck, where tumors may be adjacent to spine, orbits, optic nerves and parotid glands.