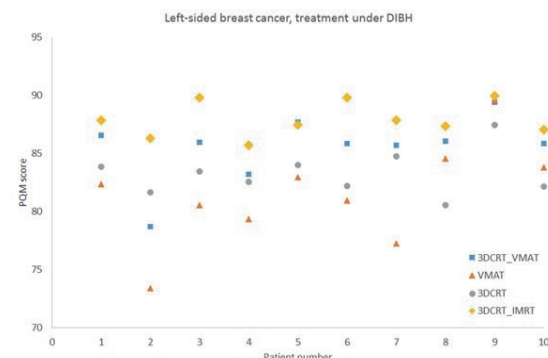


treatment during Deep Inspiration Breath Hold (DIBH). For each patient four plans were created: one conventional plan with tangential fields (3DCRT), one 3DCRT-VMAT hybrid (80:20) and one 3DCRT-IMRT hybrid (70:30) [1] as well as one VMAT plan with restricted arcs. Tolerance criteria for target and organs at risk from RTOG 1005 were utilized when analyzing the DVHs obtained for the different plans. Additional parameters, e.g. ventricle mean dose, near max heart dose, mean lung dose, gEUD, NTCP for ipsilateral lung and others, are included. The Plan Quality Metric (PQM) strategy [2] was applied identifying 14 sub-metrics to evaluate the plan quality and variation for the different treatment techniques. Three levels of performance were defined for each sub-metric using linear and non-linear scoring. Target coverage accounted for 56% of the total score. The percent for heart, lung and contralateral breast was 20, 16 and 8%, correspondingly.

Results

In general, the RTOG tolerance criteria have been fulfilled for all plans. High target coverage has been achieved with each technique and the mean values for PTV V95% and PTV T V95 were larger than 96% and 98.5%, correspondingly. PTV conformity indexes (CI) were comparable for the hybrid and VMAT plans and superior over the corresponding conventional plans (Table). The mean doses to heart and lungs in the Table indicate a smaller increase of relative risk for lung cancer and cardiac mortality than reported in [3]. Plans using 3DCRT-IMRT technique received the highest score. The relative performance of the four techniques tended to persist even on individual plan level (Figure). The small difference between the PQM scores for the different techniques may be related to the domination of the target coverage in the total score. Choice of sub-metrics and score distribution allows stratification of breast cancer patients into groups for further optimization of risk/benefit balance.

Parameter, mean	Patient group	Technique			
		3DCRT	3DCRT-IMRT	3DCRT-VMAT	VMAT
Conformity Index (PTV V95%/PTV T volume)	Left-sided, DIBH	2.31	1.56	1.38	1.35
	Left-sided, FB	2.11	1.52	1.36	1.27
	Right-sided, FB	2.42	1.56	1.43	1.42
Heart, mean dose, Gy	Left-sided, DIBH	1.1	1.0	1.3	1.6
	Left-sided, FB	2.3	2.1	2.5	2.5
	Right-sided, FB	0.3	0.3	0.6	0.7
Lungs, mean dose, Gy	Left-sided DIBH	2.2	2.0	2.5	3.0
	Left-sided, FB	2.2	2.0	2.5	2.7
	Right-sided, FB	2.9	2.7	3.4	3.6
Contralateral breast, D5%, Gy	Left-sided DIBH	0.4	0.3	1.1	1.6
	Left-sided, FB	0.3	0.3	1.2	2.3
	Right-sided, FB	0.4	0.3	1.2	1.6
PQM total score	Left-sided DIBH	83.3	87.9	85.5	81.5
	Left-sided, FB	82.0	84.9	81.9	78.7
	Right-sided, FB	85.2	89.5	86.1	83.7



Conclusion

Higher dose conformity and lower dose to heart, lungs and collateral breast can be achieved with hybrid planning techniques. Implementation of PQM evaluation

allows identification of treatment strategy based on individual risk/benefit balance.

1. S K Smith et al. J Radiother in Practice 2016; 15: 131-142
2. B E Nelms et al. PRO 2012; 2: 296-305
3. C Taylor et al. J Clin Onc 2017; 36: 1641-1650

EP-1917 Comparison of Robustness Metrics in Intensity Modulated Proton Therapy

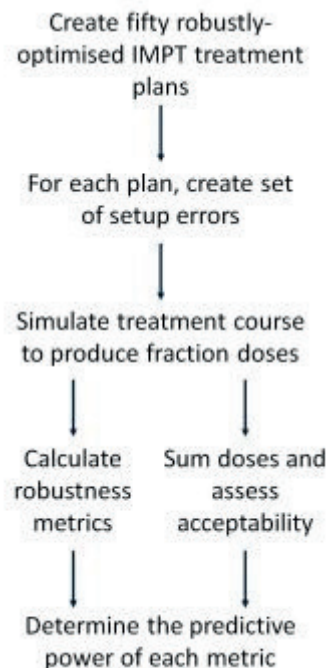
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Purpose or Objective

Five robustness metrics are assessed in intensity modulated proton treatment breast plans to determine which is the most effective at predicting the robustness of a delivered treatment plan.

Material and Methods

Fifty robustly optimised IMPT treatment plans were created and analysed using the probabilistic scenarios approach, as detailed in Figure 1. In this methodology, a set of perturbed fraction doses is created for each IMPT treatment plan. By summing the resulting dose distributions, an entire treatment course can be modelled. From these dose distributions, five robustness techniques are used to predict the clinical acceptability of the simulated treatment course, namely *DVH Area* as well as *Relative Volume Histogram*, *Dose Coverage Histogram*, *Error Bar Histogram* and *Dose Variance Histogram*. The predictive power of each metric is calculated using the Mann-Whitney U test.



Results

No single robustness method outperforms the others. Mean and maximum variance, mean and maximum dose error, error bar dose distribution, dose volume histogram area and relative volume histogram are useful for predicting target robustness. Mean and maximum variance, mean and maximum dose error, relative volume histogram, dose coverage histogram, dose volume histogram metrics are predictive of organ at risk robustness.

CTV Breast	CTV Nodes	Ipsi. Lung
DVH Area	DVH Area	-
-	RVH Area	-
$V_{eb}(4\%)$	-	-
$V_{eb}(6\%)$	$V_{eb}(6\%)$	-
$V_{eb}(\text{mean})$	$V_{eb}(\text{mean})$	-
-	$V_{eb}(\text{max})$	-
-	$V_{var}(10\%)$	-
$V_{var}(20\%)$	$V_{var}(20\%)$	-
$V_{var}(40\%)$	-	$V_{var}(40\%)$
$V_{var}(60\%)$	-	-
-	$V_{var}(\text{max})$	-
$V_{var}(\text{mean})$	$V_{var}(\text{mean})$	-
$D(95\%)_{95}$	$D(95\%)_{95}$	-
$V(95\%)_{95}$	$V(95\%)_{95}$	-
-	-	$V(20\%)_{95}$

Conclusion

The best performing metric was the dose-coverage histogram, which calculates the value a specific DVH metric is likely to reach 95% of the time. However, it was observed that different robustness metrics were significant depending on which region of interest was being assessed. The specific robustness metrics found to be significant are listed in Table 1.

In conclusion, care needs to be taken when selecting a robustness metric to evaluate a new treatment technique and the probabilistic scenarios approach can provide information about the effectiveness of each metric under consideration.

EP-1918 Dosimetric benefits of mid-position approach compared with internal target volume for esophageal RT

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Purpose or Objective

Both mid-position (MidP) and internal target volume (ITV) planning approaches can take the respiration-induced target motion (RTM) into account. For esophageal cancer RT, it is unknown whether the MidP approach can fulfill sufficient target coverage and substantially reduce the dose to organs at risk (OARs) compared to the ITV approach. In this study, we aimed to compare these two approaches in terms of CTV coverage and dose to the OARs.

Material and Methods

We retrospectively included 15 esophageal cancer patients who received neoadjuvant RT (1.8Gy×23). Per patient, a 10-phase 4D-CT was acquired with the CTV and OARs (i.e., lungs, heart, and liver) delineated on the 20% phase. First, the CTV was automatically propagated to the other 9 phases using deformable image registration (ADMIRE v2.0, Elekta). Based on the deformation vector fields (DVs), the MidP-CT was reconstructed from all 10 phases (Fig.1a). The CTV and OARs were then automatically propagated onto the MidP-CT. The ITV was also created on this MidP-CT by taking the envelope of all 10 CTVs (Monaco v5.1, Elekta). Four VMAT plans were made on the MidP-CT with respect to 4 different PTVs: PTV_{MidP-RTM}, PTV_{ITV-only}, PTV_{MidP-full}, and PTV_{ITV-full} (Oncontra v4.3, Elekta). PTV_{MidP-RTM} encompasses the random error of patient-specific RTM, based on the DV-derived RTM amplitudes; PTV_{ITV-only} equals to ITV; whereas PTV_{MidP-full} and PTV_{ITV-full} encompass, besides the RTM errors using the MidP or ITV approach, the population-based delineation and interfractional position errors, respectively. The CTV/ITV-to-PTV margins were anisotropic and dependent on the anatomical region. For all 4 plans dose was calculated on the 10 phases and the resulting dose distributions were warped to the MidP-CT using the DVs and averaged (Fig.1b). For this mean warped doses of all patients, $V_{95\%}$ of the CTV was compared between using PTV_{MidP-RTM} and PTV_{ITV-only}-based plans; Dose-volume histogram parameters (DVHp) of the OARs were compared between using PTV_{MidP-full} and PTV_{ITV-full}-based plans.

Results

The mean±SD of the RTM amplitudes in the craniocaudal (CC) direction was 4.7±2.0 and 7.6±4.0mm for the cranial and caudal region of the CTV, respectively. For both approaches, $V_{95\%}$ of the CTV was >98% except for one patient with an RTM amplitude of 19.5mm in the caudal region of the CTV in the CC direction ($V_{95\%}=96.5\%$ for the MidP approach), suggesting that the MidP approach can mostly fulfill a sufficient CTV coverage (Table 1). For the OARs, a significant reduction ($p<0.05$, Wilcoxon signed-rank test) was found in the DVHp for using the PTV_{MidP-full}-based plan compared with the PTV_{ITV-full}-based plan (Table 1). However, this reduction was small, suggesting limited dosimetric benefits in the OARs.

Conclusion

For esophageal cancer RT, the MidP approach can mostly ensure sufficient target coverage. Although the limited dose reduction to the OARs may not be clinically relevant, the MidP approach is preferred based on the as-