Effect of pre-processing on radiomics features estimation from computed tomography imaging in patients with rectal cancer.

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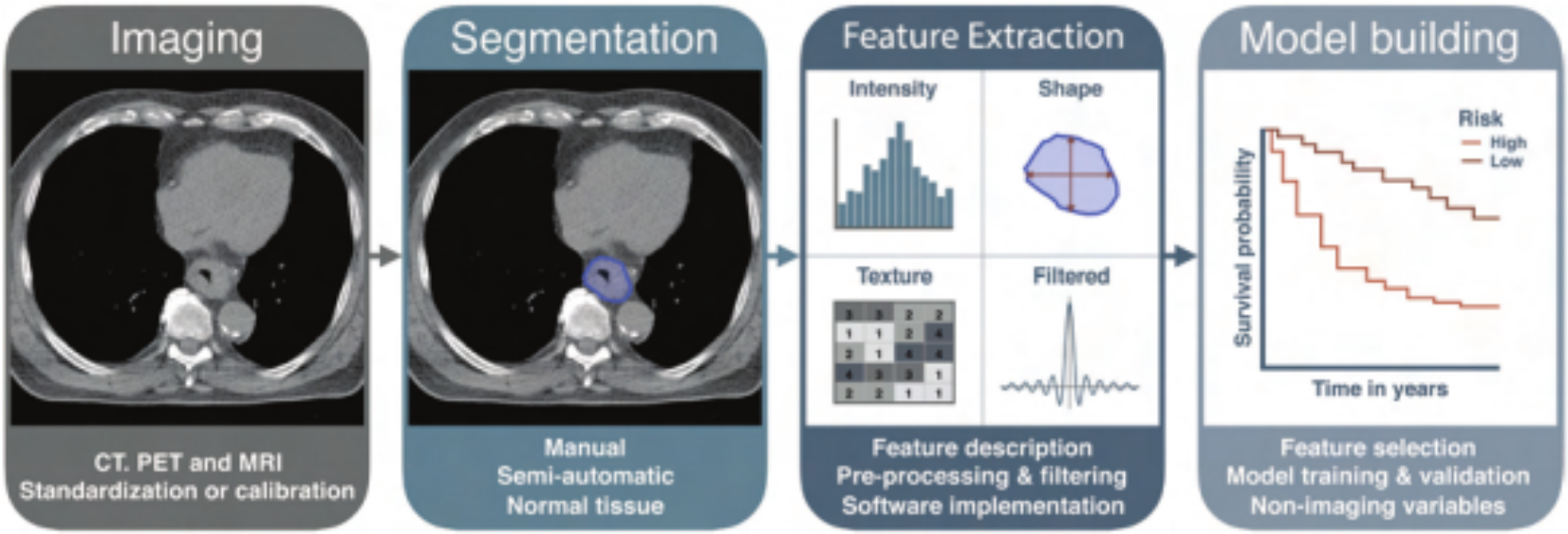
Radiomics: Images Are More than Pictures, They Are Data

"high-throughput extraction of **quantitative features** that result in the conversion of images into *mineable data* and the subsequent analysis of these data for decision support." [a]

[a] Gillies RJ et al. Radiomics: Images Are More than Pictures, They Are Data. doi:10.1148/radiol.2015151169

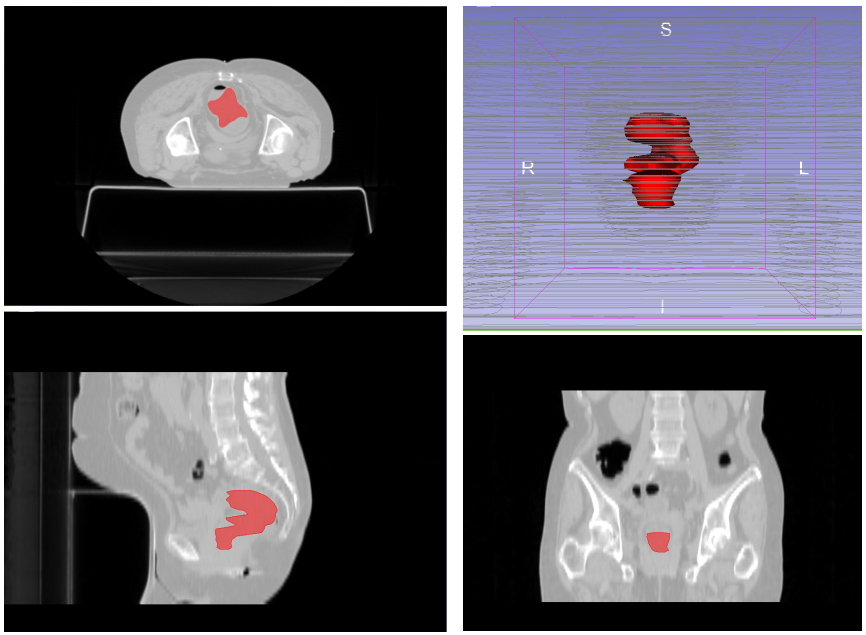


Deng, J. (Ed.), Xing, L. Big Data in Radiation Oncology. doi:10.1201/9781315207582

Images:

Computed tomography images of 20 representative patients with **rectal cancer**, undergoing preoperative radiotherapy.

- Gross tumor volume manually **segmented** by a radiation oncologist



- CT acquisitions:

Scanner	GE LightSpeed RT16
Acquisition type	Helical
Tube voltage	120 kVp
Tube load	140-170 mAs
Slice thickness	5 mm
Pixel size	0.82-1.27 mm
Matrix	512×512

- 105 **features** divided into 7 classes:

1. 14 shape
2. 18 first-order
3. 22 Gray Level Co-occurrence Matrix (glcm)
4. 14 Gray Level Dependence Matrix (gldm)
5. 16 Gray Level Run Length Matrix (glrlm)
6. 16 Gray Level Size Zone Matrix (glszm)
7. 5 Neighbouring Gray Tone Difference Matrix (ngtdm)

Features estimation with varying image pre-processing:

- Resampling:
  - 6 isotropic **voxel sizes**: 1, 1.3, 1.6, 1.9, 2.2, 2.5 mm
  - 10 **interpolation algorithms**: BSpline (BS), BlackmanWindowedSinc (BL), CosineWindowedSinc (CWS), Gaussian (G), HammingWindowedSinc (HWS), LabelGaussian (LG), LanczosWindowedSinc (LWS), Linear (L), NearestNeighbor (NN), WelchWindowedSinc (WWS)
- Quantization of gray-levels:
  - 6 **binwidths**: 3, 4, 5, 6, 7, 8 HU

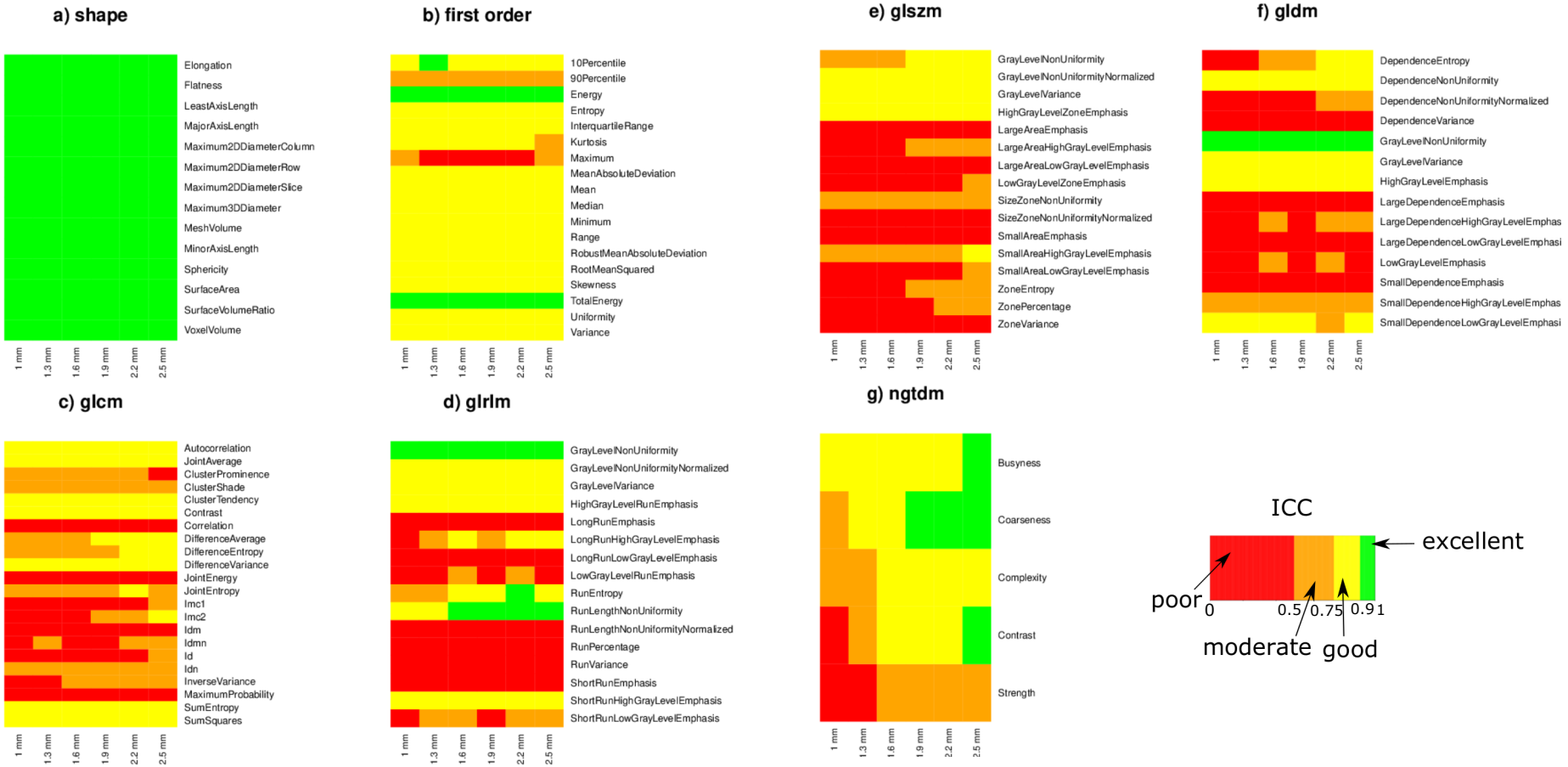
4 analyses:

1. Effect of interpolation algorithm for different voxel sizes
2. Effect of binwidth for different voxel sizes
3. Effect of voxel size for different binwidths
4. Effect of voxel size for different interpolation algorithms

Statistical analysis

- **Intraclass Correlation Coefficient (ICC):** two-way mixed effects model, single rater, absolute agreement
- **Coefficient of Variation** $COV = \frac{\sigma}{|\mu|}$

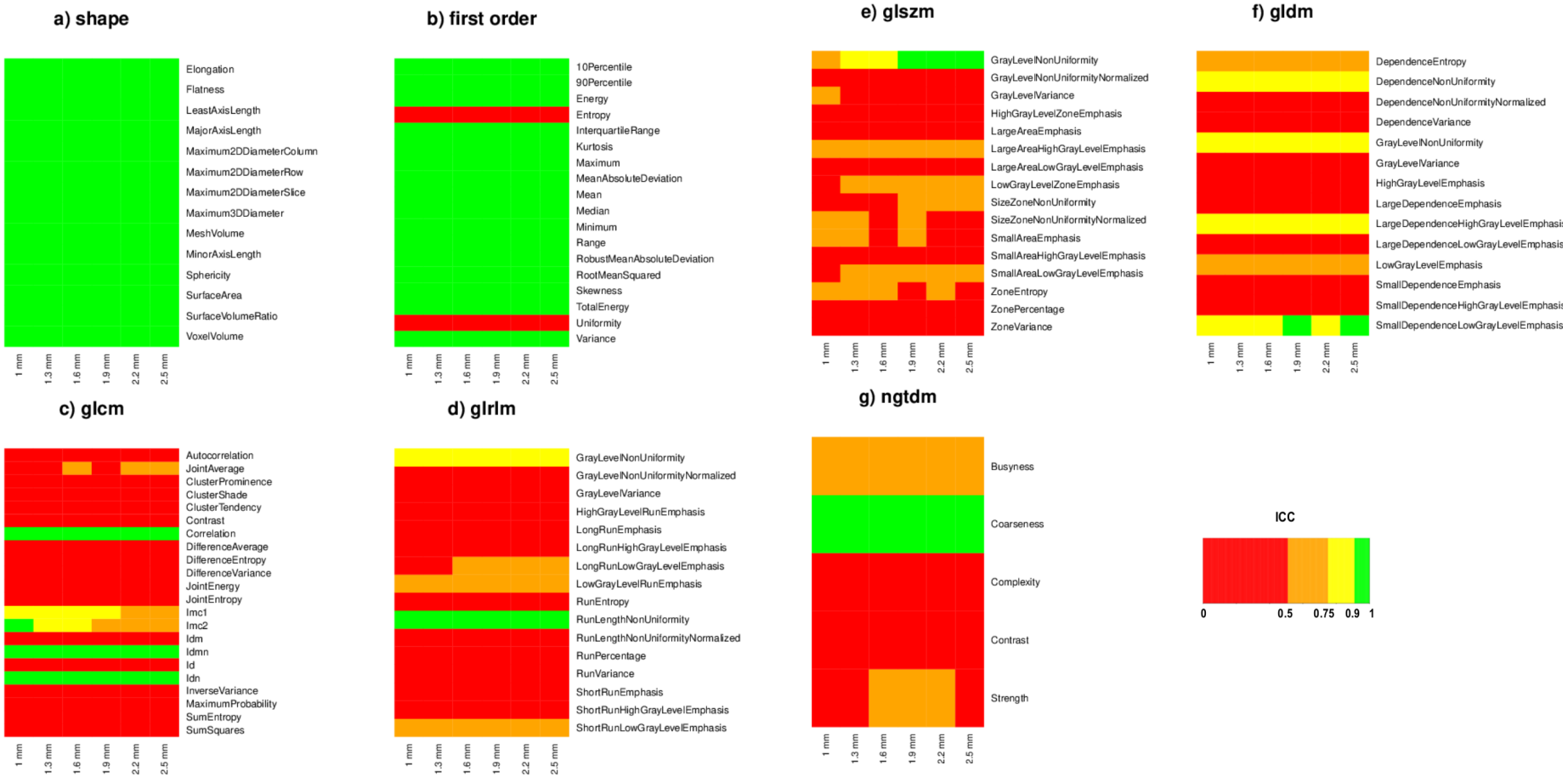
1) ICC values related to the effect of interpolation algorithm for different voxel sizes



Features are divided into **4 reliability classes** (poor, moderate, good, excellent) according to ICC values.

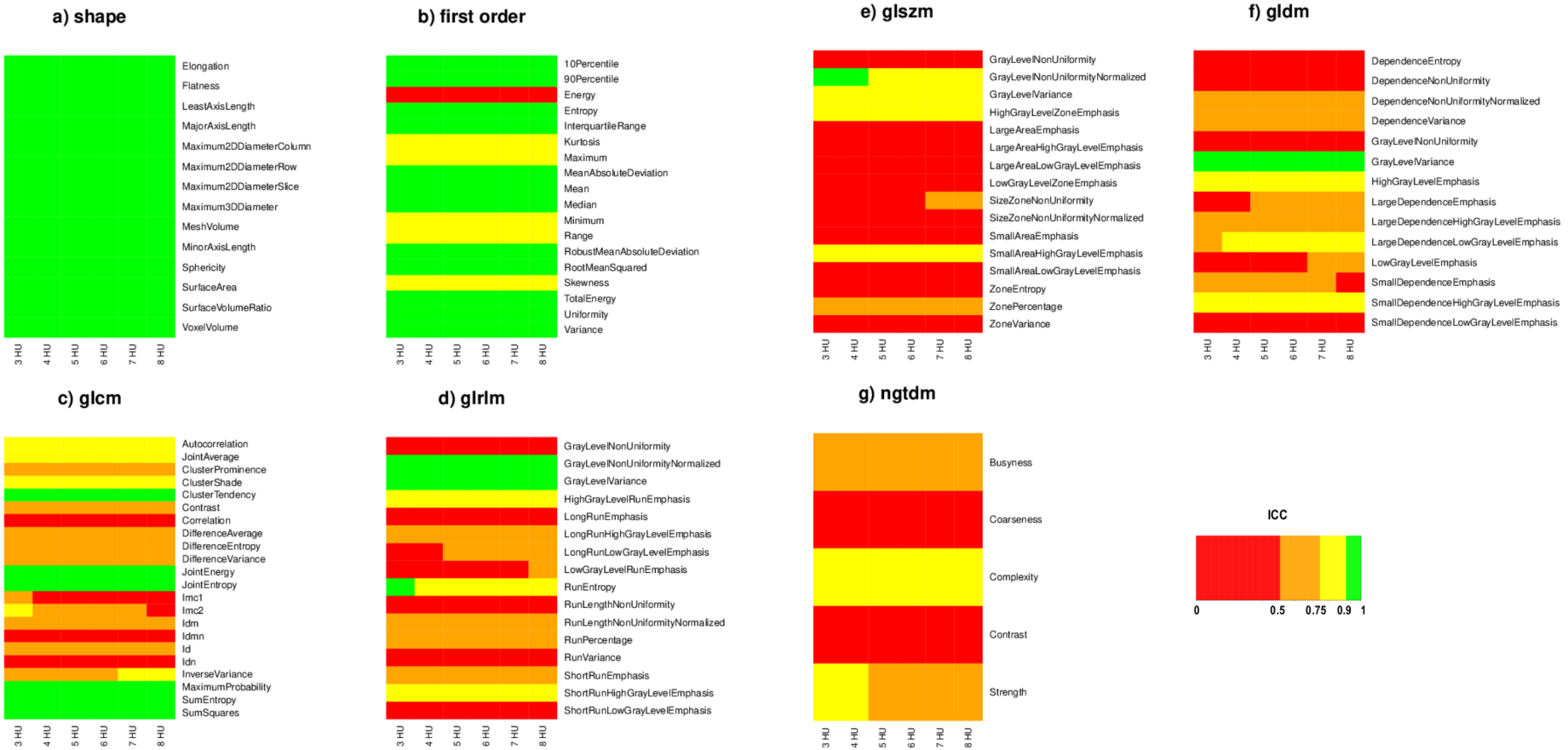
2) ICC values related to the effect of binwidth

for different voxel sizes



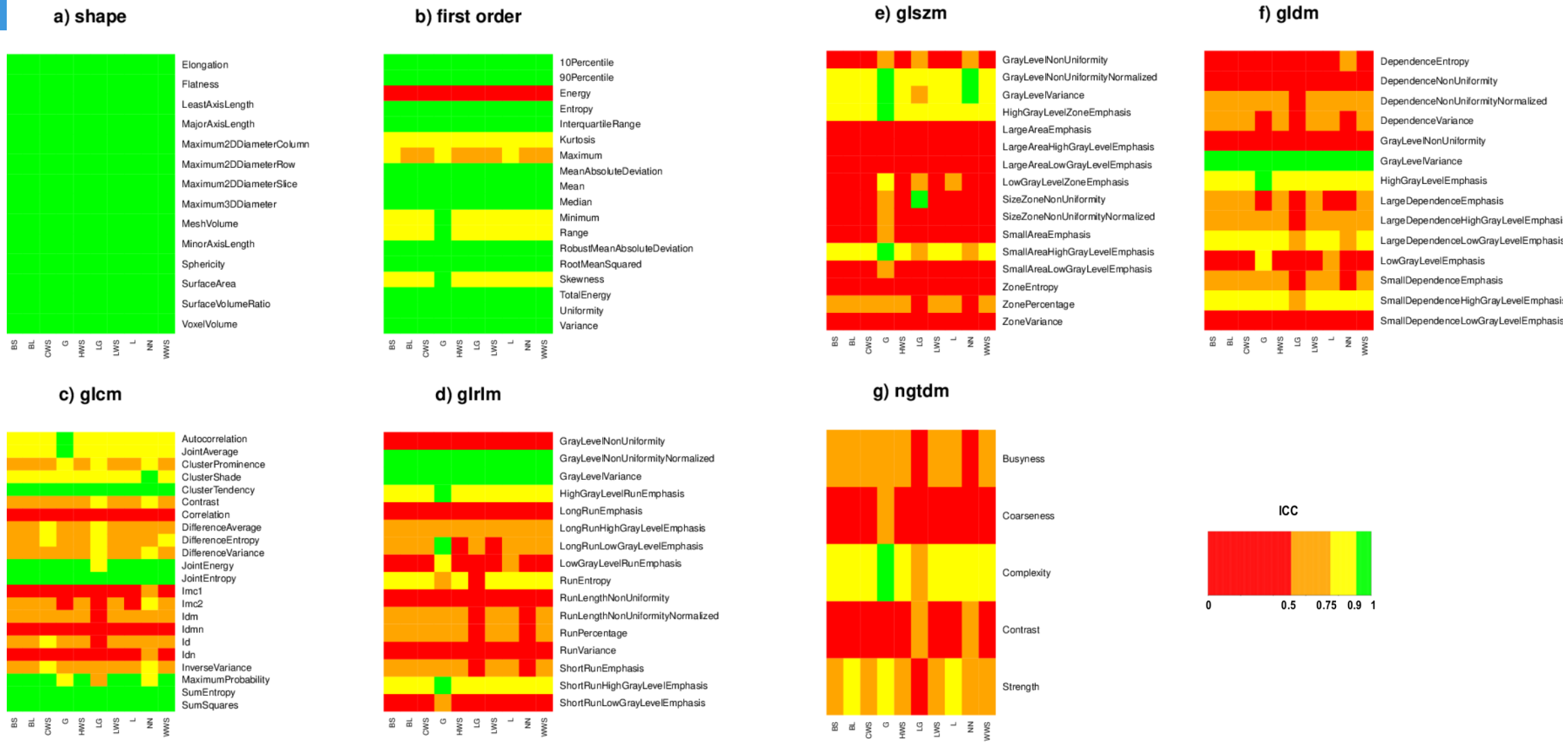
3) ICC values related to the effect of voxel size

for different binwidths



4) ICC values related to the effect of voxel size

for different interpolation algorithms



Radiomic features median COV

shape	1	2	3	4
Elongation	0,0	0,0	1,2	1,2
Flatness	0,0	0,0	1,3	1,3
LeastAxisLength	0,0	0,0	1,0	1,0
MajorAxisLength	0,0	0,0	0,6	0,6
Maximum2DDiameterColumn	0,0	0,0	1,1	1,1
Maximum2DDiameterRow	0,0	0,0	0,8	0,8
Maximum2DDiameterSlice	0,0	0,0	0,9	0,9
Maximum3DDiameter	0,0	0,0	0,8	0,8
MeshVolume	0,0	0,0	1,7	1,7
MinorAxisLength	0,0	0,0	0,6	0,6
Sphericity	0,0	0,0	2,8	2,8
SurfaceArea	0,0	0,0	3,1	3,1
SurfaceVolumeRatio	0,0	0,0	2,8	2,8
VoxelVolume	0,0	0,0	1,6	1,6

first order	1	2	3	4
10Percentile	50,5	0,0	9,6	9,8
90Percentile	6,5	0,0	0,9	0,8
Energy	0,6	0,0	97,1	97,1
Entropy	3,1	11,8	0,6	0,6
InterquartileRange	8,4	0,0	2,3	2,4
Kurtosis	23,2	0,0	21,8	18,8
Maximum	18,3	0,0	6,5	6,3
MeanAbsoluteDeviation	6,4	0,0	2,1	1,9
Mean	11,0	0,0	1,4	1,4
Median	6,8	0,0	1,0	1,2
Minimum	20,1	0,0	20,0	18,0
Range	16,3	0,0	14,8	14,3
RobustMeanAbsoluteDeviation	7,7	0,0	1,7	1,7
RootMeanSquared	0,3	0,0	0,0	0,0
Skewness	15,5	0,0	12,3	10,3
TotalEnergy	0,6	0,0	1,5	1,5
Uniformity	10,0	30,6	1,3	1,4
Variance	14,6	0,0	7,8	7,0

Note:
1) Effect of interpolation algorithm
2) Effect of binwidth
3) Effect of voxel size
4) Effect of voxel size

glcm	1	2	3	4
Autocorrelation	27,9	69,8	31,2	30,4
JointAverage	16,0	34,4	16,5	15,8
ClusterProminence	36,2	132,6	40,6	39,2
ClusterShade	26,6	104,4	30,4	27,2
ClusterTendency	12,6	70,8	13,2	11,9
Contrast	22,0	70,5	25,6	24,9
Correlation	20,7	0,4	29,8	28,1
DifferenceAverage	14,5	35,0	12,7	12,6
DifferenceEntropy	6,5	14,0	5,6	5,5
DifferenceVariance	22,1	70,1	27,1	26,1
JointEnergy	39,8	55,0	7,7	8,3
JointEntropy	4,8	12,3	1,3	1,2
Imc1	36,1	7,3	24,7	23,8
Imc2	8,3	6,0	7,4	7,0
Idm	17,7	23,0	9,3	9,9
Idmn	0,1	0,0	0,2	0,2
Id	12,2	16,2	6,4	6,8
Idn	0,6	0,0	1,0	1,0
InverseVariance	11,9	20,1	6,8	6,8
MaximumProbability	46,2	52,2	7,8	8,7
SumEntropy	2,4	10,1	1,6	1,5
SumSquares	14,1	70,7	7,2	6,7

glrlm	1	2	3	4
GrayLevelNonUniformity	5,9	25,3	94,1	93,7
GrayLevelNonUniformityNormalized	8,0	29,0	1,4	1,6
GrayLevelVariance	13,0	68,3	8,1	7,4
HighGrayLevelRunEmphasis	28,3	70,0	31,4	30,4
LongRunEmphasis	26,0	13,6	10,1	10,5
LongRunHighGrayLevelEmphasis	30,5	56,0	36,6	41,8
LongRunLowGrayLevelEmphasis	73,0	52,6	43,2	40,5
LowGrayLevelRunEmphasis	47,6	40,5	51,4	49,2
RunEntropy	2,6	6,8	2,4	2,4
RunLengthNonUniformity	11,4	11,2	90,6	90,1
RunLengthNonUniformityNormalized	7,4	7,0	4,0	3,9
RunPercentage	5,1	4,3	2,6	2,6
RunVariance	65,8	40,9	35,2	35,2
ShortRunEmphasis	4,0	3,0	1,8	1,8
ShortRunHighGrayLevelEmphasis	29,3	72,8	31,1	29,8
ShortRunLowGrayLevelEmphasis	44,4	38,4	52,6	51,4

glszm	1	2	3	4
GrayLevelNonUniformity	25,6	13,6	58,5	56,6
GrayLevelNonUniformityNormalized	8,6	23,2	6,7	6,3
GrayLevelVariance	19,9	49,4	16,0	13,9
HighGrayLevelZoneEmphasis	30,4	73,0	31,8	31,0
LargeAreaEmphasis	72,1	89,9	139,4	138,8
LargeAreaHighGrayLevelEmphasis	64,1	55,9	146,5	146,4
LargeAreaLowGrayLevelEmphasis	105,2	115,5	124,0	126,2
LowGrayLevelZoneEmphasis	49,4	47,5	48,7	46,0
SizeZoneNonUniformity	39,7	45,5	52,4	52,0
SizeZoneNonUniformityNormalized	22,6	8,5	12,5	13,7
SmallAreaEmphasis	32,9	4,4	6,7	7,4
SmallAreaHighGrayLevelEmphasis	45,3	78,4	29,9	30,3
SmallAreaLowGrayLevelEmphasis	50,8	45,8	53,5	54,4
ZoneEntropy	4,5	3,6	6,3	6,0
ZonePercentage	29,4	38,0	25,9	26,4
ZoneVariance	74,8	90,3	140,6	140,2

gldm	1	2	3	4
DependenceEntropy	2,7	2,5	3,6	3,7
DependenceNonUniformity	20,6	26,8	84,6	83,8
DependenceNonUniformityNormalized	20,6	26,8	12,7	13,6
DependenceVariance	62,8	40,9	21,7	24,2
GrayLevelNonUniformity	10,0	30,6	97,1	97,0
GrayLevelVariance	14,5	70,8	7,8	7,1
HighGrayLevelEmphasis	28,0	69,8	31,4	30,4
LargeDependenceEmphasis	57,1	42,4	26,4	27,9
LargeDependenceHighGrayLevelEmphasis	55,1	19,6	47,5	50,2
LargeDependenceLowGrayLevelEmphasis	98,0	84,3	25,2	25,8
LowGrayLevelEmphasis	45,8	40,2	51,0	49,1
SmallDependenceEmphasis	31,8	33,3	22,9	23,1
SmallDependenceHighGrayLevelEmphasis	46,1	102,4	31,4	31,4
SmallDependenceLowGrayLevelEmphasis	23,6	14,3	67,9	67,6

ngtdm	1	2	3	4
Busyness	46,2	50,6	51,7	51,8
Coarseness	22,8	0,5	68,1	68,5
Complexity	34,2	89,8	25,9	22,4
Contrast	23,1	48,3	49,7	48,5
Strength	37,2	51,8	31,8	32,0

Conclusion

The estimation of radiomics features in rectal cancer from CT imaging appreciably **depends on pre-processing**, in terms of *resampling voxel size*, *interpolation algorithm* and *quantization binwidth*.

- **ICC analysis** shows that more than half of the radiomic features have *poor* or *moderate* reliability,
- A number of features with good ICC values (ICC $>$0.75) presents a **median COV** $> 25\%$

Image pre-processing effect should be taken into account when planning a clinical study, comparing results from different studies and performing multicentric studies.