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Quantification Of Shift In Isocenter For 2-Dimensional And 3-Dimensional Radiotherapy Plans For Various Common Treatment Sites

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Abstract

2-Dimensional radiotherapy treatment planning continues to be widely used for various treatment sites in developing countries due to resource constraints. This has significant effects and treatment volumes and consequently outcomes. In this study, an attempt has been made to quantify the variations in the isocenter position in 2-dimensional radiotherapy planning compared with 3-Dimensional radiotherapy planning for various common treatment sites. It was seen that the variation was maximum in treatment planning of the breast.

INTRODUCTION

The most commonly diagnosed cancers all over the world are those of breast, lung, prostate, colorectal, stomach, esophagus, skin, bladder, cervix, liver, oral cavity etc. In India, the most common cancers among men are those of lung, stomach, head and neck and rectum. Among women, cervix and breast are the commonest sites. Since most cases are locally advanced at presentation, radiotherapy (RT) is usually an integral part of management of these cancers.

Traditionally, the dose distribution was calculated, visualized and optimized in a single plane through the patient using two-dimensional treatment planning (2DTP). In 2D planning, the anatomy is defined in a single axial slice and only coplanar beams are used for planning. The inhomogeneity inside the body is not taken into account for dose calculation. This planning method has its own limitations, as variations in the shape and density of the anatomical structures throughout the patient are not fully accounted for. Recent advances in computer technology and the introduction of three-dimensional treatment planning (3DTP) have overcome many of these limitations. 3DTP uses computed tomography (CT) datasets and improved algorithms that enable true 3D dose computation and visualization.

Three-dimensional radiotherapy treatment planning (3D-RTP) has greater resource implications compared with 2DTP because more data is needed and it is more operator intensive. 3D-RTP improves the dosimetry to tumor and reduces the surrounding normal tissues when compared to 2D planning [1,2,3,4,5,6]. Cosmesis can be improved by using 3D planning techniques for the breast rather than the conventional 2D planning [1]. Waldron J et al [3] showed that 2DTP has significant limitations in target volume coverage when compared to 3D planning for nasopharyngeal carcinoma and recommended conformal 3D planning for the same. Wilson EM et al [2] in their study on 24 patients of inoperable non-small lung cancer showed that 2D planning lead to under dosing in the tumor and increased dose to spinal cord and normal lung. Sale CA et al [4] compared 2D and 3D planning for prostate and stated that 3D planning improves radiation dosimetry to the tumor and reduces the dose to rectum and bladder compared with 2D planning. Oh CE et al [7] showed that 2D planning was associated with good dose uniformity but lead to unnecessary dose to surrounding normal tissues.

The placement of isocenter plays an important role in treatment planning. Ideally the isocenter should be placed in the center of the target volume. Treatment outcome depends on whether the radiation portals have properly covered the tumor or not. The patient is set up on the treatment machine with reference to the isocenter. In 3D image based treatment planning, the isocenter is usually placed inside the tumor and dose is prescribed at the isodose surface covering the entire

3D target volume. If we plan the same case with 2D planning, the position of the isocenter will not be the same as in the 3D planning. The placement of isocenter plays a crucial role in treatment outcome. India is a country with limited resources and most centers continue to use 2DTP. There is a need to study and quantify the isocenter shifts between targets defined in a 2D planning and 3D planning.

MATERIALS AND METHODS

In most centers where 2D planning is predominant, it is advisable to quantify the shift in the isocenter for 2D and 3D plans. This would be useful in segregating the sites where 3DTP will be more appropriate thereby optimizing use of scarce resources. In this study, the shift in the isocenter between 2D and 3D plan were quantified using Eclipse treatment planning system. An important assumption in this study was that the critical structures were not taken into account for the comparative study.

A group of 110 patients of various common malignancies such as breast, maxilla, lung, cervix, retinoblastoma, esophagus, bladder, parotid, thymus, prostate, rectum and head and neck were selected and separate 2D and 3D plans were generated. CT scans were performed for all the 110 patients for 3D planning to generate 2.5 mm thick sequential axial slices. A single CT slice was selected at the center of the tumor for 2D planning and the maximum dimensions of the tumor in other slices were superimposed on the selected CT slice. A simple 2D planning was done with the isocenter placed at the center of the tumor. In case of 3D treatment planning, the target volume was marked on the all CT slices where the tumor was visible and 3D planning was done with the isocenter placed at the center of mass of the target volume. The isocenter co-ordinates of the 2D planning (X1, Y1, Z1) and the 3D planning (X2, Y2, Z2) were noted down and the difference between the two-isocenter co-ordinates was calculated by using the Distance Formula.

Figure 1

$$D = \sqrt{(X2 - X1)^2 + (Y2 - Y1)^2 + (Z2 - Z1)^2}$$

- where X1, Y1, Z1 and X2, Y2, Z2 are the isocenter co-ordinates for 2D and 3D planning respectively.

RESULTS

The planning isocenter shift between 2D and 3D planning is shown in Fig 1 and Fig 2.

Figure 2

Figure 1: Planning isocenter shift between 2D and 3D treatment planning

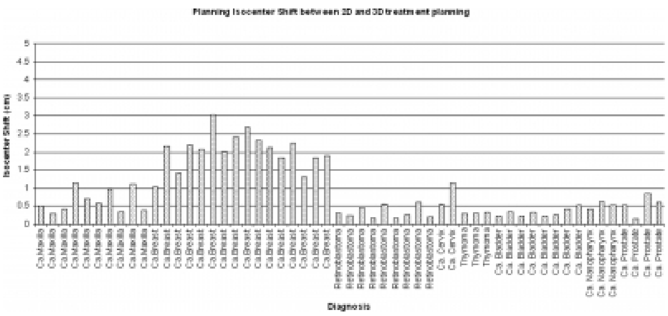
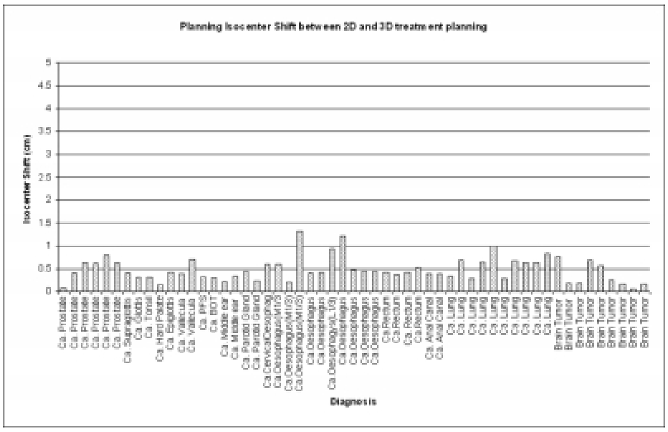


Figure 3

Figure 2: Planning isocenter shift between 2D and 3D treatment planning



Out of all the sites planned, the maximum shift in the isocenter was observed for the breast. The mean shifts in the isocenter position for the various sites in centimeters was: maxilla-0.64 ± 0.323, breast-2.04 ± 0.50, retinoblastoma-0.33 ± 0.165, cervix-0.85 ± 0.42, thymus-0.31 ± 0.022, bladder-0.32 ± 0.114, nasopharynx-0.53 ± 0.12, prostate-0.52 ± 0.26, oropharynx-0.37 ± 0.15, middle ear-0.29 ± 0.97, esophagus-0.65 ± 0.36, parotid-0.34 ± 0.15, rectum-0.44 ± 0.062, anal canal-0.40 ± 0.00, lung-0.60 ± 0.234, brain tumors-0.34 ± 0.26 . The maximum 3D shift in isocenter between 2D and 3D planning was 3.02 cm for breast followed by 1.5 cm for maxilla and less than 0.7 cm for rest of the sites. The study stresses the importance 3D planning in breast cancer.

DISCUSSION

Two-dimensional treatment planning has the limitations of not taking into account the complete anatomy of the treatment site. It is a crude approximation of 3D planning where the tumor is visualized on a single slice and less care is taken on what is the dose to surrounding critical structures. Another important drawback of 2D planning is that the complete inhomogeneity inside the body is not taken into account. The comparison of 2D and 3D planning based on isocenter shift for 110 cases of varied diagnosis shows that breast exhibits a large variation in isocenter as compared to other treatment sites when treated by standard tangential field technique versus 3D-RTP. This study gives an insight into isocenter shift between 2D and 3D planning for various treatment sites that has not been dealt with so far in literature. The main assumption in this study was that the critical structures were not taken into account for the comparative study, as it is well known that 3D planning is mandatory for those tumors, which are very close to critical structures. Our study showed that tangential field technique for breast cancer showed large isocenter shift between 2D and 3D planning when compared to other sites. The main reason why breast cancer showed a large variation in isocenter is due to the shape of the breast planning target volume (PTV). The curved shape of the target volume pulls the isocenter posteriorly when it is placed at the center of mass of the target volume. Though, it is routine in most of the centers to go for simple 2D treatment planning for breast cancer but at same time one needs to study the effect of the 2D planning from dosimetric point of view.

CONCLUSIONS

Scarcity of resources, both technical and human, compels many centers in developing countries to plan and treat most cases for radiotherapy with 2D treatment planning techniques. Many reports are now emerging in literature regarding limitations of the same. In this study, an attempt was made to quantify the difference in the position of the isocenter in 2D and 3D treatment planning. The variation was highest for breast treatment planning. Hence we conclude that 3D-RTP is a more optimal tool for planning radiotherapy for the breast.

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