RESEARCH ARTICLE

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Plan Quality Index – An Integrated Dosimetric Approach for Plan Evaluation with Consideration of Quality of Dose Coverage to Tumors and Quality of Organs' Sparing

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Abstract

Purpose: To find an integrated solution for plan evaluation with multiple dosimetric parameters in order to ensure quality of target dose coverage and sparing of organs collectively. **Materials and Methods:** A mathematical logical expression called Plan Quality Index (PQI) was formulated. It includes two integrated indices 1.Integrated Dosimetric Index for tumor (IDI_{Tumor}) dose coverage and 2.Integrated Dosimetic Index (IDI_{organs}) for Organs At Risk (OARs). PQI was used to select better dosimetric plan form multiple VMAT plans of a Nasopharynx case. In addition, the PQI was used for comparison of VMAT and IMRT plans of 64 patients with Head and Neck cancer. The plan with lesser PQI was considered as a better dosimetric plan. For statistical comparison between two techniques, paired't' and Wilcoxon signed rank test were used with consideration $p< 0.05$ as a statistically significant. **Results:** The unambiguous evaluation results with PQI showed that VMAT plan was achieved the entire given dose constraints significantly better than IMRT plan in all the patients ($p<0.001$). **Conclusion:** Plan evaluation with PQI can be an unambiguous method. It evaluates the quality of tumor dose coverage (IDITumor) and sparing of OARs (IDI_{organs}) collectively. It enables to change the priority of evaluation criteria of a specified structure based on the clinical requirements. It does not require any specialized program. It can be calculated using ordinary excel program. Using the single value as PQI, the effective determination of a quality plan among many plans can be possible and it can be used for comparison of different techniques.

Keywords: PQI- IDITumor- IDIOrgans- VMAT plan evaluation- IMRT plan evaluation

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Introduction

Radiotherapy has been evolved in many aspects such as treatment delivery, imaging and verification (Wagner et al., 2003). For achieving better therapeutic index, different types of state of art delivery techniques such as Volumetric Modulated Arc Therapy (VMAT) and Intensity Modulated Radio Therapy (IMRT) have been used widely to achieve higher dose to tumor as well as minimizing dose to Organs At Risk (OARs) (Studenski et al., 2013; Riet et al., 1997; Purdy 1997). The most common practice in radiotherapy is generating two or more plans with different beam parameters by changing gantry angle, collimator angle, field size and the available options to get better dosimetric results. While evaluating the dosimetric results of the generated plans, the relative difference in the dosimetric results can be observed from plan to plan. In this evaluation process, the better dosimetric plan has to be selected in order to avail overall dosimetric benefits efficiently. Therefore, this evaluation step would play a crucial role in the process of planning work flow. The significance of the plan evaluation is to account dose metrics, robustness of the plan, and complexity of the plan which includes all the inevitable uncertainties such as marginal error, dosimetric error, setup error and dose calculation error (Victor Hernandez et al., 2020).

There are many standards such as International Commission on Radiation Units and Measurements (ICRU), Radiation Therapy Oncology Group (RTOG), Quantitative Analyses of Normal Tissue Effects in the Clinic (QUANTEC) (Bentzen et al., 2010) etc., have been followed in the plan evaluation. ICRU recommends various indices for plan evaluation; they are conformity index, coverage index, homogeneity index and dose gradient index to evaluate the quality of tumor dose coverage along with few of dose volume constraints V107% and D95%. (ICRU Report 62, 1999).

While using multiple indices and other constraints for plan evaluation, we may observe that few of the indices would be favoured to one plan and rest of the indices be favoured to some other plan of the same patient. Therefore, drawing a conclusion in the selection of better plan for

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clinical treatment would be a difficult task (Mambretti et al., 2018).

To overcome this issue, Akpati et al., (2008) used a unified index rank system called Unified Dosimetric Index (UDI). This UDI can integrate all the four indices such as conformity, coverage, homogeneity and dose gradient. However, the used homogeneity index in this UDI system is not a recommended homogeneity index by ICRU report 62 (ICRU report 62, 1999). Moreover, other than the four indices as well as the quality of organs' sparing cannot be accounted. Besides, sparing of critical structures below the tolerance dose is also considered as important as achieving the tumor dose coverage in radiotherapy since the availability of advanced technologies are enabled us to improve the quality of Organ's sparing.

Many studies have been addressed various unified method for plan evaluation (Mambretti et al.,2018; Krishnan et al., 2017; Kirkpatrick et al.,2010), but none of the study was accounted the quality of organs' sparing as well as various dose volume constraints in the plan evaluation collectively. As a result, selecting a better plan for clinical treatment either among different plans or different techniques is still an ambiguous.

As the availability of the technological options have been evolved, the suboptimal quantification of the dosimetric results of the plan is necessary during the treatment plan evaluation. Therefore, we intended to find a collective solution for the plan evaluation precisely.

Materials and Materials

In external radiotherapy, calculated plans are evaluated using the following indices individually then select a better dosimetric plan for clinical requirement (ICRU Report 62, 1999).

(i) Conformity Index ($CI_{95\%}$) = $CI_{95\%}$ = (PI/TV) (1)

It uses to estimate the level of 95% isodose conformity to the PTV. An ideal plan would have a PI = TV then, CI95%=1.

(ii) Coverage Index (COVI) = COV95% = (TVPI/TV) (2)

It estimates the percentage volume of target encompassed by 95% of prescribed dose. For an ideal plan TVPI=TV then, COV95%=1.

(iii) Homogeneity Index (HI) = HI = $(D_{2\%} - D_{98\%}) / D_{50\%}$ (3)

Dose homogeneous within the tumor can be identified using this equation. A lower HI value indicates a better dose homogeneity. An Ideal plan would have $D_{2\%} = D_{98\%}$. Then, HI = 0.

(iv) Dose Gradient Index (DGI) = DGI = (PI / HPI) (4)

This equation finds the rate of dose fall off from tumor volume to healthy tissue which relates sparing of the critical structures. An ideal plan, DGI=1 i.e. PI = HPI.

The abbreviations are used from equation 1 to 4 as follows (ICRU Report 62, 1999): PI is the volume of 95% of prescribed isodose volume and TV is the planning target volume. TVPI represents the volume of target within the 95% of prescribed isodose volume, (D2% - D98%) is expressed as difference between 2% volume received dose (higher) and 98% volume received dose (lower), D50% is the dose received by 50% volume and HPI is the volume of half of the 95% of prescribed isodose.

While evaluating a plan by using the above said indices for clinical treatment, either each one of them or all of them may or may not be favouring for the particular plan. Besides, the organs' sparing level as per the given dose constraint as one of the clinical goal also may be differed from plan to plan.

Therefore availing the benefit of better dosimetric plan, a novel approach has been followed to select the better dosimetric plan. In this approach, a systematic index called Plan Quality Index (PQI), which is integrating all the objectives of the plan collectively, is formulated. This PQI is calculated by unifying Integrated Dosimetric Index for tumor (IDITumor) and Integrated Dosimetric Index for Organs (IDIOrgans).

Plan Quality Index (PQI) = IDITumor X IDIOrgans (5)

Where, IDITumor is a mathematical logic equation that accounts the ICRU 62 recommended indices (ICRU Report 62, 1999). In addition, any other recommended indices or dose constraints with clinical objectives also can be accounted together. The mathematical logic based IDITumor formula is

$$IDI_{Tumor} = \left\{ \prod_{i=1}^{n} .W_i . \left\{ \left| objective_i - achieved_i \right| + 0.1 \right\} \right\} \times 10^n \quad (6)$$

In the equation (6), 'W'- weightage to alter the priority of given constraint and W=1 is consider as a normal weightage,

'i'- index or a constraint's number,

'objective'- given clinical goal,

'achieved'- the achieved dosimetric results

'n'- number of indices and constraints which are used.

In the ideal condition with normal weightage, the given objective and achieved values are same, the ideal value is equal to 1. The difference between the objective and achieved reveals the magnitude of deviation. In the equation 6, multiplication factor has been used. The Multiplication factor can maintain the ideal condition remains same easily even while increasing number of indices or constraints or any other evaluation parameters for evaluating the plan.

Figure 1 shows that as IDI_{Tumor} increases as the achieved value deviates from the expected objective value i.e. ideal value. Furthermore, the Figure 1 emphasizes that even if there is a small deviation of any one of the indices from the ideal value (objective value), the IDI_{Tumor} increases rapidly. As a result, the elevated value of IDI_{Tumor} reveals the aggravate parameters which is deteriorating the plan quality. Therefore, IDI_{Tumor} is a sensitive tool for identifying the deviation and gives us clear information about the quality of dose coverage to the tumor relative to the ideal condition.

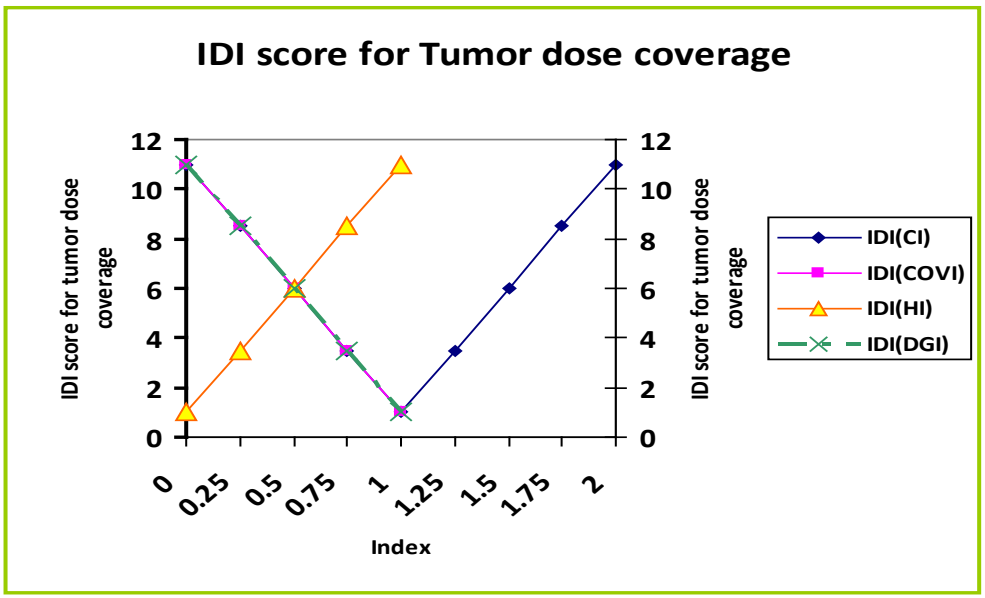

Figure 1. Logical Relation between Various Indices and IDI Score for Tumor Dose Coverage. CI, Conformity Index; COVI, Coverage Index; HI, Homogeneity Index; DGI, Dose Gradient Index; IDI, Integrated Dosimetric Index.

Concerning OARs, QUANTEC (Bentzen et al., 2010) recommends dose volume tolerance has been used widely in the routine clinical practice. This recommendation insist to analyse the maximum dose (D_{max}), mean dose, appropriate dose (X_{Gy}) received volume (V_{xGy}) and appropriate volume (X%) received dose ($D_{X\%}$) of organs. The maximum dose is a vital parameter to be analysed for serial organs, whereas mean and/or recommended dose-volumes are to be analysed in the case of for parallel organs. Similar to IDI_{Tumor}, here also multiple objectives are to be analysed for clear-cut decision. Organ sparing perspective, the achieved organ's dose/ volume can be either lesser than or equal to the objective dose/ volume for accepting the plan for clinical treatment. Achieving the organ's dose to zero is not possible practically. However, the dose to organ may be differed among the plans in a range which could be from near zero to objective value. In a plan, various organs with different dose constraints are to be analysed with respective to their clinical objectives. Drawing conclusion with single constraint is easy, whereas multiple dose constraints for various organs the analysing ask would be tough especially while using stringent constraint for the specified critical organs as a clinical requirement. In such a situation, a collective solution which can help to select the higher beneficial dosimetric plan that is achieved relatively higher sparing and satisfying all the dose constraints with respect to the other plans need to be used. To fulfil these requirements, the following mathematical logical equation called Integrated Dosimetry Index for Organs (IDI_{Organs}) can be used.

$$IDI_{Organs} = \left\{ \prod_{i=1}^{n} . W_i . e^{\{(ORI_i)-1\}} \right\} \quad (7)$$

Where,

In the equation (7), 'W'- weightage to alter the priority of given dose constraint and W=1 is consider as a normal weightage,

'i'- constraint number of organs

'n'- number of constraints of various organs which are analyzed.

Organ Risk Index (ORI) is a ratio of achieved and objective constraint of an organ.

$$\textbf{Organ Risk Index (ORI)} = \frac{achieved\ constraint}{objective\ constraint} \quad (8)$$

Where,

'objective constraint'- given clinical goal,

'achieved constraint'- the achieved dosimetric results

In the planning process, dose to organs lesser than objectives also possible and it will be additional benefits. Therefore the ideal value has been defined till reach organ's dose to nil if possible.

A good plan's Organ Risk Index (ORI) is ≤ 1. For an ideal plan, the ORI = 0. However, as mentioned earlier, this is not possible practically since the evaluated organs are within the treatment volume. If ORI >1 then the plan has to be either re-optimized or not to be considered for the treatment, especially in the case of serial organs. In the case of parallel organs, if the ORI >1, it may be accepted due to the clinical requirements in specified clinical situations.

IDI_{Organs} can be found by substituting the calculated ORI of all the objectives of the evaluating organs in the equations 7. For a good plan the IDI_{Organs} is ≤ 1.0. This logical expression can be more sensitive if a constraint deviates from the objectives of the organs. Figure 2 shows the relation between ORI and IDI_{Organs}. The IDI_{Organs} changes exponentially with ORI (Figure 2).

For example,

(i) If ORI=0, then IDI_{Organs} = 0.3678. Similarly, if 'n' constraints' ORI=0, than IDI_{Organs} = 0.3678n.

(ii) If ORI=1, then IDI_{Organs} =1. Therefore, the deviation from objective is 0.

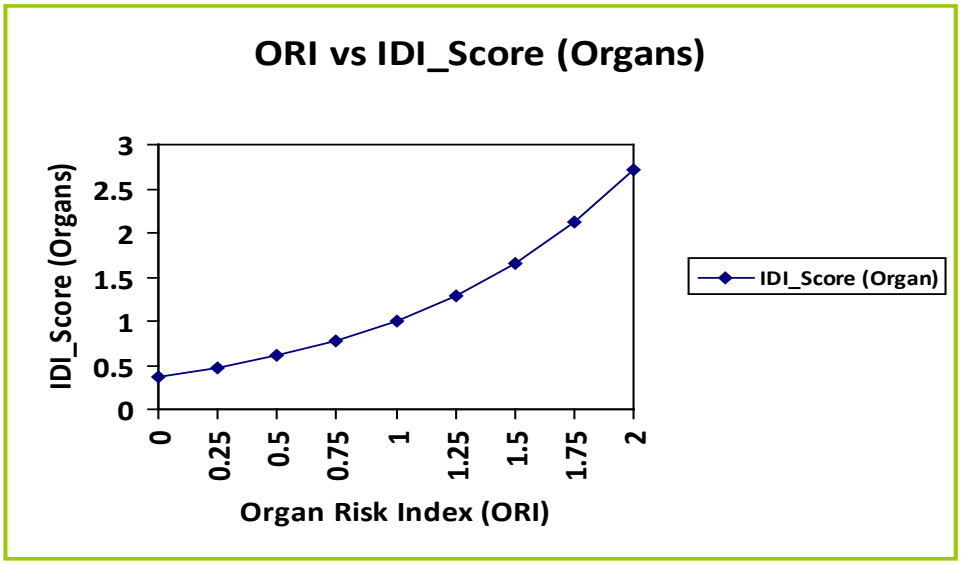

Figure 2. Logical Relation between Various ORI and IDI Score for Organ Sparing. ORI, Organs Risk Index; IDI, Integrated Dosimetric Index.

(iii) If ORI=0.5, then IDI for organ = 0.6065. This result shows the difference of 0.3935 from 1 that is 0 deviations from the objective. It indicates that 39.3% higher sparing of organ has been achieved. Though the achieved value is well below the tolerance, the IDI_{Organs} tend to ideal value 0.3678n is a smaller value.

(iv) If ORI=1.5, then IDI for organ = 1.6487. Therefore, the difference between 1.6487 from 1 that is 0 deviations from the given objective is 0.6487. It indicates that 64.87% lesser sparing of organ than expected sparing. Though the ORI increased in the same range as in case (ii), the digression of IDI_{Organs} is a larger value which indicates the severity of risk involvement with the plan. Therefore, the equation IDI_{Organs} is a useful tool to analyse the overall organs' sparing of different plans.

The ideal value of PQI is 0.3678n. At this condition, the IDI_{tumor} is 1 and the IDI_{Organs} is 0.3678n, if 'n' constraints' ORI=0, than IDI_{Organs} = 0.3678n. It means that the achieved results are equal to the given objectives and the organs received no doses. Practically, it is not possible since the evaluating organs are within the treatment volume.

Use of Indices for evaluation purpose:

A. Selection of the best dosimetric plan among many plans:

A nasopharynx case with simultaneous prescription of 70Gy to GTV and 54Gy to PTV2 in 35 fractions was selected. Eleven VMAT plans were generated for 6MV photon using Eclipse external beam planning systems(15.0.04) with various beam parameters like gantry angle, collimator angle and field size in order to achieve the given planning objectives. Dose was calculated using AAA algorithm with 2.5mm calculation grid size. To all the eleven plans, the above mentioned indices IDI_{Tumor}, IDI_{Organs} and PQI were calculated using Microsoft Excel program.

Based on PQI, all the plans were arranged either in ascending or descending order to select the least value plan. The least value plan was considered as the best plan among the all. Equal weightage (W=1) was assigned to all the indices in order to account all indices' effects equally.

B. Selection of a better dosimetric plan between techniques:

For comparison of two techniques VMAT and IMRT, the above said indices were used. 64 patients with head and neck cancers were included in this study. To all the patients, VMAT and IMRT plans were created using Eclipse planning system (15.0.04) and optimized for 6MV photon in order to achieve the given similar planning objectives for both the techniques. Dose was calculated using AAA algorithm with 2.5mm calculation grid size.

To all the eleven plans, the above mentioned indices IDI_{Tumor}, IDI_{Organs} and PQI were calculated using Microsoft Excel program. Other than these indices, Confirmation Number (CN) (Riet et al., 1997) and regularly used objectives in our institute were also calculated and reported.

$$CN\ 95\% = (TV_{PI}/TV)\ X\ (TV_{PI}/PI) \quad (9)$$

Where TV is the Planning Target Volume (PTV), PI is the volume of 95% of prescribed iso-dose volume TVPI represents the volume of target within 95% of prescribed isodose volume. An ideal plan would have a TV_{PI}=TV=PI then, $CN_{95\%}$=1.

Based on PQI, both techniques' plans were arranged either in ascending or descending order to select the lesser value plan. The lesser value plan was considered as the better plan between both the techniques' plans. Equal weightage (W=1) was assigned to all the indices of the both the plans in order to account all indices' effects equally.

Statistical analysis

For the comparison between VMAT and IMRT plans, paired't' test for normally distributed data and Wilcoxon signed rank test for abnormally distributed data were

used. p<0.05 was considered as statistically significant.

Results

A. Selection of the best dosimetric plan among many plans

The Figure 3 shows PQI (red line), IDITumor (green line), and IDIOrgans (violet line) of all the plans of a Nasopharynx case. Though most of the plans were achieved the conformal dose coverage to the tumor, the 9th plan achieved the highest sparing of Organs At Risk (OARs) among the 11 plans. As the result, the 9th plan's PQI was become the least one and this plan was considered for clinical treatment.

B. Selection of a better dosimetric plan between techniques

Figure 4 shows IDI_{Tumor} of VMAT (Red diamond) and IMRT (Blue circle) plans of the 64 patients with Head and Neck cancer. The IDI_{Tumor} of VMAT plans were relatively lesser than the IDI_{Tumor} of IMRT plans in all of the patients. The Figure 4 indicates that few of the patients' plans in both the techniques scored higher values. These higher values were noticed especially in relatively bulky patients

Table 1. Comparison Results of Dose Coverage of PTV_{70Gy}, PTV_{54Gy}, Various Indices and Sparing of Organs at Risk between VMAT and IMRT Plans.

Planning objectives		Mean ± SD		Mean difference	p
		VMAT	IMRT		
PTV_{70Gy}	D2%<74.9Gy	74.04 ± 1.29	73.93 ± 1.79	0.111	0.632*
	D98%>66.5Gy	67.81 ± 1.01	67.12 ± 1.11	0.684	<0.001*
	V107<2%	2.54 ± 6.34	3.871 ± 12.88	-1.334	0.702$
	CN	0.822 ± 0.07	0.739 ± 0.09	0.084	<0.001*
	DGI	0.113 ± 0.05	0.110 ± 0.052	0.005	0.015*
	COVI	0.980 ± 0.02	0.977 ± 0.03	0.006	0.102*
	CI	1.184 ± 0.12	1.313 ± 0.18	-1.29	<0.001*
	HI	0.087 ± 0.02	0.096 ± 0.03	-0.001	0.013*
PTV_{54Gy}	D98%>50.0Gy	51.362 ± 0.84	50.958 ± 1.63	0.404	0.031*
	HI	0.229 ± 0.05	0.248 ± 0.07	-0.019	0.013*
OARs					
Spinal Cord	Dmax<45Gy	39.685 ± 3.72	40.918 ± 5.10	-1.233	0.013*
Lt. Parotid	Mean<26Gy	21.795 ± 10.40	22.600 ± 10.74	-0.805	0.012*
Rt. Parotid	Mean<26Gy	20.857 ± 8.97	22.04 ± 8.87	-1.178	0.001*
Larynx	Mean<35Gy	38.635 ± 7.90	40.758 ± 8.24	-2.123	0.011*
Oral cavity	Mean<45Gy	33.874 ± 9.19	36.381 ± 8.77	-2.508	<0.001*

VMAT, Volumetric Modulated Arc Therapy; IMRT, Intensity Modulated Radiation Therapy; V107% – 107% of prescribed dose received volume (%),OARs, Organs At Risk; D_{max}, maximum Dose; SD, Standard Deviation; '*' Paired 't' test, $- Wilcoxon signed rank test.

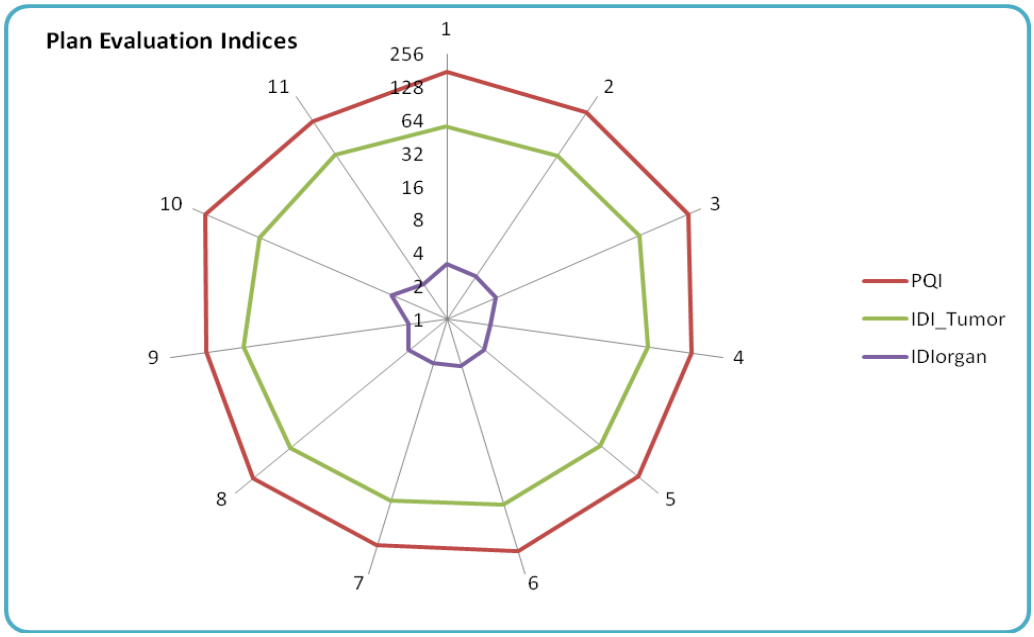

Figure 3. Plan Evaluation Indices. PQI, IDITumor, and IDIOrgan. PQI, Plan Quality Index; IDI_{Tumor}, Integrated Dosimetric Index for Tumor; IDI_{Organ}, Integrated Dosimetric Index for Organ

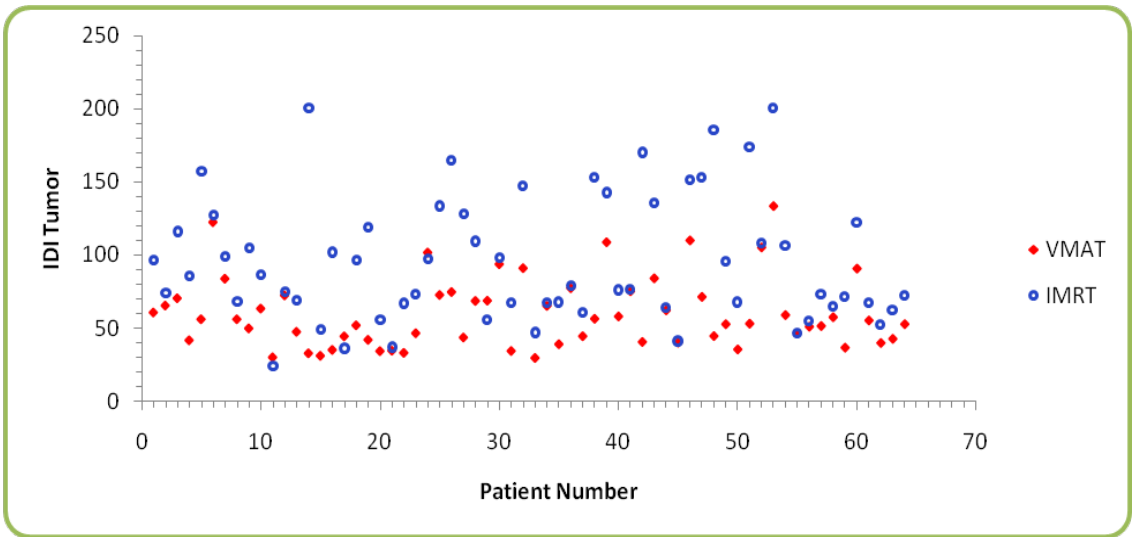

Figure 4. VMAT and IMRT Plans' Integrated Dosimetry Index for tumor (IDI_{Tumor}) of Head and Neck Cancer Patients

due to the higher dose spillages delivered to other than the target volume region. It could be reduced with higher energies.

Figure 5 shows the IDI_{Organs} of each Head and Neck cancer patient. More number of patients' IDI_{Organs} was achieved well within the objective line (violet line) with VMAT plans (red diamond) as well as IMRT plans (blue circle). However, VMAT plan's IDI_{Organ} was relatively lesser than IMRT plan's IDI_{Organ}.

Figure 6 shows the Plan Quality Index (PQI) of each patient's VMAT (Red diamond) and IMRT (blue square) plans in base 2 logarithmic scales to cover higher range values. PQI of all the VMAT plans were lesser than IMRT plans. The reason for getting higher range values was the IDI_{Tumor} of bulky patients' plan and few of the parallel organs received more than objective values and it was accepted due to the clinical requirements.

Table 1 shows that the minimum acceptable target dose

Table 2. Comparison Results of IDI_{Tumor}, IDI_{Organs} and PQI between VMAT and IMRT plans.

Indices	Mean ± SD		Mean difference	p
	VMAT	IMRT		
IDITumor	59.613 ± 24.0	95.573 ± 42.87	-35.96	<0.001*
IDIOrgans	0.652 ± 0.44	0.820 ± 0.651	-0.168	<0.001$
PQI	38.55 ± 30.51	85.76 ± 88.82	-47.21	<0.001$

VMAT, Volumetric Modulated Arc Therapy; IMRT, Intensity Modulated Radiation Therapy; SD, Standard Deviation; '*', Paired 't' test, $, Wilcoxon signed rank test.

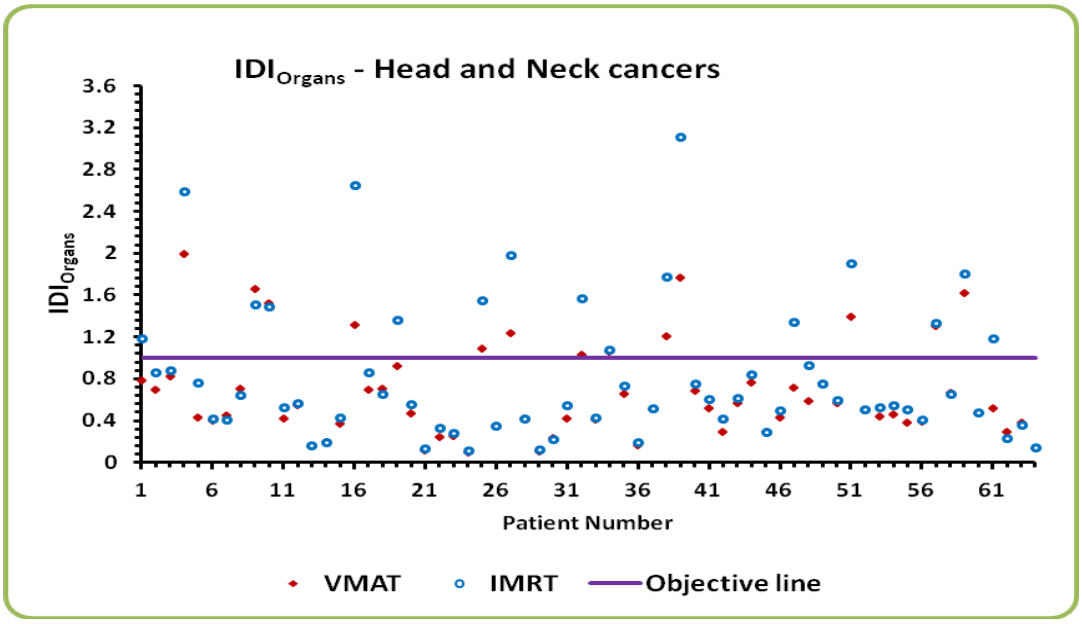

Figure 5. Integrated Dosimetric Index for Organs (IDI_{Organs}) with VMAT and IMRT Plans in the Treatment of Head and Neck Cancers

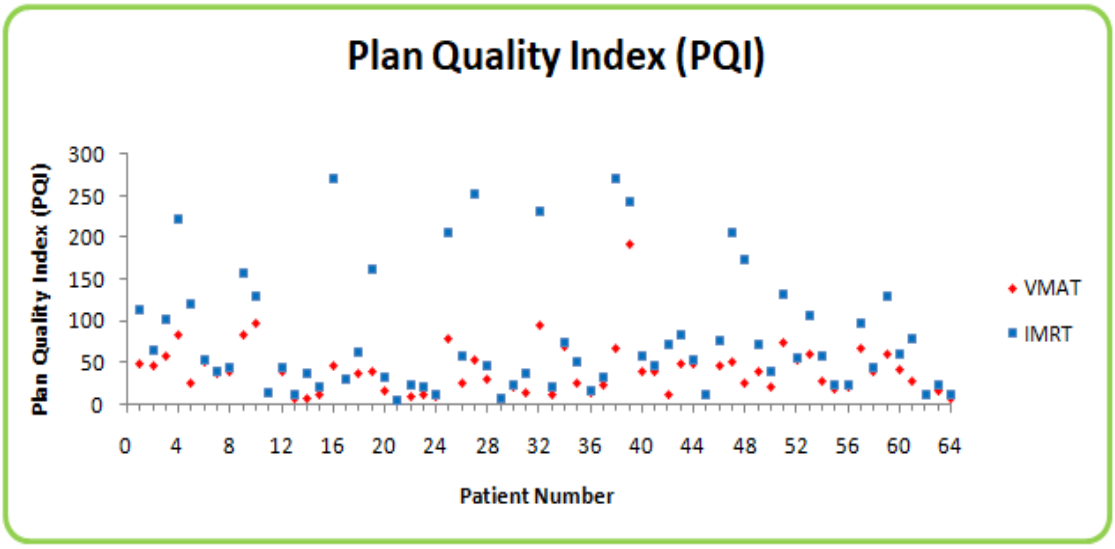

Figure 6. Plan Quality Index (PQI) of VMAT and IMRT plan. VMAT, Volumetric Modulated Arc Therapy; IMRT, Intensity Modulated Radiation Therapy.

coverage ($D_{98\%}$ > 66.5Gy) was achieved with both VMAT and IMRT plans. However, the target dose coverage ($D_{98\%}$) was achieved significantly (p<0.001) better with VMAT plans than IMRT plans without causing any hot spot ($V_{107\%}$) (p=0.702) in the treatment volume.

The organs' dose was controlled below the objectives with VMAT as well as IMRT plans except mean dose of Larynx. VMAT plans significantly (p=0.013) reduced the maximum dose of spinal cord from the given objective dose than IMRT. Likewise the mean dose of both left and right Parotids also significantly (p=0.012) reduced with VMAT than IMRT. The mean dose of uninvolved oral cavity (p<0.001) and mean dose of larynx (p=0.011) were controlled substantially with VMAT than IMRT plans

Table 2 shows the results of IDI_{Tumor}, IDI_{Organs} and PQI. It evident that all the indices were significantly favouring (p<0.001) VMAT plans than IMRT plans.

Discussion

Technological enhancement in the delivery helps to achieve better conformal dose to tumor and additional sparing of organs (Riet et al., 1997). An ideal plan is to deliver the uniform dose of the prescription to tumor and no dose to the surrounding structures. However, practically this is not possible. With the available of improved technology, the plan can be made to achieve the expected dosimetric results in a better way and it can be as closer to an ideal plan.

In practice, many of the plans are generated using either same technique or different techniques in order to achieve better dosimetric results. As a result, the various plans' dosimetric results can be closer to each other. As mentioned earlier, the selection of the best plan among many plans is a crucial task. If the plan selection is improper for clinical treatment, it may lead to lose the additional dosimetric benefits from a better plan which is mistreated due to illogical analysis (Mambretti et al., 2018).

The method of analysis of dosimetric results using a few of recommended indices for tumor coverage and each organ's sparing level individually is not an effective way to draw a conclusion about a plan. Supplementary, the unified plan evaluations are defining only about the quality of conformal dose coverage to tumor (Studenski et al., 2013; Riet et al., 1997; Purdy 1997). These tradition methods to analyse the plans which are generated by various state of art technologies' is inadequate. Many studies (Glide-Hurst et al., 2014; Krishnan et al., 2017; Kirkpatrick et al., 2010). show that the availability of various state of the art techniques such as VMAT, IMRT are not only achieving quality of dose coverage to tumor but also achieving the higher sparing of various organs.

Few studies (Ruan et al., 2012; T Song et al., 2015; Alfonso et al., 2015) proposed as dose distribution index, patient-specific dosimetric endpoints (DEs) Evolving treatment plan quality criteria. These solutions evaluate the plans using a kind of scoring method, Dose Volume Histogram (DVH) end points method. Even these methods analyse both tumor dose coverage and degrees of organ's sparing, the proposed tolls are needed a specialized program to use it and it is a complicated one to make users to understand. Moreover, the use of evaluation constraints are not fully recommended constraints by the standard protocols ICRU, RTOG and QUANTEC.

This study has proposed a straightforward solution which includes integrated indices IDITumor, IDIOrgans and PQI. These solutions can identify quality of tumor dose coverage and quality of organ's sparing using Organ Risk Index (ORI). This ORI helps us to check how well an Organ's dose volume objectives are deviated from the defined objective value. In a plan, many organs are needed to be spared at the same time it has to be accounted collectively while evaluating the plan. A better dosimetric plan would help to achieve higher therapeutic index. According to the clinical requirements, the priorities of the indices can be defined with different weightage to IDITumor and IDIorgans while calculating PQI.

In this study, these indices were used to select the best plan among many plans which were created with different

beam parameters using VMAT technique and found the quality dose coverage and organs sparing with 9th plans. To indentify and utilize the best plan, this PQI single score ranking system can be more useful otherwise averaging of all the indices' scores would lead to an ambiguous condition.

These indices were also used for comparison of two techniques in this study. The lesser PQI with VMAT plan ensures that VMAT is an appropriate option for clinical treatment. This study demonstrates further that the lesser IDIOrgans of each VMAT plan ensured sparing of organs was better than IMRT. In addition, the IDIOrgans of few VMAT and IMRT plans reached beyond the objective's line. It indicates that few of the organs received higher dose than given constraint and it could increase the risk of the toxicities. This was observed in few cases where the treatment was planned to a unilateral side; for that reason the ipsi-lateral parallel organ received higher dose. In such a case treating the tumor was the higher priority rather than avoiding the organ. At the same time, all serial organs' dose was observed below the defined tolerance dose.

Advancement in the imaging and delivery techniques helps to escalate dose to tumor and reduce the dose to critical structures further (Glide-Hurst et al., 2014). Different techniques with various degrees of freedom may result different outcomes (Akpati et al., 2008). Among all these techniques' a better plan would fulfil our clinical goal effectively. This outcome results, even smaller between various plans, would help to improve tumor control with better Quality Of Life (QOL). In these circumstances, the usage of a PQI is the most necessary for precise evaluation of plans to avail even smaller benefits.

This unique evaluation tool PQI based on mathematical logical expression which does not required any specific program. Therefore, the effective evaluation with single ranking score PQI can be performed in plan evaluation and selection process easily. Limitation of this study is that only dosimetric related parameters were accounted. Strength of this study is that the derived equations can be used by using simple excel sheet also it can be used to develop a program for auto plan evaluation. The machine parameters such as treatment time, number of monitor unit and QA pass rate will be accounted and analysed in the future study.

In conclusion, Plan evaluation with PQI can be an unambiguous method. It evaluates the quality of tumor dose coverage (IDITumor) and sparing of OARs (IDIorgans) collectively. It enables to change the priority of evaluation criteria of a specified structure based on the clinical requirements. It does not require any specialized program. It can be calculated using ordinary excel program. Using the single value as PQI, the effective determination of a quality plan among many plans can be possible and it can be used for comparison of different techniques.

Author Contribution Statement

Dr. Jayapalan Krishnan; Contribution towards the manuscript: Concepts, design, definition of intellectual content, literature search, data acquisition, data analysis, statistical analysis, manuscript preparation, manuscript editing. Dr. Suresh Rao; data analysis, plan evaluation. Dr. Sanath Hegde; data analysis, plan evaluation.

Acknowledgments

Conflict of interest
NO conflicts of interests

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