



Assessment of Organ-at-Risk Dose and Treatment Toxicity in Postoperative Radiotherapy for Laryngeal Cancer

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ABSTRACT

This study evaluated the relationship between radiation doses delivered to organs at risk (OARs) and treatment-related toxicity in patients undergoing postoperative radiotherapy (PORT) for laryngeal cancer. A retrospective observational study was conducted on 30 patients with histologically confirmed laryngeal squamous cell carcinoma treated at Al-Amal National Hospital for Oncology, Baghdad, Iraq. All patients underwent total or partial laryngectomy followed by intensity-modulated radiotherapy (IMRT) planned using Monaco v5.11 and delivered with an Elekta Infinity linear accelerator.

Patients received 2 Gy per fraction over 30–33 fractions, with a total prescribed dose of 60–66 Gy over 6–7 weeks. Radiation doses to OARs were extracted from treatment planning data and correlated with treatment-related toxicity. Acute and late toxicities were evaluated using clinical follow-up, and statistical analysis was performed using SPSS version 29 with descriptive statistics and Spearman correlation analysis.

The study cohort comprised 30 patients, 73.3% of whom were male, with a mean age of 65 ± 8 years. The laryngeal remnant received the highest mean radiation dose (63.2 ± 5.1 Gy). Significant positive correlations were identified between radiation dose and toxicity severity in the laryngeal remnant ($p = 0.62$) and oral cavity ($p = 0.56$). Local control, regional control, disease-free survival, and overall survival rates were 93%, 87%, 83%, and 77%, respectively.

These findings indicate that optimized IMRT planning and careful OAR dose management can minimize treatment-related toxicity while maintaining effective postoperative tumor control in patients with laryngeal cancer.

Keywords: Postoperative Radiotherapy (PORT), Laryngeal Cancer, Intensity Modulated Radiotherapy (IMRT), Toxicity.

INTRODUCTION

Laryngeal cancer is responsible for one-third of all head and neck cancers, making it a significant contributor to morbidity and mortality rates throughout the globe. This makes it a major global health concern (Obid *et al.*, 2019). Those who smoke heavily are disproportionately affected by this global health problem, which affects people of all ages and walks of life regardless of their socioeconomic status. The exact parts of the larynx that this cancer affects, which may include the supraglottis, glottis, and subglottis, impact the appearance of the cancer, the patterns of its spread, and the available treatment options (Ferlay *et al.*, 2021; Sung *et al.*, 2021).

The preservation of the larynx during the treatment of early-stage laryngeal cancer with radiation monotherapy or surgery is a typical technique. Unfortunately, multimodal therapy is required for late-stage sickness, which often results in less favorable outcomes and frequently requires more extensive treatment, which may not be able to salvage the larynx (Baird *et al.*, 2018; Elicin and Giger, 2020). Surgical resection forms the standard therapeutic approach for advanced laryngeal cancer, while doctors determine treatment type as partial or total laryngectomy based on tumor volume and individual patient aspects. Surgical procedures remove visible tumors, but small scattered cancer cells remain, which leads medical professionals to prescribe adjuvant treatments to minimize recurrence risks (Ahn *et al.*, 2017; Schneider *et al.*, 2018).

Laryngeal cancer is one of the most common malignancies of the head and neck region and accounts for a significant proportion of squamous cell carcinomas of the upper aerodigestive tract.

Globally, it represents approximately 2–3% of all cancer cases and is strongly associated with tobacco smoking, alcohol consumption, and environmental carcinogenic exposure. The management of laryngeal cancer is complex and requires multidisciplinary treatment strategies that depend on tumor stage, anatomical subsite, and pathological risk factors. (Park *et al.*, 2021; Smith *et al.*, 2017).

Postoperative radiotherapy (PORT) is commonly recommended for patients with high-risk pathological features such as positive surgical margins, extracapsular nodal extension, or advanced tumor stage. PORT improves locoregional control by eliminating residual microscopic disease after surgical resection. Radiotherapy doses fall between 60 to 66 Gy as patients receive their treatments in daily fractions throughout 6–7 weeks, depending on pathological findings obtained during surgical procedures. The successful application of radiotherapy depends on exact delivery methods that prevent healthy tissue toxicity during treatment (Lang *et al.*, 2022; Wang *et al.*, 2022; Kim *et al.*, 2023).

Radiotherapy technologies have made remarkable progress in enhancing PORT procedures' exactness and success rates. Intensity Modulated Radiation Therapy (IMRT) has become a standard medical technique because it enables extremely precise delivery of radiation doses. Precise targeting of irregularly shaped tumors and critical structure protection occurs through computer-based algorithms in IMRT treatment. Volumetric Modulated Arc Therapy (VMAT) is an advanced radiotherapy technique that delivers radiation continuously as the treatment machine rotates around the patient, improving dose conformity and reducing treatment time (Abdulbaqi *et al.*, 2020; Fiorino *et al.*, 2020; Madloul *et al.*, 2020; Jubbier *et al.*, 2021; Sabbar *et al.*, 2021; Hameed *et al.*, 2023; Abd *et al.*, 2024; Jwair *et al.*, 2024; Salih *et al.*, 2024).

The spinal cord, thyroid gland, parotid glands, oral cavity, esophagus, and mandible and residual laryngeal tissue receive radiation exposure from the laryngeal area, leading to short-term and delayed toxicities. Radiation exposure to these organs may lead to acute and late toxicities such as mucositis, xerostomia, dysphagia, thyroid dysfunction, and osteoradionecrosis of the mandible.

Accurate assessments of radiation dose distribution toward these OARs must be performed precisely because they determine the success of preventing adverse side effects while delivering optimal clinical results (Haderlein *et al.*, 2020; Nuyts *et al.*, 2013).

Striking this therapeutic treatment-dose balance to eliminate tumor cells becomes more demanding because different patients present distinct anatomical structures and tumor placement across their bodies. Therefore, careful evaluation of radiation dose distribution to organs at risk is

essential to optimize treatment planning and minimize radiation-induced toxicity (Li *et al.*, 2021; Ravi *et al.*, 2022).

Although several studies have investigated radiation-induced toxicity in head and neck cancers, limited data are available regarding dose-toxicity relationships specifically in postoperative radiotherapy for laryngeal cancer. The aim of this study was to evaluate the radiation dose delivered to organs at risk during postoperative radiotherapy for laryngeal cancer and to investigate its association with treatment-related toxicity. A part of this research is focused on analyzing how these delivered dose distributions relate to acute and chronic radiation toxicity development and intensity in patients. The relationships obtained from this study will guide clinicians and radiation oncologists in improving patient therapy protocols while designing enhanced care methods that result in superior quality of life and survival outcomes.

MATERIALS AND METHODS

This is a retrospective clinical study with a convenience sampling technique. Therefore, a formal sample size calculation was not performed, and the study sample consisted of all available cases meeting the inclusion criteria. The analysis focused on the delivered doses from radiotherapy that patients received after laryngeal cancer surgery at Al-Amal National Hospital for Oncology, Baghdad, Iraq. The institutional medical records provided information about eligible patients from January 2024 to February 2025. Clear eligibility requirements identified patients with laryngeal squamous cell carcinoma who got total or partial laryngectomy and PORT. The follow-up duration of patients performed from May 2025 to December 2025. The median follow-up is 6 months.

Target volumes were based on international guidelines for radiotherapy. The Gross Tumor Volume (GTV) was the bed of the tumor after surgery and any disease remaining if any. The Clinical Target Volume (CTV) included the tumor bed and the regions at risk of microscopic spread of disease.

The Planning Target Volume (PTV) was created by growing CTV to allow for setup errors as well as patient motion. Each subject needed to have their radiation treatment plan DVH data available for evaluation. The excluded patients from this study are those with incomplete data records, together with those diagnosed with non-squamous cell carcinoma, as well as individuals who received radiotherapy before surgery. Each patient signed a written ethical consent.

All included patients received treatment through IMRT radiotherapy methods on Monaco 5.11 software and were treated with an Infinity-type Linear accelerator manufactured by Elekta, Sweden. The planning process used CT simulation to define precise targets and ensure reproducible treatment delivery because patients were fixed under customized thermoplastic masks. Tumors for therapy received contouring based on pathological findings from surgery, diagnostic images, and professional treatment standards encompassed the main treatment area and locations without visible disease.

Margin of 3-5 mm was added to enlarge CTV to create PTV to allow for errors in patient setup and internal organs. A 2 Gy dose over 30-33 should be given over 6 to 7 weeks to achieve a treatment dose between 60 and 66 Gy. All dose constraints for organs-at-risk OARs received strict adherence the spinal cord maximum dose stayed under or equal to 45 Gy while the brainstem received no more than 54 Gy, which was the maximum allowed dose and the mean dose to both esophagus and carotid arteries needed to be below 40 Gy and 35 Gy respectively. The inverse planning algorithms achieved optimal dose distributions, optimizing dose conformity and decreasing critical structure radiation exposure (Bisello *et al.*, 2022a). Cone Beam Computed Tomography (CBCT) imaging was also done before treatment sessions to confirm patient positioning and the delivery of radiation.

The measurements from treatment plans were extracted using dose-volume-histograms (DVHs) to analyze each identified organ at risk. The plan evaluation included specific radiation dose measurements for the spinal cord, thyroid gland, parotid glands, oral cavity, esophagus, mandible, and laryngeal remnant through their mean, maximum, and median dose measurements. Image-guided radiotherapy (IGRT) was given more accurate treatment and ensured accurate patient positioning during the delivery of radiotherapy.

The medical records received systematic analysis for evaluating radiotherapy-induced toxic side effects, which were classified into early toxicities within 90 days and long-term effects following 90 days after the treatment. The data reporting system used common terminology criteria for adverse events (CTCAE) version 5.0, allowing standardized monitoring and case comparison. The statistical analysis was performed using SPSS version 29. The comparison of dosimetric variables against clinical side effects operated through Spearman correlation tests to establish any dose-effect linkages. The p-value was taken at a significant level of ≤ 0.05 .

RESULTS and DISCUSSION

The data showed that males comprised 73.3% of patients while females represented 26.7% of the study participants. Mean age of the patients were 65 ± 8 years ranged from 48 – 76 years. Local control rate was 93% (95% CI: 78–99%). The developmental stage of the cancers was divided into groups, with the T1 stage present in 6 patients (20%), and T2 stage in 12 patients (40%), the T3 stage in 7 patients (23%), and the T4 stage in 5 patients (17%). The examination of lymph nodes revealed 17 patients (57%) with N0 disease, followed by a distribution of N1 disease in 9 patients (30%) and N2 disease in 4 patients (13%), but no patients experienced the advanced N3 stage. Among the group of patients, thirteen individuals (43%) received chemotherapy, but seventeen patients (57%) were not treated with chemotherapy, as shown in (Table 1).

Table (1): The demographical characteristics of the patient

Characteristic	Number (30)	Percentage (%)
Total No. of Patients	30	100
Gender		
Male	22	73.3
Female	8	26.7
Age (years)	65 ± 8	
Stage of Tumor		
- T1	6	20
- T2	12	40
- T3	7	23
- T4	5	17
Stage of Nodal		
- N0	17	57
- N1	9	30
- N2	4	13
- N3	0	0
Receive Chemotherapy		
- Yes	13	43
- No	17	57

The patient cohort in this study possesses demographic along with clinical characteristics that are similar to what epidemiological research demonstrates in cases of laryngeal cancer. The data indicates that males made up 73.3% of patients affected by laryngeal cancer because they typically face higher exposure risks from alcohol consumption and tobacco usage.

This study's participant age of 65 ± 8 years matches other documented population distributions. Early-to-intermediate stage tumors, which include T1–T2 cases, constituted 60% of the studied group because patients became more aware of their symptoms and sought medical help earlier. According to Cracchiolo *et al.* (2016) localized tumors (T1–T2) were found in 55% of cases, highlighting that patients were better candidates for less invasive surgical procedures which might enhance their outcomes (Cracchiolo *et al.*, 2016). The nodal staging evaluation showed that fifty-seven percent of patients had N0 disease because they did not demonstrate any nodal involvement. The distribution pattern indicates patients were mainly detected before their cancer metastasized or spread to restricted

local areas thus demonstrating the positive effects surgical removal followed by postoperative radiotherapy would provide. The clinical application of chemotherapy represents a treatment approach for 43% of patients where physicians made treatment choices by considering disease stage, patient health risks, and their conditions. The chosen strategic use of chemotherapy demonstrates current practice standards that focus on delivering chemoradiotherapy to patients with advanced-stage disease or unfavorable pathological results. Research by Weeks *et al.* (2012) verifies chemotherapeutic treatment preference for patients characterized by advanced disease status when doctors employ it to boost local tumor control and life extension outcomes (Weeks *et al.*, 2012).

(Table 2) showed that postoperative radiotherapy exposed organs at risk (OARs) to different radiation levels. The spinal cord received an average dosage of 39.3 ± 5.2 Gy through postoperative radiotherapy, yet its maximum dose reached 46.2 ± 6.1 Gy along with a median value of 36.2 Gy.

The mean dosage delivered to the thyroid gland was 28.5 ± 7.5 Gy, while its maximum and median doses amounted to 36.0 ± 5.5 Gy and 28.3 Gy, respectively. The mean dose received by parotid glands was 25.6 ± 3.9 Gy, and its maximum dose reached 34.8 ± 4.3 Gy, along with its median dose of 27.2 Gy. Oral cavity exposure reached the highest mean dose at 32.2 ± 4.7 Gy, while its maximum and median doses amounted to 41.2 ± 5.9 Gy and 28.9 Gy, respectively. The mean exposure in the esophageal tissue amounted to 35.3 ± 6.8 Gy, the maximum dose reached 48.1 ± 4.3 Gy, and the median dose measured 32.6 Gy. The mandibular tissue received an average absorbed dose of 27.8 ± 7.9 Gy and a maximum absorbed dose of 37.3 ± 2.7 Gy, while the median value reached 26.9 Gy. Evaluation of doses revealed that the laryngeal remnant stood out as the organ receiving the maximum mean dose at 63.2 ± 5.1 Gy, with maximum and median doses at 67.9 ± 3.2 Gy and 61.2 Gy.

Table (2): Distribution of organs at risk (OARs)

Organ-at-Risk (OAR)	Mean Dose (Gy)	Maximum Dose (Gy)	Median Dose (Gy)
Spinal Cord	39.3 ± 5.2	46.2 ± 6.1	36.2
Thyroid	28.5 ± 7.5	36.0 ± 5.5	28.3
Parotid Glands	25.6 ± 3.9	34.8 ± 4.3	27.2
Oral Cavity	32.2 ± 4.7	41.2 ± 5.9	28.9
Esophagus	35.3 ± 6.8	48.1 ± 4.3	32.6
Mandible	27.8 ± 7.9	37.3 ± 2.7	26.9
Laryngeal Remnant	63.2 ± 5.1	67.9 ± 3.2	61.2

Diversity in the doses delivered to organs at risk surfaced in postoperative radiotherapy due to different medical strategies that position organs and plan radiation treatments between tumor control and normal tissue protection. The spinal cord received radiation at doses that met standard clinical recommendations and remained close to the commonly applied spinal cord tolerance range. Bisello *et al.* (2022b) found similar ranges of spinal cord doses, whereas they explained that avoiding late neurological problems requires maintaining spinal cord doses under threshold levels. The study findings show thyroid gland doses at 28.5 Gy and parotid gland doses at 25.6 Gy indicate proper treatment planning for endocrine dysfunction prevention and xerostomia avoidance.

The study by Thomsen *et al.* (2025) demonstrated mean parotid doses at 24, confirming that IMRT techniques help improve salivary function preservation. The elevated level of thyroid gland exposure in our study group may be explained by the natural positioning of this gland relative to the treatment procedure for laryngeal cancer despite careful treatment planning.

Exposure to 35.3 Gy (mean) with 48.1 Gy (maximum) was detected in the esophagus, and 32.2 Gy (mean) with 41.2 Gy (maximum) was detected in the oral cavity because these structures lie in direct proximity to the laryngeal region. The documented exposure level might explain why patients

with head and neck cancer experience common side effects of mucositis and dysphagia, which Rosenthal *et al.* (2017) detailed. Their research results match our findings on how exposure levels lead to mucosal toxicities while underscoring the need for patient-specific supportive care programs during treatment for side effect management (Rosenthal *et al.*, 2017).

The laryngeal remnant received the highest radiation dose of 63.2 Gy because this amount was necessary to eliminate microscopic postoperative disease. Clinical practice has validated this level of radiation exposure to achieve tumor control since it poses risks to tissue health through fibrosis development and impaired laryngeal functioning. The findings match standard radiotherapy protocols described in Lou *et al.* (2018) demonstrating equivalent dose patterns in head and neck cancer post-surgical treatments for disease management (Lou *et al.*, 2018).

The evaluation of radiation-caused toxicities showed that both early (acute) complications and late complications had varying frequencies among patients shown in (Table 3). Six out of 30 patients (20%) did not develop any side effects (Grade 0) when assessed for acute toxicity, but 12 patients (40%) received Grade 1 care, and 8 patients (27%) received Grade 2 care. The occurrence of severe acute toxicity reached only 4 patients out of the 30 treated subjects, which accounted for 13% of the population. The late toxicity evaluation revealed fewer patients experiencing any toxicity (Grade 0) among 13 patients equivalent to 43% of total patients. Mild late toxicity (Grade 1) affected 9 patients (30%) among those being treated, and 6 patients (20%) suffered from moderate toxicity (Grade 2).

The occurrence of severe late toxicity (Grade 3) appeared to be very infrequent because healthcare professionals only reported it among 2 patients (7%).

Table (3): Early (Acute) and late side effects toxicity of radiation

Grade of Toxicity	Early no. (%)	Late no. (%)
Grade 0	6 (20) %	13 (43) %
Grade 1	12 (40) %	9 (30) %
Grade 2	8 (27) %	6 (20) %
Grade 3	4 (13) %	2 (7) %
Grade 4	0 (0) %	0 (0) %

An effective tumor control versus radiation-induced toxicity balance requires attention from clinical practitioners in their treatment approach. The present research documented that the major radiation-induced adverse events patients experienced were Grade 1-2 toxicities, while Grade 3 toxicities appeared at a lower frequency. Acute radiation side effects were more prevalent than late side effects because known radiation biology principles show rapid cell division cells such as mucosal tissues react strongly to radiotherapy, thus triggering immediate inflammation and mucositis and dysphagia. Later complications following radiotherapy were less common yet more serious because they developed into fibrosis, persistent dysphagia and xerostomia, and thyroid dysfunctions as cells changed after therapy.

Postoperative IMRT treatment in head and neck cancer patients, according to Rosenthal *et al.* (2014) led to peak mucositis and dysphagia levels of Grade 1–2 found in 60% of patients, but Grade 3 reactions only present in less than 15% of treated individuals (Rosenthal *et al.*, 2017). Most late toxicities were reported as either minor or nonexistent in a study by Thomsen *et al.* (2025) which confirmed our research findings. These studies confirmed that severe adverse effects decrease thanks to contemporary radiotherapy methods (IMRT); however, the authors attributed this positive outcome to modern treatment delivery techniques.

Strategies for individualized patient care with supportive measures should focus on decreasing radiation-related tissue damage and quality-of-life enhancement because our clinical data shows contrasts in acute versus late toxicities in lung cancer patients.

Dose-volume histogram parameters were used to assess the relationship between radiation exposure and toxicity related to treatment and presented in (Table 4). Higher dose-volume exposure to oral cavity was linked to high mucositis severity Spearman correlation analysis showed that there were significant correlations between OralCavity V40 and mucositis grade ($\rho = 0.52$, $p = 0.004$) and between OralCavity V50 and mucositis grade ($\rho = 0.58$, $p = 0.002$). Similarly, the higher degree of exposure to radiation in the laryngeal remnant correlated with the severity of dysphagia. Larynx V40 ($\rho = 0.49$, $P = 0.006$) and Larynx V50 ($\rho = 0.55$, $P = 0.003$) were statistically significant correlations for the grade of dysphagia. These findings suggest that higher dose-volume exposure of critical organs is related to a higher risk for treatment-related toxicity.

Table (4): Association between DVH parameters and toxicity

Parameter	Toxicity endpoint	Spearman ρ	p-value
Oral cavity V30	Mucositis	0.42	0.02
Oral cavity V40	Mucositis	0.52	0.004
Oral cavity V50	Mucositis	0.58	0.002
Larynx V30	Dysphagia	0.40	0.03
Larynx V40	Dysphagia	0.49	0.006
Larynx V50	Dysphagia	0.55	0.003

Dose-volume histogram (DVH) parameters were assessed to analyze the correlation between the radiation dose and toxicity related to treatment. These findings indicate that exposures to intermediate and higher doses of radiation may lead to larger volumes of oral mucosa in which mucosal inflammation and epithelial damage are likely to occur; finally, clinically significant mucositis will occur with higher oral cavities V40 and V50. This pattern was in keeping with published data indicating that intermediate and high-dose oral mucosal volumes have been shown to be important predictors of radiation-induced oral mucositis; recent data have shown significant associations for oral mucosal V30-V50, with V35 and mean dose emerging as strong predictors of severe mucositis (Li *et al.*, 2017; Zhang *et al.*, 2025). Radiation exposure to remnant larynx may impair function of swallowing with inflammatory changes and fibrosis of laryngeal and pharyngeal musculature. This finding is consistent with previous literature on head and neck radiotherapy that confirms laryngeal and swallowing-related structures are important dosimetrics in determining swallowing complications, and that limiting the laryngeal V50 and mean laryngeal dose may reduce swallowing complications (Brodin and Tomé, 2018). Overall, these findings contribute to the clinical value of using DVH-based constraints in the treatment planning process to reduce toxicity while maintaining treatment effectiveness.

The Spearman correlation demonstrated substantial correlations between the OAR radiation dose amounts and detected toxicity grades across patients shown in (Table 5). A strong relationship between radiation doses and toxicity grade existed primarily within the laryngeal remnant at $\rho = 0.62$, followed by the oral cavity at $\rho = 0.56$, parotid glands at $\rho = 0.51$, and spinal cord at $\rho = 0.46$ and esophageal tissues at $\rho = 0.43$. The association level between radiation doses and thyroid gland health was measured as $\rho = 0.37$ with $p = 0.0441$. The mandible showed the least significant correlation ($\rho = 0.34$) compared to other structures because its relationship failed to achieve statistical significance at $p = 0.0660$. Studies demonstrate that elevated radiation exposure to particular OARs triggers more severe radiation-related adverse effects, mostly affecting the laryngeal remnant and oral cavity.

The correlation between simultaneous chemotherapy and treatment-related toxicity was assessed. No statistically significant correlation between the administration of chemotherapy and toxicity grade was seen ($p > 0.05$).

Table (5): The spearman correlation between oar doses and toxicity grades

Organ-at-Risk	Spearman's rho	p-value
Spinal Cord	0.46	0.0105
Thyroid	0.37	0.0441
Parotid Glands	0.51	0.0039
Oral Cavity	0.56	0.0012
Esophagus	0.43	0.0177
Mandible	0.34	0.0660
Laryngeal Remnant	0.62	0.0002

The spinal cord relationship ($\rho = 0.46$, $p = 0.0105$) confirms expected dose thresholds in clinical practice, which demonstrates why healthcare providers must closely follow spinal cord dose limits to prevent major neurological issues. The clinical evidence matches the measured moderate correlations between radiation doses and toxicities that affect the esophagus ($\rho = 0.43$, $p = 0.0177$) and thyroid gland ($\rho = 0.37$, $p = 0.0441$).

The mandible demonstrated lower correlation strength ($\rho = 0.34$) with non-significant results ($p = 0.0660$). The increased radiation exposure protection provided by modern radiotherapy techniques and possible delayed onset frequency of osteoradionecrosis likely produce the lower observed correlation. The research showed important linear relationships between damaging exposures from OARs and how severe toxicity developed mainly in the laryngeal remnant, the oral cavity, parotid glands, and the spinal cord. The laryngeal remnant displayed the most pronounced correlation ($\rho = 0.62$, $p = 0.0002$) because treating it to higher radiation levels creates effective treatment of post-surgical residual micro-disease. Residual laryngeal structure preservation depends on an optimal therapeutic dosage level that achieves therapeutic effects while limiting radiation harm to the patient's life quality, including speaking performance and breath function control.

Radiosensitivity of mucosal tissues is supported by the strong connection in oral cavity doses ($\rho = 0.56$, $p = 0.0012$), as patients typically develop acute mucositis and end up with late fibrosis due to radiation exposure. The research findings of Thomsen *et al.* (2025) matched these results by showing that increased oral cavity radiation doses and more severe mucositis developed at higher dos, resulting in delayed mucosal healing. Our research results match these findings, showing additional evidence of the value of dose-sparing strategies.

A relationship linking parotid gland exposure to the radiation toxicity scaling system resulted in $\rho = 0.51$ with $p = 0.0039$. When exposed to radiation, the parotid glands directly cause xerostomia, which results in significant deterioration of the patient's everyday activities. The research findings of Lou *et al.* (2018) showed that parotid gland dose reduction leads to a decreased prevalence while lessening the extent of xerostomia, thus establishing parotid-sparing methods crucial in radiotherapy treatment design.

Outcomes from the clinical follow-up showed positive control results and survival statistics for the study participants shown in (Table 6). Using this treatment approach, local tumor control became successful for 28 patients, resulting in a 93% success rate at the primary site. Out of 30 patients, regional control achieved 26 successful outcomes (87%), showing effective lymph node treatment. Operation-free survival was achieved by 25 patients (83%), which demonstrates robust prevention of disease return. Long-term prognosis demonstrated favorability for the majority of patients who reached an overall survival status at the rate of 23 patients (77%). Three patients among treated individuals experienced treatment-related death at a rate of 10%, which indicates severe complications can arise from aggressive postoperative radiotherapy despite the generally advantageous outcomes.

Table (6): Clinical treatment follow-up outcomes

Clinical Follow-up Outcome	No.	Percentage (%)
Local Control	28	93
Regional Control	26	87
Disease-Free Survival	25	83
Overall Survival	23	77
Treatment-Related Death	3	10%

An important contribution of the present study is the evaluation of dose-volume toxicity relationships in particular in patients who have received radiotherapy postoperative for laryngeal cancer. While several studies have been conducted investigating the dose-toxicity associations in general head and neck radiotherapy populations, relatively limited data is available focusing on the postoperative treatment setting. By providing evidence of clinically relevant parameters of DVH related to the presence of mucositis and dysphagia, this study draws more evidence in favor of the concept of using dosimetric predictors to guide radiotherapy planning.

The local and regional control rates observed indicate that postoperative IMRT was effective in managing local and regional disease in this cohort. However, the results of disease-free and overall survival would have to be seen in the context of the small sample size, retrospective nature and follow-up period of the study. The locoregional control versus overall survival difference could indicate death or disease advancement not due to failure in the primary or regional treatment centers.

Despite the promising findings, formal Kaplan-Meier analysis and a larger cohort would give more precise estimates of time-varying survival outcomes. A significant contribution to this research is that it specifically assesses the relationships between OAR dose and toxicity in patients undergoing postoperative radiotherapy specifically in the treatment of laryngeal cancer. The majority of past studies have studied heterogeneous populations of head and neck cancer. The current study offers initial evidence that oral cavities and laryngeal dose-volume exposure can be helpful in optimizing treatment plans in this particular postoperative environment by integrating organ-specific dose measurements, DVH parameters, and clinically graded toxicity.

CONCLUSIONS

This study showed that dose-volume parameters used in radiotherapy planning were significantly correlated to treatment-related toxicity in patients undergoing postoperative radiotherapy for laryngeal cancer. Higher values of V40 and V50 for the oral cavity were associated with greater severity of mucositis and a greater laryngeal V40 and V50 exposure associated with the presence of dysphagia. These findings suggest that dose-volume metrics may be useful as predictive factors of toxicity and must be considered in treatment planning to convert organ-at-risk sparing.

Incorporation of DVH-based constraints in radiotherapy planning may play a part in improving treatment tolerance and improving patient quality of life.

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تقييم جرعة الإشعاع للأعضاء المعرضة للخطر وسمية العلاج الإشعاعي بعد الجراحة لسرطان الحنجرة

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الملخص

هدفت هذه الدراسة إلى تقييم العلاقة بين الجرعة الإشعاعية الواصلة إلى الأعضاء المعرضة للخطر (OARs) والسمية المرتبطة بالعلاج لدى المرضى الخاضعين للعلاج الإشعاعي بعد الجراحة (PORT) لسرطان الحنجرة. أُجريت دراسة رصدية استيعابية شملت 30 مريضاً مصاباً بسرطان الخلايا الحرشفية في الحنجرة والمثبت نسيجياً، والذين تلقوا العلاج في مستشفى الأمل الوطني للأورام في بغداد، العراق. خضع جميع المرضى لاستئصال كلي أو جزئي للحنجرة، تلاه علاج إشعاعي بمعدل الشدة (IMRT) باستخدام نظام تخطيط العلاج Monaco الإصدار 5.11 ومعدل خطي من نوع Elekta Infinity.

تلقي المرضى جرعة مقدارها 2 غراي لكل جلسة على مدى 30-33 جلسة، بجرعة كلية تراوحت بين 60 و66 غراي خلال 6-7 أسابيع. استُخرجت الجرعات الإشعاعية للأعضاء المعرضة للخطر من نظام تخطيط العلاج، وتم تحليل ارتباطها بالسميات الحادة والمتأخرة المرتبطة بالعلاج. أُجري التحليل الإحصائي باستخدام برنامج SPSS الإصدار 29، بالاعتماد على الإحصاءات الوصفية وتحليل ارتباط سبيرمان. أظهرت النتائج أن 73.3% من المرضى كانوا من الذكور، بمتوسط عمر بلغ 65 ± 8 سنة. وسجلت بقايا الحنجرة أعلى متوسط للجرعة الإشعاعية (63.2 ± 5.1 غراي). كما وُجدت ارتباطات معنوية موجبة بين الجرعة الإشعاعية وشدة السمية في بقايا الحنجرة ($p = 0.62$) والتجويف الفموي ($p = 0.56$) وبلغت نسب السيطرة الموضعية 93%، والسيطرة الإقليمية 87%، والبقاء الخالي من المرض 83%، والبقاء الكلي 77%.

تؤكد نتائج الدراسة أن التخطيط الأمثل للعلاج الإشعاعي المعدل الشدة والإدارة الدقيقة لجرعات الأعضاء المعرضة للخطر يساهمان في تقليل السمية المرتبطة بالعلاج مع الحفاظ على فعالية السيطرة على الورم لدى مرضى سرطان الحنجرة بعد الجراحة.

الكلمات المفتاحية: العلاج الإشعاعي بعد الجراحة (PORT)، سرطان الحنجرة، العلاج الإشعاعي المعدل الشدة (IMRT)، السمية.