# MODEL 3 CLUSTERING TECHNIQUE

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## Comparing the following clustering technique results:

(A) K-Means
(B) Hierarchical
(C) Model Based Without considering the binary output and categorical variables in the dataset.

# LOAD PACKAGES

```
# Helper packages

library(dplyr)         # for data wrangling
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(tidyverse)     # for filtering
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
```

```
## v ggplot2 3.4.0     v purrr   0.3.5
## v tibble  3.1.8     v stringr 1.4.1
## v tidyr   1.2.1     v forcats 0.5.2
## v readr   2.1.3
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(readr)         # load dataset
library(bestNormalize) # for normalizing the dataset
library(ggplot2)       # data visualization
library(stringr)       # for string functionality
library(gridExtra)     # for manipulaiting the grid
```

```
##
## Attaching package: 'gridExtra'
##
```

```
## The following object is masked from 'package:dplyr':
##
##     combine
```

```
library(mclust)        # for model-based clustering
```

```
## Package 'mclust' version 6.0.0
## Type 'citation("mclust")' for citing this R package in publications.
##
## Attaching package: 'mclust'
##
## The following object is masked from 'package:purrr':
##
##     map
```

```
# Modeling packages

library(cluster)       # for general clustering algorithms
library(factoextra)    # for visualizing cluster results
```

```
## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa
```

Note that we used the reprocessed data of radiomics_complete.csv (*RAD. NORMAL DATA.CSV*) in performing clustering technique.

# LOAD THE REPROCESSED DATASET

Radiomics Dataset 197 Rows (Observations) of 431 Columns (Variables) Failure.binary: binary property to predict

```
radiomicsdt <- read_csv("RAD. NORMAL DATA.CSV")
```

```
## Rows: 197 Columns: 431
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr   (1): Institution
## dbl (430): Failure.binary, Failure, Entropy_cooc.W.ADC, GLNU_align.H.PET, Mi...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

```
View(radiomicsdt)
head(radiomicsdt)
```

```
## # A tibble: 6 x 431
##   Institution Failure.~1 Failure Entro~2 GLNU_~3 Min_h~4 Max_h~5 Mean_~6 Varia~7
##   <chr>            <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
## 1 A                    0   1.15     12.9  -0.433  -0.270 -0.257   -0.192  0.0509
## 2 A                    1  -0.533    12.2  -1.02    0.671  0.405    0.490  0.687
## 3 A                    0   2.24     12.8   0.179  -1.41  -1.57    -1.53  -1.57
## 4 A                    1  -0.140    13.5   2.00   -0.218  0.0764  -0.153  0.0127
## 5 A                    0   0.787    12.6   0.153  -1.06  -1.15    -1.45  -1.91
## 6 A                    1  -2.80     13.2   0.391  -1.57  -1.91    -1.72  -1.84
## # ... with 422 more variables: Standard_Deviation_hist.PET <dbl>,
## #   Skewness_hist.PET <dbl>, Kurtosis_hist.PET <dbl>, Energy_hist.PET <dbl>,
## #   Entropy_hist.PET <dbl>, AUC_hist.PET <dbl>, H_suv.PET <dbl>,
## #   Volume.PET <dbl>, X3D_surface.PET <dbl>, ratio_3ds_vol.PET <dbl>,
```

```
## #   ratio_3ds_vol_norm.PET <dbl>, irregularity.PET <dbl>,
## #   tumor_length.PET <dbl>, Compactness_v1.PET <dbl>, Compactness_v2.PET <dbl>,
## #   Spherical_disproportion.PET <dbl>, Sphericity.PET <dbl>, ...
```

## Scaling/Standardizing the Data

Scaling is a way to compare data that is not measured in the same way. The scale function in R handles this task for you by providing a way to normalize the data so that the differences are weeded out which help us to make comparisons.

```
radiomicsdf <- scale(radiomicsdt[c(3:431)]) # Large matrix (84513 elements, 787.9 kb)
```

# CHECKING FOR NULL AND MISSING VALUES

The result for checking null and missing values is 0 using *sum(is.n())*. Thus, there is no null and missing values.

```
sum(is.na(radiomicsdf))
```

```
## [1] 0
```

# (A) K-MEANS CLUSTERING

K-means clustering is a method of vector quantization, originally from signal processing, that aims to partition n observations into k clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster.

```
kmeans(radiomicsdf, centers = 3, iter.max = 100, nstart = 100)
```

```
## K-means clustering with 3 clusters of sizes 50, 103, 44
##
## Cluster means:
##       Failure Entropy_cooc.W.ADC GLNU_align.H.PET Min_hist.PET Max_hist.PET
## 1  0.08214575         0.04845450     -0.092060043   0.85874157   0.87682607
## 2  0.06537718        -0.04573823     -0.009433942  -0.43645422  -0.46197403
## 3 -0.24638949         0.05200710      0.126697686   0.04585696   0.08504594
##   Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET Skewness_hist.PET
## 1    0.87027835         0.4855907                   0.8620350         0.7998965
## 2   -0.45868782        -0.3330976                  -0.4359917        -0.1564058
## 3    0.08479383         0.2279436                   0.0410318        -0.5428415
##   Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET AUC_hist.PET  H_suv.PET
## 1       -0.03996330       0.8199868        1.2527361   1.26100621  0.8788341
## 2        0.04878509       0.1319279       -0.5425300  -0.09790924 -0.3530821
## 3       -0.06878862      -1.2406345       -0.1535503  -1.20376496 -0.1721421
##   Volume.PET X3D_surface.PET ratio_3ds_vol.PET ratio_3ds_vol_norm.PET
## 1  0.5238526       0.5381188       0.913655462             0.92008868
## 2 -0.4473168      -0.3137553      -0.002504806            -0.05148286
## 3  0.4518410       0.1229739      -1.032381320            -0.92503862
##   irregularity.PET tumor_length.PET Compactness_v1.PET Compactness_v2.PET
## 1        1.2610062        1.0140643         1.01743912         0.68218335
## 2       -0.2025772       -0.3577728        -0.04053042        -0.33148005
## 3       -0.9587467       -0.3148322        -1.06130280         0.00075632
##   Spherical_disproportion.PET Sphericity.PET Asphericity.PET Center_of_mass.PET
## 1                  0.92008868      0.8352405      0.90801714          0.7294319
```

```
## 2                -0.05148286     -0.4090411     -0.04633856         -0.2830070
## 3                -0.92503862      0.0083911     -0.92336330         -0.1664062
##   Max_3D_diam.PET Major_axis_length.PET Minor_axis_length.PET
## 1       0.8110522             0.8729280            1.03991352
## 2      -0.5666852            -0.5486413           -0.54545457
## 3       0.4049083             0.2923557            0.09513965
##   Least_axis_length.PET Elongation.PET Flatness.PET Max_cooc.L.PET
## 1             0.8921472      1.2344841    1.2004416      0.8469546
## 2            -0.5446258     -0.2539493   -0.3408235      0.1175852
## 3             0.2611157     -0.8083506   -0.5663013     -1.2377046
##   Average_cooc.L.PET Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET
## 1          1.1833043           0.9553804          1.2610062       1.1293779
## 2         -0.3625706          -0.1758933         -0.4974238      -0.2725761
## 3         -0.4959192          -0.6739093         -0.2685377      -0.6453081
##   DVAR_cooc.L.PET DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET
## 1       0.9890675       1.2610062       1.1830377       0.9917348
## 2      -0.1910234      -0.3106751      -0.3631785      -0.1977607
## 3      -0.6767720      -0.7056993      -0.4941932      -0.6640316
##   SENT_cooc.L.PET ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## 1       1.2610062      0.8100606           0.7988492                1.1293779
## 2      -0.2141247      0.1319836          -0.1507953               -0.2725761
## 3      -0.9317152     -1.2294851          -0.5547851               -0.6453081
##   Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## 1           1.2485871                1.2610062      1.1850979
## 2          -0.2739537               -0.2643276     -0.1969052
## 3          -0.7775483               -0.8141946     -0.8857651
##   IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## 1           1.2610062          1.1902440              1.0057979
## 2          -0.1988353         -0.1927562             -0.3350398
## 3          -0.9675063         -0.9013253             -0.3586545
##   Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## 1                  0.8966523           0.9917348       0.46328300
## 2                 -0.2523420          -0.1977607      -0.06389272
## 3                 -0.4282134          -0.6640316      -0.37689090
##   Prominence_cooc.L.PET  IC1_.L.PET IC2_.L.PET Coarseness_vdif_.L.PET
## 1            0.70108893 -0.57114691   1.257101              0.8116326
## 2           -0.06490617  0.28950284  -0.182536              0.1389880
## 3           -0.64475251 -0.02866924  -1.001224             -1.2476681
##   Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## 1            0.6729049            0.5630744              1.1194203
## 2           -0.0251084           -0.3710415             -0.1975675
## 3           -0.7058882            0.2287172             -0.8095809
##   Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
## 1            0.4990703       1.2610062       1.2610062        0.4470734
## 2            0.1338226      -0.0623856      -0.2800131       -0.3996385
## 3           -0.8803918      -1.2869226      -0.7774763        0.4274795
##   RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## 1        0.4112341      1.2610062     0.9938768247        0.9243479
## 2       -0.4023296     -0.0660082     0.0003068724       -0.2607318
## 3        0.4745056     -1.2784424    -1.1301238429       -0.4400459
##   LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## 1       0.998225215         0.9222450      0.9638737792         0.9371156
## 2       0.001502125        -0.2534191     -0.0002882839        -0.2916630
## 3      -1.137863173        -0.4547746     -1.0946362665        -0.3821475
```

```
##   GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## 1            1.03170588            1.26100621         0.9875870
## 2            0.05026552           -0.08931007        -0.2128020
## 3           -1.29006007           -1.22389485        -0.6241077
##   RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET  LGLZE.L.PET
## 1        1.01764663           1.2610062  1.2610062  1.1499756  1.009328147
## 2       -0.02325062          -0.4819232 -0.1121704 -0.4488779 -0.002221956
## 3       -1.10198903          -0.3048233 -1.1703808 -0.2560081 -1.141762407
##   HGLZE.L.PET  SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET GLNU_area.L.PET
## 1   0.9364576  1.026013796   0.9352729  0.86951623   0.8741557       0.4582570
## 2  -0.2603457  0.001672616  -0.2328767 -0.02473818  -0.3087426      -0.4004704
## 3  -0.4547108 -1.169840211  -0.5176669 -0.93017679  -0.2706204       0.4167183
##   ZSNU.L.PET  ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET GLVAR_area.L.PET
## 1  0.4306853  1.2610062      1.03108296       1.2610062        1.0040719
## 2 -0.4105445 -0.1546823      0.04990501      -0.1801911       -0.2148491
## 3  0.4716323 -1.0708645     -1.28850827      -1.0111507       -0.6380485
##   ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET Average_cooc.H.PET
## 1   0.8976727          1.2610062      0.5507615          1.2610062
## 2  -0.2133959         -0.5138845      0.1789068         -0.2415968
## 3  -0.5205423         -0.2300047     -1.0446699         -0.8674055
##   Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET DVAR_cooc.H.PET
## 1           1.2355844          1.1902276       1.2594515       1.2513196
## 2          -0.5538043         -0.5131234      -0.4673835      -0.4582690
## 3          -0.1076677         -0.1513560      -0.3370926      -0.3491879
##   DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET SENT_cooc.H.PET
## 1       1.2071013       1.2610062       1.2404064       0.9810288
## 2      -0.5105001      -0.2970724      -0.5089699      -0.1374373
## 3      -0.1766716      -0.7375421      -0.2181004      -0.7930772
##   ASM_cooc.H.PET Contrast_cooc.H.PET Dissimilarity_cooc.H.PET
## 1      0.5649668           1.1990625                1.2594515
## 2      0.2173848          -0.4441699               -0.4673835
## 3     -1.1508857          -0.3228096               -0.3370926
##   Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET IDM_cooc.H.PET
## 1           1.0678502                1.2610062     0.92747697
## 2          -0.1146295               -0.1152681    -0.05603959
## 3          -0.9451290               -1.1631295    -0.92276752
##   IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET Correlation_cooc.H.PET
## 1           1.2610062          0.94056271              1.0162458
## 2          -0.0859426          0.03016403             -0.3677423
## 3          -1.2317778         -1.13943252             -0.2939734
##   Autocorrelation_cooc.H.PET Tendency_cooc.H.PET Shade_cooc.H.PET
## 1                  1.2477485          1.21612779       -0.6083698
## 2                 -0.2312947         -0.55524643        0.2897603
## 3                 -0.8764561         -0.08218198        0.0130268
##   Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET Coarseness_vdif.H.PET
## 1            0.93091786  -0.1764838   1.1963955             0.8006591
## 2           -0.47608722   0.3322440  -0.4237839             0.1366371
## 3            0.05661571  -0.5772033  -0.3675008            -1.2296950
##   Contrast_vdif.H.PET Busyness_vdif.H.PET Complexity_vdif.H.PET
## 1          0.62258911           0.4189154            0.96099961
## 2         -0.05878702          -0.4359746           -0.07510634
## 3         -0.56987256           0.5445366           -0.91622789
##   Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET RLNU_align.H.PET
## 1           0.3356476       1.2610062       1.0649372        0.4122865
```

```
## 2           0.2376470      -0.3704284      -0.2154755       -0.4139000
## 3          -0.9377278      -0.5658223      -0.7057473        0.5003948
##   RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET LGSRE_align.H.PET
## 1      1.2610062        0.8118850        1.2450986         0.8118850
## 2     -0.3898962        0.1184958       -0.2737050         0.1188289
## 3     -0.5202500       -1.1999846       -0.7741663        -1.2007644
##   HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET GLNU_norm_align.H.PET
## 1         1.2610062         0.8141708         0.8813322            0.82132550
## 2        -0.3251965         0.1173371        -0.1801486            0.03759345
## 3        -0.6717061        -1.1998696        -0.5798024           -1.02132727
##   RLNU_norm_align.H.PET GLVAR_align.H.PET RLVAR_align.H.PET Entropy_align.H.PET
## 1             1.2610062        1.19580011        0.62413140          1.26100621
## 2            -0.4321049       -0.54797206       -0.01910859         -0.57178319
## 3            -0.4214434       -0.07611098       -0.66450875         -0.09446914
##   SZSE.H.PET LZSE.H.PET LGLZE.H.PET HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET
## 1  1.2241745  0.3928016   0.8115249   1.2401327   0.8114437   1.1993854
## 2 -0.4032952 -0.0746649   0.1186081  -0.3370729   0.1196279  -0.3808504
## 3 -0.4470299 -0.2715817  -1.1998381  -0.6201846  -1.2021333  -0.4714018
##   LZLGE.H.PET  LZHGE.H.PET GLNU_area.H.PET ZSNU.H.PET  ZSP.H.PET
## 1   0.4589019  0.350101318       0.4829101  0.3394070  1.0428037
## 2   0.1835682  0.002524456      -0.4066093 -0.3660541 -0.3881463
## 3  -0.9511959 -0.403751927       0.4030738  0.4712095 -0.2763891
##   GLNU_norm.H.PET ZSNU_norm.H.PET GLVAR_area.H.PET ZSVAR_H.PET
## 1       0.8478342       1.0704220        1.1805080  0.30473420
## 2       0.0191874      -0.3843304       -0.5270962  0.02643966
## 3      -1.0083639      -0.3167062       -0.1076021 -0.40818170
##   Entropy_area.H.PET Max_cooc.W.PET Average_cooc.W.PET Variance_cooc.W.PET
## 1         1.26100621      0.6431925          0.8522186           0.4650814
## 2        -0.59031130      0.2203858         -0.4616517          -0.3256100
## 3        -0.05109651     -1.2468037          0.1122544           0.2337219
##   Entropy_cooc.W.PET DAVE_cooc.W.PET DVAR_cooc.W.PET DENT_cooc.W.PET
## 1          1.2458016     0.868377736       0.4907641       1.2369607
## 2         -0.5588924    -0.424423328      -0.3224611      -0.5233676
## 3         -0.1073673     0.006743546       0.1971657      -0.1804813
##   SAVE_cooc.W.PET SVAR_cooc.W.PET SENT_cooc.W.PET ASM_cooc.W.PET
## 1       0.8510408       0.4525392       1.2588138      0.7033977
## 2      -0.4625522      -0.3286516      -0.4564338      0.1986421
## 3       0.1157009       0.2550944      -0.3620001     -1.2643186
##   Contrast_cooc.W.PET Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET
## 1           0.5130087              0.868377736           1.1669140
## 2          -0.3226168             -0.424423328          -0.1656669
## 3           0.1722521              0.006743546          -0.9382274
##   Inv_diff_norm_cooc.W.PET IDM_cooc.W.PET IDM_norm_cooc.W.PET
## 1                1.2610062     0.98263103           1.2610065
## 2               -0.2462824    -0.08803608          -0.1919857
## 3               -0.8564369    -0.91054172          -0.9835407
##   Inv_var_cooc.W.PET Correlation_cooc.W.PET Autocorrelation_cooc.W.PET
## 1          1.0707077              1.0072099                 0.4694111
## 2         -0.1191630             -0.3424528                -0.3622375
## 3         -0.9377635             -0.3429057                 0.3145434
##   Tendency_cooc.W.PET Shade_cooc.W.PET Prominence_cooc.W.PET IC1_d.W.PET
## 1           0.4525392        0.1989252             0.2390007  -0.2468033
## 2          -0.3286516       -0.1931742            -0.2587149   0.3873344
## 3           0.2550944        0.2261518             0.3340363  -0.6262563
```

```
##   IC2_d.W.PET Coarseness_vdif.W.PET Contrast_vdif.W.PET Busyness_vdif.W.PET
## 1   1.2471245             0.7401759           0.7737748           0.4578856
## 2  -0.3973578             0.1744151          -0.2219072          -0.1647786
## 3  -0.4870084            -1.2493989          -0.3598249          -0.1345930
##   Complexity_vdif.W.PET Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET
## 1             0.3704793          0.56801686       1.2610062       1.2135624
## 2            -0.3066483         -0.09774272      -0.2823784      -0.2477785
## 3             0.2968367         -0.41666689      -0.7719393      -0.7990212
##   GLNU_align.W.PET RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET
## 1        0.4937597        0.4140726      1.2610062       0.77507770
## 2       -0.3664176       -0.4106382     -0.3197891       0.04876726
## 3        0.2966597        0.4907296     -0.6843643      -0.99492983
##   HGRE_align.W.PET LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET
## 1        0.4727298         0.8185419         0.4623397        0.62500029
## 2       -0.3650626         0.0359557        -0.3577645        0.07777343
## 3        0.3173854        -1.0143302         0.3121082       -0.89228814
##   HGLRE_align.W.PET GLNU_norm_align.W.PET RLNU_norm_align.W.PET
## 1         0.4929801            0.82077967             1.2610062
## 2        -0.3797422            0.09076661            -0.3834814
## 3         0.3287373           -1.14518054            -0.5352664
##   GLVAR_align.W.PET RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET
## 1         0.4835994        0.69580736           1.2610062  1.2610062
## 2        -0.3403325        0.03915467          -0.5741016 -0.3787938
## 3         0.2471427       -0.88234771          -0.0890419 -0.5462398
##    LZSE.W.PET LGLZE.W.PET HGLZE.W.PET SZLGE.W.PET SZHGE.W.PET LZLGE.W.PET
## 1  0.61893278  0.80676466   0.4779095  0.92755803   0.4676471   0.3732041
## 2 -0.05497139  0.03611711  -0.3615562  0.01378553  -0.3414232   0.1222846
## 3 -0.57464968 -1.00132489   0.3032912 -1.08631389   0.2678236  -0.7103528
##   LZHGE.W.PET GLNU_area.W.PET ZSNU.W.PET  ZSP.W.PET GLNU_norm.W.PET
## 1   0.5384512       0.4988679  0.3927581  1.2540128      0.84243633
## 2  -0.3858164      -0.3916938 -0.3954672 -0.4244237      0.07912406
## 3   0.2912848       0.3500241  0.4794367 -0.4314773     -1.14253625
##   ZSNU_norm.W.PET GLVAR_area.W.PET ZSVAR.W.PET Entropy_area.W.PET Min_hist.ADC
## 1       1.2464255        0.4771697  0.39476218         1.26100621    0.5364140
## 2      -0.4345812       -0.3295647  0.05368149        -0.58825341   -0.1380119
## 3      -0.3990774        0.2292427 -0.57425688        -0.05591386   -0.2864881
##   Max_hist.ADC Mean_hist.ADC Variance_hist.ADC Standard_Deviation_hist.ADC
## 1    1.2561211     1.2505455        0.69994940                   1.1316575
## 2   -0.4114837    -0.4407905       -0.09472315                  -0.2638962
## 3   -0.4641644    -0.3892240       -0.57365875                  -0.6682174
##   Skewness_hist.ADC Kurtosis_hist.ADC Energy_hist.ADC Entropy_hist.ADC
## 1        0.44308961        0.29508771       0.8093408        1.2610062
## 2       -0.18767783       -0.16671301       0.1307215       -0.4219947
## 3       -0.06417418        0.05493307      -1.2257127       -0.4451103
##   AUC_hist.ADC Volume.ADC X3D_surface.ADC ratio_3ds_vol.ADC
## 1    1.2610066  0.5077740       0.6206037         1.0668403
## 2   -0.2621283 -0.4233601      -0.2753462        -0.1974654
## 3   -0.8193435  0.4140316      -0.0606709        -0.7500699
##   ratio_3ds_vol_norm.ADC irregularity.ADC Compactness_v1.ADC Compactness_v2.ADC
## 1              1.2610062        1.2610062         1.06245022          1.1027687
## 2             -0.3699450       -0.3304811         0.03142066         -0.2321898
## 3             -0.5669541       -0.6593353        -1.28088272         -0.7096110
##   Spherical_disproportion.ADC Sphericity.ADC Asphericity.ADC Center_of_mass.ADC
## 1                   1.2610062      1.2610062       1.1346735         0.45185687
```

```
## 2                 -0.3699450     -0.2588976      -0.3557791        -0.08729681
## 3                 -0.5669541     -0.8269058      -0.4565552        -0.30911982
##   Max_3D_diam.ADC Major_axis_length.ADC Minor_axis_length.ADC
## 1       0.9507846             1.0978355             0.9858357
## 2      -0.3644002            -0.4005435            -0.3813531
## 3      -0.2274094            -0.3099045            -0.2275549
##   Least_axis_length.ADC Elongation.ADC Flatness.ADC Max_cooc.L.ADC
## 1             0.9159888      1.2575906    1.2290955     0.90345319
## 2            -0.3769359     -0.4157332   -0.4105727     0.08253485
## 3            -0.1585236     -0.4558866   -0.4355862    -1.21985793
##   Average_cooc.L.ADC Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC
## 1          1.2537804           0.8859954          1.2610062       1.1659338
## 2         -0.4661050          -0.1419750         -0.3451227      -0.2977163
## 3         -0.3336411          -0.6744625         -0.6250607      -0.6279979
##   DVAR_cooc.L.ADC DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC
## 1       0.8758394       1.2610062       1.2537804       0.8589402
## 2      -0.1347764      -0.3058882      -0.4662314      -0.1329086
## 3      -0.6797727      -0.7169051      -0.3333451      -0.6649414
##   SENT_cooc.L.ADC ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## 1       1.0164629      0.8376521           0.8140680                1.1659338
## 2      -0.3230180      0.1097121          -0.1426598               -0.2977163
## 3      -0.3989158     -1.2087035          -0.5911236               -0.6279979
##   Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## 1           1.2587946                1.2610066      1.2124027
## 2          -0.2645293               -0.1704452     -0.2355299
## 3          -0.8112094               -1.0339652     -0.8263762
##   IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## 1           1.2610062          1.2201921              1.0215036
## 2          -0.1049439         -0.2449825             -0.2080744
## 3          -1.1872975         -0.8131001             -0.6737162
##   Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC Prominence_cooc.L.ADC
## 1              1.0573171           0.8589402   0.23801119           0.536698976
## 2             -0.3809032          -0.1329086  -0.08932906           0.009646047
## 3             -0.3098370          -0.6649414  -0.06135605          -0.632465720
##   IC1_.L.ADC IC2_.L.ADC Coarseness_vdif_.L.ADC Contrast_vdif_.L.ADC
## 1 -0.5808334  1.2497107              0.7062694          0.673943788
## 2  0.4224645 -0.2431110              0.1832338         -0.004267165
## 3 -0.3289130 -0.8510251             -1.2315126         -0.755856168
##   Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC Strength_vdif_.L.ADC
## 1            0.6868307              1.1396278           0.40022386
## 2           -0.1267904             -0.2880789          -0.04141227
## 3           -0.4836846             -0.6206652          -0.35785747
##   SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC RLNU_align.L.ADC
## 1      1.26100689       1.2610062      0.487777562       0.50586065
## 2     -0.08703695      -0.2827799     -0.240932986      -0.22553738
## 3     -1.22921678      -0.7709996      0.009709534      -0.04687914
##   RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC LGSRE_align.L.ADC
## 1      1.2610062        0.7921281        1.1320453          0.793452
## 2     -0.1057014        0.1449922       -0.3947405          0.144266
## 3     -1.1855243       -1.2395592       -0.3623635         -1.239364
##   HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC GLNU_norm_align.L.ADC
## 1         1.1340029         0.7790980         1.1316036            1.16474183
## 2        -0.3915385         0.1519871        -0.4122198           -0.04116189
## 3        -0.3720836        -1.2411265        -0.3209441           -1.22721402
```

```
##   RLNU_norm_align.L.ADC GLVAR_align.L.ADC RLVAR_align.L.ADC Entropy_align.L.ADC
## 1             1.2610066         0.9365524        1.07762492           1.2610062
## 2            -0.1605091        -0.1603817       -0.09828869          -0.2952016
## 3            -1.0572248        -0.6888250       -0.99448887          -0.7419215
##   SZSE.L.ADC LZSE.L.ADC LGLZE.L.ADC HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC
## 1  1.2610065  1.2013018   0.8017407   1.1489979   0.8036711   1.1441480
## 2 -0.1626442 -0.3956262   0.1400977  -0.4020896   0.1377293  -0.3952206
## 3 -1.0522267 -0.4389908  -1.2390250  -0.3644243  -1.2356743  -0.3749926
##   LZLGE.L.ADC LZHGE.L.ADC GLNU_area.L.ADC ZSNU.L.ADC  ZSP.L.ADC GLNU_norm.L.ADC
## 1   0.7000477   1.0764639     0.493310907  0.5103219  1.2610062      1.15835965
## 2   0.1873437  -0.4083600    -0.238174927 -0.2279717 -0.2354227     -0.03059644
## 3  -1.2340635  -0.2673208    -0.003034725 -0.0462503 -0.8818584     -1.24469430
##   ZSNU_norm.L.ADC GLVAR_area.L.ADC ZSVAR.L.ADC Entropy_area.L.ADC
## 1       1.2610063        0.9497431   0.7545401          1.2610062
## 2      -0.2522613       -0.1628163  -0.2001315         -0.3142415
## 3      -0.8424410       -0.6981154  -0.3889422         -0.6973508
##   Max_cooc.H.ADC Average_cooc.H.ADC Variance_cooc.H.ADC Entropy_cooc.H.ADC
## 1      0.8212163          1.2610062           1.2610062          1.2610062
## 2      0.1227091         -0.4134314          -0.4431704         -0.5071259
## 3     -1.2204511         -0.4651563          -0.3955399         -0.2458259
##   DAVE_cooc.H.ADC DVAR_cooc.H.ADC DENT_cooc.H.ADC SAVE_cooc.H.ADC
## 1       1.2610062       1.2584940       1.2610060       1.2610062
## 2      -0.4365730      -0.4225223      -0.4037945      -0.4165922
## 3      -0.4109838      -0.4410205      -0.4877151      -0.4577571
##   SVAR_cooc.H.ADC SENT_cooc.H.ADC ASM_cooc.H.ADC Contrast_cooc.H.ADC
## 1       1.2610062       1.2610062      0.8100568           1.2128288
## 2      -0.3760006      -0.4058169      0.1277874          -0.4344390
## 3      -0.5527784      -0.4829811     -1.2196578          -0.3612323
##   Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC Inv_diff_norm_cooc.H.ADC
## 1                1.2610062            1.260690                1.2610062
## 2               -0.4365730           -0.107623               -0.1089863
## 3               -0.4109838           -1.180666               -1.1778345
##   IDM_cooc.H.ADC IDM_norm_cooc.H.ADC Inv_var_cooc.H.ADC Correlation_cooc.H.ADC
## 1     1.23952812          1.26100621         1.24254086              1.0181188
## 2    -0.08635799         -0.09385398        -0.07470963             -0.2054811
## 3    -1.20639848         -1.21325796        -1.23708979             -0.6759406
##   Autocorrelation_cooc.H.ADC Tendency_cooc.H.ADC Shade_cooc.H.ADC
## 1                  1.2610062           1.2610062        0.3897301
## 2                 -0.3730721          -0.3760006       -0.1719959
## 3                 -0.5596337          -0.5527784       -0.0402483
##   Prominence_cooc.H.ADC IC1_d.H.ADC IC2_d.H.ADC Coarseness_vdif.H.ADC
## 1             1.2610062  -0.4668555   1.2582578             0.7052453
## 2            -0.3866573   0.3519148  -0.2796836             0.1823866
## 3            -0.5278320  -0.2932829  -0.7751245            -1.2283655
##   Contrast_vdif.H.ADC Busyness_vdif.H.ADC Complexity_vdif.H.ADC
## 1           1.2606890           0.6097390             1.2551479
## 2          -0.4189158          -0.1962940            -0.4478493
## 3          -0.4519574          -0.2333788            -0.3779299
##   Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC GLNU_align.H.ADC
## 1          0.35354067      1.26100647       1.2610062       0.51456579
## 2         -0.03718193     -0.06277931      -0.1428652      -0.22768808
## 3         -0.31471124     -1.28600125      -1.0985272      -0.05173676
##   RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC HGRE_align.H.ADC
## 1       0.51690981     1.26100654       1.04219323        1.2610062
```

```
## 2      -0.23013578    -0.06806875       0.03987414       -0.3712255
## 3      -0.04867056    -1.27361922      -1.27765222       -0.5639565
##   LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC HGLRE_align.H.ADC
## 1        1.03407602         1.2610062       1.104277676         1.2610062
## 2        0.04337941        -0.4115386       0.007475531        -0.4446970
## 3       -1.27663363        -0.4695871      -1.272360535        -0.3919663
##   GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC GLVAR_align.H.ADC
## 1            0.98723733              1.261007         1.2610062
## 2            0.05820082             -0.098490        -0.4161673
## 3           -1.25810344             -1.202406        -0.4587517
##   RLVAR_align.H.ADC Entropy_align.H.ADC SZSE.H.ADC LZSE.H.ADC LGLZE.H.ADC
## 1       1.074153583           1.2610065  1.2610069  1.2610685  1.02590149
## 2       0.006019786          -0.3110083 -0.1278884 -0.3011638  0.04242133
## 3      -1.234720843          -0.7049199 -1.1335874 -0.7280354 -1.26510163
##   HGLZE.H.ADC SZLGE.H.ADC SZHGE.H.ADC  LZLGE.H.ADC LZHGE.H.ADC GLNU_area.H.ADC
## 1   1.2610062  0.99516588   1.2610062  1.043730718   1.2600443       0.5145991
## 2  -0.3455989  0.05397137  -0.4144067 -0.003059701  -0.3705110      -0.2300161
## 3  -0.6239460 -1.25721240  -0.4628732 -1.178895154  -0.5645359      -0.0463249
##    ZSNU.H.ADC  ZSP.H.ADC GLNU_norm.H.ADC ZSNU_norm.H.ADC GLVAR_area.H.ADC
## 1  0.51727138  1.2610069      0.98719188       1.2610069        1.2610062
## 2 -0.23482238 -0.1850766      0.05953909      -0.2387489       -0.4428720
## 3 -0.03811053 -0.9997149     -1.26118455      -0.8740728       -0.3962385
##   ZSVAR.H.ADC Entropy_area.H.ADC Max_cooc.W.ADC Average_cooc.W.ADC
## 1  0.81981081          1.2610062      0.8108473          1.0315968
## 2 -0.02620128         -0.3481281      0.1290821         -0.3723147
## 3 -0.87026837         -0.6180253     -1.2235870         -0.3007142
##   Variance_cooc.W.ADC DAVE_cooc.W.ADC DVAR_cooc.W.ADC DENT_cooc.W.ADC
## 1          0.67023569       1.1723403      0.72522689       1.2610062
## 2         -0.08008876      -0.2961704     -0.09076978      -0.3067316
## 3         -0.57415096      -0.6388969     -0.61163767      -0.7149309
##   SAVE_cooc.W.ADC SVAR_cooc.W.ADC SENT_cooc.W.ADC ASM_cooc.W.ADC
## 1       1.0329682      0.62016420       0.9908981      0.8100633
## 2      -0.3680932     -0.07792817      -0.3284037      0.1276739
## 3      -0.3121548     -0.52230929      -0.3572574     -1.2193996
##   Contrast_cooc.W.ADC Dissimilarity_cooc.W.ADC Inv_diff_cooc.W.ADC
## 1           0.7421931                1.1723403           1.1933853
## 2          -0.1102574               -0.2961704          -0.1119249
## 3          -0.5852988               -0.6388969          -1.0941138
##   Inv_diff_norm_cooc.W.ADC IDM_cooc.W.ADC IDM_norm_cooc.W.ADC
## 1                1.2610062     1.19959202            1.261006
## 2               -0.1707681    -0.09023132           -0.106168
## 3               -1.0332091    -1.15194943           -1.184432
##   Inv_var_cooc.W.ADC Correlation_cooc.W.ADC Autocorrelation_cooc.W.ADC
## 1         1.19165885              1.0212158                  0.7154998
## 2        -0.09551775             -0.2088642                 -0.2458585
## 3        -1.13055941             -0.6715404                 -0.2375357
##   Tendency_cooc.W.ADC Shade_cooc.W.ADC Prominence_cooc.W.ADC IC1_d.W.ADC
## 1          0.62016420       0.18632920             0.3042644 -0.59736087
## 2         -0.07792817      -0.08233801             0.0284408  0.32940186
## 3         -0.52230929      -0.01899192            -0.4123323 -0.09228064
##   IC2_d.W.ADC Coarseness_vdif.W.ADC Contrast_vdif.W.ADC Busyness_vdif.W.ADC
## 1   1.2610062             0.7350778          0.67072573          0.98767477
## 2  -0.2634185             0.1694735         -0.03596539         -0.01152585
## 3  -0.8163227            -1.2320377         -0.67799661         -1.09537673
```

```
##   Complexity_vdif.W.ADC Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC
## 1             0.4930819          0.58013345      1.26100621       1.2610062
## 2            -0.1148090         -0.04369006     -0.05920658      -0.1167717
## 3            -0.2915629         -0.55696810     -1.29436439      -1.1596097
##   GLNU_align.W.ADC RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC
## 1       0.56966346       0.50445226     1.26100621        0.7924356
## 2      -0.28927950      -0.22823909    -0.06050738        0.1438929
## 3       0.02983217      -0.03895424    -1.29131932       -1.2373352
##   HGRE_align.W.ADC LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC
## 1        0.7336310         0.7948126         0.7333584         0.7785801
## 2       -0.2417845         0.1424456        -0.2405162         0.1510334
## 3       -0.2676759        -1.2366483        -0.2703353        -1.2383055
##   HGLRE_align.W.ADC GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC
## 1         0.7403751             0.9389794            1.26100657
## 2        -0.2442399             0.0744557           -0.07240495
## 3        -0.2695919            -1.2413161           -1.26346860
##   GLVAR_align.W.ADC RLVAR_align.W.ADC Entropy_align.W.ADC  SZSE.W.ADC
## 1        0.71036498        1.01043022           1.2610062  1.26100648
## 2       -0.09723098        0.03271082          -0.4314584 -0.09517497
## 3       -0.57962404       -1.22478921          -0.4229567 -1.21016596
##   LZSE.W.ADC LGLZE.W.ADC HGLZE.W.ADC SZLGE.W.ADC SZHGE.W.ADC LZLGE.W.ADC
## 1  1.2610062   0.7980986   0.7339098   0.8025415   0.7322124   0.7159958
## 2 -0.2381821   0.1397825  -0.2416793   0.1360943  -0.2403086   0.1828247
## 3 -0.8753990  -1.2341484  -0.2682391  -1.2305634  -0.2695190  -1.2416075
##   LZHGE.W.ADC GLNU_area.W.ADC  ZSNU.W.ADC  ZSP.W.ADC GLNU_norm.W.ADC
## 1   0.7570032      0.57324783  0.49289235  1.2610062      0.92051780
## 2  -0.2543883     -0.29235655 -0.22628969 -0.1099935      0.08404481
## 3  -0.2647312      0.03296213 -0.03038134 -1.1754768     -1.24278422
##   ZSNU_norm.W.ADC GLVAR_area.W.ADC ZSVAR.W.ADC Entropy_area.W.ADC
## 1       1.2610062        0.7174119  1.02332617          1.2610062
## 2      -0.1529165       -0.1004131 -0.03697058         -0.3865660
## 3      -1.0749981       -0.5801828 -1.07632587         -0.5280456
##
## Clustering vector:
##   [1] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [38] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [75] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 3 2 3 3 3 2 2 2 3 3 3 3 2 2 2 2 2
## [112] 2 3 3 2 2 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 2 3 3 3 2 3 3 3 3 3 3 3 1
## [149] 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
## [186] 1 1 1 1 1 1 1 1 1 1 1 1
##
## Within cluster sum of squares by cluster:
## [1] 13419.94 24997.15 10412.77
##  (between_SS / total_SS =  41.9 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
clusters <- kmeans(radiomicsdf, centers = 3, iter.max = 100, nstart = 100)
```

## Hence,

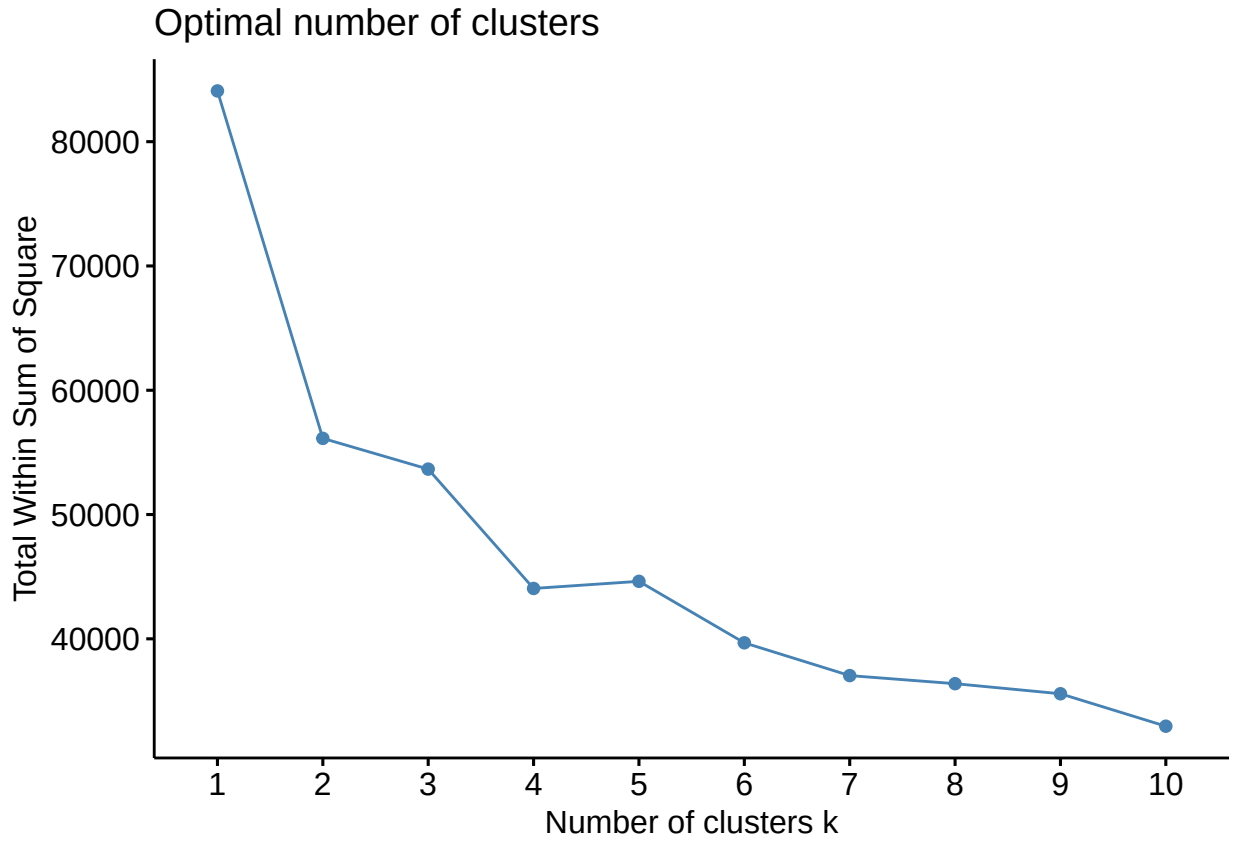
Within cluster sum of squares by cluster: [1] 10412.77 24997.15 13419.94 (between_SS / total_SS = 41.9 %)

Available components:

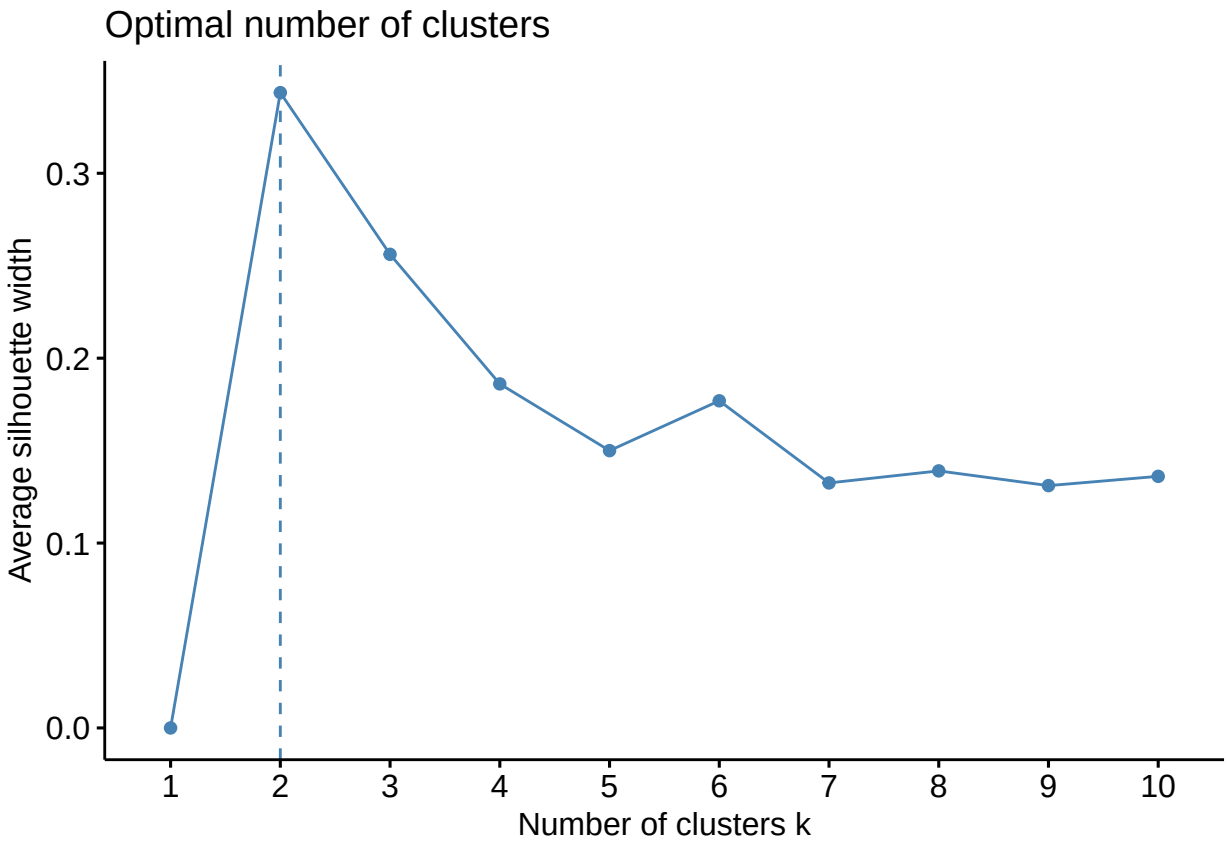
[1] “cluster” “centers” “totss” “withinss”
[5] “tot.withinss” “betweenss” “size” “iter”
[9] “ifault”

# DETERMINING AND VISUALIZING OPTIMAL NUMBER OF CLUSTERS

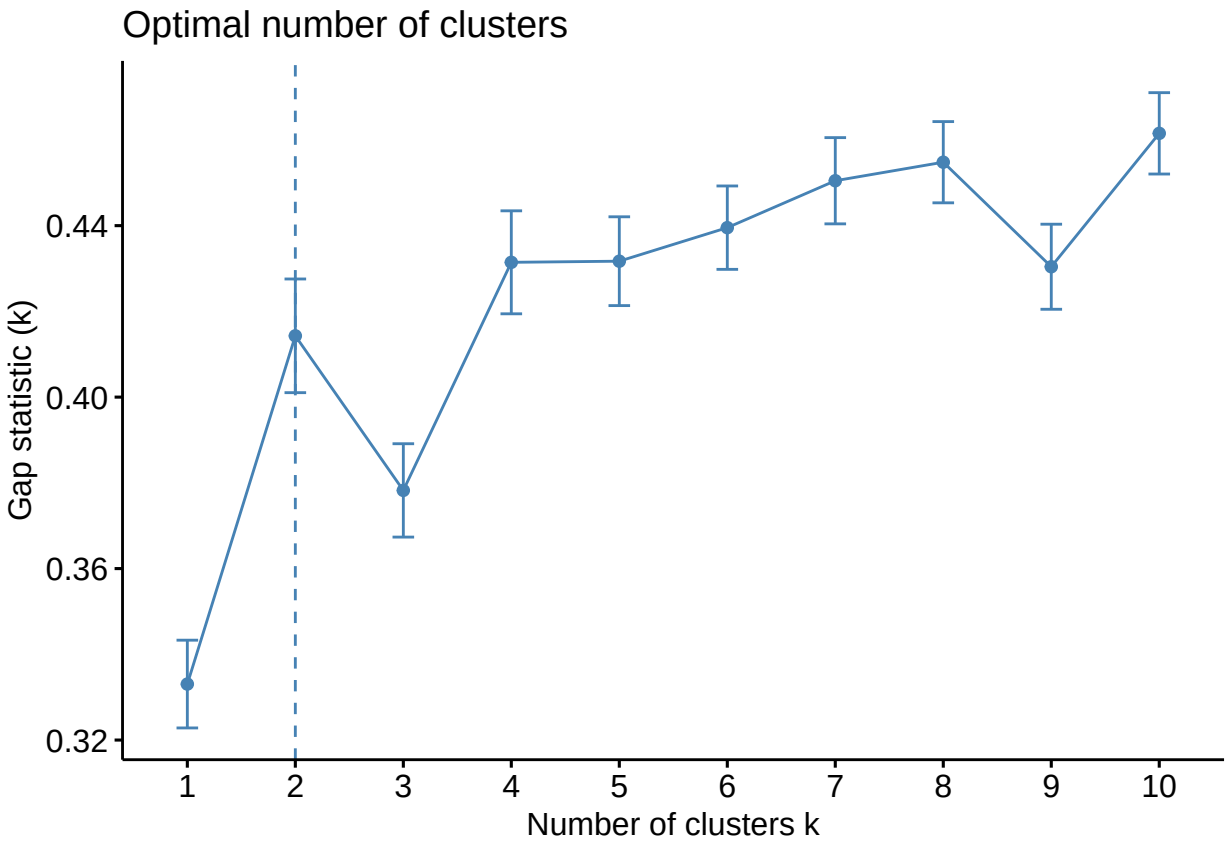
```
set.seed(123) # Determining Optimal Number of Clusters

fviz_nbclust(radiomicsdf, kmeans, method = "wss")
```



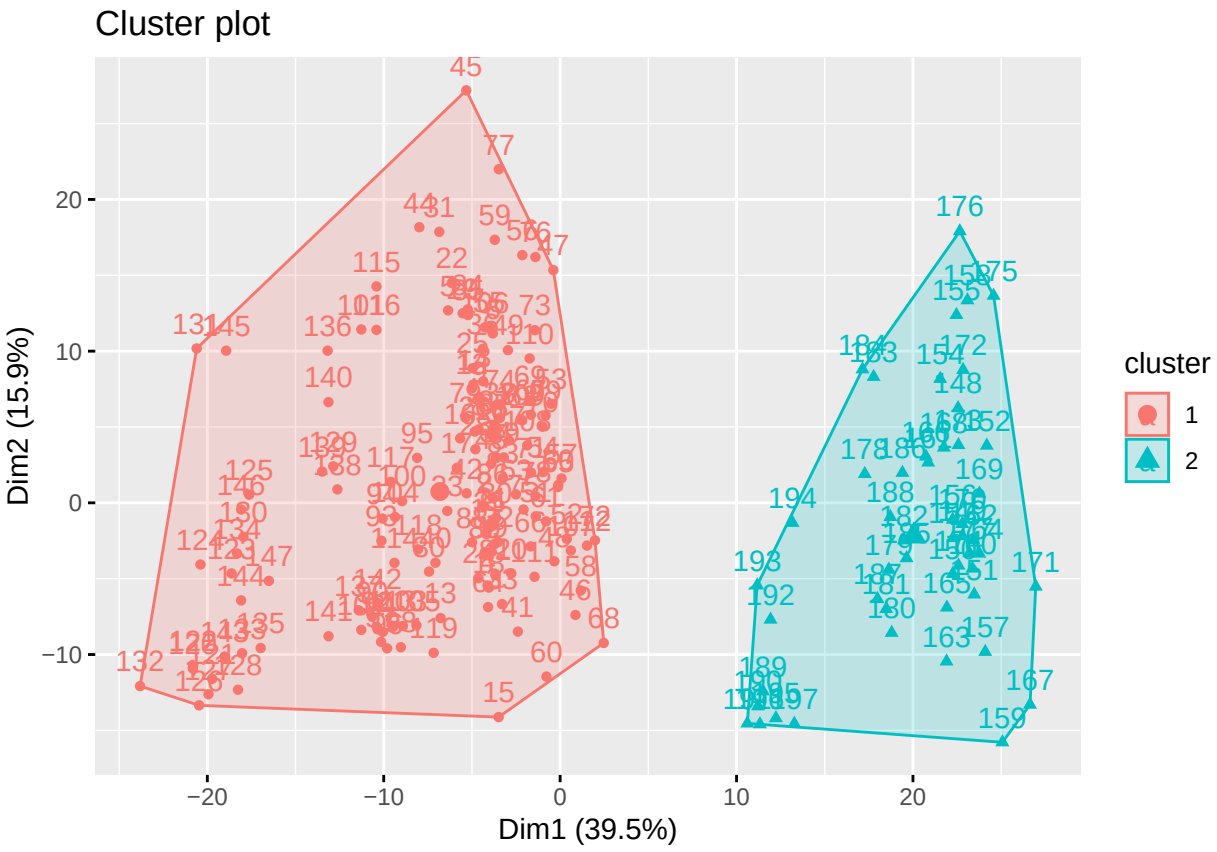

```
fviz_nbclust(radiomicsdf, kmeans, method = "silhouette")
```




```
fviz_nbclust(radiomicsdf, kmeans, method = "gap_stat")
```




```
clusters <- kmeans(radiomicsdf, centers = 2, iter.max = 100, nstart = 100)
fviz_cluster(kmeans(radiomicsdf, centers = 2, iter.max = 100, nstart = 100), data = radiomicsdf)
```



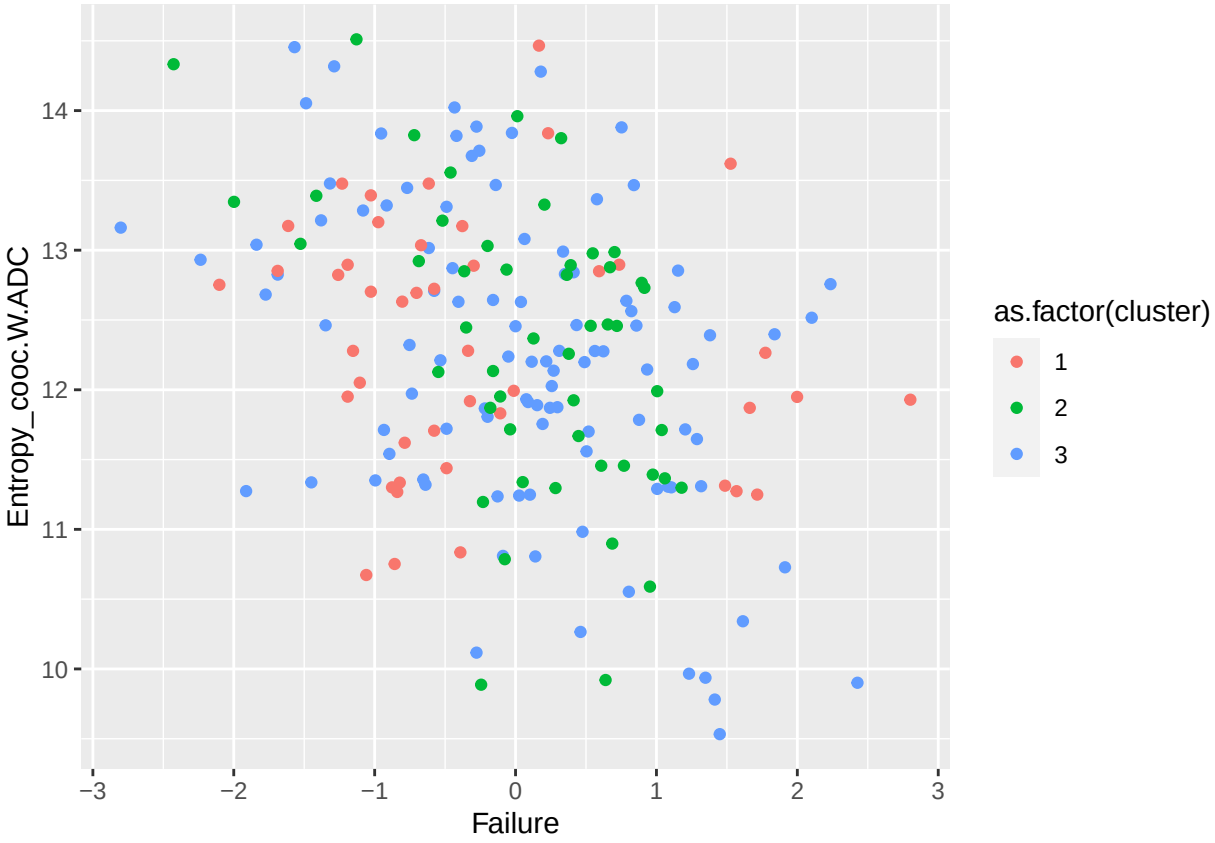

## QUALITY OF K-MEANS PARTITION

```
clusters$betweenss / clusters$totss
```

```
## [1] 0.3324795
```

## VISUALIZING CLUSTERS USING ORIGINAL VARIABLES

```
clusters <- kmeans(radiomicsdf, centers = 3, iter.max = 100, nstart = 100)
radiomicsdt <- radiomicsdt |> mutate(cluster = clusters$cluster)
radiomicsdt |> ggplot(aes(x = Failure, y = Entropy_cooc.W.ADC, col = as.factor(cluster))) + geom_point()
```



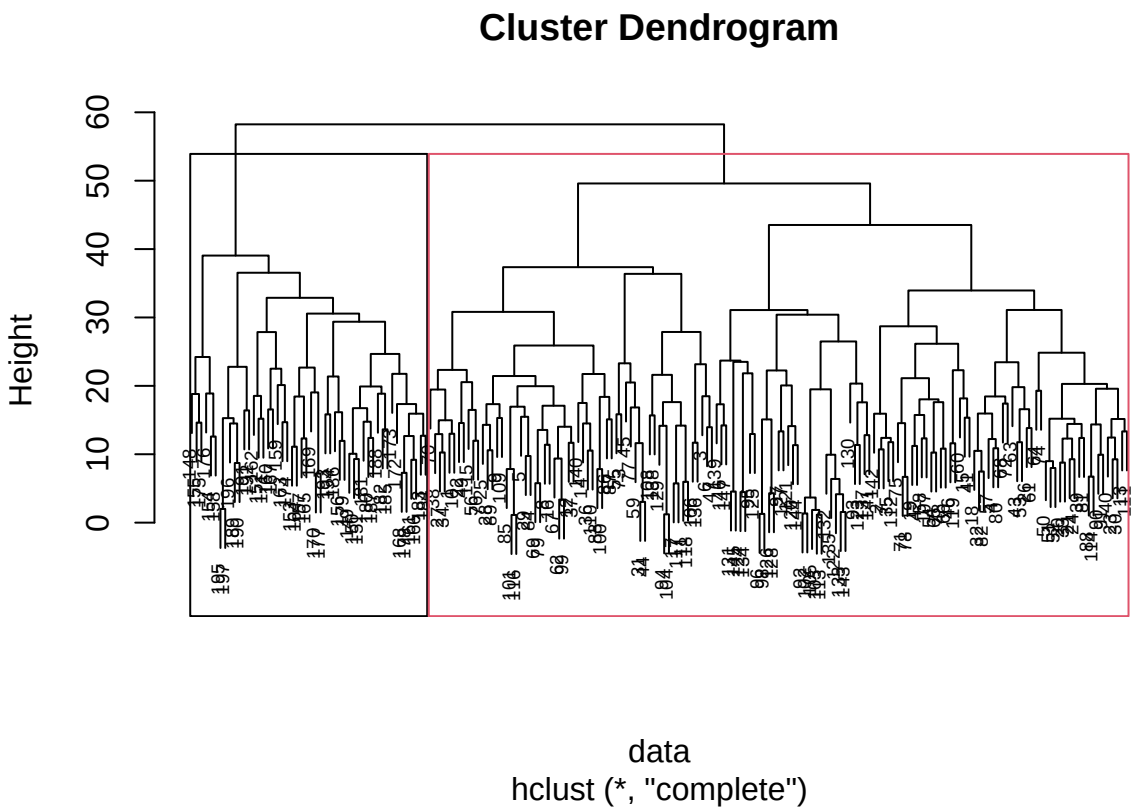

# (B) HEIRARCHICAL CLUSTERING

Hierarchical clustering is an alternative approach to k-means clustering for identifying groups in a data set. In contrast to k-means, hierarchical clustering will create a hierarchy of clusters and therefore does not require us to pre-specify the number of clusters. Furthermore, hierarchical clustering has an added advantage over k-means clustering in that its results can be easily visualized using an attractive tree-based representation called a dendrogram.

```
radiomicsdts <- radiomicsdt%>%
  select_if(is.numeric) %>%  # selecting numeric columns
  select(-Failure.binary) %>% # removing target column
  mutate_all(as.double) %>%
  scale()
data <- dist(radiomicsdts, method = "euclidean")
```

# USING COMPLETE LINKAGE

```
ht1 <- hclust(data, method = "complete")
plot(ht1, cex = 0.6)
rect.hclust(ht1, k = 2, border = 1:4)
```




# COMPUTING MAXIMUM LINKAGE CLUSTERING WITH AGNES

```
set.seed(123)
ht2 <- agnes(radiomicsdts, method = "complete")
ht2$ac
```

```
## [1] 0.8072963
```

# COMPUTING DIVISIVE HIERARCHICAL CLUSTERING

```
ht3 <- diana(radiomicsdts)
```

# DIVISE COEFFICIENT

```
ht3$dc
```

```
## [1] 0.7915983
```

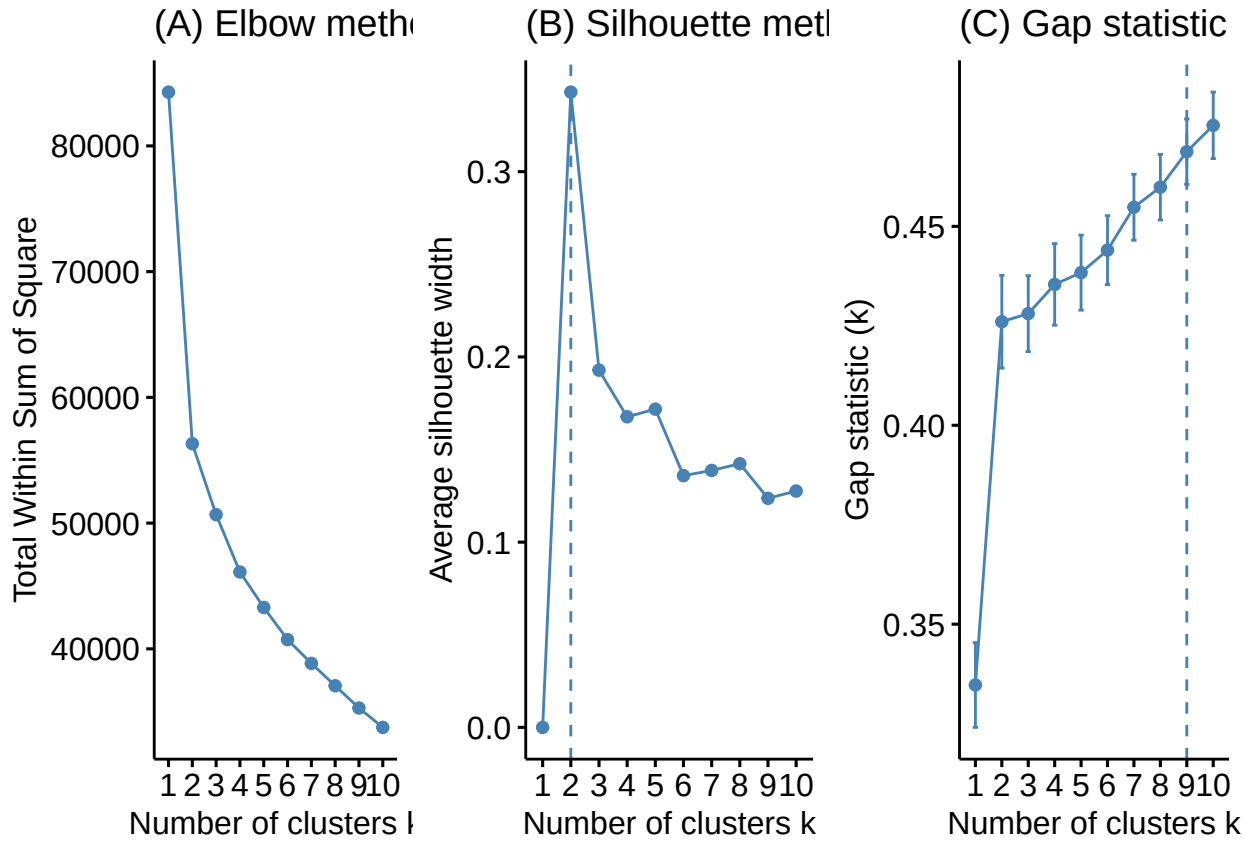
# PLOTTING CLUSTER RESULTS

```
plot1 <- fviz_nbclust(radiomicsdts, FUN = hcut, method = "wss",
                      k.max = 10) +
  ggtitle("(A) Elbow method")
plot2 <- fviz_nbclust(radiomicsdts, FUN = hcut, method = "silhouette",
```

```
                    k.max = 10) +
  ggtitle("(B) Silhouette method")
plot3 <- fviz_nbclust(radiomicsdts, FUN = hcut, method = "gap_stat",
                    k.max = 10) +
  ggtitle("(C) Gap statistic")
```

## DISPLAYING PLOT SIDE BY SIDE

```
gridExtra::grid.arrange(plot1, plot2, plot3, nrow = 1)
```




## WARDS METHOD

```
ht4 <- hclust(data, method = "ward.D2" )

#  Cuting tree into 4 groups

sub_grp <- cutree(ht4, k = 8)

# Number of members in each cluster

table(sub_grp)
```

```
## sub_grp
```

```
##  1  2  3  4  5  6  7  8
## 71 33 12 21 10 19 22  9
```

# (C) MODEL BASED CLUSTERING

Model-based clustering is a statistical approach to data clustering. The observed (multivariate) data is assumed to have been generated from a finite mixture of component models. Each component model is a probability distribution, typically a parametric multivariate distribution.

```
# APPLYING GMM MODEL WITH 3 COMPONENTS

model3 <- Mclust(radiomicsdf[,1:10], G=3)
summary(model3)
```

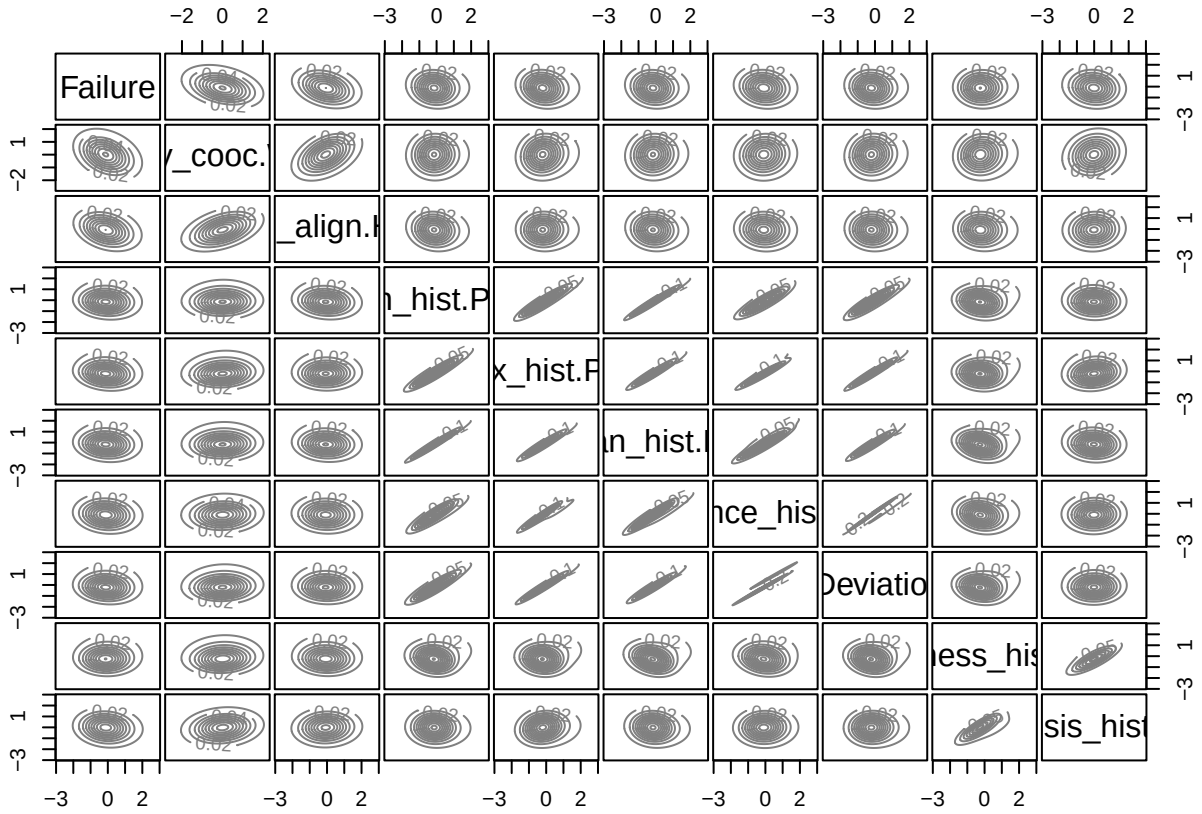
```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEE (ellipsoidal, equal shape and orientation) model with 3 components:
##
##  log-likelihood   n df       BIC      ICL
##       -1074.583 197 89 -2619.371 -2638.94
##
## Clustering table:
##   1   2   3
## 111  50  36
```

```
model4 = Mclust(radiomicsdf, 1:9)

summary(model4)
```

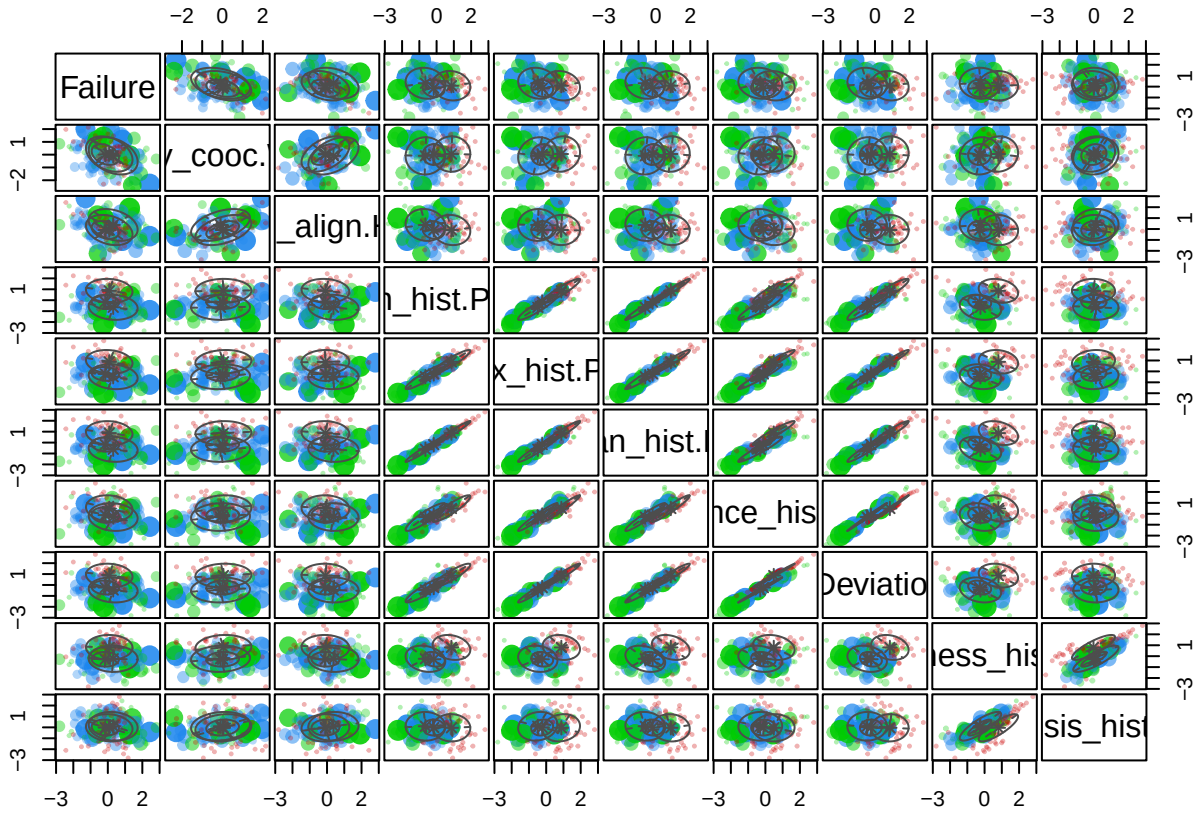
```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEI (diagonal, equal shape) model with 9 components:
##
##  log-likelihood   n   df       BIC       ICL
##       -77829.42 197 4306 -178408.3 -178408.3
##
## Clustering table:
##  1  2  3  4  5  6  7  8  9
## 32 29 25 11 21 41 19 10  9
```

# PLOTTING THE RESULTS

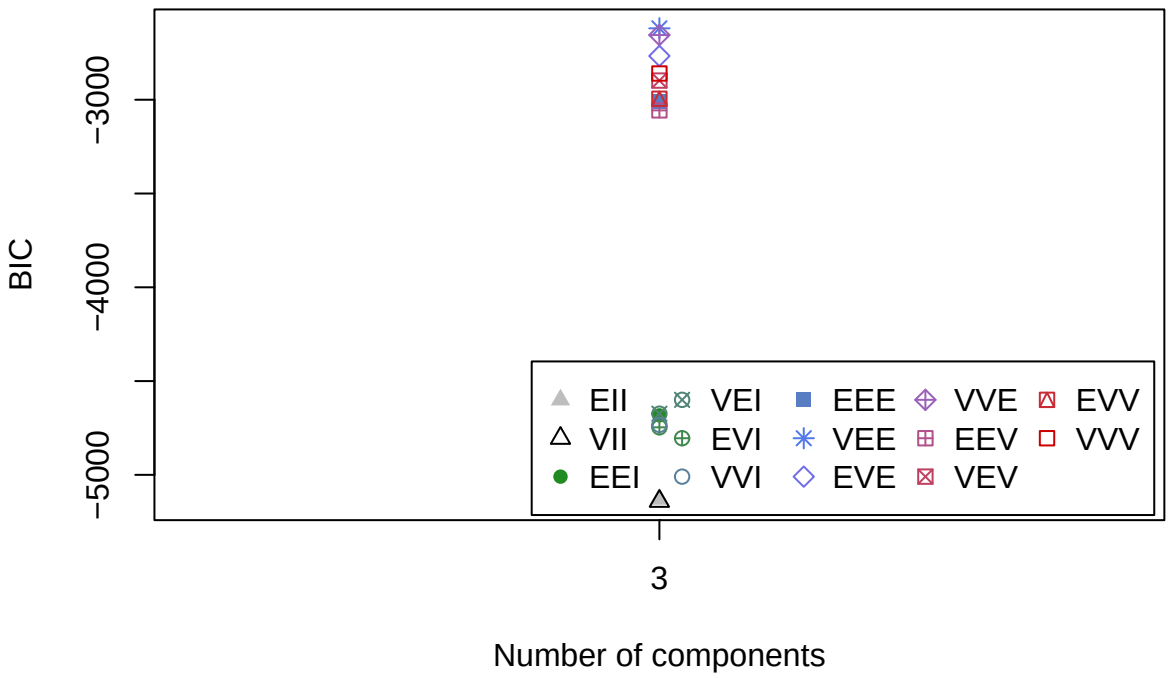
```
plot(model3, what = "density")
```



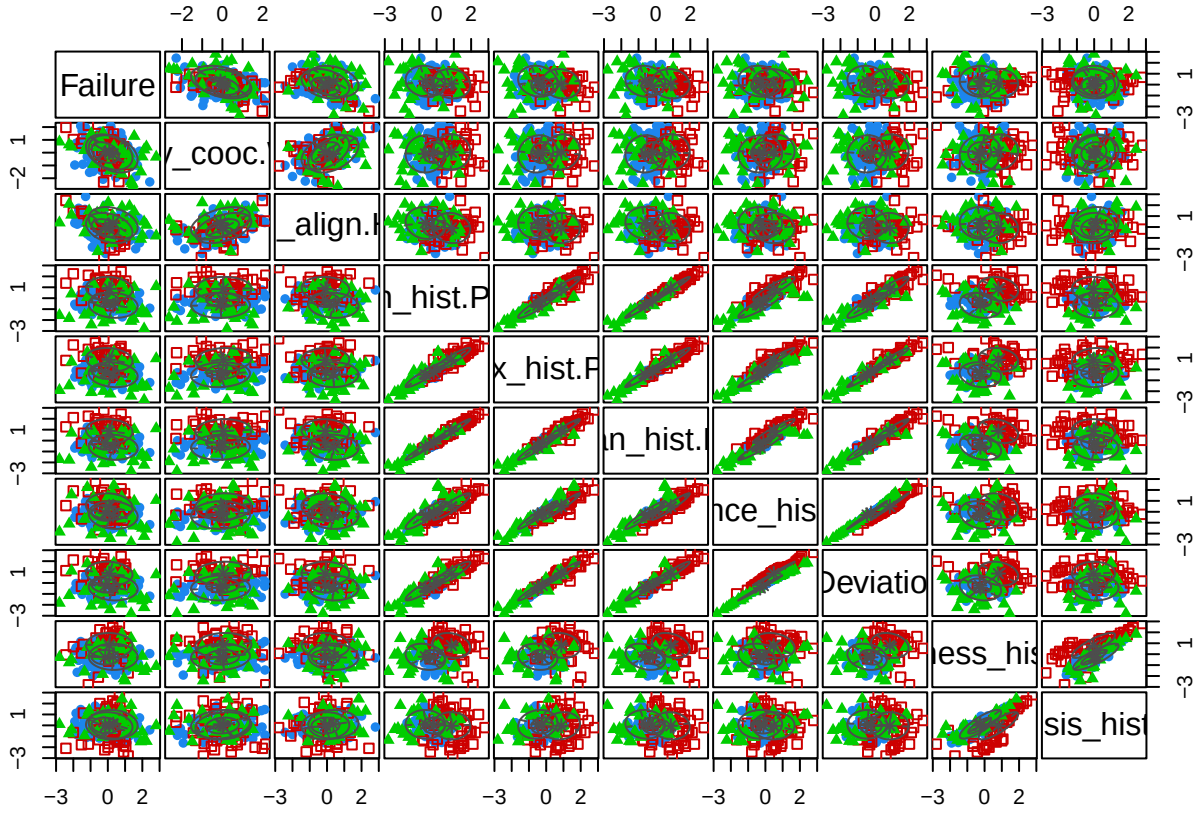

```
plot(model3, what = "uncertainty")
```



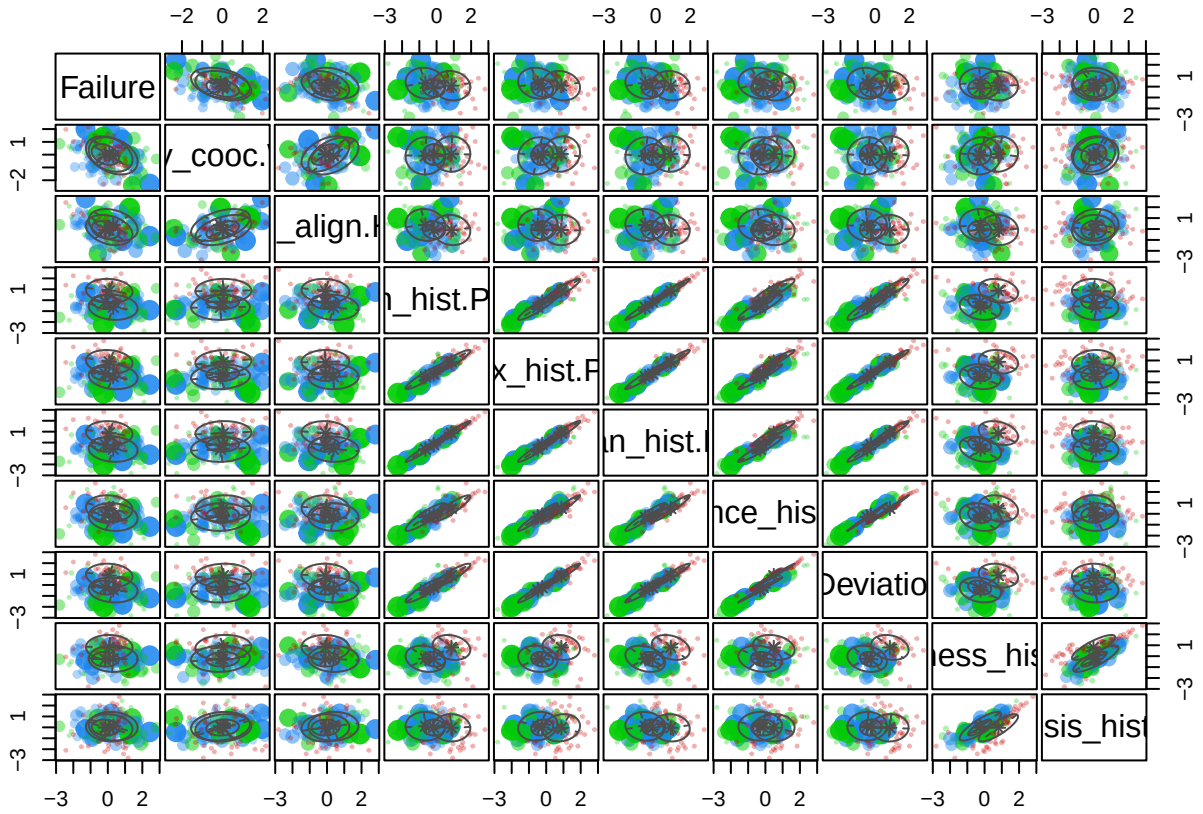

```
legend_args <- list(x = "bottomright", ncol = 5)
plot(model3, what = 'BIC', legendArgs = legend_args)
```




```
plot(model3, what = 'classification')
```

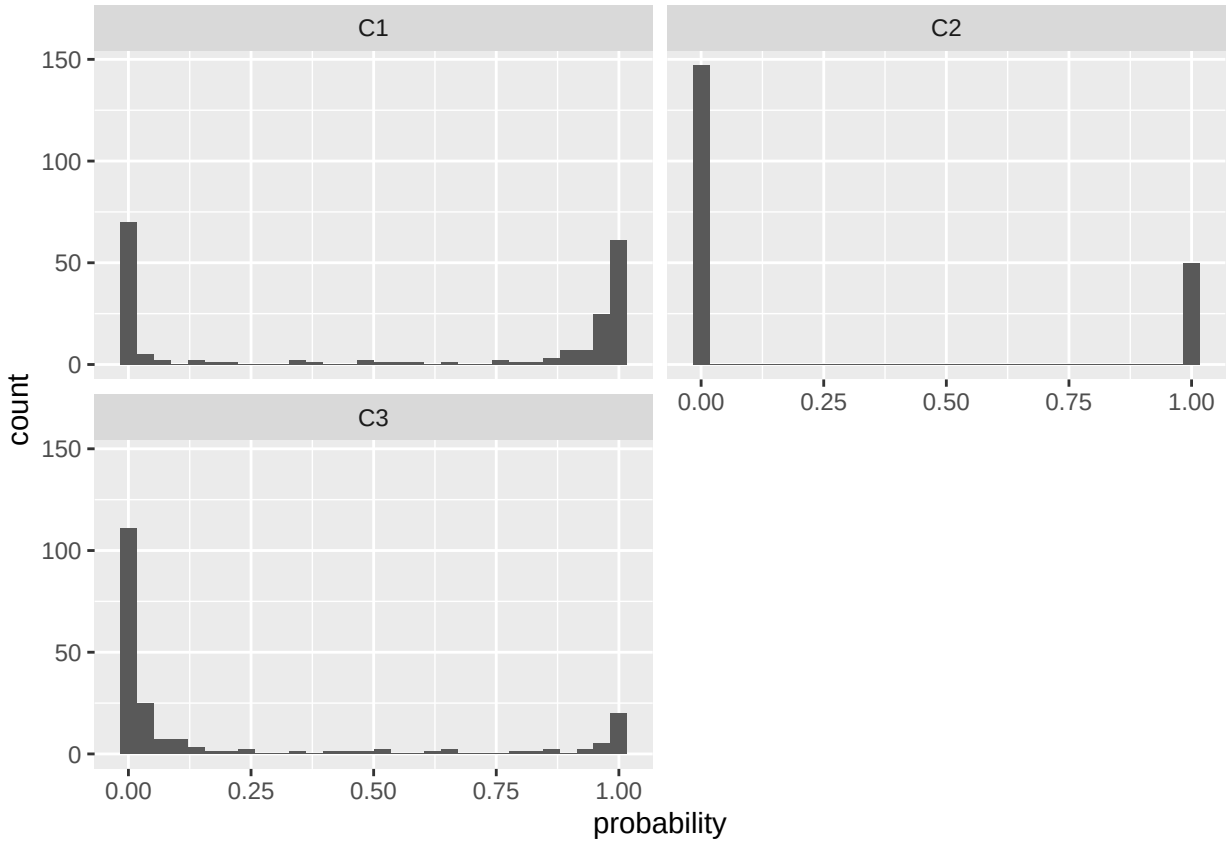



```
plot(model3, what = 'uncertainty')
```

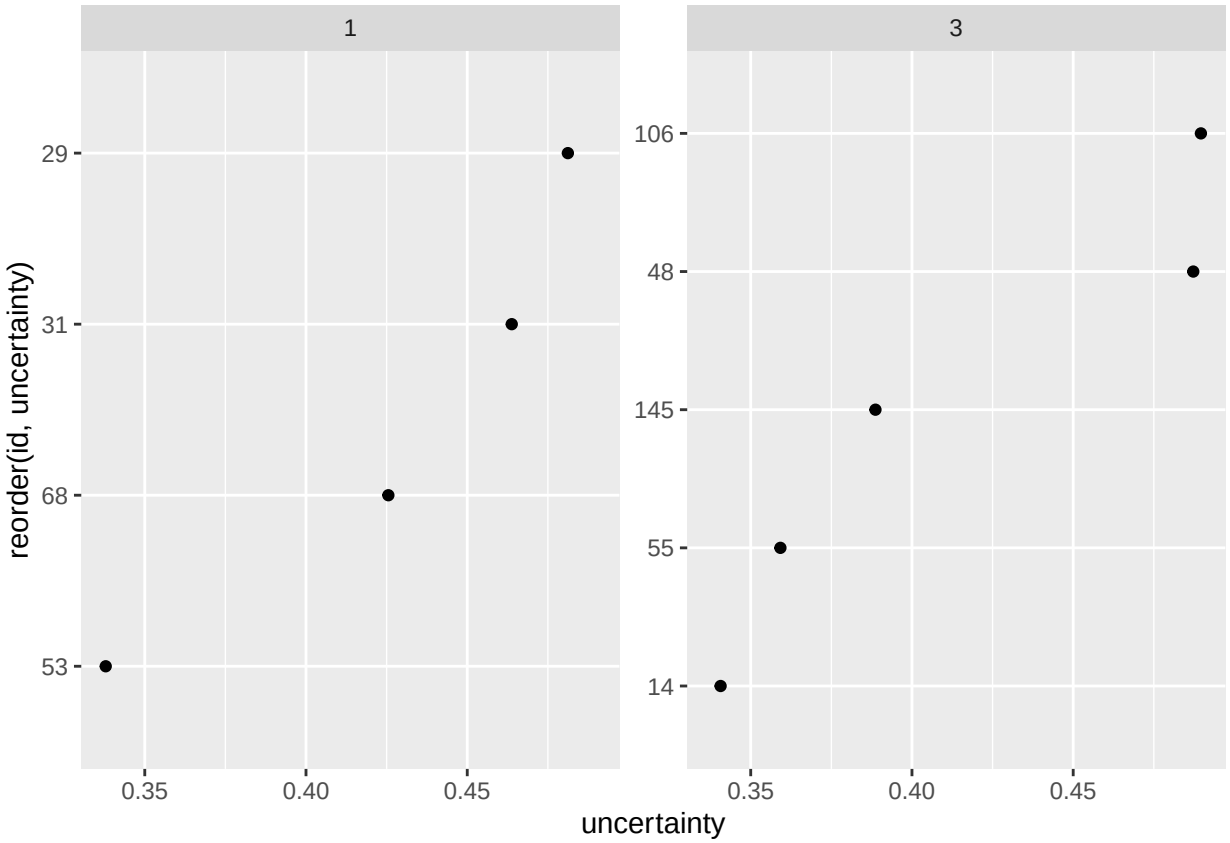



```
probabilities <- model3$z
colnames(probabilities) <- paste0('C', 1:3)

probabilities <- probabilities %>%
  as.data.frame() %>%
  mutate(id = row_number()) %>%
  tidyr::gather(cluster, probability, -id)

ggplot(probabilities, aes(probability)) +
  geom_histogram() +
  facet_wrap(~ cluster, nrow = 2)
```

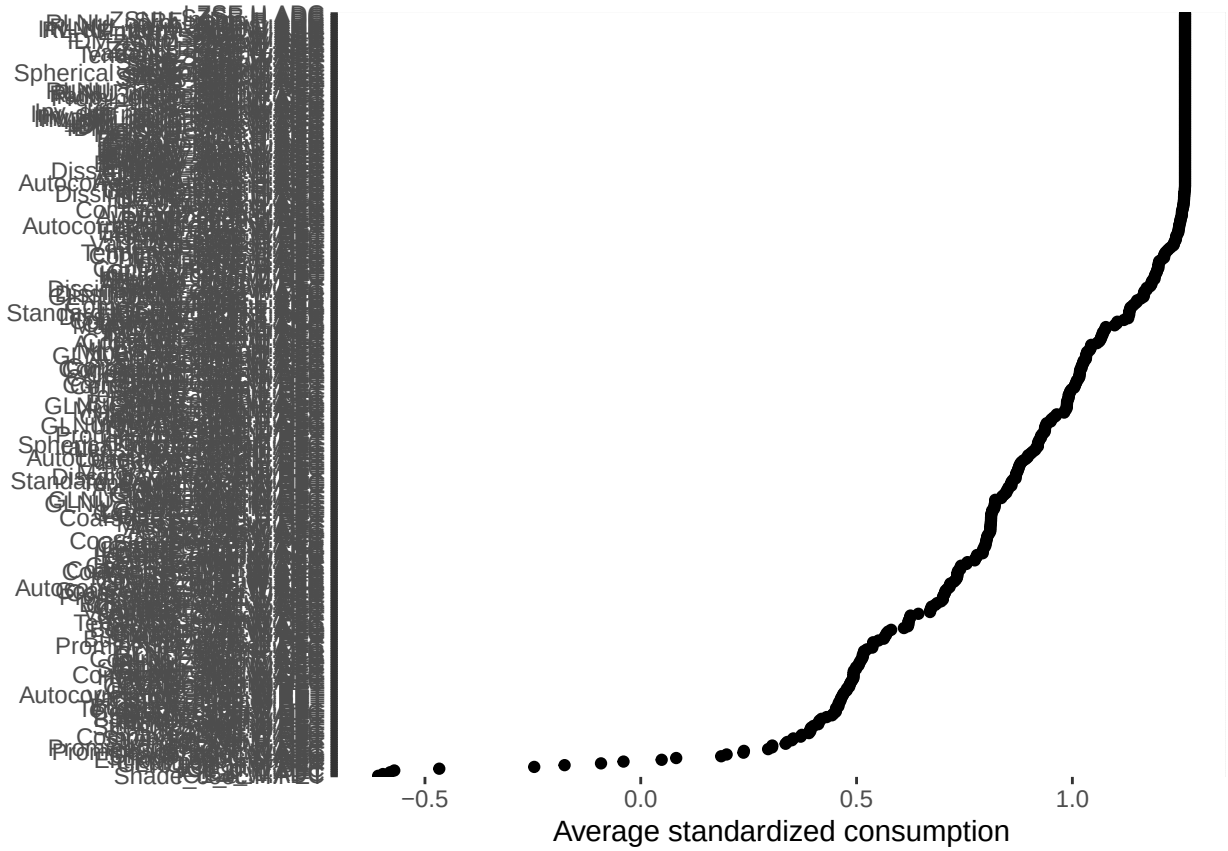
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
uncertainty <- data.frame(
  id = 1:nrow(radiomicsdf),
  cluster = model3$classification,
  uncertainty = model3$uncertainty
)
uncertainty %>%
  group_by(cluster) %>%
  filter(uncertainty > 0.25) %>%
  ggplot(aes(uncertainty, reorder(id, uncertainty))) +
  geom_point() +
  facet_wrap(~ cluster, scales = 'free_y', nrow = 1)
```




```
cluster2 <- radiomicsdf %>%
  scale() %>%
  as.data.frame() %>%
  mutate(cluster = model3$classification) %>%
  filter(cluster == 2) %>%
  select(-cluster)

cluster2 %>%
  tidyr::gather(product, std_count) %>%
  group_by(product) %>%
  summarize(avg = mean(std_count)) %>%
  ggplot(aes(avg, reorder(product, avg))) +
  geom_point() +
  labs(x = "Average standardized consumption", y = NULL)
```




Thus, based on the data we get above;

K-means clustering is the best number of clusters is 2 with SSwithin = 33.2%. Hierarchical, gap statistics suggest 9 clusters with 84.90% ac and 84.29%. Model based suggested 3 optimal number of clusters with BIC -2632.206.