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Comparison of Different Number of Beams in Intensity Modulated Radiotherapy in Head and Neck Cancer

Radiotherapy Techniques

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Abstract:-

- ***Purpose***

The aim of the work was to determine the best beams number and segments in order to improve the plans conformity and homogeneity that generate low monitor units (MUs) and faster irradiated time for different types of head and neck cancer (HNC).

- ***Methods***

This study includes 30 patients with different HNC. Intensity modulated radiotherapy (IMRT) treatment planning techniques were done with step and shoot delivery technique, 5, 7 and 9 beams IMRT were carried out for each patient. The treatment plans for all patients were calculated and optimized using fast superposition algorithm. All plans were generated using equal spaced odd beam number around the target. 6 MV were used in all beams. Multiple segments were created for each beam. Typically maximum iteration was carried out to achieve optimized plans. The beam weight optimized to generate the plan, then the segment weight optimized for all plans by using sliding window methods. The final optimization maps were converted into a way of step and shoot sequence map which delivered by linear accelerator using multi leaf collimator (MLC). IMRT plans were compared based on several criteria: Isodose distributions, the mean and standard deviation with p-values for planning target volume (PTV) 95%, conformity index (CI), homogeneity index (HI), organs at risk (OARs), number of segments, MUs and total irradiated time were presented and compared in all patients. Statically analyses were compared for all patients used ANOVA testes.

- ***Results***

The total results showed that, there was significant difference between 5, 7 and 9 beams IMRT in term of mean values for PTV95% coverage were 96.76, 97.51 and 98.22 respectively with p = 0.005. The conformation mean values were1.60, 1.49 and 1.34 with p = 0.007. HI values for the PTV were 0.14 ± 0.05, 0.13 ± 0.05 and 0.12 ± 0.04 with p = 0.001. Right parotid were 21.96, 20.72 and 20.43 with p = 0.003. Left parotid were22.14, 21.04 and 20.70 with p = 0.100. Spinal cord 45.34, 44.51 and 43.23 with p = 0.003. Brain stem were 49.52, 49.77 and 48.74 with p = 0.058. Number of segments were 79.85, 106.55 and 131.80 with p = 0.001. MUs were 23879.8, 24252.6and 22501.8with p = 0.003and the total irradiated time were 79.60, 80.84 and 75.0 respectively with p = 0.003. In fact that, the plan quality improved with an increasing the number of intensity modulated beams.

- ***Conclusions***

From this study we can conclude that, the 9 beams IMRT is superior to techniques using less number of beams (5 and 7) where, the 9 beams IMRT significantly improved the PTV coverage, dose distribution, conformity, homogeneity to the PTV with better sparing OARs and reduce the dose to surrounding normal tissues. Moreover, the 9 beams significantly reduced the mean MUs and pure irradiated time compared with 5 and 7 beams IMRT.

***Keyword*:-** *IMRT, Radiotherapy Techniques, Beam Number, Treatment Planning.*

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I. INTRODUCTION

The goal of radiotherapy is to deliver a homogenous dose of radiation to tumor, while delivering a dose as low as possible to healthy surrounding tissues [(1)]. Conventional three-dimensional conformal radiotherapy (3DCRT) delivers a homogenous dose to tumor volume with acceptable low dose to normal structures[(2)] . However, in some tumor sites with concave shape such as in HNC, limits the ability of conventional radiotherapy to shape the dose to the target volumes and to spare the OARs [(3)].

Significant advances in imaging technology resulted in more precise localization of the tumor and critical organs in three-dimensional (3D).These developments have been mainly driven by the need to reduce the dose to normal tissues. To that end, newer IMRT have been developed [(4, 5)]. IMRT is an advanced form of high precision of 3DCRT, which use linear accelerator to deliver precise radiation dose to tumor [(6, 7)]. IMRT allows to deliver radiation dose to conform more precisely to 3D concave shape tumor by modulating the intensity of radiation beam in multiple segments which minimizes the dose to surrounding healthy tissues [(5, 8)]. Typically, combination radiation beams intensity modulated fields coming from different beam directions produce precise shape of radiation dose [(9)]. IMRT techniques for treatment of HNC replaced conventional 3DCRT, which resulted in much better dose conformity, sparing of OARs and less radiation toxicity [(10)].

IMRT includes forward and inverse planning. In the forward planning, the planner selects the planning parameters, the computer then calculates the dose distribution and the plans are optimized by the manual iteration. The inverse planning begins by defining the prescription dose to the targets volumes with clinical objectives then the planning system algorithm determine the beams parameters which results dose distribution for the targets and the system undergo thousands of iterations to find the best solution for the treatment plans [(11, 12)]. Inverse IMRT for HNC is complex due to the large number of OARs locates near to the PTV [(13)] , so the correct selection of the beam number and direction in HNC IMRT improve the planning target volume (PTV) coverage as well as sparing the OARs [(14)].

The IMRT can delivered by three delivery techniques: step and shoot IMRT, dynamic IMRT and intensity modulated arc therapy (IMAT) with tomotherapy or volumetric arc therapy (VMAT) [(3, 9, 15)]. The step and shoot is most commonly available in cancer treatment centers. In this delivery techniques, the beams divided into different segments and the radiation is turn off between the segments. The MLC shape the first segments then the radiation turn on to delivers into the segment, the radiation then turn off to allow the MLC move to create the next segment. In the dynamic the radiation delivered as the leaves are moving [(3)].

The IMRT process consist of multiple steps for treatment planning until delivery of radiation [(17)]. IMRT is more conformity for irregular targets and reduce the dose to the OARs. The main disadvantage is increase the treatment delivery times and MUs [(18)]. This lead to patient discomfort, reduce the machine output and increase the dose to the surrounding healthy tissues around the PTV which arise from the MLC transmission and scatter radiation from the linear accelerator, these doses proportional to the number of MUs. These scatter radiation can increase the risk of secondary malignances [(19, 20)]. Reduction of irradiated time can be achieved by using different numbers of beams or segments or by using high modern delivery techniques such as VMAT [(8)].

The treatment planning optimization system helps to determine the distribution of the beam intensity which across the treatment volumes[(21)]. The optimization explores these possibilities to find the optimum intensity maps that are matches the dose and volumes constraints with objectives for PTV and OARs using system priorities [(3)]. The different plans can be evaluated and compared to select the optimum intensity modulation. The optimum pattern then converted to a complex sequences of beams segment [(16)].

II. PATIENTS AND METHODS

Thirty HNC patients were enrolled in this study. Seventy percent nasopharynx, 10 % hypopharnx, 6 % neck lymph nodes, 10 % tongue and 4 % check cancer. The patients included 13 males and 17 females with a mean age of 39 years (range 16 - 76 years). The patients were at different stages I, II and III with exclusion metastatic IV stage. Patients were recruited from Ayadi Al-Mostakbal Oncology Center, Alexandria, Egypt.

- *Immobilization and Computed Tomography Simulation*

Computed tomography (CT) simulator images were obtained in the supine position with a head and neck support. Patients were immobilized using thermoplastic mask. CT images were done for all patients with thickness 2 mm, using SomAtom Emotion Duo Computed tomography, Siemens.

- *IMRT Target Volumes and OARs Delineation*

In the contouring, the CT slices of selected patients were transferred to focal pro computer system by DICOM network, where outlining of the target volumes and OARs were done according to the RTOG guidelines.

- *Planning Objectives*

For all HNC patients, the treatment goal was to delivers the prescribed dose to achieve minimum dose more than 95% of the prescribed dose and maximum lower than 107% for the primary target volumes PTV. In all IMRT plans, the objectives were applied to achieve minimum doses to OARs without compromising the PTV coverage. The mean dose to the right and left parotid was aimed to be below 26 Gy, maximum dose allowed for spinal cord was 45 Gy and for brain stem 54 Gy.

➢ *IMRT Planning Techniques*

IMRT treatment planning techniques were done on Xio computerized treatment planning system. Inverse IMRT planning were used with step and shoot IMRT delivery technique using ARTISTE Linear Accelerator, Siemens, with modulator MLC include 160 leafs with 0.5 cm thickness to deliver the treatment. The IMRT planning parameters were defined and selected manually. For each patient 5, 7 and 9 beams IMRT plans were carried out.

The treatment plans for all patients were calculated and optimized using fast superposition algorithm to generate beam modulation as a specific objectives and constraints. All IMRT plans were generated using equal spaced odd beam number around the target to avoided opposing beams. In all IMRT beams 6 MV were used. The gantry angle started from 180 in all cases as the following: The gantry angles in 5 beams were 40, 110, 180, 250, 320, in 7 beams were 30, 80,130, 180, 230, 280, 320 and in 9 beams were 20, 60, 100, 140, 180, 220, 260, 300, 340 for all IMRT HNC techniques. All plans were normalized to the PTV to achieve coverage of the PTV by at least 95 % of the prescribed dose. Objectives were generated priority as the following: PTV, right and left parotids, spinal cord and brain stem. The IMRT dose prescription and constraints for each PTV and OARs were adjusted to achieve results as the planning goals.

With delivery method step and shoot inverse IMRT treatments planning each optimization were started with generation the flunce map. Multiple segments were created for each beam. Typically maximum iteration was carried out to achieve optimized plans. The segmentation parameters were specified using sliding window methods with discrete intensity levels10, minimum segment size 2 cm to reduce the number of segments, in the segment weight optimization gird spacing 0.3 cm with minimum segment MU 5 were used. The beam weight optimized to generate the plan, then the segment weight optimized for all IMRT HNC plans by using sliding window methods. In the optimization process, the optimal maps were calculated according to priorities, constraints and objectives. The final optimization maps were converted into a way of step and shoot sequence map which delivered by linear accelerator using MLC. The plans were transferred to the LANTIS system for verification and approval by medical physicist and radiation oncologist and were clinically considered acceptable.

➢ *IMRT Plans Comparison*

For each patents 5, 7 and 9 beams IMRT plans were carried out and compared. IMRT plans were compared based on several criteria:

Isodose distributions were compared visually on different images slices with respect the degree of conformity of the prescribed dose to the PTV. The PTV volumes (PTV95%) receiving 95% of the prescribed dose were compared. The HI was used to assess the dose uniformity with the PTV. The ideal values of HI is 0 so, greater value indicate heterogeneity inside the PTV [24] and is defined as HI = D2% -D98% / D50%[25]. The CI also calculated to assess the conformation of the dose to the PTV. The ideal conformation is 1 so, the greater conformity than 1 indicates greater healthy tissues irradiated around the PTV and the CI defined as CI = VTV/VPTV [25, 26]. OARs sparing were compared in term of maximum and mean received doses for all plans. Dose volume histograms (DVHs) were used to assess and compare the different coverage of the PTV and the doses received to OARs. The number of segments was compared to assess the plan efficiency for all IMRT plans. The MUs and pure irradiation time were calculated and compared as important parameters for all patients. The pure irradiated time defined as MU/D where MU is the monitor units and the D is the dose rate (Mu/min) [27]. Statically analyses were compared for all patients used ANOVA testes.

III. RESULTS

The total results including the mean and standard deviation with p-values for PTV95%, CI, HI, right and left parotids, spinal cord , brain stem, DVHs, number of segments, MUs and total irradiated time were presented and compared in all HNC patients.

➢ *PTV95%:*

Most IMRT plans for HNC were considered acceptable in term of PTV95% coverage of the prescribed dose in this study except some plans when using 5 beams IMRT. In general, the plans were acceptable if the 95% of the isodose surface covers the 100% of the PTV. In fact, the larger number of intensity modulated beams, the better PTV coverage by 95% of the prescribed dose. As present in **Table (1) and Fig. (1)** the means and standard deviations comparison between 5, 7 and 9 beams IMRT according to PTV95% coverage were 96.76 ± 2.17, 97.51 ± 2.15 and 98.22 ± 1.61 respectively. Statically, there were significantly difference between 5, 7 and 9 beams in mean PTV95% coverage by the prescribed dose $p < 0.05$. Results show that, the 9 beams for HNC was superior in PTV95% coverage of the prescribed dose compared with 5 and 7beam IMRT.

Table 1 Comparison between 5, 7 and 9 Beams IMRT According to PTV

PTV95% (%)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Min. – Max.	91.80 – 99.93	91.60 – 99.88	95.15 – 99.99	
Mean ± SD.	96.76 ± 2.17	97.51 ± 2.15	98.22 ± 1.61	0.005*
Median	96.74	97.75	98.57	

*: Statistically significant at $p \leq 0.05$

Table 2 Comparison between 5, 7 and 9 Beams IMRT According to CI

CI (No)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Min. – Max.	1.18 – 2.93	1.17 – 2.89	0.84 – 1.79	
Mean ± SD.	1.60 ± 0.43	1.49 ± 0.38	1.34 ± 0.24	0.007*
Median	1.39	1.34	1.36	

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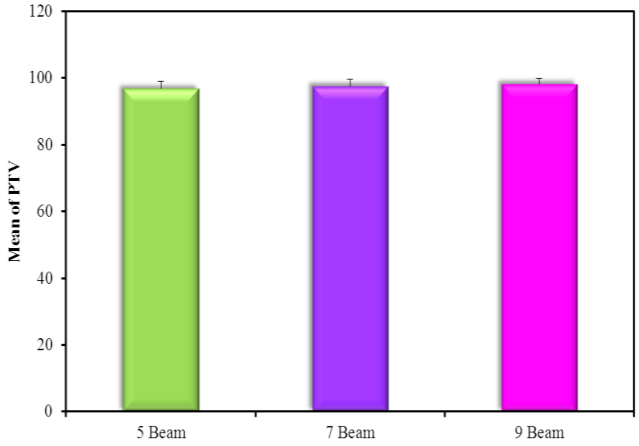

Fig 1 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to PTV95% for all HNC Patients.

- *Isodose Distributions:*

Clinically, the dose distribution in most IMRT plans for HNC was acceptable except few cases in 5 beams. The dose distribution comparison between 5, 7 and 9 beams IMRT as shows in Fig. (2), a typical isodose distribution was superior in 9 beams compared with 5 and 7 beams. The isodose lines were showed comparable between the different beams. Some areas received high doses outside the PTV and more normal tissues irradiated in 5 beams were observed. The dose is more conformed to the PTV as well as the dose reduced to the surrounded healthy tissues in 9 beams compared with 5 and 7 beams IMRT. In fact, the increasing in number of beams lead to reduce the doses received to the normal tissues and the dose were more conformed with more homogenous doses to the PTV.

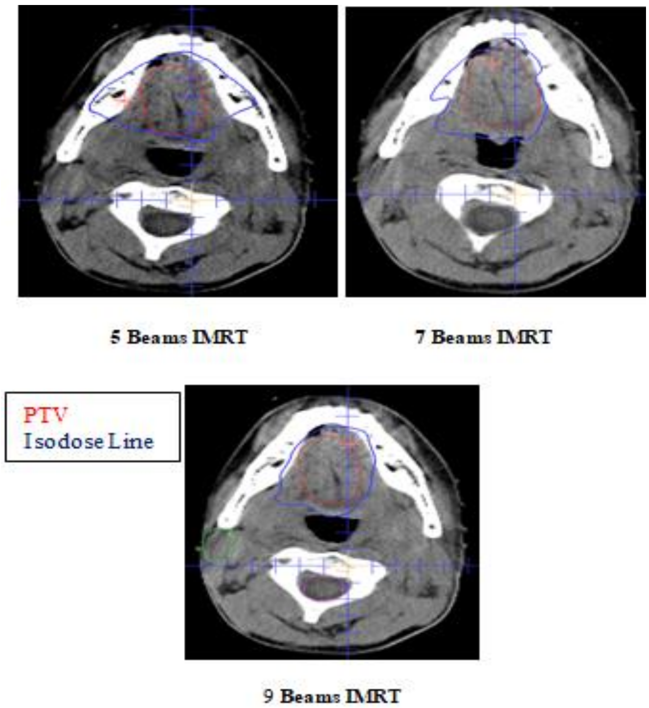

Fig 2 Shows comparison of dose distribution between 5, 7 and 9 beams for patient No 4 in axial images. The PTV coverage by 95% of the prescribed dose is similar in 5 and 7 beams compared with 9 beams IMRT.

- *DVH:*

The DVHs were calculated for all PTV and OARs in all IMRT HNC patients. **Fig. (3)** shows the DVHs comparison between 5, 7 and 9 beams IMRT according to PTV coverage and OARs received doses include right and left parotid, spinal cord and brain stem as example HNC case. The DVHs were not sufficient to evaluate the dose distribution for PTV, so the conformity and homogeneity were considered. DVHs showed higher doses received by the right and left parotids in 5 beams compared with 7 and 9 beams. The 9 beams were superior in PTV coverage of prescribed dose and OARs sparring compared with 5 and 7 beams IMRT.

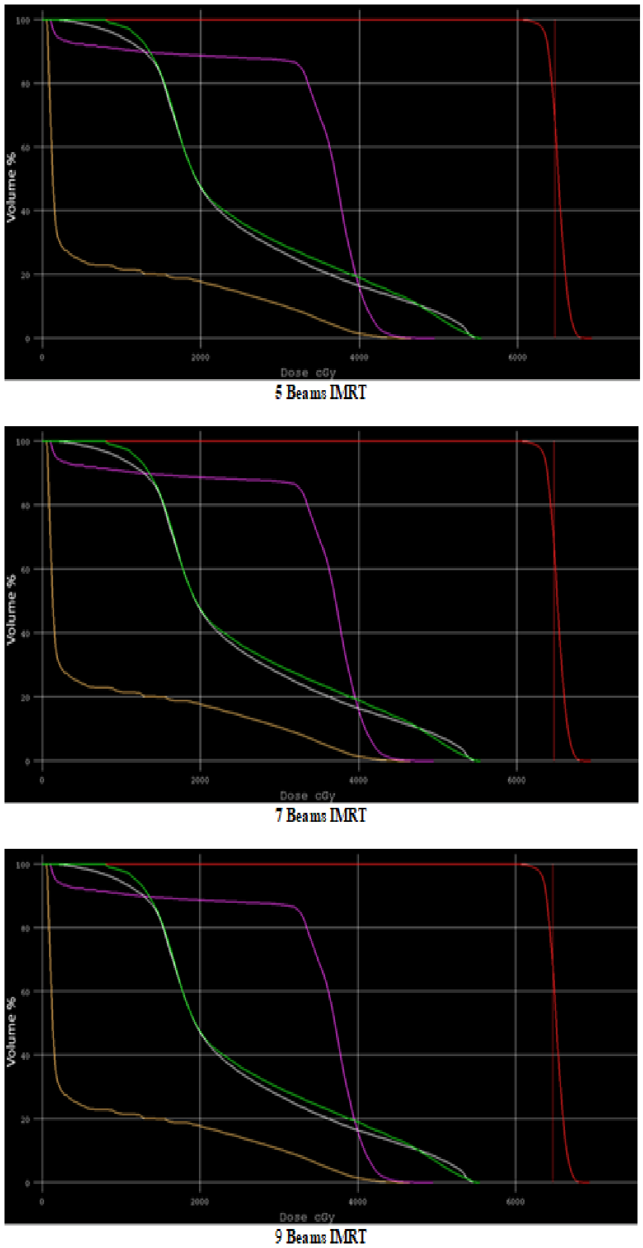

Fig 3 Shows DVHs comparison between 5, 7 and 9 beams IMRT for patient No 4. The PTV coverage by 95% of the prescribed dose is better in 9 beams compared with 5 and 7 beams. The doses received by right and left parotids were low in 9 beams. Spinal cord received lower maximum dose in 7 beams. The dose was reduced to brain stem in 5 beams compared with 7 and 9 beams IMRT.

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➢ *CI of PTV:*

The means and standard deviations comparison between 5, 7 and 9 beams IMRT according to CI of the PTV were showed in **Table (2) and Fig. (4)**. The conformation values were1.60 ± 0.43, 1.49 ± 0.38 and 1.34 ± 0.24 respectively. The 5 beams was the worst conformation compared with 7 and 9 beams, in fact that, due to the beam number not sufficient to conform the radiation dose exactly to the PTV. The conformation improve was observed when the number of the beams increased from 7 to 9 beams IMRT. There were significant differences between 7 and 9 beams when compared according to conformity degree, with $p < 0.05$. The 9 beams were superior in conformation the dose to the PTV with reduced the radiation received to the healthy surrounding tissues for HNC IMRT treatment.

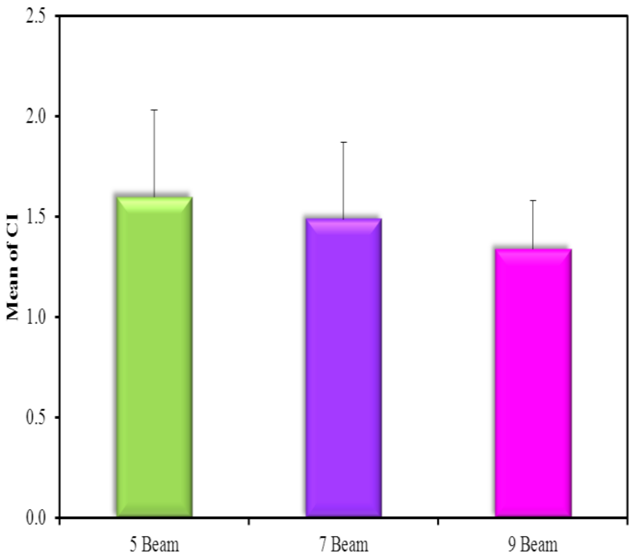

Fig 4 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to CI of PTV for all HNC patients.

➢ *HI of PTV:*

The dose uniformity inside the PTV was evaluated by the HI. The means and standard deviations values comparison between 5, 7 and 9 beams IMRT for all HNC patients were presented in **Table (3) and Fig. (5).** The HI values for the PTV were 0.14 ± 0.05, 0.13 ± 0.05 and 0.12 ± 0.04 respectively. There were significant differences in the dose homogeneity inside the PTV when compared the different beams with $p < 0.05$. The HI was indicated that, the dose homogeneity was inferior in 5 beams. The results showed that when increased the beam number from 7 to 9 beams, the dose uniformity within the PTV were improved compared with 5 beams. The typical dose uniformity inside the PTV was achieved by the 9 beams IMRT.

Table 3 Comparison between 5, 7 and 9 Beams IMRT According to HI

HI (No)	5 Beams	7 Beams	9 Beams	p
Min. – Max	0.06 – 0.24	0.07 – 0.26	0.06 – 0.20	
Mean ± SD.	0.14 ± 0.05	0.13 ± 0.05	0.12 ± 0.04	0.001*
Median	0.15	0.13	0.13	

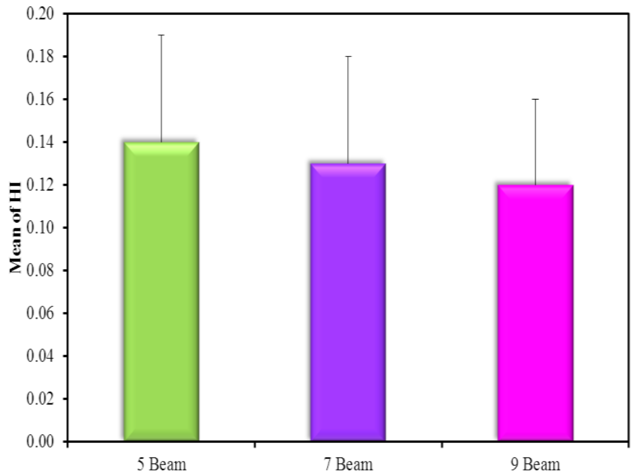

Fig 5 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to HI of PTV for all HNC patients.

➢ *Right Parotid:*

The comparison values between 5, 7 and 9 beams IMRT for right parotid in all HNC patients were listed in **Table (4) and Fig. (6)**. The means and standard deviations for mean dose to the right parotid were 21.96 ± 2.30, 20.72 ± 3.41and 20.43 ± 2.19 respectively. The mean dose to the right parotid was aimed to be below the 26 Gy to preserve the parotid function and reduce the xerostomia. Most techniques were meet the requirements criteria except the 5 beams, due to hot areas were found surrounding the PTV, in fact that related to the number of beams not conform the dose exactly to the PTV and the radiation received to the normal surrounding tissues. There were significant differences between 5, 7 and 9 beams were observed. The significant lower mean doses to the right parotid were achieved by using 9 beams compared with 5 and 7 beams IMRT with the $p < 0.05$.

➢ *Left Parotid:*

The effect of beams number also evaluated by comparison the doses received by the left parotid. The means and standard deviations comparison between 5, 7 and 9 beams for mean dose to the left parotid were 22.14 ± 2.72, 21.04 ± 3.89 and 20.70 ± 2.77 respectively. As mentioned before when compared the means and standard deviations of mean dose received by the right parotid, when compared different beams IMRT, the results were close to it in term of sparing. The left parotid sparing was improved when the number of beams increased. The results showed that, there were significant differences with $p < 0.05$ as presented in **Table (4) and Fig. (6)**.

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Table 4 Comparison between 5, 7 and 9 Beams IMRT According to Right and Left Parotids

Parotids (Gy)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Right				
Min. – Max.	17.93 – 25.32	12.54 – 26.40	16.85 – 25.04	
Mean ± SD.	21.96 ± 2.30	20.72 ± 3.41	20.43 ± 2.19	0.003*
Median	21.67	20.68	20.30	
Left				
Min. – Max.	16.05 – 25.76	10.16 – 26.23	12.93 – 25.41	
Mean ± SD.	22.14 ± 2.72	21.04 ± 3.89	20.70 ± 2.77	0.100
Median	22.58	21.62	21.24	

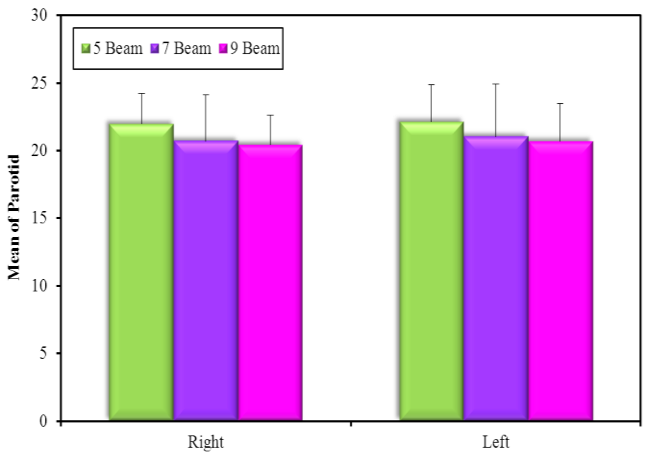

Fig 6 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to right and left parotids for all HNC patients.

➢ *Spinal Cord:*

The relationship between the mean maximum dose to spinal cord and the number of the beams for all patients were showed in **Table (5) and Fig. (7)**. The means and standard deviations comparison between 5, 7 and 9 beams IMRT were 45.34 ± 3.15, 44.51 ± 3.31 and 43.23 ± 2.37 respectively. In this study, the maximum dose allowed for spinal cord was below 45 Gy. In all patients, most plans were meet the constraints criteria except some cases with 5 beams. The means maximum dose to spinal cord was showed a significant difference between different IMRT plans with $p < 0.05$. In this study, the number of the beams have significant effect on the maximum dose to the spinal cord, so when increased the number of the beams, the maximum dose to spinal cord reduced. The spinal cord received low doses in 9 beams compared with 5 and 7 beams IMRT.

Table 5 Comparison between 5, 7 and 9 Beams IMRT According to Spinal Cord

Spinal Cord (Gy)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Min. – Max.	38.62 – 49.57	38.65 – 50.18	36.34 – 46.22	
Mean ± SD.	45.34 ± 3.15	44.51 ± 3.31	43.23 ± 2.37	0.003*
Median	45.46	44.44	43.73	

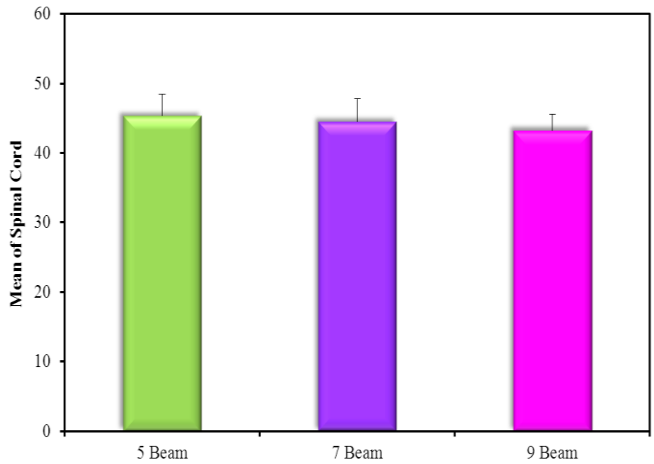

Fig 7 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to spinal cord for all HNC patients.

➢ *Brain Stem:*

In brain stem, the maximum dose was aimed to be below 54 Gy to protect it from radiation. The means and standard deviations comparison between 5, 7 and 9 beams IMRT were showed in **Table (6) and Fig. (8)** for all patients. The values of means and standard deviations were 49.52 ± 7.27, 49.77 ± 5.78 and 48.74 ± 6.41 respectively. The results showed significant difference with $p < 0.05$. The dose reduced to the brain stem in 9 beams compared with 5 and 7 beams for all HNC treated by IMRT.

Table 6 Comparison between 5, 7 and 9 Beams IMRT According to Brain Stem

Brain Stem (Gy)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Min. – Max.	30.67 – 57.93	38.96 – 57.12	31.39 – 55.48	
Mean ± SD.	49.52 ± 7.27	49.77 ± 5.78	48.74 ± 6.41	0.058
Median	51.70	52.56	51.46	

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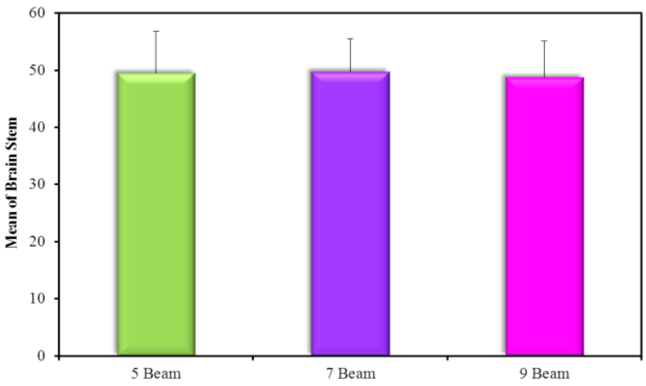

Fig 8 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to brain Stem for all HNC patients.

➢ *Number of Segments:*

All IMRT beams with different segments were compared for all HNC patients. The means and standard deviations comparison between 5, 7 and 9 beams IMRT showed in **Table (7) and Fig. (9)**. The values of means and standard deviations were 79.85 ± 13.74, 106.55 ± 16.72 and 131.80 ± 24.62 respectively. In this study, the quality of the plans was associated with the number of segments and irradiated times. When the number of segments decreases, the quality of the plans was worse in PTV coverage and the doses received by the surrounding normal tissues were high. In most patients the results related to number of segments were acceptable except some plans with 5 beams. The results showed that, there were significant difference between 5, 7 and 9 beams with $p < 0.05$. Moreover, when the number of beams increased the number of segment increased as well as the dose was improved to the PTV and the irradiated time was reduced.

Table 7 Comparison between 5, 7 and 9 Beams IMRT According to Number of Segments

No of Segments	5 Beams	7 Beams	9 Beams	p
Min. – Max.	60.0 – 105.0	78.0 – 139.0	99.0 – 185.0	
Mean ± SD.	79.85 ± 13.74	106.55 ± 16.72	131.80 ± 24.62	<0.001*
Median	77.50	105.0	125.0	

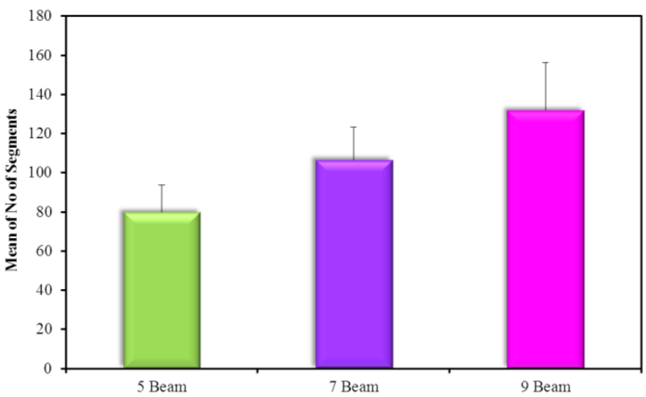

Fig 9 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to number of Segments for all HNC patients

➢ *MUs:*

The means and standard deviations comparison between 5, 7 and 9 beams IMRT according to total MUs for all HNC patients were showed in **Table (8) and Fig. (10)**. The values of means and the standard deviations were 23879.8±4308.1, 24252.6±4891.9 and 22501.8±3566.97 respectively. In this study, the MUs in all plans were not restricted by the constraints. In few cases with 5 beams, the MUs were lowest with fewest numbers of segments but the PTV coverage was worst and the surrounding normal tissues received high dose. On the other hand, the longest MUs were observed with 7 beams IMRT in all cases. Statically, there were significant differences between the different IMRT beams with $p < 0.05$. The lowest MUs were achieved with 9 beams as well as the number of segments were highest with better PTV coverage and the dose received by the normal surrounding tissues were reduced in most cases compared with 5 and 7 beams IMRT.

Table 8 Comparison between 5, 7 and 9 Beams IMRT According to MUs

MUs	5 Beams	7 Beams	9 Beams	p
Min. – Max.	14759.3–30017.1	15972.3–32650.1	15209.6–27365.4	
Mean ± SD.	23879.8±4308.1	24252.6±4891.9	22501.8±3566.97	0.003*
Median	24225.36	25270.35	23553.32	

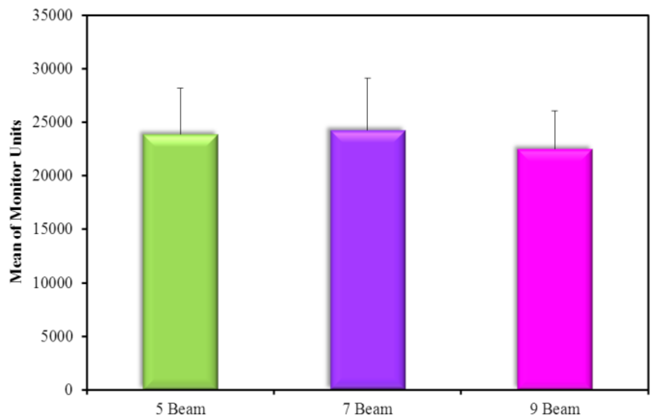

Fig 10 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to MUs for all HNC patients

➢ *Total Irradiated Time:*

The total pure irradiated time were calculated and compared for all HNC patients. The means and standard deviations comparison between 5, 7 and 9 beams IMRT showed in **Table (9) and Fig. (11)**. The values of means and standard deviations were 79.60 ± 14.36, 80.84 ± 16.31and 75.0 ± 11.89 respectively. The results showed that, increased the number of MUs lead to increase the irradiated time in all IMRT cases. On the other hand, when the number of segments increased due to increase in number of IMRT beams, that lead to reduced in MUs as well as the irradiated time were reduced, in fact, Few cases with 5 beams, the irradiated time were shortest but the PTV coverage were worst and the surrounding normal tissues were received high dose. The longest irradiated time with 7 beams were observed in most IMRT cases. There were significantly difference between the 5, 7 and 9 beams with $p < 0.05$. The shortest pure irradiated time were achieved with 9 beams with better in PTV coverage, homogeneity, conformity and the surrounding normal tissues received low dose compared with 5 and 7 beams IMRT for treatment HNC patients.

Table 9 Comparison between 5, 7 and 9 Beams IMRT

Total Irradiated Time (Minute)	**5 Beams**	**7 Beams**	**9 Beams**	**p**
Min. – Max.	49.19 – 100.06	53.24 – 108.83	50.69 – 91.22	
Mean ± SD.	79.60 ± 14.36	80.84 ± 16.31	75.0 ± 11.89	0.003*
Median	80.85	84.24	78.51	

According to the Total Irradiated Time.

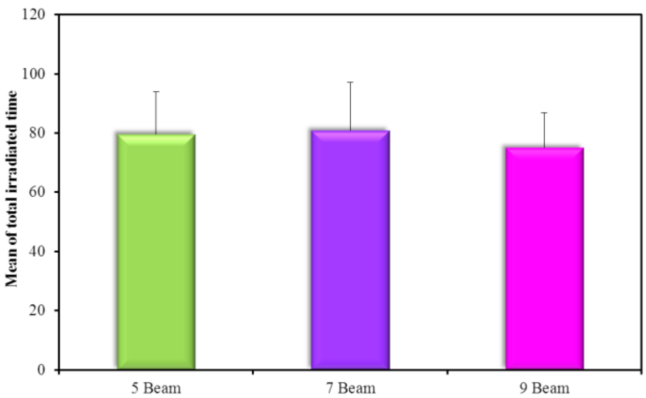

Fig 11 Shows the means and standard deviations comparison between 5, 7 and 9 IMRT beams according to total irradiated time for all HNC patients.

IV. DISCUSSION

IMRT is an advanced form of radiotherapy that delivers higher radiation dose to the target with strict constraints for the OARs (28). High dose of IMRT can be achieved better dose distribution in the PTV with better sparing of OARs and surrounding normal tissues compared with 3DCRT (29, 30). HNC is one of the most technically treatments in radiotherapy, due to the number of concave complex targets with different dose prescription. IMRT is one option treatment planning for HNC (31). The beam number selection affects the optimized dose distribution particularly for concave HNC targets, so the increase of beams in HNC treatment more than 5 beams is optimal option (29).

Currently, the beam number selection in IMRT is depended on the experience of treatment planners, many researchers have attempted to automate the beam selection in IMRT. Moreover, such as in complex concave situations, it is difficult to decide a suitable number of beams without trails, errors and compromise in dose distribution and sparing of OARs. Before optimization process, it is important to placement the appropriate number of beams to obtain acceptable IMRT plans (32). For HNC patients treatment usually requires 5 to 9 beams IMRT (26, 33-36). In this study, the aim was to determine the best beams number and segments in order to improve the plans conformity and homogeneity that generate low MUs and faster treatment time for different types of HNC. Moreover, attention to reach the desired dose distribution as well as sparing the surrounding normal tissues.

In this feasibility study, we compared 5, 7 and 9 beams step and shoot IMRT for HNC in term of PTV coverage, dose distributions in the target, conformity and homogeneity the dose to the PTV, OARs sparing which include right and left parotids, spinal cord and brain stem, also number of segments, the total number of MUs and total pure irradiated time for 30 patients HNC. In this comparative planning study, we depended on the defined of IMRT objectives and planning constraints for any individualized HNC patients before optimization process.

To our knowledge, none evidence previous studies compared between 5, 7 and 9 beams static IMRT for treatment HNC. Narayanan VS, etal and Derbyshire SJ, etal clear that, when increase the number of beams in IMRT provide greater dose distribution to the PTV and more sparing of OARs (37, 38). Obtaining better of dose distributions with lower number of MUs basically require suitable selections of beams and their angles (37).

In IMRT, the PTV coverage was acceptable if 95% of the volume were covered by 95% of the prescribed dose (39). The results indicated that, the 5, 7 and 9 beams IMRT were show comparable in PTV coverage. The 9 beams IMRT were able to provide acceptable target coverage with better sparing of OARs, it was more difficult to meet all criteria of IMRT when using 5 beams IMRT in this study. It is evident from the shape of DVH and isodose distribution when increase the number of beams improved the dose distribution and reduced the radiation doses to the OARs and surrounding normal tissues.

In the current study, the conformity of the dose to the PTV was better in 9 beams IMRT compared with 5 and 7 beams with statically significant difference $p < 0.05$. The mean of CI in 9 beams IMRT indicate better values when compared with 5 and 7 beams IMRT. The homogeneity of the dose inside the PTV was better in 9 beams compared with 5 and 7 beams IMRT with statically significant difference $p < 0.05$. The dose received by the right and left parotids, spinal cord and brain stem was reduction with 9 beams IMRT compared with 5 and 7 beams IMRT with significant difference $p< 0.05$.

In general, when increase the number of the beams in static step and shoot IMRT the MUs were decreased (37, 38, 40). The reduced in number of MUs should lead to less leakage of radiation from the collimator head. This reductions lead to less peripheral doses (41, 42). The dose to the healthy tissues around the PTV arise from the collimator

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transmission and scatter radiation from the linear accelerator, this dose is proportional to the number of MUs. This scatter radiation can increase the risk of secondary malignances (19, 41, 43). It is important to know that, the number of MUs is one factor which influences in the peripheral doses with others factors like linear accelerator head shielding and collimator system such as materials, shapes and MLC thickness (2). Sabatino M, etal suggested that, the low number of MUs is the main reasons for the shortest treatment times, the reasons of this time saving are the creation of fluence modulation. For the low dose exposure, two reasons could be responsible: chosen of gantry angles and the dose calculation algorithms. More number of IMRT beams lead to reduce the number of MUs as well as lead to reduce the irradiated time using step and shoot IMRT(41). It is to be noted that, in the step and shoot IMRT, the algorithms used for beam intensity optimization and segmentation can also influence on the final beam numbers obtained results (37). In this study, the MUs were significantly reduced in 9 beams compared with 5 and 7 beams IMRT with $p< 0.05$, this associated with above previous studies.

Our finding that, the fast pure treatment time when compared the 5, 7 and 9 beams IMRT, 9 beams IMRT is sufficient to produce a better dose distribution, PTV conformity, homogeneity and OARs sparing with faster comparable pure irradiated time in 75.0 minutes while 5 beams may require79.60 minutes and 7 beams require 80.84 minutes as a mean total pure irradiated time. Chang SX, etal and Qi P, etal mentioned that, used more segments improved the conformity and play an important role in MUs reduction as well as the treatment time decreased (40, 44). It is important to note that, the pure irradiated time were shortest in 9 beams step and shoot IMRT using Xio software treatment planning system and artist linear accelerator for treatment HNC patients.

V. CONCLUSION

From this study we can conclude that, the 9 beams IMRT is superior to techniques using less number of beams (5 and 7) where, the 9 beams IMRT significantly improved the PTV coverage, dose distribution, conformity, homogeneity to the PTV with better sparing OARs and reduce the dose to surrounding normal tissues. Moreover, the 9 beams significantly reduced the mean MUs and pure irradiated time compared with 5 and 7 beams IMRT.

RECOMMENDATIONS

- In view of the results of this study and significant of superiority of 9 beams plans compared to the 5 and 7 beams in IMRT of HNC, we recommend using more number of beams in treatment planning preferably 9 beams.
- More studies comparing different beams number is encourage to consolidate our results.
- Conducting similar studies on different tumor sites.
- We recommend study the integral dose using the same methods.
- Studying the different between beam numbers using different IMRT delivery techniques include dynamic or sliding window and arc therapy.

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