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Evaluation treatment planning system for oropharyngeal cancer patient using machine learning

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ABSTRACT

Oropharyngeal cancer (OPC) comprises a group of various malignant tumours that grow in the throat, larynx, mouth, sinuses, and nose.

The research aims: to investigate the performance of the OPC VMAT model by comparison to clinical plans in terms of dosimetric parameters and normal tissue complication probabilities.

Purpose: Tune the model which at least matches the performance of clinical created photon treatment plans and analyse and find the most appropriate strategic plan scheme for OPC.

Methods and materials: The machine learning (ML) plans are compared to the reference plans (clinical plans) based on dose constraints and target coverage. VMAT oropharynx ML model of Raystation development 11B version (non-clinical) was used. A model was trained by using different modalities. A different strategy of machine learning and clinical plans was performed for five patients. The dose Prescribed for OPC is 70 Gy, 2 Gy per fraction (2Gy/Fx). The PTV was derived for the primary tumour and secondary tumour, PTV+7000 cGy and PTV_5425 cGy volumetric modulated arc therapy (VMAT) were used with beams performing a full 360° rotation around the single isocenter.

Results: Organs at risk were observed that the volume of L-Eye in clinical plan (AF) for the case1 treatment planning could be successfully used ensuring efficiency and lower than MLVMAT and MLVMAT-org plans were 372 cGy, 697 cGy and 667 cGy respectively, while showed case2, case3, case4 and case5 are better to protect the critical organs in ML plan compare with a clinical plan. DHI for the PTV-7000 and PTV-5425 is between 1 and 1.34, While DCI for PTV-7000 and PTV-5425 is between 0.98 and 1.

1. Introduction

Oropharyngeal cancer (OPC) is defined as a common and complex cancer, which induces a change in the voice or a sore that does not heal. Some may experience a sore throat that does not go away. In those with advanced disease, there may be facial pain, unusual bleeding, swelling or numbness, and visible lumps on the outside of the oral cavity or neck. Given the site of these cancers, trouble with breathing might also be present. The human head is a highly evolved structure with several important functions. It houses and protects important sense organs such as the eyes, nose, ears, tongue, and related structures. Besides the regular arrangement of different components between the head and neck, diseases produced in these vital structures and organs may threaten the health of a person. Head and neck cancer comprises a group of various malignant tumours that grow in the throat, larynx, mouth, sinuses, and nose. HNC are among the most common worldwide cancers and are located in sixth place in terms of importance (Ruiz-Pulido et al., 2021). ***The goal*** of the research is to investigate the performance of the OPC VMAT model by comparison to clinical plans in terms of dosimetric parameters and normal tissue complication probabilities. machine learning photon automatic planning in radiotherapy, tune the model which at least matches the performance of clinical created photon

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Fig. 1. TPS from Raystation software.

treatment plans and analyse and find the most appropriate strategic plan scheme for OPC. The machine learning (ML) plans are compared to the reference plans (clinical plans) based on dose constraints and target coverage. To create an ML plan for head and neck cancer, applying volumetric modulated arc therapy in Raystation for five patients and evaluate an outcome of oropharyngeal cancer (OPC) irradiation procedure, analyse the main dosimetric parameters of the planned treatment plans for ML and clinical plans.

Dosimetrically criteria for the plan analysis.

- Dose homogeneity index (DHI)
- Dose conformity index (DCI)
- Target coverage and organ at risk

2. Literature review

Approximately 630,000 new patient cases are diagnosed annually, and 350,000 deaths are reported every year. Head-neck cancer squamous cell carcinomas (HNSCCs), which arise from the mucosal surfaces of the oral cavity, oropharynx, and larynx, include 90% of head and neck cancer cases. Incidence and anatomy distributions of HNC squamous cell carcinomas may depend on different geographical locations (Ruiz-Pulido et al., 2021).

There are two available commercial automatic treatment planning systems. The first one is the Auto-Planning module of Pinnacle3 (Philips Medical System, Fitchburg, WI) which is established on an advanced optimization algorithm, the other is Varian's RapidPlan (Varian Medical Systems, Palo Alto, CA, USA) which employs a database of previously treated plans (knowledge-based) (Gallio et al., 2018). Automated treatment planning for HNC established on deep learning auto-segmented for critical organs is likely to apply, and the outcomes in plans emphasizing overall normal tissue dose sparing also outside the prescribed clinical dose-volume criteria. In addition, including new dose-volume criteria for novel auto-segmented masticatory OARs into this framework has provided a rapid evaluation and proven feasibility and refinement of dose-volume criteria to minimize trismus risk. One study demonstrates that plans created using automated treatment planning were comparable to clinical plans. The time is saved and less than the manual plan and enables the planner to implement more resources for more complex cases. Planner independence promotes the standardization of plan quality (Gallio et al., 2018; Thor et al., 2021).

2.1. Radiotherapy

Radiotherapy (RT) is one of the most effective treatments for cancer or in combination with chemotherapy. The linear accelerator generates x-ray photons and electrons, which are used to treat cancer in deep or superficial localized. The common energy used in RT is 6 MV–15 MV for photon and from 4 MeV to 25 MeV for the electrons (Nuraini and Widita, 2019; Pashazadeh et al., 2019). Proton therapy less effect damage to healthy tissue and use high energy to treat the tumour cause proton is effective to treat deeply located targets. The secondary particle such as neutrons is produced as a result of nuclear interactions of protons. The secondary neutrons can cause an uncontrolled dose to increase in organs at risk vicinity of the tumour site. The secondary electrons do not acquire enough energy to travel more than a few millimetres (mm) from the proton track (Pehlivanlı and Bölükdemir, 2022; Newhauser and Zhang, 2015). Volumetric-modulated arc therapy (VMAT) has been widely adopted in the clinic due to its superior ability to produce optimal dose distributions that deliver prescription doses to target volumes while reducing the dose to critical organs. Moreover, VMAT is more efficient and spends fewer monitor units as well as taking less time to deliver a dose distribution to the patient. To acquire the optimal dose distribution, VMAT modulates photon beam intensities by varying multi-leaf-collimator (MLC) positions, gantry rotation speed, and dose rate, simultaneously, while rotating the gantry around the patient. The target is placed at the isocentre of the tumour, and the machine gantry is rotated around the patient in one or more arcs while the beam is on. (Hartmann, 2012; Park et al., 2016).

2.2. Machine learning

Machine learning (ML) has the potential to revolutionize the field of radiation oncology in many processes and workflows to improve the

Table 1
Recommendations of clinical goals for head and neck cancer schedules.

ROI	Clinical Goal
spinal cord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume
Eye_Post_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume
Eye_Post_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume
Parotid_R	AtMost 2600.0 cGy (RBE) average dose
Parotid_L	AtMost 2600.0 cGy (RBE) average dose
Eye_Ant_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume
Eye_Ant_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume
BrainStem	AtMost 5600.0 cGy (RBE) dose at 0.1 cm^3 volume
PTV_7000	AtLeast 6950.0 cGy (RBE) average dose
PTV_7000	AtMost 7050.0 cGy (RBE) average dose
Submandibular_L	AtMost 4000.0 cGy (RBE) average dose
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose
Cerebrum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume
PTV_5425	AtLeast 98.0% volume at 5154.0 cGy (RBE) dose
PTV_7000	AtLeast 98.0% volume at 6650.0 cGy (RBE) dose

quality and efficiency of patient care. ML algorithms use computational methods to "learn" information directly from data. There are two main types of learning: unsupervised learning and supervised learning. Automated plans achieved an average of 0.6% higher dose for target coverage evaluation criteria, and 2.4% lower dose at the organs at risk criteria levels evaluated compared with manual treatment planning in clinical (McIntosh et al., 2017). The "treatment planning" component of managing a radiotherapy patient currently consumes hours, even days, of human effort. The time and workforce demand of the current planning paradigm can expose patients to delays and potentially substandard treatments, all while standing as seemingly insurmountable roadblocks to radiotherapy (Moore, 2019). In radiotherapy workflow, from consult to follow-up represent by patient assessment, simulation and treatment planning with the treatment delivery (Feng et al., 2018).

3. Materials and methods

Oropharyngeal cancer (OPC) RT was performed for five patients' treatment planning. The treatment planning system (TPS) Raystation was used for the dose calculation. Raystation is a flexible, innovative treatment planning system chosen by many of the leading cancer centres worldwide (Fig. 1).

VMAT oropharynx ML model of Raystation development 11B version (non-clinical) was used. A model was trained by using different modalities: computer tomography (CT), magnetic resonance imaging (MRI) and positron emission computed tomography (PETCT) images set for every treatment positioning, the TPS for the gross tumour volume (GTV), clinical target volume (CTV) and planning target volume (PTV) and organ at risk (OAR). Different strategy plans were performed machine learning plan (Plan + ML) and clinical plan (Plan + AF). Volumetric modulated arc therapy (VMAT) was used with the beams performing a full 360° rotation around the single isocenter. The gantry rotated from 181.0° to 180.0° CW and the second Arc from 180.0° to 181.0° CCW for ML and AF plans. The collimator was 20° and 6 MeV energy for both plans, the main parameters used in treatment planning are shown in Table 1. The dose Prescribed for OPC was 70 Gy, 2 Gy per fraction (2Gy/Fx). The PTV was derived for the primary tumour and secondary tumour, PTV_7000 cGy and PTV_5425 cGy as shown in Fig. 2. The prescribed dose for PTV differed from MinDVH 95% to MaxDVH 107%.

3.1. Evaluation of the plans

Treatment plans were evaluated using different dosimetric parameters obtained from the dose-volume histogram (DVH) of the target and OARs as "The main treatment planning strategies" (Fig. 3). Using a DVH were evaluated dose parameters, such as maximum dose, minimum dose for the target, and irradiation doses delivered to the OARs. Dose-volume histogram constraints for OARs were adapted to our clinical constraints as presented in Table 1.

Dosimetric criteria for the Plan + ML and Plan + AF:

Dose conformity index (DCI) is calculated by using equation (1) to define how prescription isodose volume V_{PI} covered TV by prescribed isodose:

$$DCI = \frac{V_{PI}}{TV}, \tag{1}$$

Dose homogeneity index (DHI) is calculated by using equation (2) where D5 is the minimum dose covered by 5% of the volume, D95 is the minimum dose covered by 95% of the volume:

$$DHI = \frac{D_5}{D_{95}}; \tag{2}$$

DCI and DHI for all plans were estimated using the Radiation

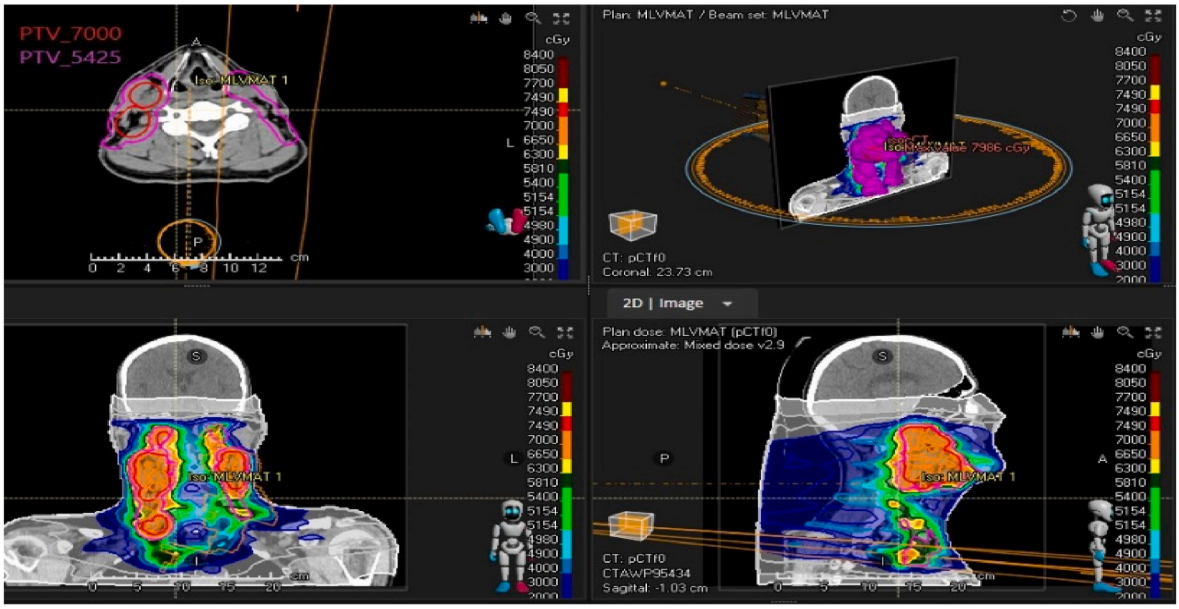

Fig. 2. PTVs volumes in OPC.

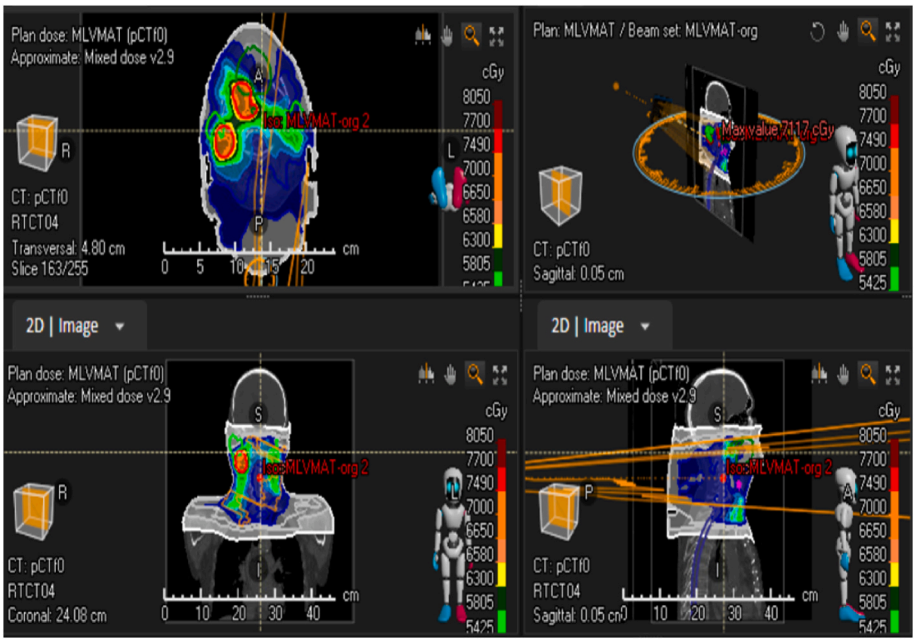

Fig. 3. Isodose distribution for the OPC radiotherapy procedure (planned to use two different strategic planning (Plan + ML and Plan + AF) with 7000 cGy (200 cGy/fr.).

Table 2
DCI and DHI for the MLVMAT, MLVMAT-org and AF plans.

Parameters	Plan-ML					Plan-AF				
PTV-7000	Case 1	Case 2	Case 3	Case 4	Case 5	Case 1	Case 2	Case 3	Case 4	Case 4
DHI	1.05	1.06	1.02	1.03	1.04	1.07	1.08	1.03	1.05	1.06
DCI	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
PTV-5425										
DHI	1.34	1.34	1.34	1.33	1.20	1.36	1.34	1.31	1.33	1.34
DCI	0.98	0.99	1	0.98	0.99	0.98	0.98	0.98	0.98	0.99

Therapy Oncology Group definitions (Ghandour et al., 2015).

4. Results and discussions

The treatment plan for the head and neck cancer was planned within a Raystation TPS, using the VMAT RT treatment planning technique (Fig. 3).

Three different plans were performed for five patients, the first Machine learning plan (MLVMAT-org) the original plan generated without optimization, the second Machine learning plan (MLVMAT) after

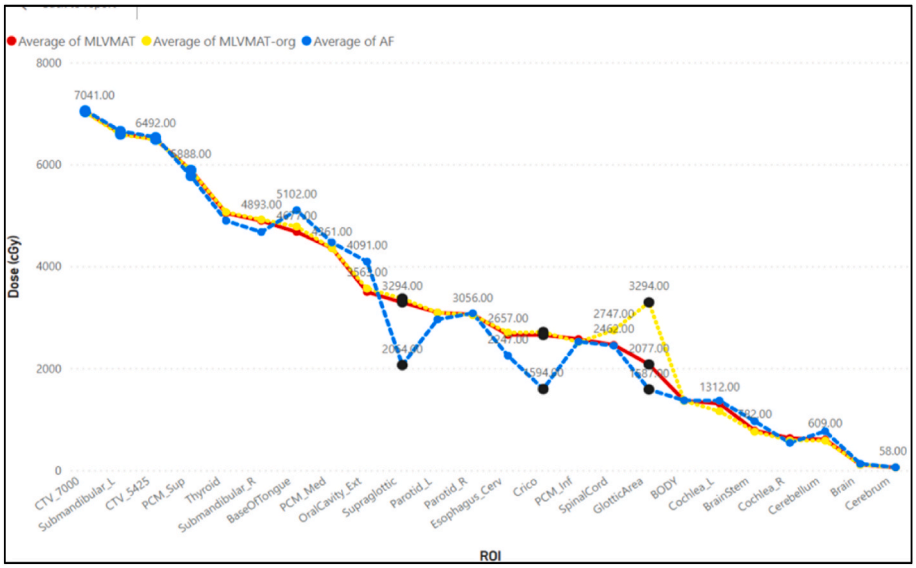

Fig. 4. Scheme illustration Organs at risk in AF (blue), MLVMAT (red) and MLVMAT-org (yellow) plans in case1.

Table 3
Clinical goals for case1.

ROI	Parameter	MLVMAT-org	MLVMAT	AF
SpinalCord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3974.00	3818.00	2887.00
Eye_Post_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	667.00	697.00	372.00
Eye_Post_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	471.00	482.00	406.00
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	2772.00	2801.00	3212.00
Parotid_R	AtMost 2600.0 cGy (RBE) average dose	3044.00	3056.00	3080.00
Parotid_L	AtMost 2600.0 cGy (RBE) average dose	3094.00	3093.00	2960.00
Eye_Ant_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	475.00	471.00	295.00
Eye_Ant_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	370.00	391.00	294.00
BrainStem	AtMost 5600.0 cGy (RBE) dose at 0.1 cm^3 volume	2418.00	2337.00	2389.00
Submandibular_L	AtMost 4000.0 cGy (RBE) average dose	6587.00	6610.00	6655.00
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose	4918.00	4893.00	4675.00
Cerebrum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	875.00	954.00	750.00
BrainStem	AtMost 5000.0 cGy (RBE) dose at 0.0 cm^3 volume	2703.00	2643.00	2640.00

Table 4
Clinical goals for case 2.

ROI	Parameter	MLVMAT-org	MLVMAT	AF
spinal cord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3302.00	3301.00	4544.00
Eye_Post_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	111.00	118.00	130.00
Eye_Post_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	115.00	115.00	140.00
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	403.00	400.00	453.00
Parotid_R	AtMost 2600.0 cGy (RBE) average dose	2241.00	2257.00	2500.00
Parotid_L	AtMost 2600.0 cGy (RBE) average dose	1756.00	1753.00	2041.00
Eye_Ant_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	85.00	90.00	101.00
Eye_Ant_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	97.00	99.00	120.00
Submandibular_L	AtMost 4000.0 cGy (RBE) average dose	6022.00	6085.00	6132.00
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose	6173.00	6192.00	6198.00
Cerebrum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	167.00	163.00	204.00
PTV_5425	AtLeast 98.0% volume at 5154.0 cGy (RBE) dose	0.99	0.99	1.00
PTV_7000	AtLeast 98.0% volume at 6650.0 cGy (RBE) dose	0.99	0.98	0.99
SpinalCord	AtMost 0.03 cm^3 volume at 5425.0 cGy (RBE) dose	0.00	0.00	13.30

optimising and the third Clinical plan (AF). Presents the colour-wash OPC for different plans. The plans ML-ORG, ML and AF, each patient planned with different strategies and models.

4.1. Evaluation of the treatment plans using different parameters

These plans were evaluated using different parameters, like dose-volume histogram (DVH), conformity index (CI) and homogeneity index (HI) to get the best result and then improve the treatment planning.

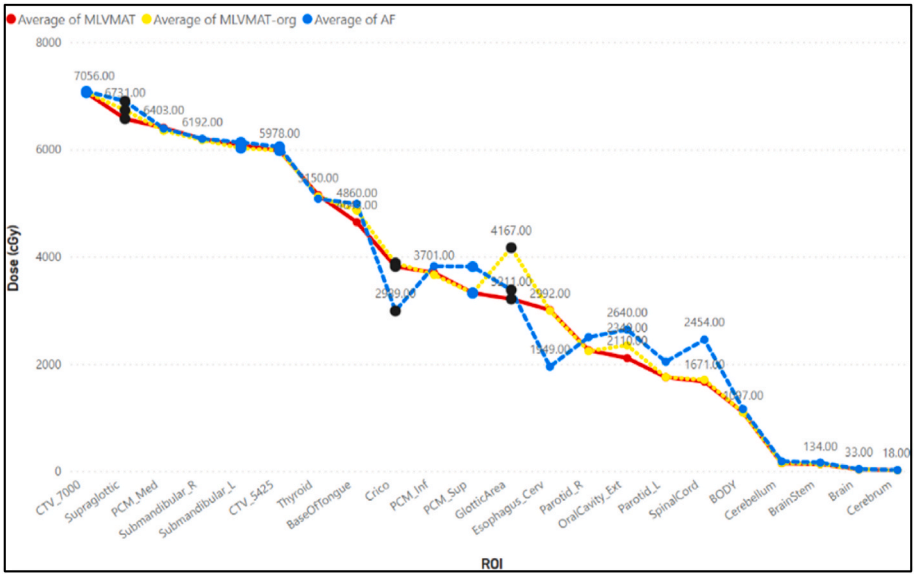

Fig. 5. Scheme illustration at risk in AF (blue), MLVMAT (red) and MLVMAT-org (yellow) plans in case 2.

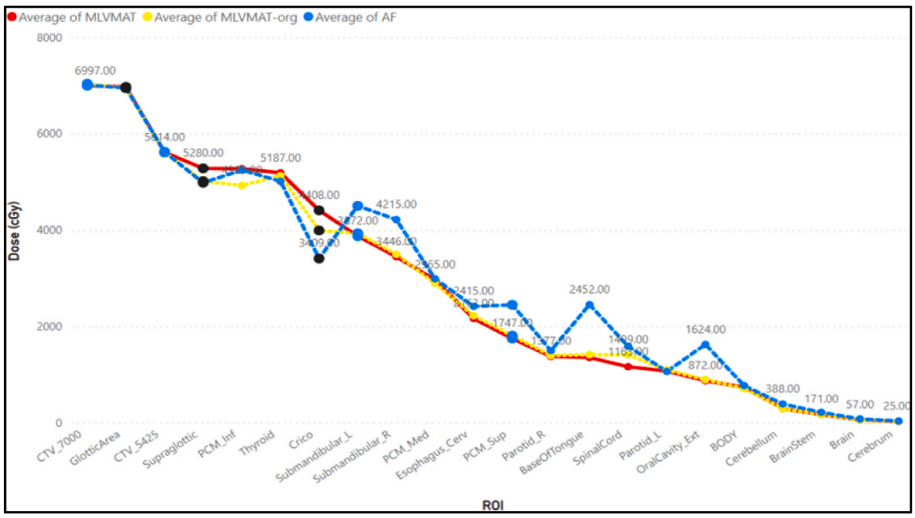

Fig. 6. Scheme illustration of the organ at risk in case 3.

Table 5
Clinical goals for the patient 3.

ROI	Parameter	MLVMAT-org	MLVMAT	AF
SpinalCord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3981.00	4016.00	3945.00
Eye_Post_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	50.00	51.00	58.00
Eye_Post_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	46.00	48.00	57.00
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	1565.00	1603.00	2371.00
Parotid_R	AtMost 2600.0 cGy (RBE) average dose	1396.00	1377.00	1497.00
Parotid_L	AtMost 2600.0 cGy (RBE) average dose	1096.00	1072.00	1065.00
Eye_Ant_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	33.00	33.00	42.00
Eye_Ant_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	28.00	29.00	42.00
BrainStem	AtMost 5600.0 cGy (RBE) dose at 0.1 cm^3 volume	1312.00	1312.00	1699.00
Submandibular_L	AtMost 4000.0 cGy (RBE) average dose	3931.00	3872.00	4502.00
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose	3496.00	3446.00	4215.00

Table 6
Clinical goals for case 4.

ROI	Parameter	MLVMAT-org	MLVMAT	AF
SpinalCord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3919.00	4526.00	3939.00
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3918.00	4854.00	4663.00
Parotid_R	AtMost 2600.0 cGy (RBE) average dose	3813.00	4541.00	4069.00
Parotid_L	AtMost 2600.0 cGy (RBE) average dose	3294.00	2647.00	3298.00
BrainStem	AtMost 5600.0 cGy (RBE) dose at 0.1 cm^3 volume	3924.00	3996.00	3995.00
Submandibular_L	AtMost 4000.0 cGy (RBE)	6369.00	6880.00	6388.00
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose	6999.00	7021.00	6997.00
Cerebrum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	1386.00	2164.00	1407.00
PTV_5425	AtLeast 98.0% volume at 5154.0 cGy (RBE) dose	0.99	0.99	1.00
PTV_7000	AtLeast 98.0% volume at 6650.0 cGy (RBE) dose	0.99	1.00	1.00

4.1.1. Dose homogeneity index (DHI) and dose conformity index (DCI)

The treatment plans were estimated using calculated DHI and DCI values according to the radiation therapy oncology group (RTOG) (Shaw et al., 1993). Analysing this project work data DCI values for PTV_7000 and PTV_5425 were insignificant different for all cases. The ideal value for the CI is equal to 1 if the value is higher than 1 it means the dose exceeds the volume of the target and part of the critical organ. Where the value is less than 1 that means the part of the target volume is radiated. In this work, the value of DCI for PTV-7000 and PTV-5425 between 0.98 and 1 were accordance with the protocol. While DHI for the PTV-7000 and PTV-5425 is between 1 and 1.34 It means, that dose distribution in the target volumes is homogeneous and covered the tumour. It means, that plans are following the protocol as shown in Table 2.

4.1.2. Organ at risk (OAR)

For the critical organ in case 1 as shown in Fig. 4 and Table 3 was found 667 cGy, 697 cGy and 372 cGy receive from the L-Eye for MLVMAT-org, MLVMAT and AF plans respectively, and the volume for submandibular(L&R) receive (6655 & 4675) cGy, (6610 & 4893) cGy and (6587 & 4918) cGy for AF, MLVMAT and MLVMAT-org plans, were found the AF plan better than ML plans depending in our results for the L-Eye and the submandibular (L&R) severe deviation for each plan without following the protocol. In Fig. 5 and Table 4 for case 2 found in the volume of submandibular(L&R) received (6132 & 6198) cGy, (6085 & 6192) cGy and (6022 & 6173) cGy for AF, MLVMAT and MLVMAT-org plans, were found in the volume of submandibular (L&R) severe deviation for all plans without following the protocol. The volume of submandibular(L&R) in case 3 received (4502 & 4215) cGy, (3872 & 3446) cGy and (3931 & 3496) cGy for AF, MLVMAT and MLVMAT-org plans, were found the AF plan in the volume of submandibular receive high

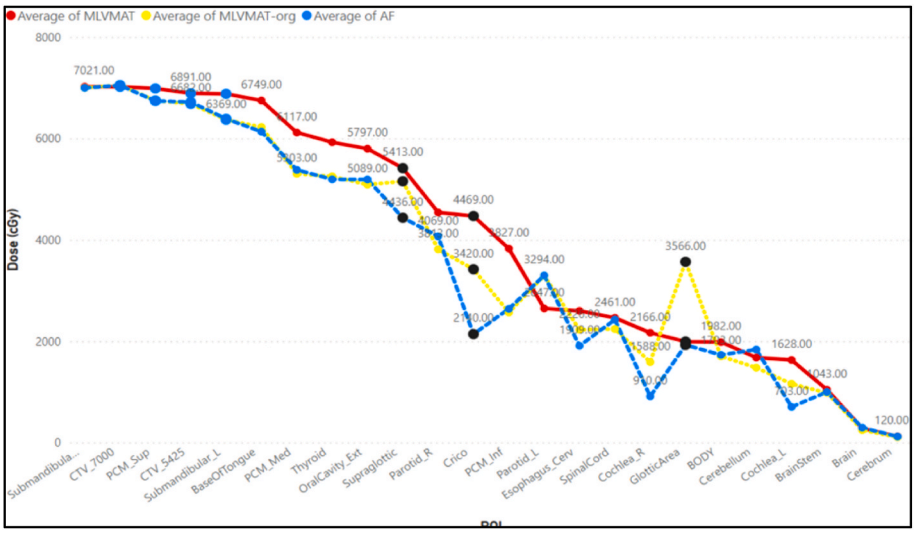

Fig. 7. Scheme illustration of the organ at risk in case 4.

Table 7
Clinical goals for the case 5.

ROI	Parameter	MLVMAT-org	MLVMAT	AF
SpinalCord	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	3854.00	3816.00	5496.00
Eye_Post_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	144.00	145.00	171.00
Eye_Post_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	141.00	143.00	158.00
Cerebellum	AtMost 5000.0 cGy (RBE) dose at 0.1 cm^3 volume	2859.00	2789.00	3843.00
Parotid_R	AtMost 2600.0 cGy (RBE) average dose	2742.00	2765.00	3624.00
Parotid_L	AtMost 2600.0 cGy (RBE) average dose	2380.00	2373.00	3339.00
Eye_Ant_L	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	95.00	97.00	114.00
Eye_Ant_R	AtMost 500.0 cGy (RBE) dose at 0.1 cm^3 volume	96.00	96.00	108.00
BrainStem	AtMost 5600.0 cGy (RBE) dose at 0.1 cm^3 volume	3297.00	3265.00	4024.00
Submandibular_L	AtMost 4000.0 cGy (RBE) average dose	4172.00	4168.00	4065.00
Submandibular_R	AtMost 4000.0 cGy (RBE) average dose	4849.00	4802.00	4863.00

dose compared with ML plans as shown in Fig. 6 and Table 5. For the critical organ in case4 found (3294 & 4069) cGy, (2647 & 4541) cGy and (3298 & 3813) cGy receive from the parotid (L&R) for MLVMAT-org, MLVMAT and AF plan respectively, and the volume of submandibular (L&R) receive (6388 & 6997) cGy, (6880 & 7021) cGy and (6369 & 6999) cGy for AF, MLVMAT and MLVMAT-org plans respectively, were found in the volume of submandibular (L&R) and parotid (L&R) severe deviation for AF and ML plans without following the protocol as shown in Table 6. In case5 was found the volume of the spinal cord receive 5496 cGy, 3816 cGy and 3854 cGy for AF, MLVMAT and MLVMAT-org plans, and the volume of submandibular(L&R) received (4065 & 4863) cGy, (4168 & 4802) cGy and (4172 & 4849) cGy for AF, MLVMAT and MLVMAT-org plans respectively, while the volume of the parotid (L&R) receive (3339 & 3624) cGy, (2373 & 2765) cGy and (2380 & 2742) cGy for AF, MLVMAT and MLVAMT-org plans respectively, were found in the volume of L-parotid and spinal cord receives high dose with AF plan compare with ML plans. R-parotid and submandibular (R & L) receive high doses for all plans as shown in Fig. 7 and Table 7 without following the protocol.

4.1.3. *Dosimetry analysis of the AF and ML plans*

In case 1, Analysing these results (Fig. 4) were observed oral cavity had the highest dose in the AF plan than MLVMAT and MLVMAT-org plans were 4091 cGy, 3497 cGy and 3536 cGy respectively. In the Glottic area was observed that MLVMAT received a higher dose than MLVMAT and FA plans 3294, 2077 and 1587 cGy respectively. While supraglottic had a lower dose in AF than MLVMAT and MLVMAT-org plans 2064, 3294 and 3370 cGy respectively. In the Crico was observed that the AF plan received a dose less than MLVMAT and MLVMAT-org plans 1594, 2655 and 2713 cGy respectively. The base of the tongue had a higher dose in the AF plan than MLVMAT and MLVMAT-org plans 5102, 4677 and 4738 cGy respectively.

In clinical goals was absorbed a significant difference between plans for the Eye and submandibular. Were observed Eye had the highest dose in ML than AF plans. Submandibular high dose for each plan. Were MLVMAT and MLVMAt-org comparable and were less than AF in terms of critical organ sparing and a significant difference for the Eye, In Table 3. The red colour represents the organs that do not follow the protocol as the left eye, right and left submandibular.

In case 2, Analysing these results (Fig. 5) observed spinal cord, the base of the tongue and the oral cavity had the highest dose in the AF plan than ML plans. In the Esophagus and Crico was observed that AF received less dose compared with ML plans. In Glottic area had a significantly higher dose in MLVMAT-org.

As you see in Table 4 was found a significant difference between plans for the spinal cord, parotid and submandibular. Were observed spinal cord and parotid had the highest dose in AF plan than ML plans but within the protocol. Submandibular received a high dose with all plans and doesn't follow the recommendation of clinical goals.

In case 3, Analysing these results (Fig. 6) were observed oral cavity, the submandibular, base of the tongue and oral cavity had the highest dose in the AF plan compared with ML plans. In the Esophagus and Crico was observed that AF received less dose than ML plans and the Glottic area had a higher dose in MLVMAT-org than MLVMAT and AF plans. As you see in Table 5 Was found a significant difference between plans in submandibular. Were observed submandibular had the highest dose in AF than ML plans without following the protocol.

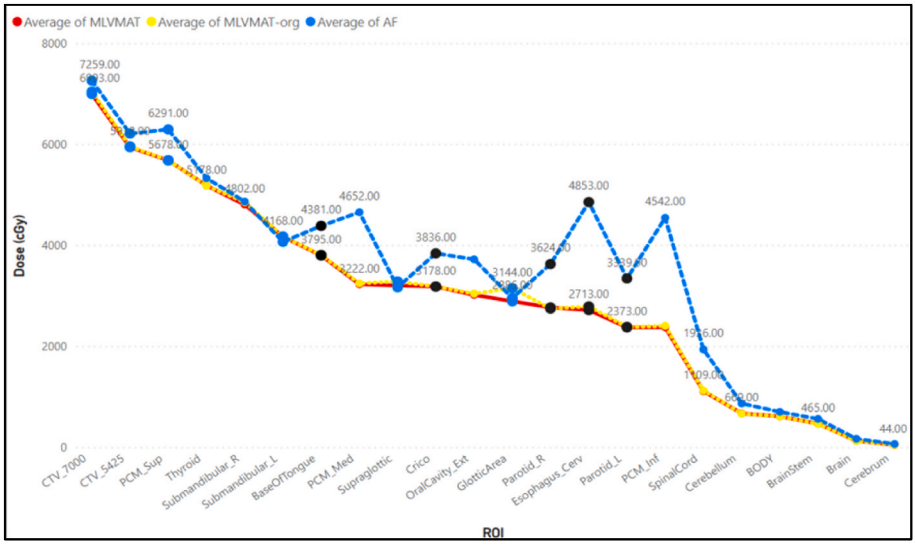

Fig. 8. Scheme illustration of the organ at risk in case 5.

In case 4, Analysing these results (Fig. 7) were observed cochlea had a lower dose in the AF plan than MLVMAT and MLVMAT-org plans. In the glottic area was observed that MLVMAT-org received a significantly higher dose than MLVMAT and AF plans. As you see in Table 6 Was found a significantly higher dose was in all plans. Were observed submandibular (left & right) and parotid (left & right) had the highest dose in AF and ML plans without following the protocol.

In case 5, Analysing these results (Fig. 8) observed PCM, parotid (L&R), Esophagus, Crico and base of tongue had received a significantly higher dose in the AF plan than ML plans. Clinical goals in clinical plan found the OAR at a significantly higher dose compared with ML plans as shown in Table 7. In each plan was observed submandibular (left & right) and parotid (left & right) received high doses without following the protocol while in the AF plan observed Spinal cord and L-parotid receive a high dose compared with ML plans without following the protocol.

5. Conclusion

This work demonstrated the main changes in machine learning ML compared with AF plans. It was found that the difference between DCI and DHI for the plans was not significant, DHI for the PTV-7000 and PTV-5425 is between 1 and 1.34 Which means, that dose distribution in the target volumes is homogeneous and covered the tumour while DCI for PTV-7000 and PTV-5425 between 0.98 and 1 it means, that plans are following the protocol. In organs at risk was observed that the volume of L-Eye in AF plan for the case1 treatment planning could be successfully used ensuring efficiency and lower than ML plans were 372 cGy, 697 cGy and 667 cGy for AF, MLVMAT and MLVMAT-org plans respectively, while showed case2, case3, case4 and case5 are better with ML plan to compare with a clinical plan. Showed that Case 3 in ML plans are within tolerance limits. Showed that Case5 received a high dose in the AF plan compared with ML plans in the spinal cord and L-parotid were 5496 cGy and 3339 cGy respectively. Normal tissue complication probability increased significantly for the AF plan compared with the ML plan. To further improve the performance of the VMAT model, future research should investigate the constraints of the clinical goal.

CRediT authorship contribution statement

Ahmed Ghanim Glayl: Methodology. **Karrar Hazim Salem:** Project administration. **Dalael Saad Abdul-Zahra:** Writing – review & editing. **Naeem Shareef Abdalhussien:** Formal analysis.

Declaration of competing interest

None declared.

Data availability

The data that has been used is confidential.

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