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Stability and Reproducibility Studies of Radiomics Features of CT Using a Bio-phantom

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4]
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INTRODUCTION

Current oncology practices involve extensive use of image techniques. This promotes the use of quantitative image, as minable data, termed radiomics, for both diagnosis and prognosis purpose. Radiomics is an active and blooming field, showing promise of revolutionizing the current standard care of cancer, however, challenges remain to apply it broadly due to the radiomics features being vulnerable to variations such as protocol, machine, imaging processing and analyzing.

INNOVATION

A phantom with known composition and geometry will serve as a good platform to benchmark all these dependencies. Previously, several phantoms have been developed to test stability of CT radiomics phantom but none of them contains any biological or tissue-like materials. In this study we developed a novel 3D-printed biological phantom, performed test-retest scans and scans with various CT acquisition parameters, and examined the variation of the radiomics feature with the protocol and time. With the fixed geometry and a similar composition and texture to a patient, our phantom provides a valuable test platform to benchmark the features stability and reproducibility.

RESULTS

Non reproducible or stable RF features based on CV	Scanner	Tube Voltage		Tube Current		Pitch		Slice Thickness		Acquisition mode	FOV		Reconstruction Kernel		Orientation		Test - retest
Average number	182/709	135	106	202	25	160	2	148	173	78	295	199	57	327	457	119	16
Maximum number	379	343	352	377	177	392	4	397	315	227	452	346	269	450	537	513	89
Worst materials	Plaster, Solid water, Wood	Polystyrene, Liver, Solid water	Liver, Solid water, Brain	Polystyrene, Liver, Rough Grids	Solid water, Liver, Heart	Polystyrene, Liver, Wood	Brain, Polystyrene, Spinal cord	Polystyrene, Wood, Chia seeds	Liver, Wood, Fine Gyroid	Fine Gyroid, Rough Gyroid, Wood	Rough Gyroid, Fine Grids, Liver	Body, Fine Grids, Fine Gyroid	Polystyrene, Liver, Solid water	Solid water, Chia seeds, Liver	Wood, Polystyrene, Fine Gyroid	Spinal cord, Fine Grids, Fine Gyroid	Polystyrene, Spinal Cord, Chia seeds

Table 2: Based on the CV values, the average and maximum number of non-reproducible or nonstable radiomics features due to different variations of the scan. Average is taken with respect to the different materials. The first three materials with the most non-reproducible or nonstable features are listed. Two columns under the same variation are data from two different scanners. Axial acquisition mode is not available on the Siemens scanner. All scans with variations are compared to the scan using the standard protocol.

Non reproducible or stable materials based on CCC or ICC values	Scanner	Tube Voltage		Tube Current		Pitch		Slice Thickness		Acquisition mode	FOV		Reconstruction Kernel		Orientation		Test - retest
Gradient Orient Histogram (GOH)	0/18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gray Level Coocurrence Matrix25 (GLCM25)	6	1	0	1	0	1	0	1	1	0	3	1	0	5	0	3	6
Gray Level Cooccurence Matrix3 (GLCM3)	6	1	0	0	0	1	0	1	1	1	3	1	0	5	0	3	6
Gray Level Run Length Matrix25 (GLRLM25)	3	6	6	1	2	3	0	2	4	1	4	9	5	12	1	1	3
Intensity Direct (ID)	0	0	0	18	0	0	0	1	18	1	17	18	0	0	0	3	0
Intensity Histogram (IH)	3	1	0	1	0	1	0	1	0	0	0	1	0	4	1	4	3
Neighbor Intensity Difference3 (NID3)	0	5	6	6	0	8	0	8	13	0	13	3	3	17	1	2	0
Shape	0	0	0	18	0	0	0	0	18	0	17	17	0	0	0	1	0

Table 3: Base on the ICC or CCC values, number of materials with non-reproducible or nonstable radiomics features for each category due to different variations of the scan. Total number of materials in the phantom is 18. ICC is used for comparison of two sets of data while CCC is used when the datasets to be compared is more than two.

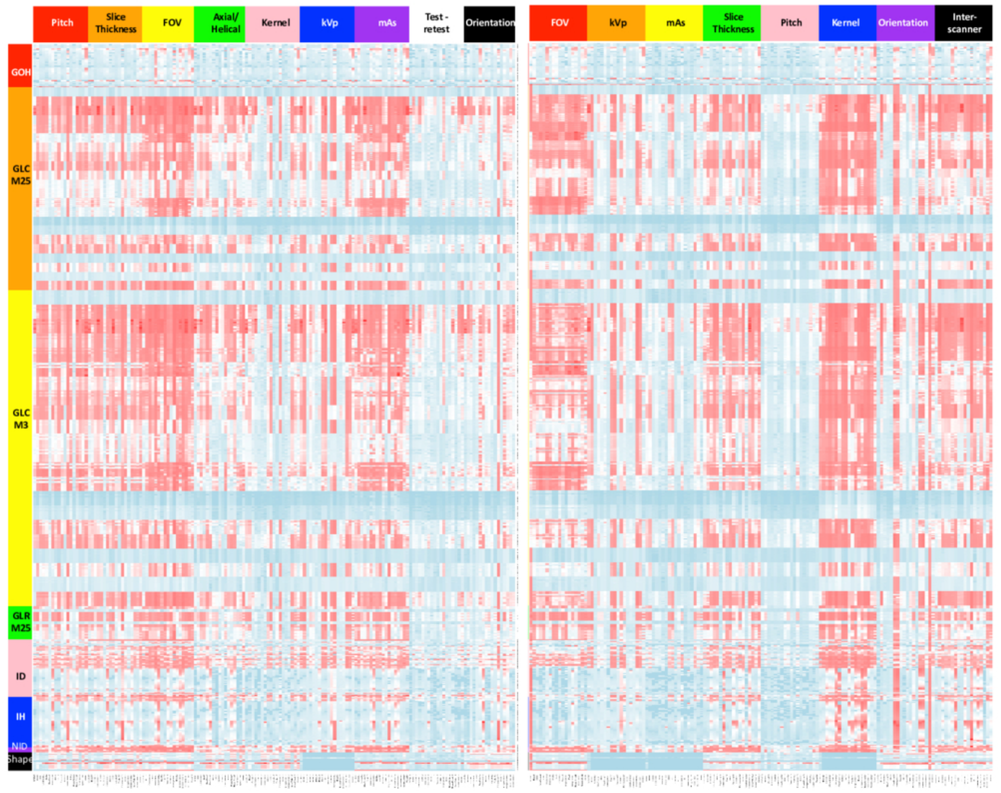

Fig 3: Heat map of the CV as a function of different radiomics features and different parts of the phantom on scans taken on the GE scanner (left) and the Siemens scanner (right). Light blue is for zero variation, red denotes features with CV >20%.

METHOD

A radiomics phantom consisting of different materials (plaster bricks, cork, wood, polystyrene, solid water, rice, cereal, chia seeds and peanuts) and 3D-printed texture patterns, as well as a mini pig, was constructed. The phantom was scanned using various combinations of kVp, mAs, orientation, slice thickness, pitch, and acquisition modes on two different CT scanners. Test-retest scan is performed on one of scanners as well. We then use Eclipse to draw contours on different parts of the phantom, including organs in the mini-pig such as spinal cord, liver, heart and brain. Images with different orientations were fused via rigid registration. A total of 709 radiomics features, including 60 shape-based, 105 histogram-based and 546 texture-based, were extracted using IBEX. The reproducibility and stability for all the features were evaluated based on the coefficient of variation (CV), the concordance correlation coefficient (CCC) and intra-class correlation coefficient (ICC). We choose 20% as the lower bound of stability and reproducibility for CV and 0.9 for the CCC and the ICC.

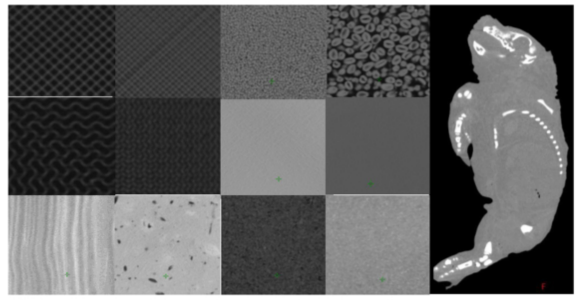

Fig 1: CT image of cross section of the different parts of the phantom: 3D pattern (rough grids, fine grids, rough gyroid, fine gyroid), rice, peanuts, chia seeds, polystyrene, wood, plaster, cereal, cork and mini pig.

Fig 2: A physical picture of phantom. Peanuts, chia seeds, cereal and rice were fixed inside acrylic boxes, which were stacked and glued together. Different materials are glued to a piece of cork underneath as a platform. When scanned in CT, the mini pig was immobilized using Vaclock bag.

	Scanner	Tube Voltage	Tube Current	Pitch	Slice Thickness	Acquisition mode	FOV	Reconstruction Kernel	Orientation	Test - retest
Varied Values	GE	120kVp	110mA	1.375	1.25mm	Helical	25cm	Standard	Straight	Two days apart
	Siemens	80kVp	70mA	1.75	2.5mm	Axial	50cm	Soft	Clockwise Rotation	
		140kVp	200mA	0.562	0.625mm		65cm	Bone	Counter Clockwise rotation	

Table 1: Variations of the CT scans. The first line of parameters are used as the standard protocol. All the parameters listed here are for the scans performed on the GE scanner. The protocols used on the Siemens scanner are close to these but not exactly the same. Test-retest is only performed on the GE scanner.

CONCLUSIONS

Features from test-retest scans are highly reproducible.

Inter-scanner variation are high for most materials in the phantom but not as high for liver, heart and body of the mini pig.

For intra-scanner protocol variation, feature categories of lower order, such as shape, gradient orient histogram (GOH) and intensity-based features are more stable than those of higher order in general. Low-order features are more sensitive to those variations affecting the resolution, such as FOV.

Reconstruction kernels that influence the SNR have a greater impact on the stability of higher order features.

CONTACT INFORMATION

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