QUANTIFICATION OF INTERFRACTIONAL MOTION OF ORGANS AT RISK IN LIVER STEREOTACTIC BODY RADIATION THERAPY

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PURPOSE

To approximate and evaluate the effect of interfractional gastrointestinal motion of organs at risk (OARs), for cases of liver stereotactic body radiation therapy (SBRT), on dose to OARs using multiple CT scans.

INTRODUCTION

Previous studies have addressed the respiratory effects on motion of patients receiving SBRT to liver targets (1-2). This study seeks to quantify the additional impact of interfractional motion caused by gastrointestinal processes. Liver SBRT planning is done on static CT scan image data, but gastrointestinal processes can cause relevant deformation of gastrointestinal organs over the course of treatment (3-4). Considering multiple days of CT scans can give the planner insight into the variation in expected organ location and daily dose distributions.

Fiducials are placed near the target in the liver and used for localization for liver SBRT cases at Massachusetts General Hospital. The planning process begins with a two-day radiation mapping session yielding two days of CT scans. The *Day 1 scan* is an average intensity scan created from a 4D CT scan taken on the first day of mapping. The *Day 2 scan* is an average intensity scan created from a 4D CT scan taken after giving the patient 450 mL of neutral contrast on the second day of mapping, and is currently used for target contour definition and planning. Because specific dietary instructions are not given for cases of liver SBRT, the variation in organ filling between the two scans can be used to represent the interfractional variation in filling and deformation.

Relevant Constraint Metrics

Tissue	Constraint
Cord + .5 cm	22 Gy maximum
Bowel + .5 cm	**V5 cc < 30 Gy**
Stomach + .5 cm	**V5 cc < 30 Gy**
Duodenum + .5 cm	**30 Gy maximum**
Kidneys	$\frac{2}{3}V_{total}$ < 15 Gy, V90 = 7 Gy
Heart	20 Gy
Chest Wall	40 Gy
Maximum dose	110-120% within the target

Organ at risk constraints used for this project were defined by RTOG-1112 and MGH standards. The gastrointestinal organs considered in this study were the large and small bowel, the stomach, and the duodenum.

The current planning risk volume (PRV) expansion model used during planning to account for setup uncertainties and internal organ motion is based on target setup uncertainty defined by a minimum of .3 cm by RTOG-1112 (5). For these cases, PRVs were created during planning using **.5 cm isotropic expansions** of OARs. The PRV for an organ contour within a scan indicates the **expected range of motion** over the course of treatment.

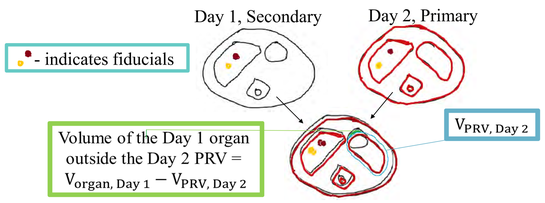
Within the treatment process, the Day 2 scan is considered the *primary scan* because it is used for planning. The Day 1 scan is considered the *secondary scan* because it is not used for planning. PRVs are created using the primary scan only.

METHODS

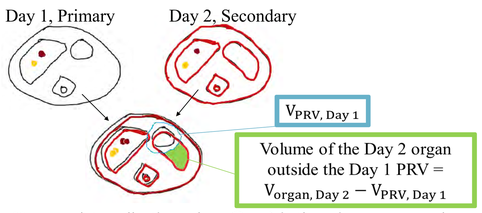
The population studied was 7 patients who had been treated with Liver SBRT at MGH and had two days of CTs available without coversheet immobilization devices. Day 1 and Day 2 scans were contoured to determine locations of the stomach, duodenum, small bowel, and hepatic flexure of the large bowel within proximity to the target. The scans were fused via nondeformable image registration according to the fiducials.

For this project, when the Day 1 scan was considered the primary scan, the Day 2 scan was considered the secondary scan, and when the Day 2 scan was considered the primary, the Day 1 scan was considered the secondary. $V_{outside}$, defined by the difference in expected organ volume and location (defined by the .5 cm isotropic PRV) from the actual organ volume and location (defined by the secondary scan), was collected for the case of Day 1 = primary and Day 2 = primary.

$V_{outside}$ Data Collection Using Image Registration



$V_{outside}$ data collection where Day 2 is the primary scan and Day 1 is the secondary scan.



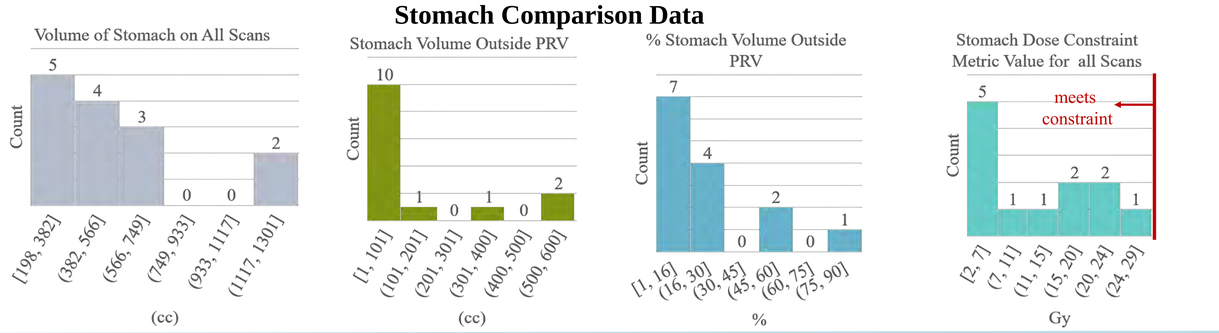
$V_{outside}$ data collection where Day 1 is the primary scan and Day 2 is the secondary scan.

The dose distribution of the treatment plan created using the Day 2 scan was transferred via nondeformable image registration to the Day 1 scan and the values of relevant constraint metrics were compared to approximate a treated dose distribution. Change in dose to each organ was represented as a ratio of Day 1 scan metric value for a relevant constraint to Day 2 scan metric value for the same constraint ($D_{\text{organ metric, Day 1}} : D_{\text{organ metric, Day 2}}$).

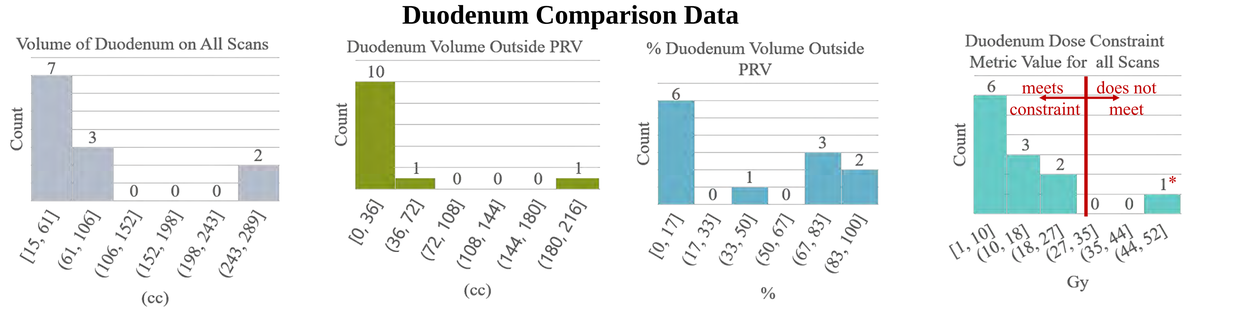
With 7 sets of scans, organ location information was available for 14 different expected vs. actual stomach and small bowel volume pairs. Organ location information was available for 12 different expected vs. actual duodenum and large bowel volume pairs, due to patient anatomy.

RESULTS

Stomach Comparison Data

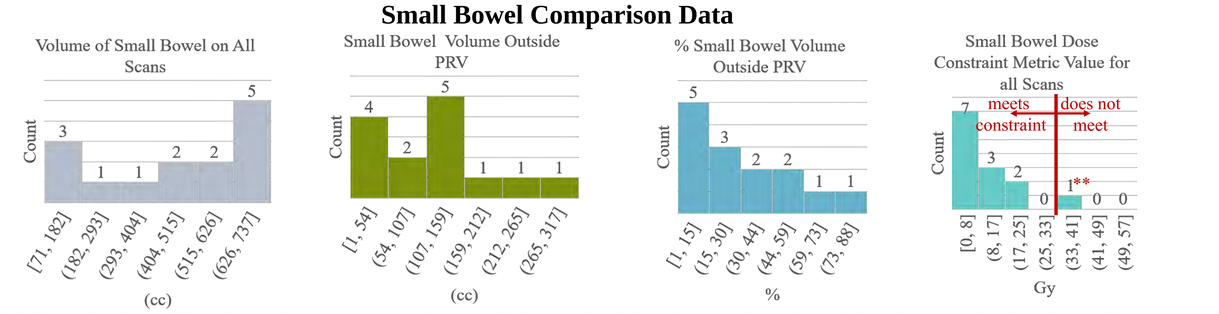


Duodenum Comparison Data



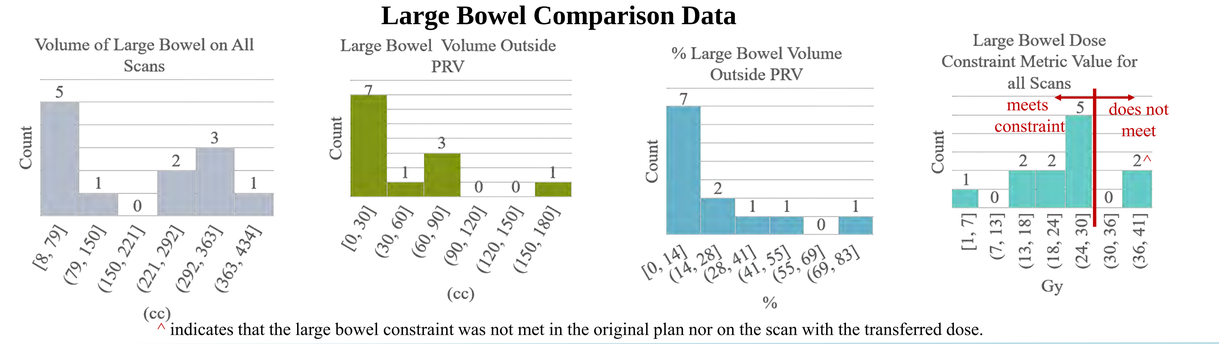
* indicates that the duodenum constraint was not met on the scan with the transferred dose (the approximated second day of treatment for that volume pair).

Small Bowel Comparison Data



** indicates that the small bowel constraint was not met on the scan with the transferred dose (the approximated second day of treatment for that volume pair).

Large Bowel Comparison Data



^ indicates that the large bowel constraint was not met in the original plan nor on the scan with the transferred dose.

Summary of Comparison Data

OAR	Average $V_{outside\ PRV}$ (cc)	Average % ($V_{outside\ PRV}/V_{organ}$)	Average Ratio of Doses ($D_{organ\ metric,\ Day\ 1} : D_{organ\ metric,\ Day\ 2}$)
Stomach	158.64	27.31	0.89
Hepatic Flexure	43.83	31.89	0.78
Small Bowel	111.20	32.73	**1.11**
Duodenum	13.46	42.84	**2.30**

CONCLUSION

For the stomach and hepatic flexure, the secondary constraint value was 11% and 22% less than the primary constraint value. In contrast, for the small bowel and duodenum, the secondary constraint value was 11% and 130% greater than the primary constraint value. For the duodenum and small bowel, an isotropic .5 cm PRV may not be an adequate planning tool, but for the large bowel and stomach, the plans created with .5 cm PRVs that met constraints were adequate to meet constraints on a representation of another day of treatment. Future research could be done to determine an optimal PRV or to determine another planning tool to compensate for digestive motion.

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