A Practical Method to Automatically Delineate Gas Regions for MR-Guided Online Adaptive Radiotherapy of Abdominal Tumors

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Ergun E Ahunbay and X Allen Li
Medical College of Wisconsin, Milwaukee WI

MEDICAL COLLEGE OF WISCONSIN
RADIATION ONCOLOGY

INTRODUCTION

Auto-delineating gas regions on daily MRI for MR-guided online adaptive radiotherapy (MRgOART) of abdomen is challenging since the gas regions occur randomly and their MR intensities can be similar to other tissue types. A novel method is presented to auto-delineate gas regions on MRI considering uncertainty of deformable image registration (DIR).

METHOD

Previously we reported a method to generate synthetic CT , by transferring the electron density information from a reference CT image by deformable image registration (DIR) [1]. This method works well for the patient voxels in general, however cannot accurately generate the abdominal air/gas volumes, since those volumes happen randomly, and may not be present in the reference image. The gas regions are hard to determine on MR images automatically, because although air is very low signal intensity, several other tissue/bone/artery regions would also result in low signal intensity, therefore thresholding should be regionally confined to where gas is expected, e.g. the organs of the GI track, stomach, bowels, colon, rectum, and duodenum. Thapa et al reported an automated method [2] to delineate those regions, by applying threshold to a "bowel region" (combination of GI organs) that is transferred from a reference image by DIR. However the DIR inaccuracies are large, especially around GI structures, therefore increase the chance of misidentification in the transfer of the bowel region. The method proposed by Thapa et al expands the transferred bowel region by a uniform 1cm margin to be able to capture any gas regions that may be missed due to DIR inaccuracies.

The proposed method here also utilizes the transfer of contours from a reference image set via DIR, however instead of uniform expansion, the deformed bowel region is expanded only in the regions with high DIR inaccuracy. The regions of high DIR inaccuracies are identified by a G-metric, which is which is $\frac{|I_R - I_{Def}|}{\nabla I_R}$, where I_R is the reference image, I_{Def} is the deformed daily (which should be the same as the reference if DIR is perfect), and ∇I_R is the image gradient on reference image. By analyzing deformed contours and testing with synthetic deformation fields, G was found to be a better predictor of DIR errors than other metrics (e.g. absolute difference or Jacobian determinant).

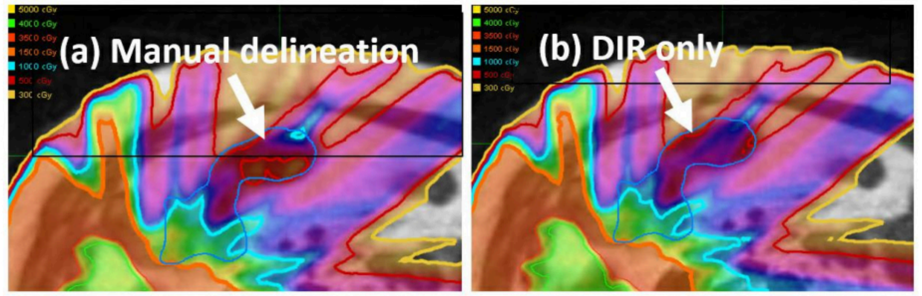
The high inaccuracy DIR region is defined as the region with G>85th percentile over all bowel, which is empirically determined. After applying thresholding on the EBR, only the air pockets that overlap by >50% with the initial DBR are selected as true gas region. The threshold value for the final step is dependent on the MR sequence, and should be determined earlier on. The online component of the process is completely automatic, and takes as long as the run of DIR, approximately less than 1 minute. The method is tested on 8 cases with 5 different MR sequences, with both T1 and T2 contrast, and 4D sorted (midposition and motion averaged) as well as triggered 2D and 3D variants on a 1.5T MR-Linac. The comparisons were made with the ground truth (a manually delineated bowel region and the same threshold value as used for the proposed method) as well as using only DIR with uniform expansions of 0, 0.5, 1 and 2cm on deformed bowel region.

RESULTS

As can be seen in Table 1 below, the proposed method increases the DC to > 95.5% for all cases tested. The use of DIR only is sufficient for several days, but did not perform well for some (DC 75.6%). In figure 1, one such case is shown where the deformation did not capture a large portion of the air, while the high G region correctly identified that region. The dose differences between manual and uniform expansion was ~40% off, while almost identical for the one generated by the proposed method (Figure 2a,b,c).

An MRL plan dose was calculated using both the manual and auto-delineated gas region density of 0.01g/cc and found identical in DVH (Figure 3).

The proposed method is fully automated and executed within 1 minute.



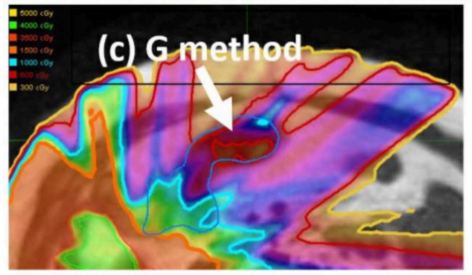


Figure 2: Dose differences at the air pocket region. The air pocket is identified correctly by the proposed G-method (c), and the dose is similar to the one with the manual delineation. The air pocket here was missed by the method of only applying DIR, and the dose is quite different (b)

	Dice Agreement of air volume with manual contours							
Case#:	1	2	3	4	5	6	7	8
DIR	84.4%	95.3%	95.5%	**75.6%**	96.9%	98.8%	94.2%	**78.6%**
DIR+0.5	92.0%	94.1%	95.3%	82.9%	96.2%	99.4%	97.3%	90.4%
DIR+1cm	84.7%	82.6%	94.5%	91.2%	94.9%	98.5%	96.7%	87.7%
DIR+2cm	62.3%	58.4%	83.4%	94.1%	85.3%	96.9%	95.0%	59.9%
G-method	**95.5%**	**98.3%**	**95.5%**	**99.8%**	**96.9%**	**98.8%**	**97.2%**	**95.7%**

Table 1: The DICE similarity coefficient (Intersection/Union) between the auto-generated vs. manual air regions by different methods. The DIR only method performs satisfactory for most days (DICE>95%) but for can go below 80% for certain days. Expanding the volume generated by DIR improves the DICE value or most days, but there is no single expansion value that would always result >90%. The proposed G-method achieved >95% for all days.

Figure 1. The demonstration of how the region identified by G map (magenta) correctly identifies a large air region, missed by DIR transfer.

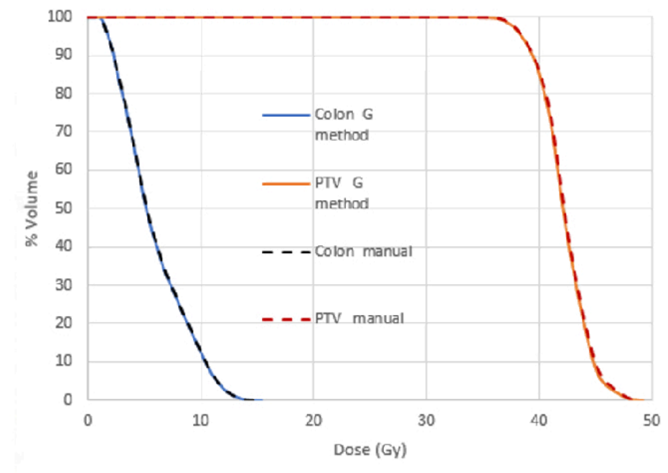


Figure 3: The DVH of the target and the colon, where the gas pocket resides for the proposed G method and the manual contouring of the air region. The DVHs are indistinguishable.

REFERENCES

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CONCLUSIONS

The proposed method can quickly and automatically delineate gas/air regions on daily MRI for MRgOART of abdominal tumors.

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CONTACT INFORMATION

eahunbay@mcw.edu