RESEARCH ARTICLE

An efficacy of protection the organs at risks comparison between the intensity-modulated radiotherapy therapy (IMRT) and the three-dimensional conformal radiotherapy (3DCRT)

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Abstract

Objective: To compare the efficiency of three-dimensional conformal radiotherapy and intensity-modulated radiation therapy techniques.

Method: The cross-sectional study was conducted from February to August 2021 at Al-Amal National Hospital, Baghdad, Iraq, and comprised patients aged 19-45 years with cancerous head and neck tumours of size 2-7cm. All the patients underwent magnetic resonance imaging or computed tomography simulation scans. Treatment planning techniques used for each patient were three-dimensional conformal radiotherapy and intensity-modulated radiotherapy. After evaluating patterns, a better plan and treatment with an X-ray beam was chosen. Data was analysed using SPSS 24.

Results: The study involved thirty participants, with 17(57%) females and 13(43%) males, aged 19-45, and 28 patients having chemotherapy. Six out of thirty had craniotomy surgery. The intensity-modulated radiation therapy had a safer radiation dose than the three-dimensional conformal radiotherapy for spinal cord (p=0.3203), brain stem (p= 0.17924), right parotid gland (p=0.8556) and left parotid gland (p=0.2193). The three-dimensional conformal radiotherapy protected the organs better than intensity-modulated radiation therapy for left optic nerve (p=0.1227), right optic nerve (p=0.0032), left eye (p=0.3859), right eye (p=0.1189), left lens (p=0.0004), right lens (p=0.0001), optic chiasm (p=0.0320) and pituitary gland (p=0.9162).

Conclusion: The intensity-modulated radiation therapy technique protected the spinal cord, brain stem, and right and left parotid glands. The three-dimensional conformal radiotherapy was safe for left and right optic nerves, left and right eyes, left and right lenses, optic chiasm and pituitary glands.

Key Words: Radiotherapy, Parotid Gland, Optic Chiasm, X-Rays, Pituitary Gland, Radiation, Spinal Cord, Brain Stem, Craniotomy, Tomography

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Introduction

In radiotherapy with external photon beams, most therapies use uniform-intensity radiation beams across the field. Wedges are often used to adjust the beam's intensity to offset contour irregularities and/or achieve more uniform composite dose distributions. This process is called intensity modulation[1,2].

Intensity-modulated radiation therapy (IMRT) is an RT technique that uses a non-uniform intensity to deliver radiation to the tumour, allowing better dose conformity with planning target volume (PTV) and sparing organs at risk (OARs). The growing complexity of IMRT treatments demands an efficient and systematic quality assurance (QA) programme both in terms of precision delivery of treatment machines and treatment planning system (TPS)[3-5]. IMRT's use in treating head and neck (H&N) cancer goes back no more than a decade. As an evolving technology for radiation oncology, IMRT is being carefully evaluated for conformity[6].

IMRT provides lower toxicity and higher survival in various disease locations, including the H&N region. It also allows different degrees of dose specification to multiple target quantities, allowing for versatility in simultaneous integrated boosting treatments in the shape of differential dosing. Because IMRT is an inverse planning technique, finding an exact dose delivery solution is complex, resulting in non-uniform dose distribution across the target. This contrasts with three-dimensional conformal radiotherapy (3DCRT) planning, which uses a uniform beam profile to generate homogeneous dose distributions when adequately prepared[7].

The critical normal structures are tissues that could experience severe morbidity if irradiated, and may affect treatment preparation and dose prescription. All non-target tissues may, in theory, be considered OARs.

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However, considering normal tissues as OARs in clinical practice typically depends on their radioactivity and the dosage to which their total or fractional volume is exposed for a given dose recommended for the target dose.[8] The H&N region includes various OARs. The intricately arranged organs are necessary for fundamental physiological functions and appearance, speech and social interactions. While accounting for about 4% of cancers[9] these organs are divided into parallel and serial organs. The parallel organs are where all functional subunits perform the same parallel function, and the organ output is the sum of the functional subunit outputs. Serial organs are the ones where damage to one functional subunit damages the entire organ[10,11].

The current study was planned to compare the efficiency of IMRT and 3DCRT planning techniques.

Materials and Methods

The cross-sectional study was conducted from February to August 2021 at Al-Amal National Hospital, Baghdad, Iraq. After approval from the ethics review committee of the College of Medicine, Mustansiriyah University, Baghdad, the sample was raised using convenience sampling technique. Those included were patients aged 19-45 years with cancerous H&N tumours of size 2-7cm. Patients outside the age range and those with psychological issues were excluded.

After taking informed consent, all the patients underwent magnetic resonance imaging (MRI) or computed tomography (CT) simulation scans.

The radiation oncologist specified the prescribed dose and delineated target volumes and OARs. The radiation dose was prescribed for each patient by the oncologist, depending on the tumour type, patient history and histopathological findings. The planning was performed using Monaco 5.1. The physicist performed 3DCRT and IMRT with step and shoot type. The oncologist then approved the planning technique that reduced the dose to OARs, and increased the tumour dose.

Data was analysed using SPSS 24. Paired student t-test was used to compare the two techniques. P<0.05 was considered significant.

Results

This research had a total of thirty patients as participants. A total of 17 (57%) females and 13 (43%) males were present. People ranging in age from 19 to 45 were included. There were twenty-eight patients who had previously had chemotherapy. It was determined that six individuals out of thirty had craniotomy surgery.

Table: Comparison of the dose (cGy) that reached the organs at risk using 3DCRT and IMRT treatment planning techniques.

OARs	3DCRT	IMRT	p-value
Spinal Cord	4502.7 ± 1519.05	4092.38 ± 1472.41	0.3203
Brain Stem	3950.92 ± 2130.22	3747.83 ± 2109.29	0.17924
Lt. Optic Nerve	1655.14 ± 748.13	2060.57 ± 1322.14	0.1227
Rt. Optic Nerve	1130.07 ± 505.91	1880.88 ± 228.61	0.0032*
Lt. Eye	1447.8 ± 402.24	1736.6 ±210.65	0.3859
Rt. Eye	1253.13 ± 416.35	1766.45 ± 233.81	0.1189
Lt. Lens	267.4 ± 20.77	580.02 ±23.58	0.0004*
Rt. Lens	220 ± 147.56	663.32 ±300.64	0.0001*
Optic Chiasm	2455.9 ± 297.59	3327.5 ± 183.17	0.0320*
Rt. Parotid	1462.71 ± 112.73	1380.03 ± 796.61	0.8556
Lt. Parotid	1864.25 ± 738.77	1154.25 ± 89.46	0.2193
Pituitary Gland	667.55 ± 75.15	716.78 ± 58.54	0.9162

*Significant difference at a level less than 0.05.
cGy: Centigray, OAR: Organ at risk, 3DCRT: Three-dimensional conformal radiotherapy, IMRT: Intensity-modulated radiation therapy, Lt: Left, Rt: Right.

The IMRT had a safer radiation dose than 3DCRT for spinal cord (p=0.3203), brain stem (p= 0.17924), right parotid gland (p=0.8556) and left parotid gland (p=0.2193). The 3DCRT protected the organs better than IMRT for left optic nerve (p=0.1227), right optic nerve (p=0.0032), left eye (p=0.3859), right eye (p=0.1189), left lens (p=0.0004), right lens (p=0.0001), optic chiasm (p=0.0320) and pituitary gland (p=0.9162). The difference between 3DCRT and IMRT plans was significant related to right optic nerve, left and right lens, and optic chiasm (Table).

Discussion

It is critical to protect OARs because cancer patients must not be exposed to early or late radiation toxicity. The current study focussed on organs in the H&N region during IMRT and 3DCRT planning, and found that 3DCRT was better than IMRT for lowering the dose to the right and left optic nerves, left and right eyes, right and left lenses, optic chiasm and pituitary glands. In comparison, IMRT showed a superiority with respect to the other studied organs.

Ferreira et al.[12] evaluated the radiobiological effects of IMRT on H&N tumours, and found that IMRT, as inversely optimised, was radiobiologically and dosimetrically significantly superior to 3DCRT. Concerning damage in the parotids, they reported that the number of injuries decreased by 20% without allowing the dosage in the spinal cord to exceed the allowable dosage. It should be noted that problems are now more common in the oral cavity and mandible, which both get a higher dosage today. Radiation treatment of patients with H&N tumours also affects some essential organs, such as the spinal cord, parotids, oral cavity and mandible. Generally, they are not highly irradiated structures, and thus, not defined[13,14].

El Zayat et al.[15] compared IMRT with 3DCRT, and focussed mainly on the parotid glands, and their findings agreed with the current results. Deasy et al.[16] showed better protection with IMRT for salivary glands.

Chandra A et al.[17], agreeing with the current findings, reported that IMRT was more efficient than 3DCRT in reducing toxicity to normal organs for patients with distal oesophageal cancer.

Cardinale et al.[18] studied the effect of 3DCRT plans and compared it with IMRT on non-spherical intracranial targets. They reported that IMRT decreased the dose to healthy brain tissue. Dandan Xu et al. found no significant difference in the maximum dose that reached the spinal cord when they compared 3DCRT and IMRT plans.[19]

As inverse planning, IMRT can easily generate a good plan for a large target, reported Ding et al.[20] who discovered that IMRT was more effective in curing brain cancers than 3DCRT, particularly for cancers with irregular forms and close to essential organs. Additional treatment improvements may be expected when intensity modulation is added to a fixed-field configuration.[19,21].

Limitation: The current study has limitations as the sample size was not calculated, which could have affected the power of the study.

Conclusion

IMRT protected the spinal cord, brain stem, and right and left parotid glands, while 3DCRT was safe for left and right optic nerves, left and right eyes, left and right lenses, optic chiasm and pituitary glands.

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