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Comparison of Radiomic Feature Variability between Different MR Pulse Sequences in Brain Metastases

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INTRODUCTION

Radiomic features have been used in many predictive models to assist clinical decisions. However, radiomic feature reproducibility is affected by numerous factors.[1] Previous studies have investigated the impact of contouring[2] and various data preprocessing steps.[3] We consider this study to be innovative because it addresses a key aspect of reproducibility in MRI radiomics studies: the sensitivity of features to the input imaging data parameters. No previous studies have compared variability of radiomics features derived from different common MR pulse sequences. This information contributes to the design of high-quality, reproducible radiomics studies.

AIM

The purpose of this work is to quantitatively compare the stability of radiomic features extracted from 2-D and 3-D MR images of brain metastases to inform data acquisition for reliable and reproducible radiomics studies.

METHOD

Under IRB approval, a retrospective cohort of 29 patients with brain metastases who had contrast-enhanced T1-weighted MR images acquired using 2-D spin echo (SE) and 3-D spoiled gradient echo (SPGR) sequences within one exam included in this analysis. Tumor volumes were contoured using semi-automated methods by experienced physicians. 2-D radiomic features (0.4297×0.4297 ×5-mm spatial normalization (SN) , 64-bin intensity discretization (ID)) and 3-D radiomic features (3×3×3 -mm SN, 64-bin ID) were extracted using PyRadiomics. Coefficient of variation (CV) was computed for all 2-D and 3-D features extracted from both the 2-D SE and 3-D SPGR MR images. Though not representative of MRI, CV was computed for features from synthetic white noise images with resolution matching patient images as proof of concept.

RESULTS

Of the 100 2-D and 3-D radiomic features selected a priori, using a robustness threshold of CV<10%, 11 were robust for both 2-D and 3-D image sets; 4 were robust only for 2-D image sets and 2 were robust for only 3-D image sets (Table 1). The variability of these features was quite similar whether derived from 2-D spin echo images or 3-D spoiled gradient echo images. All features that met the robustness threshold in at least one image set had CV < 13% for the other. Generally, however, both 2-D and 3-D features were less variable when derived from 2-D spin echo images (Figures 1a and 1b). The CV was smaller for 79% of 2-D features (median CV difference 4.86%) and 72% of 3-D features (median CV difference 4.40%) when derived from 2-D SE image sets vs. 3-D SPGR.

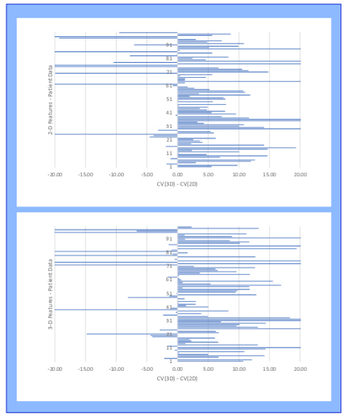

Figure 1. Difference in coefficient of variation between features derived from spoiled 3-D gradient echo and 2-D spin echo images for a) 2-D features from patient images and b) 3-D features from patient images. Positive values indicate less variability in features from 2-D spin echo images.

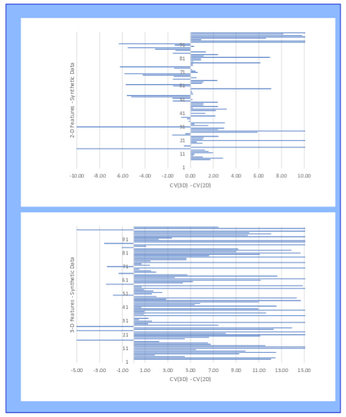

Figure 2. Difference in coefficient of variation between features derived from a) 2-D features from synthetic white noise images and b) 3-D features from synthetic white noise images. Positive values indicate less variability in features from 2-D spin echo images.

Similar results were obtained by repeating the same procedure on synthetically generated white noise images with identical resolutions to the patient images (Figures 2a and 2b). 72% of 2-D features and 89% of 3-D features were less variable when derived from synthetic 2-D images. The median CV difference between 3-D and 2-D synthetic image sets was 0.34% and 6.57% for 2-D and 3-D features, respectively. These results suggest that radiomic features derived either from 2-D spin echo images or images with comparable spatial resolution are less variable.

2-D Feature (Class)	2-D CV (%)	3-D CV (%)	3-D Feature (Class)	2-D CV (%)	3-D CV (%)
Entropy (First Order)	7.58	9.78	Median (First Order)	12.55	9.66
Root Mean Squared (First Order)	12.72	9.56	Difference Variance (GLCM)	1.67	3.02
Correlation (GLCM)	2.67	2.37	Joint Entropy (GLCM)	1.63	1.79
Joint Entropy (GLCM)	8.22	11.85	Informational Meas. of Corr. 2 (GLCM)	2.91	2.85
Informational Meas. of Corr. 2 (GLCM)	0.74	0.88	Gray Level Non Uniformity (GLRLM)	3.76	4.57
Inverse Difference Moment Norm. (GLCM)	0.17	0.18	Long Run Emphasis (GLRLM)	8.32	9.13
Inverse Difference Normalized (GLCM)	0.95	1.07	Long Run Low Gray Level Emphasis (GLRLM)	2.17	2.74
Sum Entropy (GLCM)	6.49	8.45	Low Gray Level Run Emphasis (GLRLM)	1.17	1.46
Run Entropy (GLRLM)	4.86	6.07	Run Length Non Uniformity (GLRLM)	0.86	1.09
Run Length Non Uniformity Norm. (GLRLM)	9.00	10.17	Large Area Low Gray Level Emph. (GLSZM)	6.88	6.82
Run Percentage (GLRLM)	6.46	7.70	Size Zone Non Uniformity Norm. (GLSZM)	9.21	8.38
Short Run Emphasis (GLRLM)	4.33	4.72	Small Area Low Gray Level Emph. (GLSZM)	9.84	8.88
Small Area Emphasis (GLSZM)	8.32	10.73	Small Dep. Low Gray Level Emph.(GLDM)	9.74	12.02
Zone Entropy (GLSZM)	4.05	3.93			
Dependence Entropy (GLDM)	3.84	4.18			

Table 1. Robust 2-D (left) and 3-D (right) radiomics features derived from 29 MR images of brain metastases. 2-D CV indicates coefficient of variation of feature values from 2-D spin echo MR images, and 3-D CV indicates the same from 3-D spoiled gradient echo MR images.

CONCLUSIONS

This work indicates that similar radiomic features of brain metastases are robust when derived from either 2-D spin echo or 3-D gradient echo MR images. Features with the smallest coefficients of variation are consistent between image sets. However, features derived from 2-D spin echo images are generally less variable. This may result from generally higher SNR in 2-D spin echo images with comparable acquisition times. Additionally, higher in-plane resolution in the 2-D image set may be significant for radiomic feature reproducibility. Future work will investigate the impact of specific acquisition parameters on radiomic feature reproducibility and compare predictive performance between these data sets.

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