**Texture analysis methodology**

Texture analysis wad applied to the CT images using in-house software (AK, version 3.2.2, GE Healthcare). A region of interest (ROI) was delineated initially around the tumor outline for the 3D ROI area. 396 imaging texture features from the category of histogram, the Grey level co-occurrence matrix(GLCM), the gray level size zone matrix(GLSZM), the gray level Run-length matrix(RLM), and Shape and size based features were finally extracted from one single image **Table S1.**

**Table S1:**

**Summary of radiomic features used in this study**

|  |  |  |
| --- | --- | --- |
| Feature classes | No. of features | 3 representative features |
| Histogram | 42 | FrequencySize, MaxIntensity, MeanValue,… |
| GLCM | 144 | ClusterProminence, ClusterShade, Correlation,… |
| GLSZM | 11 | SizeZoneVariability, HighIntensityEmphasis, IntensityVariability,… |
| RLM | 180 | GreyLevelNonuniformity, HighGreyLevelRunEmphasis, LongRunEmphasis,… |
| Formfactor | 9 | Compactness1, Maximum3DDiameter, Sphericity,… |
| Haralick | 10 | HaraEntroy, contrast, differenceEntropy,… |
| Total | 396 |  |

GLCM= the Grey level co-occurrence matrix, GLSZM =the gray level size zone matrix, RLM= the gray level Run-length matrix

312 features were considered excellent reproducibility with ICC > 0.75 in intra-and interobserver.

First, The general univariate analysis was used to select features.

parameters setted: {'P value for threshold in': 0.05}

num of remained features: 288

remained features:

[['ShortRunLowGreyLevelEmphasis\_angle45\_offset7']

 ['Correlation\_angle90\_offset1']

 ['ClusterShade\_AllDirection\_offset4']

 ['HaralickCorrelation\_angle45\_offset1']

 ['HighGreyLevelRunEmphasis\_angle135\_offset4']

 ['ClusterShade\_angle90\_offset4']

 ['HaralickCorrelation\_angle90\_offset1']

 ['ClusterProminence\_angle0\_offset7']

 ['Correlation\_angle45\_offset7']

 ['ShortRunEmphasis\_AllDirection\_offset1']

 ['Inertia\_angle90\_offset7']

 ['GreyLevelNonuniformity\_angle135\_offset7']

 ['InverseDifferenceMoment\_angle135\_offset4']

 ['Sphericity']

 ['Inertia\_angle135\_offset7']

 ['HaralickCorrelation\_angle90\_offset7']

 ['ClusterProminence\_AllDirection\_offset7\_SD']

 ['GLCMEntropy\_angle0\_offset7']

 ['GLCMEnergy\_AllDirection\_offset4\_SD']

 ['ShortRunEmphasis\_angle135\_offset7']

 ['ShortRunHighGreyLevelEmphasis\_AllDirection\_offset1\_SD']

 ['Inertia\_AllDirection\_offset1']

 ['ShortRunEmphasis\_angle45\_offset1']

 ['GreyLevelNonuniformity\_angle0\_offset4']

 ['GLCMEntropy\_angle0\_offset1']

 ['Inertia\_AllDirection\_offset7\_SD']

 ['GreyLevelNonuniformity\_AllDirection\_offset7']

 ['Correlation\_AllDirection\_offset7\_SD']

 ['GreyLevelNonuniformity\_angle90\_offset1']

 ['GLCMEnergy\_angle135\_offset7']

 ['RunLengthNonuniformity\_angle45\_offset1']

 ['HighGreyLevelRunEmphasis\_angle45\_offset4']

 ['InverseDifferenceMoment\_angle45\_offset4']

 ['ClusterProminence\_angle45\_offset4']

 ['differenceEntropy']

 ['ClusterShade\_AllDirection\_offset7']

 ['HighGreyLevelRunEmphasis\_AllDirection\_offset4']

 ['HaralickCorrelation\_angle45\_offset4']

 ['GreyLevelNonuniformity\_angle45\_offset7']

 ['RunLengthNonuniformity\_angle135\_offset1']

 ['Inertia\_AllDirection\_offset1\_SD']

 ['LowGreyLevelRunEmphasis\_AllDirection\_offset7\_SD']

 ['HaralickCorrelation\_angle0\_offset4']

 ['Variance']

 ['FrequencySize']

 ['ShortRunLowGreyLevelEmphasis\_angle0\_offset7']

 ['GLCMEntropy\_angle90\_offset1']

 ['GreyLevelNonuniformity\_angle90\_offset7']

 ['InverseDifferenceMoment\_AllDirection\_offset4']

 ['GLCMEnergy\_angle0\_offset1']

 ['contrast']

 ['ShortRunLowGreyLevelEmphasis\_angle45\_offset1']

 ['LongRunHighGreyLevelEmphasis\_AllDirection\_offset7\_SD']

 ['ShortRunEmphasis\_angle135\_offset4']

 ['HighGreyLevelRunEmphasis\_angle45\_offset1']

 ['histogramEntropy']

 ['Correlation\_angle0\_offset7']

 ['Correlation\_AllDirection\_offset1\_SD']

 ['Inertia\_angle0\_offset4']

 ['LowGreyLevelRunEmphasis\_angle90\_offset1']

 ['LowGreyLevelRunEmphasis\_angle135\_offset1']

 ['LowGreyLevelRunEmphasis\_angle45\_offset4']

 ['GLCMEntropy\_angle135\_offset7']

 ['ShortRunEmphasis\_AllDirection\_offset7\_SD']

 ['InverseDifferenceMoment\_AllDirection\_offset7']

 ['ShortRunEmphasis\_angle0\_offset7']

 ['sumVariance']

 ['LongRunHighGreyLevelEmphasis\_angle0\_offset7']

 ['InverseDifferenceMoment\_angle45\_offset1']

 ['LowGreyLevelRunEmphasis\_AllDirection\_offset7']

 ['VolumeCount']

 ['LowGreyLevelRunEmphasis\_AllDirection\_offset4']

 ['VoxelValueSum']

 ['ClusterProminence\_angle135\_offset1']

 ['GLCMEnergy\_AllDirection\_offset1']

 ['LongRunHighGreyLevelEmphasis\_AllDirection\_offset1\_SD']

 ['HaraVariance']

 ['ShortRunLowGreyLevelEmphasis\_angle90\_offset1']

 ['LowGreyLevelRunEmphasis\_angle90\_offset7']

 ['GLCMEnergy\_angle135\_offset1']

 ['GLCMEnergy\_angle0\_offset7']

 ['GLCMEntropy\_angle45\_offset7']

 ['ClusterProminence\_angle45\_offset1']

 ['LowGreyLevelRunEmphasis\_angle0\_offset7']

 ['ShortRunLowGreyLevelEmphasis\_angle90\_offset4']

 ['inverseDifferenceMoment']

 ['InverseDifferenceMoment\_angle135\_offset1']

 ['ClusterShade\_angle45\_offset4']

 ['LowGreyLevelRunEmphasis\_angle45\_offset1']

 ['ClusterShade\_AllDirection\_offset4\_SD']

 ['RunLengthNonuniformity\_angle45\_offset4']

 ['ShortRunEmphasis\_angle90\_offset4']

 ['Inertia\_angle45\_offset7']

 ['HighGreyLevelRunEmphasis\_AllDirection\_offset7']

 ['ClusterProminence\_angle135\_offset7']

 ['RunLengthNonuniformity\_angle90\_offset7']

 ['GreyLevelNonuniformity\_angle0\_offset1']

 ['ClusterShade\_angle90\_offset1']

 ['SphericalDisproportion']

 ['LongRunHighGreyLevelEmphasis\_angle0\_offset1']

 ['VolumeCC']

 ['ClusterShade\_AllDirection\_offset1']

 ['Inertia\_angle135\_offset4']

 ['HighGreyLevelRunEmphasis\_angle90\_offset1']

 ['Percentile95']

 ['ClusterProminence\_AllDirection\_offset1\_SD']

 ['LongRunEmphasis\_AllDirection\_offset1']

 ['ClusterProminence\_angle135\_offset4']

 ['GreyLevelNonuniformity\_angle135\_offset1']

 ['RunLengthNonuniformity\_angle0\_offset4']

 ['sumEntropy']

 ['GLCMEntropy\_AllDirection\_offset1\_SD']

 ['Inertia\_angle0\_offset7']

 ['Percentile85']

 ['HaralickCorrelation\_angle135\_offset1']

 ['HighGreyLevelRunEmphasis\_angle90\_offset4']

 ['GreyLevelNonuniformity\_angle0\_offset7']

 ['GLCMEntropy\_AllDirection\_offset4']

 ['ClusterProminence\_angle0\_offset1']

 ['GLCMEnergy\_angle0\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_angle135\_offset7']

 ['LongRunHighGreyLevelEmphasis\_angle135\_offset1']

 ['InverseDifferenceMoment\_AllDirection\_offset1']

 ['RunLengthNonuniformity\_angle0\_offset1']

 ['ClusterProminence\_AllDirection\_offset4']

 ['GreyLevelNonuniformity\_AllDirection\_offset7\_SD']

 ['RunLengthNonuniformity\_angle90\_offset1']

 ['GLCMEnergy\_angle90\_offset7']

 ['GreyLevelNonuniformity\_AllDirection\_offset4']

 ['ShortRunEmphasis\_angle0\_offset4']

 ['GLCMEnergy\_angle45\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_angle0\_offset1']

 ['LongRunHighGreyLevelEmphasis\_angle90\_offset4']

 ['Correlation\_AllDirection\_offset1']

 ['InverseDifferenceMoment\_angle135\_offset7']

 ['Inertia\_angle45\_offset1']

 ['LongRunHighGreyLevelEmphasis\_angle45\_offset1']

 ['ClusterProminence\_AllDirection\_offset1']

 ['HaralickCorrelation\_angle0\_offset7']

 ['ClusterShade\_angle135\_offset7']

 ['LongRunEmphasis\_AllDirection\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_AllDirection\_offset1']

 ['GLCMEntropy\_angle90\_offset7']

 ['LongRunHighGreyLevelEmphasis\_AllDirection\_offset4\_SD']

 ['LongRunEmphasis\_AllDirection\_offset4\_SD']

 ['LongRunEmphasis\_angle90\_offset1']

 ['ClusterShade\_angle0\_offset7']

 ['Correlation\_angle45\_offset1']

 ['Quantile0.975']

 ['ShortRunEmphasis\_AllDirection\_offset4\_SD']

 ['HighGreyLevelRunEmphasis\_angle0\_offset1']

 ['ShortRunLowGreyLevelEmphasis\_angle135\_offset4']

 ['HaralickCorrelation\_angle135\_offset4']

 ['ShortRunEmphasis\_AllDirection\_offset4']

 ['GreyLevelNonuniformity\_angle45\_offset1']

 ['ShortRunEmphasis\_angle45\_offset7']

 ['HaralickCorrelation\_AllDirection\_offset1']

 ['GLCMEntropy\_angle45\_offset1']

 ['GLCMEnergy\_angle45\_offset7']

 ['HighGreyLevelRunEmphasis\_angle45\_offset7']

 ['Compactness1']

 ['GLCMEnergy\_angle45\_offset1']

 ['LowGreyLevelRunEmphasis\_angle135\_offset4']

 ['HaralickCorrelation\_angle45\_offset7']

 ['HaralickCorrelation\_AllDirection\_offset4']

 ['Correlation\_angle135\_offset1']

 ['LongRunLowGreyLevelEmphasis\_AllDirection\_offset1\_SD']

 ['LongRunEmphasis\_angle0\_offset1']

 ['Inertia\_angle0\_offset1']

 ['LongRunEmphasis\_AllDirection\_offset1\_SD']

 ['InverseDifferenceMoment\_angle90\_offset4']

 ['Inertia\_angle135\_offset1']

 ['stdDeviation']

 ['LongRunHighGreyLevelEmphasis\_angle90\_offset1']

 ['HighGreyLevelRunEmphasis\_angle135\_offset1']

 ['ClusterShade\_angle135\_offset4']

 ['RunLengthNonuniformity\_angle90\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_AllDirection\_offset7']

 ['uniformity']

 ['ShortRunLowGreyLevelEmphasis\_angle135\_offset1']

 ['SurfaceVolumeRatio']

 ['GLCMEntropy\_angle45\_offset4']

 ['RunLengthNonuniformity\_AllDirection\_offset1\_SD']

 ['RunLengthNonuniformity\_AllDirection\_offset7']

 ['ClusterShade\_angle135\_offset1']

 ['LongRunEmphasis\_angle0\_offset4']

 ['ClusterProminence\_angle45\_offset7']

 ['HaralickCorrelation\_AllDirection\_offset7']

 ['GLCMEnergy\_angle90\_offset1']

 ['ShortRunEmphasis\_angle90\_offset7']

 ['Inertia\_AllDirection\_offset4']

 ['InverseDifferenceMoment\_angle90\_offset1']

 ['RunLengthNonuniformity\_AllDirection\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_angle0\_offset4']

 ['Range']

 ['GreyLevelNonuniformity\_angle90\_offset4']

 ['LongRunHighGreyLevelEmphasis\_angle45\_offset4']

 ['VolumeMM']

 ['GLCMEnergy\_AllDirection\_offset7']

 ['LowGreyLevelRunEmphasis\_angle90\_offset4']

 ['GLCMEntropy\_AllDirection\_offset1']

 ['GLCMEnergy\_AllDirection\_offset1\_SD']

 ['InverseDifferenceMoment\_angle0\_offset4']

 ['AngularSecondMoment']

 ['InverseDifferenceMoment\_angle45\_offset7']

 ['LowGreyLevelRunEmphasis\_angle45\_offset7']

 ['LowGreyLevelRunEmphasis\_angle0\_offset1']

 ['RunLengthNonuniformity\_angle135\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_AllDirection\_offset4']

 ['LongRunHighGreyLevelEmphasis\_angle0\_offset4']

 ['ShortRunEmphasis\_AllDirection\_offset7']

 ['HaraEntroy']

 ['ClusterProminence\_angle0\_offset4']

 ['ClusterProminence\_AllDirection\_offset7']

 ['SurfaceArea']

 ['GLCMEntropy\_AllDirection\_offset7']

 ['HaralickCorrelation\_angle135\_offset7']

 ['RunLengthNonuniformity\_angle0\_offset7']

 ['InverseDifferenceMoment\_angle90\_offset7']

 ['ClusterShade\_AllDirection\_offset7\_SD']

 ['GreyLevelNonuniformity\_AllDirection\_offset4\_SD']

 ['RunLengthNonuniformity\_AllDirection\_offset7\_SD']

 ['RunLengthNonuniformity\_angle45\_offset7']

 ['RunLengthNonuniformity\_AllDirection\_offset4\_SD']

 ['LongRunEmphasis\_angle45\_offset1']

 ['LongRunHighGreyLevelEmphasis\_AllDirection\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_angle90\_offset7']

 ['ShortRunEmphasis\_angle90\_offset1']

 ['ClusterProminence\_angle90\_offset4']

 ['HighGreyLevelRunEmphasis\_angle0\_offset4']

 ['ClusterProminence\_angle90\_offset1']

 ['GLCMEntropy\_angle135\_offset1']

 ['ShortRunLowGreyLevelEmphasis\_angle45\_offset4']

 ['histogramEnergy']

 ['LowGreyLevelRunEmphasis\_AllDirection\_offset1']

 ['LowGreyLevelRunEmphasis\_angle0\_offset4']

 ['HaralickCorrelation\_angle0\_offset1']

 ['GLCMEntropy\_angle0\_offset4']

 ['ClusterProminence\_AllDirection\_offset4\_SD']

 ['LongRunHighGreyLevelEmphasis\_AllDirection\_offset1']

 ['ShortRunLowGreyLevelEmphasis\_AllDirection\_offset7\_SD']

 ['GLCMEnergy\_angle135\_offset4']

 ['HaralickCorrelation\_AllDirection\_offset1\_SD']

 ['ClusterShade\_angle0\_offset1']

 ['Inertia\_AllDirection\_offset7']

 ['InverseDifferenceMoment\_angle0\_offset7']

 ['GreyLevelNonuniformity\_AllDirection\_offset1\_SD']

 ['ShortRunHighGreyLevelEmphasis\_AllDirection\_offset7\_SD']

 ['ShortRunEmphasis\_angle45\_offset4']

 ['Inertia\_angle90\_offset1']

 ['ShortRunEmphasis\_angle0\_offset1']

 ['Correlation\_angle0\_offset1']

 ['sumAverage']

 ['RunLengthNonuniformity\_angle135\_offset7']

 ['ClusterShade\_angle0\_offset4']

 ['GLCMEnergy\_AllDirection\_offset7\_SD']

 ['differenceVariance']

 ['HighGreyLevelRunEmphasis\_angle135\_offset7']

 ['GreyLevelNonuniformity\_AllDirection\_offset1']

 ['ShortRunHighGreyLevelEmphasis\_AllDirection\_offset4\_SD']

 ['HighGreyLevelRunEmphasis\_AllDirection\_offset4\_SD']

 ['GLCMEntropy\_angle90\_offset4']

 ['Inertia\_angle45\_offset4']

 ['GreyLevelNonuniformity\_angle45\_offset4']

 ['RunLengthNonuniformity\_AllDirection\_offset1']

 ['HighGreyLevelRunEmphasis\_angle0\_offset7']

 ['Inertia\_angle90\_offset4']

 ['HighGreyLevelRunEmphasis\_AllDirection\_offset1']

 ['Inertia\_AllDirection\_offset4\_SD']

 ['Correlation\_AllDirection\_offset4\_SD']

 ['GLCMEnergy\_AllDirection\_offset4']

 ['ClusterShade\_angle45\_offset1']

 ['HaralickCorrelation\_angle90\_offset4']

 ['ShortRunLowGreyLevelEmphasis\_AllDirection\_offset4\_SD']

 ['ShortRunEmphasis\_angle135\_offset1']

 ['HighGreyLevelRunEmphasis\_angle90\_offset7']

 ['LowGreyLevelRunEmphasis\_angle135\_offset7']

 ['Compactness2']

 ['Correlation\_AllDirection\_offset7']

 ['GLCMEnergy\_angle90\_offset4']

 ['ClusterShade\_angle90\_offset7']

 ['GreyLevelNonuniformity\_angle135\_offset4']

 ['Percentile90']

 ['MaxIntensity']

 ['ClusterProminence\_angle90\_offset7']

 ['InverseDifferenceMoment\_angle0\_offset1']

 ['ClusterShade\_angle45\_offset7']

 ['GLCMEntropy\_angle135\_offset4']]

Then the least absolute shrinkage and selection operator (LASSO) was applied to select

the most useful features from the primary data.

parameters setted: {'alpha': 0.008957598878169343}

num of remained features: 7

remained features:

['Sphericity']

['Inertia\_angle135\_offset7']

['histogramEntropy']

['Correlation\_angle0\_offset7']

['GLCMEntropy\_angle135\_offset7']

['VoxelValueSum']

['MaxIntensity']