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Impact of interfractional anatomic variations on breath-hold SBRT for pancreatic cancer

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INTRODUCTION

Unresectable pancreatic cancer has a remarkably low 5-year overall survival at <5% [1]. Recently, SBRT has become a viable treatment option for such patients, with prospective clinical trials showing increased rates of local control over standard radiation therapy and chemotherapy approaches [2].

While SBRT can provide highly conformal doses, the reduced number of fractions may increase the magnitude of dosimetric uncertainties from interfractional motion. Moreover, the GI luminal structures are extremely sensitive to motion due to respiratory effects, as well as transient anatomical changes such as gas-filling [3]. This produces a delicate situation in which the highly radiosensitive GI luminal structures, which are typically located near the target volume, may move even closer between treatment fractions.

CT-on-Rails (CTOR) imaging acquired immediately prior to treatment can accurately reflect the treated anatomy using diagnostic quality CTs that can be used for radiation therapy planning [4].

AIM

This study aimed to evaluate the dosimetric impact of interfractional anatomical changes on pancreas cancer patients treated with SBRT using breath-hold motion management. This included differences in planned vs. delivered (i.e., accumulated) doses to OARs (stomach, duodenum, & small bowel), as well as GTV coverage.

METHODS

- Study populations consisted of 10 pancreatic cancer patients treated with SBRT (30–40 Gy in 5 fractions) using daily CTOR image guidance and breath-hold motion management
- Prior to each treatment fraction, the couch was shifted to align to the GTV or spare OARs, based on the planned isodose lines superimposed to the daily anatomy
- Planned and delivered doses were compared for the GTV (100% coverage dose and mean dose), as well as the small bowel, duodenum, and stomach (D0.3cc, D3.0cc, V20 and V35)
- Delivered doses were calculated by:
  - Propagating each structure's planning segmentation to each fraction's CTOR imageset
  - Re-calculating plan dose on each fraction's CTOR imageset
  - Accumulating the 5 fractional DVHs into a single DVH for comparison with the original planed dose
- Paired Wilcoxon signed-rank test ($p<0.05$) was used to analyze differences between planed and delivered dose metrics

RESULTS

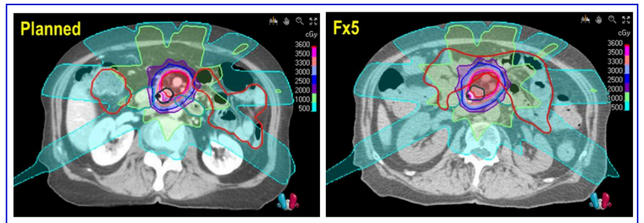

Fig. 1: (Top row) Dosimetric comparison of planned dose to the final SBRT fraction for an example patient. We can observe considerable difference in the small bowel anatomy (red contours) between plan and daily imaging; further, the small bowel has moved into the high-dose region for this fraction. (Bottom right) The planned and delivered DVH for the GTV and OARs of an example patient. Both loss of GTV coverage and increased dose to the duodenum is observed when delivered dose is considered.

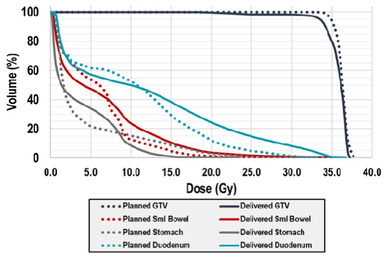

Table 1: Dosimetric comparison of planned and delivered doses for the GTV, duodenum, small bowel, and stomach (n=10). The paired Wilcoxon signed-rank test was used for analysis (*P<0.05 for significance).

	Dose Metric	Plan	Delivered	Abs. Diff.	>20% Diff. (n)	P-val
Small Bowel	D0.3cc (Gy)	27.9 (16.5–36.5)	26.1 (13.3–37.3)	-1.8 (-9.8–5.7)	2/10	0.28
	D3.0cc (Gy)	24.4 (14.6–33.0)	22.8 (11.8–32.6)	-1.6 (-7.5–9.5)	4/10	0.11
	V35 (cc)	0.1 (0.0–0.5)	0.3 (0.0–1.6)	0.2 (-0.1–1.6)	5/10	0.19
	V20 (cc)	8.3 (0.0–22.4)	6.9 (0.0–20.3)	-1.4 (-11.1–17.8)	8/10	0.13
Stomach	D0.3cc (Gy)	20.8 (1.7–32.3)	23.3 (7.3–34.9)	2.5 (-6.7–13.2)	5/10	0.28
	D3.0cc (Gy)	17.7 (1.5–27.1)	19.9 (5.8–31.4)	2.1 (-4.1–10.6)	5/10	0.23
	V35 (cc)	0.0 (0.0–0.0)	0.0 (0.0–0.2)	0.0 (0.0–0.2)	3/10	0.25
	V20 (cc)	4.2 (0.0–13.1)	5.6 (0.0–22.4)	1.4 (-2.4–9.3)	6/10	0.56
Duodenum	D0.3cc (Gy)	29.4 (16.6–35.5)	29.5 (13.5–36.7)	0.1 (-4.4–3.4)	2/10	0.38
	D3.0cc (Gy)	26.3 (14.0–34.4)	26.2 (11.5–34.2)	-0.1 (-3.5–4.2)	1/10	0.32
	V35 (cc)	0.1 (0.0–0.5)	0.2 (0.0–0.8)	0.2 (0.0–0.6)	7/10	**0.02***
	V20 (cc)	17.6 (0.0–64.1)	14.0 (0.0–41.4)	-3.6 (-22.7–6.0)	5/10	0.16
GTV	100% Cov. Dose (Gy)	31.1 (24.5–40.5)	29.5 (19.4–39.9)	-1.5 (-7.5–1.5)	3/12	0.27
	Mean dose (Gy)	36.0 (30.8–41.1)	36.0 (29.3–42.0)	0.0 (-2.9–1.7)	3/12	0.63

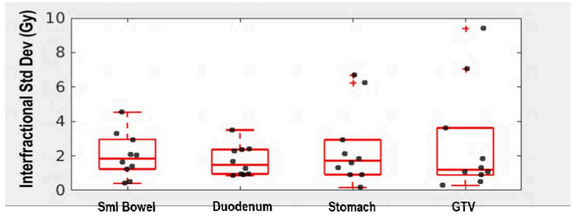

Fig. 2: Boxplots of interfractional variations in OAR D0.3cc and GTV 100% coverage dose. The standard deviation of each metric was calculated for each patient's planned vs. delivered OAR D0.3cc and 100% GTV coverage dose, across all 5 fractional CT-on-rails daily images. Large variance in D0.3cc is observed for all 3 OARs. Additionally, several patients had noticeable reductions in GTV dose coverage, according to delivered dose. Note that doses were calculated with the full prescription on each fractional CT.

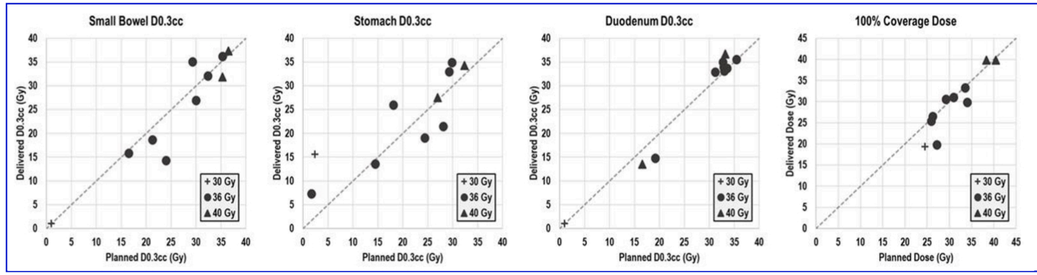

Fig. 3: Plots of planned vs. delivered OAR D0.3cc and 100% GTV coverage dose. Large variances in D0.3cc are observed for all 3 OARs. Additionally, several patients had noticeable reductions in GTV dose coverage, according to delivered dose.

CONCLUSIONS

Considerable differences were found between planned and delivered doses to the most radiosensitive GI OARs (stomach, duodenum, small bowel). In addition, some patients had larger reductions in GTV coverage.

Delivered and planned doses can vary greatly for pancreas SBRT. Therefore, the use of planned dose for daily image guidance may not be dosimetrically robust for pancreas SBRT treatments.

More robust methods, including daily online adaptation, could potentially be employed to account for anatomical variations of GI anatomy and optimize SBRT treatments

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