- Bar plot of AUCs using ggplot2

R Notebook

```
# Load libraries
library(aplore3)
library(caret)
```

```
## Loading required package: ggplot2
## Loading required package: lattice
```

```
library(pROC)
```

```
## Type 'citation("pROC")' for a citation.
##
## Attaching package: 'pROC'
## The following objects are masked from 'package:stats':
##
##     cov, smooth, var
```

```
library(randomForest)
```

```
## randomForest 4.7-1.1
## Type rfNews() to see new features/changes/bug fixes.
##
## Attaching package: 'randomForest'
## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
library(class)
library(rpart)
library(xgboost)
library(ROSE)
```

```
## Loaded ROSE 0.0-4
```

```
library(smotefamily)
library(memoise)
library(doParallel)
```

```
## Loading required package: foreach
## Loading required package: iterators
```

```
## Loading required package: parallel
```

```
# Load data

data("glow_bonemed")

glow_bonemed$fracture <- as.factor(glow_bonemed$fracture)


# Remove less predictive identifiers

trimmed_data <- glow_bonemed[, !(names(glow_bonemed) %in% c("sub_id",
"site_id", "phy_id"))]


# Handling class imbalance with ROSE

set.seed(123)

rose_data <- ROSE(fracture ~ ., data = trimmed_data, seed = 1)$data


# Splitting data into training, validation, and test sets

set.seed(123)

# Split into temporary training and a test set

temp_train_indices <- createDataPartition(rose_data$fracture, p = 0.8, list =
FALSE)

train_temp <- rose_data[temp_train_indices, ]

test_set <- rose_data[-temp_train_indices, ]


# Further split the temporary training set into actual training and
validation sets

index <- createDataPartition(train_temp$fracture, p = 0.8, list = FALSE)

train_set <- train_temp[index, ]

validation_set <- train_temp[-index, ]


# Set up parallel processing

cl <- makeCluster(detectCores() - 1)  # Use one less than the total number of
cores

registerDoParallel(cl)


# Feature selection using recursive feature elimination

control <- rfeControl(functions = rfFuncs, method = "cv", number = 10,
returnResamp = "all", saveDetails = TRUE)

results <- rfe(train_set[, -ncol(train_set)], train_set$fracture, sizes =
c(1:5), rfeControl = control)
```

```r
# Set control for training models

fit_control <- trainControl(method = "cv", number = 10, savePredictions =
"final", classProbs = TRUE, verboseIter = TRUE, allowParallel = TRUE)

list(train_set = train_set, validation_set = validation_set,
test_set=test_set, results = results, control=control)
```

```
## $train_set

##     priorfrac      age    weight   height      bmi premeno momfrac
armassist

## 1          No 76.57131  63.88782 157.0700 23.17194      No      No
No

## 4          No 73.27055  51.91283 155.7938 24.26608      No      No
No

## 5          No 66.69603  52.28338 167.9820 24.54984      No     Yes
Yes

## 6         Yes 87.65635  52.99006 163.4894 16.05605      No      No
No

## 8          No 68.04976  86.31009 169.1141 24.32254     Yes      No
Yes

## 9         Yes 80.27934  74.98722 155.9962 25.25380      No      No
No

## 10         No 58.33089  76.35809 156.9728 28.18456      No      No
No

## 11        Yes 63.54905  72.69218 158.6275 33.15255      No      No
No

## 13         No 60.14699  58.58503 167.0455 22.99401      No      No
No

## 16         No 57.84117  50.66219 156.1355 19.99090      No     Yes
No

## 17         No 52.86429  70.37763 166.7190 27.88284      No      No
No

## 20        Yes 74.51750  70.22003 166.2621 28.92920      No      No
Yes

## 22         No 59.63402  92.06890 169.2035 29.97890     Yes     Yes
Yes

## 23         No 60.95411  88.46920 155.0449 31.42366      No      No
No

## 25         No 65.35568  43.73006 162.8557 22.37878      No      No
No

## 26         No 63.80493  72.70912 161.7124 31.06083      No      No
No
```

```
## 29         No 72.40462  87.42665 165.9957 20.91771      No      No
No
## 30         No 58.02408  54.57663 153.6212 22.34889      No      No
No
## 32         No 61.16975  49.78011 155.0126 20.56597      No      No
No
## 33         No 76.43237  89.18340 157.6523 30.02923      No     Yes
Yes
## 34         No 65.55628  72.76036 197.6156 15.12155      No      No
No
## 35         No 49.70777  70.30708 161.6883 37.27509      No      No
No
## 37         No 50.18331  80.75951 161.7041 25.72136      No      No
No
## 38         No 61.70856  73.35858 150.6925 28.17296      No      No
No
## 39         No 65.69610  48.32013 163.8642 20.84948      No      No
No
## 40         No 67.09018  37.43641 155.3514 25.44229      No      No
No
## 41         No 63.06337  61.76295 161.7022 25.54845     Yes      No
No
## 42        Yes 89.71297  54.92796 148.2578 27.42241      No      No
No
## 43         No 68.38781  72.27746 166.3598 25.10359     Yes      No
Yes
## 45         No 57.58984  73.86638 161.9960 28.95851      No      No
No
## 46         No 55.78411  90.47149 159.5099 38.03624     Yes     Yes
Yes
## 48         No 67.43021  97.81432 164.1404 32.72300      No      No
Yes
## 49         No 63.88991  79.74476 159.4074 32.01824      No      No
No
## 50         No 71.61804  72.29098 161.8455 24.89789      No      No
No
## 51         No 48.06555  73.23659 199.5345 16.06424      No      No
No
## 53         No 76.55119  61.64445 154.4373 25.95900      No      No
No
## 55        Yes 64.82297  69.88371 162.0614 22.12841     Yes      No
No
```

```
## 57         No 68.55877  79.70077 160.0377 29.33269      No      No
No
## 58        Yes 81.34873  65.39016 156.1578 26.41587      No      No
No
## 59         No 60.23245  81.13798 158.1197 31.39832      No      No
No
## 60         No 63.29111  66.72906 179.6172 24.65570      No      No
No
## 61         No 68.42247  54.39467 172.3637 19.21300      No      No
No
## 63         No 73.67577  60.43332 155.3129 23.84775      No      No
No
## 64         No 74.05605  83.64089 156.8395 33.71213     Yes      No
No
## 66         No 71.93684  62.82082 155.3228 30.45029      No      No
No
## 67         No 56.69458  93.55792 152.4289 43.40528      No      No
Yes
## 68         No 61.40555  68.65670 165.5752 24.00874      No      No
No
## 69         No 65.37224  59.39231 162.2945 28.90244      No      No
No
## 70        Yes 76.08935  42.28548 149.5545 23.41127      No      No
No
## 72         No 57.20965  69.53457 161.3670 19.66897      No      No
No
## 74         No 69.42618  70.05748 167.6061 20.65429      No      No
No
## 75         No 77.95200  61.45815 161.8999 24.47534      No      No
No
## 76         No 75.95498  70.16400 168.1501 24.33465      No      No
No
## 77         No 69.92030  65.30667 151.8914 25.16314      No      No
No
## 78         No 60.44902  59.85023 160.5904 27.57348     Yes      No
No
## 79         No 72.54137  71.62773 165.3125 28.55999     Yes      No
No
## 80         No 73.45231  85.34661 164.4443 36.13777      No      No
Yes
## 81         No 65.91401  86.96654 150.4487 34.04721      No      No
Yes
```

```
## 82         No 69.34865  81.49230 156.2082 31.98439      No     Yes
Yes
## 85         No 68.64869  93.73309 164.4083 43.25205     Yes      No
Yes
## 86        Yes 88.75806  54.72523 151.6941 29.81687      No      No
Yes
## 87         No 78.81139  38.27674 148.8836 23.04740      No      No
No
## 89         No 52.91022  71.04832 158.4762 26.98634      No      No
No
## 90         No 69.08347  65.71074 166.5208 29.84021      No      No
Yes
## 91         No 65.35362  77.38872 161.9371 24.70073      No      No
Yes
## 93        Yes 89.02528  50.75574 162.0195 19.74167      No      No
Yes
## 97        Yes 69.72050  78.37471 166.4963 28.38413      No      No
No
## 98         No 54.56123  65.13978 156.9619 28.13794      No      No
No
## 100        No 61.21514  62.44052 155.2634 25.55189     Yes      No
No
## 102       Yes 53.26732  83.23469 171.2607 30.93954      No      No
No
## 104        No 48.18090  82.69982 163.2234 32.72950      No      No
No
## 105        No 66.63236  52.49367 169.1644 21.60059      No      No
No
## 106        No 75.92141  83.79043 167.6849 27.91311      No      No
No
## 108       Yes 62.52021 131.35988 160.7475 44.57432      No     Yes
Yes
## 110        No 57.95767  63.78739 166.6214 25.29923      No      No
Yes
## 111        No 60.07390  57.82318 157.6502 18.08299      No      No
No
## 112        No 66.57753  60.98836 161.0837 31.57782      No      No
No
## 113        No 77.01021  48.51803 168.0461 17.66690      No      No
No
## 116        No 77.97838  50.39413 148.0934 17.93720      No      No
No
```

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## 117        No 83.39859  68.71358 155.3717 19.76527      No      No
No
## 120        No 53.89866  66.68286 155.7395 30.25693      No      No
No
## 121        No 57.51412  66.76642 167.0738 24.99912     Yes      No
No
## 122        No 67.63735  89.32317 163.6974 25.95975      No      No
No
## 126        No 73.25314  57.30743 167.1577 23.59360     Yes      No
No
## 128       Yes 61.99341  76.69313 162.8776 26.86351      No      No
No
## 136        No 50.77891  86.45181 168.8790 30.58167     Yes     Yes
Yes
## 137        No 75.55462  89.99825 166.4626 29.65927      No      No
Yes
## 138        No 54.93355  49.85433 160.2234 19.96277      No     Yes
No
## 139        No 62.91543  60.96426 165.4807 19.69004      No      No
No
## 140        No 59.60464  99.24209 156.8374 42.76232      No      No
Yes
## 141        No 54.49651  63.30765 158.5724 30.05205      No      No
Yes
## 142        No 78.18879  60.36907 159.1585 23.96904      No      No
No
## 144        No 68.05407  68.22116 162.8419 29.26544     Yes      No
No
## 146        No 58.60195  54.40269 162.7842 24.65475      No      No
No
## 148        No 81.68119  65.63787 157.1828 24.67861      No      No
No
## 150        No 70.80581  79.16308 166.3999 18.92818      No      No
No
## 151        No 71.94866  53.20442 154.7816 27.73584      No      No
No
## 155       Yes 89.76802  67.20458 159.1340 23.60328      No     Yes
Yes
## 156       Yes 74.71325  72.00507 163.0891 28.30332      No      No
Yes
## 157       Yes 66.01006 108.00381 163.2054 33.98613      No      No
Yes
```

```
## 158        No 72.33118  81.53428 178.1060 24.67447     Yes      No
No
## 159        No 65.61970  67.01288 160.6549 23.93118      No      No
No
## 161       Yes 60.25266  66.35102 162.0286 32.87381     Yes      No
Yes
## 163        No 62.56367 112.88887 165.1064 41.80804      No      No
Yes
## 164       Yes 74.21691  99.40347 164.5443 37.79016      No      No
Yes
## 165        No 63.75080  73.66900 167.2403 19.81545     Yes      No
No
## 166        No 76.41093  49.52507 150.1695 26.09081      No      No
No
## 168        No 72.47964  68.20754 156.0775 29.92989      No     Yes
No
## 169       Yes 74.99600  70.84466 174.7185 32.69411      No      No
Yes
## 172        No 65.80582  60.05149 148.5044 25.05805      No      No
No
## 175        No 64.55336  97.04869 170.8184 30.03135      No     Yes
No
## 176       Yes 74.63085  50.89590 138.0992 28.15615     Yes     Yes
No
## 177       Yes 72.06779  72.27865 166.7321 27.35570      No      No
No
## 180        No 58.66876  85.22196 157.8631 33.26541      No      No
No
## 182        No 83.29858  65.45462 164.9832 23.56385      No      No
Yes
## 184        No 70.65003  56.49347 158.4865 28.28204      No      No
No
## 186        No 55.50082  64.63458 203.8041 20.79209      No      No
No
## 189        No 63.51063  51.02529 175.0532 19.24852      No      No
No
## 195        No 72.04903  57.47064 153.1823 30.72493      No     Yes
No
## 198        No 65.35718  54.94204 160.2074 22.85795      No      No
No
## 199        No 65.42057  66.22243 174.3681 31.92492     Yes     Yes
No
```

```
## 200        No 58.91906  90.31151 171.2119 38.42359     Yes      No
No
## 201       Yes 58.91353  84.45100 165.5047 32.31964      No      No
No
## 204        No 73.56971  56.26158 167.4063 25.24790      No      No
No
## 205        No 72.61347  59.08490 159.3913 25.40538      No      No
No
## 207       Yes 64.85298  64.44741 171.3122 24.47002      No      No
Yes
## 208        No 54.42656  67.48847 159.9195 23.11739      No      No
No
## 209        No 55.71590 115.67785 155.4795 45.59054      No      No
Yes
## 210        No 67.81973  81.00106 163.5243 31.16564     Yes      No
No
## 211        No 53.54565 118.99520 180.8187 38.07503      No      No
No
## 213        No 76.54151  93.89820 161.0139 44.34131      No      No
Yes
## 214        No 65.25090 105.90474 159.3252 41.25197      No      No
Yes
## 217       Yes 85.95233  44.66521 164.0144 18.71667      No      No
No
## 218        No 79.61854  62.56336 165.9123 18.76737      No     Yes
Yes
## 220        No 59.47491  77.53020 164.4164 29.50211     Yes     Yes
No
## 221        No 77.74262  72.92677 166.6596 22.41741      No     Yes
Yes
## 222        No 67.15308  73.08640 166.6697 23.63502      No      No
No
## 223        No 69.71343 103.81132 162.2581 42.75891      No      No
No
## 224       Yes 84.41827  79.66844 152.8082 31.20696      No      No
Yes
## 225        No 75.59390  60.15435 152.3581 18.95020     Yes      No
Yes
## 226       Yes 64.29895 104.24826 164.7552 40.33710      No      No
Yes
## 229        No 85.92501  51.95494 157.7248 18.71197      No      No
Yes
```

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## 230       Yes 62.98702  63.67187 159.5823 25.22235      No      No
No
## 233       Yes 84.59392  83.62911 159.5016 25.23858      No      No
No
## 234        No 69.58875  59.69897 173.4377 22.00298      No      No
No
## 235        No 69.36775  62.44358 171.0205 20.10247      No      No
No
## 236        No 60.74788  67.03377 168.2304 24.06565     Yes      No
No
## 237       Yes 73.78915  64.74122 155.9576 24.29327      No      No
No
## 239        No 59.43999  47.09039 153.8264 23.76203      No      No
No
## 240        No 61.65398  83.00894 166.9995 25.24862      No      No
No
## 241        No 59.76665  77.31561 169.0312 20.72614      No      No
No
## 242        No 50.35766  84.15904 160.1023 29.76986      No      No
No
## 243        No 75.68233 104.15423 166.3423 40.28856      No      No
Yes
## 244        No 64.52847  53.90379 154.5395 20.40071     Yes      No
Yes
## 247        No 75.63243  49.13884 158.2997 27.57038      No      No
No
## 248        No 63.84105 106.38291 160.5449 35.90612      No     Yes
Yes
## 250       Yes 78.47852  62.20900 155.2304 28.79397     Yes      No
No
## 252       Yes 64.65015  89.39522 163.9750 41.95445      No      No
Yes
## 253        No 61.95383  88.51438 158.5410 35.44151     Yes      No
No
## 254        No 58.82361  35.00009 157.2596 22.80042      No      No
No
## 256        No 66.94031  89.82896 164.8864 33.70176      No     Yes
No
## 257        No 77.40710  72.75074 148.9472 29.61313      No      No
No
## 258       Yes 72.28360  70.93814 159.1046 23.61519      No      No
No
```

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## 259        No 70.20572  66.09578 163.3483 26.16281      No     Yes
No
## 260        No 79.94988  61.97135 165.5186 18.60005      No      No
No
## 262        No 76.24805  59.31223 167.6599 28.79785      No      No
No
## 263        No 57.19995  54.06564 158.6906 24.25501      No      No
No
## 264        No 69.21154  43.10518 153.6337 21.50761      No      No
No
## 265        No 72.07484  77.11514 159.7339 28.10677      No      No
No
## 266        No 76.70386  50.31156 146.8502 27.22026      No      No
No
## 267        No 70.49334  68.87288 155.2312 24.74905      No      No
No
## 269       Yes 69.82384  83.89373 152.2026 33.32893      No      No
No
## 270        No 57.75567  59.92168 171.8263 18.55866      No      No
No
## 273        No 60.60236  55.08829 160.1128 26.12361     Yes      No
No
## 274        No 83.26318  77.34916 152.8539 30.79100      No      No
No
## 275       Yes 46.38760  41.24459 140.3337 24.97969      No      No
No
## 276       Yes 70.70922  76.11559 166.3300 24.16084     Yes      No
Yes
## 278        No 78.43923  36.64810 156.1258 22.29567      No     Yes
No
## 279       Yes 82.76426  71.03725 170.2358 34.16549      No     Yes
Yes
## 280        No 67.70097  73.54600 160.7048 28.65408      No      No
Yes
## 281        No 65.44666  89.68101 164.3759 21.14638     Yes      No
No
## 282        No 63.78925  53.72173 155.2027 18.94224      No      No
Yes
## 283        No 58.88615  57.55866 156.7307 26.61142     Yes     Yes
No
## 285       Yes 73.88806  53.46309 165.7779 26.10380      No      No
Yes
```

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## 286       Yes 80.43553  42.68423 165.8210 22.76357      No      No
No
## 289       Yes 72.72439  82.04630 174.5991 21.69065      No      No
Yes
## 290        No 57.66083  65.88925 161.3818 24.91021     Yes      No
No
## 291        No 81.32728  68.86735 162.9779 28.89571      No      No
Yes
## 292       Yes 69.41974  38.61288 156.9267 12.45061      No      No
Yes
## 293        No 56.35275  70.12563 158.3167 23.58519      No      No
No
## 294        No 66.43960  81.58341 157.4434 28.08125      No      No
Yes
## 295       Yes 84.15183  52.74020 169.9008 16.18418      No      No
Yes
## 296        No 73.18179  77.97488 157.3349 29.77726     Yes      No
Yes
## 297       Yes 74.32053  82.76845 155.6278 34.97146     Yes      No
Yes
## 300        No 66.03087  79.61865 159.8150 30.37141      No      No
No
## 301        No 74.44096  66.16692 156.4194 19.82553     Yes      No
Yes
## 303       Yes 67.03523  78.07136 169.6737 31.34369      No     Yes
Yes
## 305        No 70.18265  95.02379 157.0005 37.04174      No      No
No
## 306       Yes 74.85203  44.21353 157.4777 28.12140      No      No
No
## 309        No 85.74815  48.02739 152.4419 27.53492      No      No
No
## 310        No 67.43684  84.96143 168.0770 21.62557      No     Yes
No
## 311        No 45.93424  73.84658 158.7269 29.21502      No      No
No
## 313       Yes 63.73754  61.97923 146.5170 26.43730      No      No
No
## 314        No 83.78102  74.62683 148.8877 39.47253     Yes      No
Yes
## 317        No 83.90723  78.19699 156.5916 25.64706      No     Yes
Yes
```

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## 318        No 57.77232  81.45207 165.7451 29.28221      No      No
Yes
## 319       Yes 53.61253 108.74047 165.3843 44.18439      No      No
Yes
## 320        No 72.11990  80.49063 160.5797 24.34752     Yes     Yes
No
## 321       Yes 82.05523  45.46947 157.1072 21.29910      No      No
No
## 323       Yes 69.66840  50.61663 172.8842 25.04158      No      No
Yes
## 325        No 83.27259  60.98643 164.6032 19.88682      No      No
No
## 326       Yes 61.28914  67.11543 161.1054 26.91154     Yes      No
Yes
## 327        No 54.79197  56.65707 161.3790 21.27140      No      No
No
## 331        No 69.08169  68.40223 160.1028 26.32341      No      No
Yes
## 333        No 83.79515  64.67362 179.4338 29.54568      No     Yes
Yes
## 335       Yes 69.43885  58.02443 163.5135 29.21528     Yes     Yes
No
## 336        No 83.79528  40.78875 153.9163 22.32644      No      No
No
## 337       Yes 60.34269 111.06965 158.4508 46.33546     Yes      No
Yes
## 340        No 78.48926  65.48700 161.4876 33.78708     Yes      No
Yes
## 343       Yes 55.60156  93.98092 158.3243 36.86835     Yes      No
Yes
## 344        No 93.76116  85.04453 150.5849 35.53928      No      No
No
## 347       Yes 75.90286  87.27356 164.8871 28.14711      No     Yes
No
## 348       Yes 75.79509  70.44906 152.3840 29.39584      No     Yes
Yes
## 350       Yes 67.70744 101.60508 178.0232 31.93218      No      No
Yes
## 351        No 82.85464  59.53088 158.9277 26.68091      No      No
Yes
## 352        No 68.50650  95.05596 174.6840 26.03142     Yes      No
Yes
```

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## 353       Yes 71.10523  52.36601 142.0781 26.04843      No      No
No
## 354        No 52.23012  73.92121 165.7124 28.44697      No      No
No
## 355       Yes 84.80850  41.52257 151.2255 23.49013      No     Yes
Yes
## 356        No 67.93811  56.01038 168.9477 22.46949      No      No
No
## 357        No 67.88753  76.96048 169.8851 26.35606     Yes      No
Yes
## 358        No 74.01736  44.68971 152.8482 21.17373      No      No
No
## 360       Yes 80.93773  56.98814 172.9701 19.49347      No      No
Yes
## 361       Yes 51.48472  64.84106 146.5000 24.58107      No      No
No
## 363       Yes 60.81080  86.97586 156.8702 41.90067     Yes      No
Yes
## 364       Yes 92.04128  49.57913 150.9309 28.28054      No     Yes
Yes
## 366        No 72.27856  66.76499 144.2238 18.79390      No      No
No
## 368       Yes 69.24661  82.95092 168.1683 29.18698     Yes      No
Yes
## 374       Yes 76.98615  66.39509 152.1185 27.92886      No      No
No
## 376        No 69.43302  92.43833 149.6821 34.01435      No      No
Yes
## 378        No 71.34491  52.54473 163.0945 15.79146      No      No
No
## 379        No 65.13542  61.99858 169.0656 27.40711      No      No
No
## 380        No 63.60819  85.51391 161.1634 35.66653     Yes      No
Yes
## 381        No 74.71948  89.89549 180.3986 27.15927      No     Yes
Yes
## 382        No 59.49796  80.10863 162.7134 30.12211      No      No
Yes
## 383       Yes 76.26880  85.10175 163.3067 25.23924      No     Yes
No
## 384       Yes 70.41872  73.79582 164.7054 31.43898      No     Yes
Yes
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## 385       Yes 52.33628  61.52211 155.3891 34.73393      No      No
No
## 387        No 69.42894  73.79435 141.7311 36.93245     Yes      No
Yes
## 389       Yes 81.09563  71.68336 151.1852 27.32187      No     Yes
Yes
## 390        No 73.41555  49.07399 161.8871 21.52896      No      No
No
## 393       Yes 52.86023 125.93325 165.4718 44.09721      No      No
Yes
## 395        No 69.72005  57.05186 163.2748 21.57143      No      No
No
## 397       Yes 56.28671  81.19006 162.1750 28.37678      No      No
No
## 398        No 66.79389  70.63431 140.0545 34.36417     Yes      No
Yes
## 399        No 58.40492  49.72487 163.7034 30.75719      No      No
No
## 403       Yes 78.85778  74.17253 156.8189 31.64947      No      No
Yes
## 406       Yes 65.86120 113.27631 160.5898 43.06834     Yes      No
Yes
## 407        No 57.25641  92.66655 162.2872 33.40318     Yes      No
Yes
## 411       Yes 78.13499  88.05451 174.5775 30.92752      No      No
Yes
## 412       Yes 83.25946  71.44112 159.3535 14.43559      No     Yes
No
## 413        No 98.08873  86.25317 152.9809 32.17877      No      No
No
## 415       Yes 74.67588  94.79964 152.1410 47.52916      No      No
Yes
## 416       Yes 87.23929  77.01296 149.9864 25.19950      No      No
Yes
## 418       Yes 62.59765  69.47001 158.4488 27.38662     Yes      No
Yes
## 420       Yes 73.61288  55.25366 155.8657 30.63091      No      No
No
## 421       Yes 56.93751  71.31165 149.7523 30.02160      No      No
No
## 423       Yes 62.68611  93.71993 154.9837 43.33611      No      No
Yes
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## 424       Yes 80.98066  91.89845 169.5168 27.78036      No      No
Yes
## 426       Yes 84.52892  83.12032 147.5401 31.21707      No      No
Yes
## 428       Yes 60.01296 130.87512 177.5659 37.15756      No      No
Yes
## 429        No 67.93614  92.35300 160.2896 39.48748      No      No
Yes
## 430        No 80.42645  66.15513 162.0124 22.16638      No      No
No
## 431        No 59.36833  47.12627 152.7150 21.55162      No      No
No
## 432       Yes 84.71175  39.19898 171.5876 15.76485      No      No
No
## 433       Yes 54.53825  70.16895 160.5709 26.68173      No      No
No
## 434        No 57.88193  80.52171 168.1039 30.10928     Yes      No
No
## 435        No 90.06783  83.93441 153.6768 24.64934      No     Yes
Yes
## 437        No 83.54955  74.90091 134.1323 42.97548      No      No
Yes
## 438       Yes 54.31973  95.13594 162.4912 43.35716      No      No
Yes
## 439       Yes 82.06854  48.09827 153.9309 21.10450      No      No
Yes
## 440        No 86.88456 102.66682 168.4586 34.64790      No      No
Yes
## 443       Yes 58.07873 116.83126 156.4798 45.36278      No      No
Yes
## 444       Yes 84.48926  37.64577 155.8863 16.23828      No      No
No
## 445       Yes 67.10743 124.83317 175.7802 43.61234      No      No
Yes
## 446       Yes 65.89133  56.39671 167.0893 21.18577      No      No
No
## 447       Yes 68.26818  97.12359 157.2665 45.24504     Yes      No
Yes
## 448       Yes 74.90943  60.76673 163.4109 21.10342      No      No
Yes
## 449        No 55.84162  54.28435 162.3112 17.80550      No      No
No
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## 451       Yes 73.69203  63.52946 169.0309 25.54758      No      No
Yes
## 452        No 73.04945  84.56930 167.2016 23.76979     Yes      No
Yes
## 453       Yes 75.68019  80.95962 163.7927 25.31748      No     Yes
No
## 454        No 84.36394  50.20492 147.1212 22.96047      No      No
Yes
## 455        No 72.90050  88.17149 153.4256 33.31107      No      No
Yes
## 456        No 75.11071  77.44199 163.0177 21.75546     Yes      No
No
## 457        No 83.95010  62.04546 152.0883 14.62292      No      No
No
## 458        No 53.54874  89.15939 165.9391 27.92747      No      No
Yes
## 462        No 58.10834  77.06126 160.4586 26.01875      No      No
No
## 463        No 81.52549  52.69483 161.9888 24.76120      No      No
No
## 465       Yes 86.76560  49.16408 164.2629 25.17198      No      No
Yes
## 468        No 56.98651  54.92472 154.1229 25.24119      No      No
No
## 469       Yes 76.88964  59.71273 165.8057 28.15299      No     Yes
No
## 471        No 71.49142  66.99815 168.8577 22.82492     Yes      No
No
## 474        No 47.61039 101.22313 159.7559 38.50385     Yes     Yes
No
## 476        No 75.92687  54.37467 154.5943 22.05478      No      No
Yes
## 477        No 66.26418  71.70206 172.1890 19.12922     Yes      No
No
## 478        No 69.77042  65.94128 156.1697 26.20175      No      No
No
## 479        No 87.98983  98.27926 170.6731 34.34495      No      No
No
## 480       Yes 75.14289 129.03760 174.0125 39.81371      No      No
Yes
## 481       Yes 89.92041  57.68064 156.3366 23.69545      No      No
Yes
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## 482       Yes 63.72045  68.55941 159.8879 30.57240      No      No
Yes
## 484        No 79.82220  87.31804 165.4748 34.98575      No      No
Yes
## 486        No 50.18171  54.62860 153.4871 17.87525      No      No
No
## 488       Yes 80.37850  83.17213 153.5205 31.07070      No      No
Yes
## 490       Yes 74.80035  90.11384 172.2727 26.42260      No      No
Yes
## 491       Yes 57.77853  60.26583 152.6209 28.33146      No      No
No
## 493       Yes 86.48388  78.10339 150.2436 33.98332      No      No
Yes
## 494       Yes 86.42408  59.42103 151.9400 23.80311      No      No
No
## 495        No 71.57434  66.60855 156.2115 18.39726      No      No
No
## 496        No 79.26159  79.16509 149.9979 36.64621      No      No
No
## 497        No 76.43735  61.25051 157.5315 24.29828      No      No
Yes
##     smoke raterisk   fracscore fracture bonemed bonemed_fu bonetreat
## 1     Yes     Less  3.83759409       No      No         No        No
## 4     Yes     Less  3.61050088       No      No         No        No
## 5      No     Same  4.67662112       No      No         No        No
## 6      No     Same  7.97972892       No      No         No        No
## 8      No     Same  1.91930779       No      No         No        No
## 9      No     Same  9.37991205       No     Yes         No        No
## 10     No     Less -0.29720967       No      No         No        No
## 11     No     Same -0.57161644       No     Yes        Yes       Yes
## 13     No     Same  4.19968804       No      No         No        No
## 16     No  Greater  1.72022768       No      No         No        No
## 17     No     Same  1.10917965       No      No         No        No
## 20     No  Greater  7.86864237       No     Yes        Yes       Yes
## 22     No  Greater  2.14947103       No      No         No        No
## 23     No     Same  1.55837104       No      No         No        No
## 25     No     Less  5.58875758       No      No         No        No
## 26     No     Less  1.53032026       No      No         No        No
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## 29     No     Same  1.74389847       No     Yes        Yes        Yes
## 30     No  Greater  0.72137763       No     Yes        Yes        Yes
## 32     No  Greater  1.67753630       No     Yes        Yes        Yes
## 33     No     Same  5.40393523       No      No         No         No
## 34     No  Greater -0.94346031       No      No         No         No
## 35     No  Greater -1.89181545       No      No         No         No
## 37     No  Greater  0.38755828       No      No         No         No
## 38     No     Same  0.75463181       No      No         No         No
## 39     No     Less  0.36011610       No      No         No         No
## 40     No     Same  2.29998503       No      No         No         No
## 41     No     Less -0.59676707       No      No         No         No
## 42     No     Same  5.28997421       No      No         No         No
## 43     No     Same  2.32195631       No      No         No         No
## 45     No  Greater  0.91809922       No      No         No         No
## 46    Yes     Same  4.82979454       No      No         No         No
## 48     No     Same  5.64646695       No      No         No         No
## 49     No     Same -1.33034671       No      No         No         No
## 50     No     Same  3.42778556       No      No         No         No
## 51     No  Greater -0.85115244       No      No         No         No
## 53     No     Less  2.96667684       No      No         No         No
## 55    Yes     Same  4.40149336       No      No         No         No
## 57     No     Less  2.90479878       No     Yes        Yes        Yes
## 58     No     Same  6.34254605       No     Yes        Yes        Yes
## 59     No  Greater  0.56522284       No      No         No         No
## 60     No     Less  2.11332631       No      No         No         No
## 61     No     Less  2.20643604       No      No         No         No
## 63     No     Same  2.54618443       No     Yes        Yes        Yes
## 64     No     Less  3.37526857       No      No         No         No
## 66    Yes     Less  4.11758493       No      No         No         No
## 67     No     Less  0.58494981       No      No         No         No
## 68     No  Greater -0.11277842       No     Yes        Yes        Yes
## 69     No     Less  1.35465941       No      No         No         No
## 70     No     Same  9.46372589       No     Yes        Yes        Yes
## 72     No  Greater  0.25139293       No      No         No         No
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##  74     No     Less  2.79172364       No      No         No         No
##  75     No     Same  5.41916388       No      No         No         No
##  76    Yes     Less  4.01164162       No      No         No         No
##  77     No     Less  4.88239072       No      No         No         No
##  78     No     Same  1.61787629       No      No         No         No
##  79     No     Same -0.70121139       No      No         No         No
##  80     No     Same  6.54630627       No      No         No         No
##  81     No     Less  1.74312446       No      No         No         No
##  82     No     Same  5.41206052       No      No         No         No
##  85     No     Same  3.23666373       No      No         No         No
##  86     No  Greater  6.24604846       No     Yes        Yes        Yes
##  87     No     Less  7.62044725       No      No         No         No
##  89     No  Greater  0.96132537       No      No         No         No
##  90     No  Greater  5.98288799       No      No        Yes         No
##  91     No     Less  4.09530392       No     Yes        Yes        Yes
##  93     No  Greater  7.68602608       No     Yes        Yes        Yes
##  97     No     Less  4.41630194       No      No         No         No
##  98     No  Greater  0.86149313       No      No         No         No
## 100     No     Same  1.26402125       No      No         No         No
## 102     No     Same  0.06143779       No      No         No         No
## 104     No  Greater  0.80289120       No      No         No         No
## 105     No     Less  2.95242075       No      No         No         No
## 106    Yes     Less  6.39837376       No      No         No         No
## 108     No  Greater  5.46331638       No      No         No         No
## 110     No  Greater  4.11845619       No      No         No         No
## 111     No     Same  1.80489271       No     Yes        Yes        Yes
## 112     No     Same  3.41782867       No      No         No         No
## 113     No     Less  8.66209965       No      No         No         No
## 116     No  Greater  6.32224666       No     Yes        Yes        Yes
## 117     No     Less  6.72116350       No      No         No         No
## 120     No  Greater  0.91600782       No      No         No         No
## 121     No     Same  2.64741170       No      No         No         No
## 122     No     Same  1.96819217       No      No         No         No
## 126    Yes     Same  1.65817796       No      No         No         No
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##  128    No     Same  1.01335040       No     Yes        Yes        Yes
##  136    No  Greater  4.15709998       No      No         No         No
##  137    No     Same  5.00593736       No      No         No         No
##  138    No  Greater  3.91846473       No      No         No         No
##  139    No  Greater  1.34607412       No     Yes        Yes        Yes
##  140    No     Less  2.24827519       No      No         No         No
##  141    No     Less  3.13449794       No      No         No         No
##  142    No     Same  4.72811380       No     Yes        Yes        Yes
##  144   Yes     Same  2.75933046       No      No         No         No
##  146    No     Same  1.35927350       No      No         No         No
##  148    No     Less  4.67670228       No      No         No         No
##  150    No     Less  4.01717896       No      No         No         No
##  151    No     Less  3.34076610       No     Yes        Yes        Yes
##  155    No  Greater  8.82376100       No     Yes        Yes        Yes
##  156    No     Less  6.21062877       No      No         No         No
##  157    No     Less  3.55709921       No      No         No         No
##  158    No     Same -0.78232166       No     Yes         No         No
##  159    No     Same  1.39095269       No      No         No         No
##  161    No     Same  3.17921267       No      No         No         No
##  163    No     Same  3.22457894       No      No         No         No
##  164    No  Greater  7.36120004       No      No         No         No
##  165    No     Same  0.16551703       No      No         No         No
##  166    No  Greater  2.56570551       No     Yes        Yes        Yes
##  168   Yes     Less  2.14492035       No      No         No         No
##  169    No     Less  4.05002328       No      No         No         No
##  172    No     Same  6.24836531       No     Yes        Yes        Yes
##  175    No     Same  3.24949051       No      No         No         No
##  176    No     Same  5.12047459       No      No         No         No
##  177    No     Same  4.82913003       No     Yes        Yes        Yes
##  180    No     Less  1.74976774       No      No         No         No
##  182    No     Less  9.35442251       No      No         No         No
##  184    No     Less  3.52374206       No      No         No         No
##  186    No  Greater  0.41132174       No      No         No         No
##  189    No     Less  1.89773269       No      No         No         No
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## 195   Yes     Less  3.93790350       No      No         No         No
## 198    No  Greater  5.15289018       No      No        Yes         No
## 199    No     Less  2.94497644       No      No         No         No
## 200    No     Same  1.15646949       No      No         No         No
## 201    No     Same  4.01190225       No     Yes        Yes        Yes
## 204    No     Same  5.80295445       No      No        Yes         No
## 205    No  Greater  1.92560829       No     Yes        Yes        Yes
## 207    No  Greater  4.96325237       No     Yes        Yes        Yes
## 208    No     Less -0.75996179       No      No         No         No
## 209    No     Same  1.33522410       No      No         No         No
## 210    No  Greater  3.64666439       No     Yes        Yes        Yes
## 211    No     Same -0.68956506       No      No         No         No
## 213    No     Same  6.76817482       No      No         No         No
## 214    No     Less  2.53174105       No     Yes         No         No
## 217    No     Same 11.38953826       No      No         No         No
## 218    No     Less  5.74726402       No      No         No         No
## 220    No     Less  3.00970224       No      No         No         No
## 221    No     Less  8.08118412       No      No         No         No
## 222    No     Less  2.18976499       No      No         No         No
## 223    No     Less  2.71172989       No      No         No         No
## 224    No  Greater  7.70617402       No     Yes        Yes        Yes
## 225    No     Same  5.96325680       No     Yes        Yes        Yes
## 226    No     Less  5.52486190       No      No         No         No
## 229    No  Greater  7.85038748       No      No         No         No
## 230    No     Same  1.97593277       No     Yes        Yes        Yes
## 233    No     Less  4.86599201       No      No         No         No
## 234    No     Less  1.31834184       No      No         No         No
## 235    No  Greater  2.34047610       No      No        Yes         No
## 236    No     Same  0.74733630       No      No         No         No
## 237    No     Less  4.72446095       No      No         No         No
## 239    No     Less  3.38120993       No      No         No         No
## 240    No     Less -1.44870730       No      No         No         No
## 241    No     Less -0.08508828       No      No         No         No
## 242    No     Same  1.00250349       No      No         No         No
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## 243    No     Less  6.24785082       No      No         No         No
## 244   Yes     Same  4.76098298       No      No         No         No
## 247    No     Same  3.49947135       No     Yes        Yes        Yes
## 248    No     Less  2.50698263       No      No         No         No
## 250    No     Less  4.77173214       No      No         No         No
## 252    No     Less  4.35302363       No      No         No         No
## 253    No     Same -0.29269025       No      No         No         No
## 254    No  Greater  0.10665709       No      No         No         No
## 256    No     Less  4.00016084       No      No         No         No
## 257    No     Less  4.35152115       No      No         No         No
## 258    No     Less  5.26076836       No      No         No         No
## 259    No     Same  6.22948927       No     Yes        Yes        Yes
## 260    No     Less  2.72741566       No      No         No         No
## 262    No     Same  4.77155449       No      No        Yes         No
## 263   Yes     Less  0.44426206       No      No         No         No
## 264    No     Less  3.37439077       No     Yes        Yes        Yes
## 265    No     Less  2.93519922       No      No         No         No
## 266    No     Less  6.06190764       No      No         No         No
## 267    No  Greater  0.64458540       No     Yes        Yes        Yes
## 269   Yes     Same  3.62753645       No      No         No         No
## 270    No     Less  0.97131656       No      No         No         No
## 273    No  Greater -0.74247039      Yes     Yes        Yes        Yes
## 274    No     Same  1.04932962      Yes     Yes        Yes        Yes
## 275    No     Less  2.00076566      Yes      No        Yes         No
## 276    No  Greater  7.09897052      Yes      No         No         No
## 278    No     Same  4.57201173      Yes     Yes        Yes        Yes
## 279    No     Same  9.07508688      Yes      No         No         No
## 280    No     Less  4.25636994      Yes      No         No         No
## 281    No     Less  2.79437514      Yes      No         No         No
## 282    No     Same  7.70009891      Yes     Yes        Yes        Yes
## 283    No     Same  2.76857740      Yes      No         No         No
## 285    No  Greater  8.43658594      Yes      No         No         No
## 286    No     Less  4.88255349      Yes     Yes        Yes        Yes
## 289   Yes  Greater  8.41256590      Yes     Yes        Yes        Yes
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## 290    No  Greater  4.70468281      Yes      No         No        No
## 291    No     Less  7.65297226      Yes      No         No        No
## 292    No  Greater  8.74110735      Yes     Yes        Yes       Yes
## 293    No     Same  0.68373865      Yes      No         No        No
## 294    No     Less  1.20483122      Yes      No         No        No
## 295    No  Greater  7.44023714      Yes     Yes        Yes       Yes
## 296    No  Greater  4.75523137      Yes      No        Yes        No
## 297    No  Greater  4.50419323      Yes      No         No        No
## 300    No  Greater -0.81279302      Yes     Yes        Yes       Yes
## 301    No     Same  9.28621670      Yes      No        Yes        No
## 303    No     Same  8.61168071      Yes      No         No        No
## 305    No     Less  3.06827022      Yes      No         No        No
## 306    No     Less  7.89000782      Yes     Yes        Yes       Yes
## 309    No     Less  7.35009023      Yes      No        Yes        No
## 310    No  Greater  5.41858461      Yes      No         No        No
## 311    No     Same  0.07860770      Yes      No         No        No
## 313    No     Less -1.60743367      Yes      No        Yes        No
## 314    No     Less  4.38902205      Yes      No         No        No
## 317    No     Same  8.67012308      Yes      No         No        No
## 318    No  Greater  2.39796235      Yes      No         No        No
## 319    No     Same  5.27285794      Yes      No        Yes        No
## 320   Yes  Greater  7.30820682      Yes     Yes        Yes       Yes
## 321    No     Less  8.24887754      Yes      No         No        No
## 323   Yes  Greater  8.57396577      Yes     Yes        Yes       Yes
## 325    No     Less  2.83372252      Yes     Yes         No        No
## 326    No  Greater  6.64971075      Yes      No         No        No
## 327    No  Greater  1.61319386      Yes      No         No        No
## 331    No     Less  6.66910425      Yes      No         No        No
## 333    No     Less  6.77158807      Yes      No         No        No
## 335    No  Greater  3.54798426      Yes      No         No        No
## 336    No  Greater  4.14695512      Yes     Yes        Yes       Yes
## 337    No  Greater  6.55935310      Yes     Yes        Yes       Yes
## 340    No     Less  4.12696607      Yes     Yes        Yes       Yes
## 343    No  Greater  4.11011950      Yes      No         No        No
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## 344    No     Less  3.50104796      Yes      No         No        No
## 347    No     Same  4.37117044      Yes      No         No        No
## 348    No  Greater  8.92591560      Yes      No        Yes        No
## 350    No  Greater  6.54746904      Yes      No         No        No
## 351    No     Same  8.68206001      Yes      No        Yes        No
## 352    No     Less  4.90885976      Yes      No         No        No
## 353    No     Less  2.59822439      Yes      No        Yes        No
## 354    No     Same -2.06900789      Yes      No         No        No
## 355    No  Greater  9.14902357      Yes     Yes        Yes       Yes
## 356    No     Less  2.25699386      Yes      No         No        No
## 357    No     Less  6.06177509      Yes      No         No        No
## 358    No     Less  5.93677359      Yes      No        Yes        No
## 360    No  Greater  7.18480313      Yes      No         No        No
## 361    No     Less  2.74603901      Yes      No        Yes        No
## 363    No  Greater  4.27769782      Yes     Yes        Yes       Yes
## 364    No  Greater  9.55470266      Yes     Yes        Yes       Yes
## 366    No  Greater  3.25784588      Yes     Yes        Yes       Yes
## 368    No  Greater  2.55554187      Yes      No         No        No
## 374    No     Less  7.97002598      Yes     Yes        Yes       Yes
## 376    No     Same  6.71271146      Yes     Yes         No        No
## 378    No     Less  3.71843159      Yes     Yes         No        No
## 379    No     Same  1.03408930      Yes      No         No        No
## 380   Yes     Same  3.66020718      Yes      No         No        No
## 381    No     Less  8.46664486      Yes      No         No        No
## 382    No  Greater  2.87390524      Yes      No         No        No
## 383    No     Same  5.69059976      Yes      No         No        No
## 384    No     Same  8.23919202      Yes      No         No        No
## 385    No  Greater  2.50111483      Yes      No        Yes        No
## 387    No     Less  4.21229887      Yes      No         No        No
## 389    No  Greater 10.51828391      Yes      No        Yes        No
## 390    No     Same  6.09667514      Yes     Yes        Yes       Yes
## 393    No     Same  3.62304272      Yes      No        Yes        No
## 395    No     Less  3.65280768      Yes      No         No        No
## 397    No  Greater  1.67440945      Yes      No         No        No
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## 398    No     Less  5.42553906      Yes      No         No         No
## 399    No     Same  4.29952991      Yes     Yes        Yes        Yes
## 403    No     Same  8.66020579      Yes      No         No         No
## 406    No  Greater  6.57287655      Yes     Yes        Yes        Yes
## 407   Yes     Same  4.03329352      Yes      No         No         No
## 411    No     Less  5.81824491      Yes      No         No         No
## 412    No  Greater  6.61803071      Yes      No        Yes         No
## 413    No     Less  6.49168115      Yes      No         No         No
## 415    No     Less  6.45346885      Yes      No         No         No
## 416    No  Greater 10.56253259      Yes     Yes        Yes        Yes
## 418    No  Greater  3.77006630      Yes      No         No         No
## 420    No     Same  5.49290971      Yes     Yes        Yes        Yes
## 421    No  Greater  0.16956908      Yes      No        Yes         No
## 423    No  Greater  3.86185642      Yes      No         No         No
## 424   Yes     Same  6.19195701      Yes     Yes        Yes        Yes
## 426    No     Same  8.10231111      Yes      No         No         No
## 428    No  Greater  5.87738639      Yes      No         No         No
## 429    No     Same  4.73173900      Yes     Yes         No         No
## 430    No     Same  6.73148245      Yes     Yes        Yes        Yes
## 431    No  Greater  1.58219216      Yes     Yes        Yes        Yes
## 432    No     Less  8.70965457      Yes     Yes         No         No
## 433    No     Same  4.58052431      Yes      No         No         No
## 434    No     Less  1.87377794      Yes      No         No         No
## 435    No     Same  6.41442423      Yes      No         No         No
## 437    No     Same  8.53356949      Yes     Yes        Yes        Yes
## 438    No     Same  2.71069991      Yes      No        Yes         No
## 439    No     Same 10.54521592      Yes     Yes         No         No
## 440   Yes  Greater  9.60187570      Yes      No         No         No
## 443    No  Greater  4.97391836      Yes      No         No         No
## 444    No     Same  6.17806939      Yes     Yes        Yes        Yes
## 445    No  Greater  4.49621430      Yes      No         No         No
## 446   Yes  Greater  3.27451231      Yes      No         No         No
## 447    No  Greater  6.46355061      Yes     Yes        Yes        Yes
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## 453    No     Same  5.68820022      Yes      No         No         No
## 454    No     Same 10.21613213      Yes      No         No         No
## 455    No     Same  2.05726891      Yes     Yes         No         No
## 456    No     Same  0.53483305      Yes      No         No         No
## 457    No     Less  8.00477902      Yes      No         No         No
## 458    No     Less  4.52556961      Yes      No         No         No
## 462    No     Less  2.26869445      Yes      No         No         No
## 463    No     Same  7.45526175      Yes     Yes        Yes        Yes
## 465    No  Greater 11.56377469      Yes      No         No         No
## 468    No     Less  0.58444062      Yes      No         No         No
## 469    No     Same  5.27943661      Yes      No         No         No
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## 474    No     Same -2.77595806      Yes      No         No         No
## 476    No  Greater  5.59218704      Yes      No        Yes         No
## 477    No  Greater  3.07443269      Yes      No         No         No
## 478    No     Same  5.09854000      Yes     Yes        Yes        Yes
## 479    No     Less  5.31110242      Yes      No         No         No
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## 481    No     Less  9.18075236      Yes     Yes         No         No
## 482    No     Same  3.59515664      Yes      No         No         No
## 484    No  Greater  5.42323021      Yes      No         No         No
## 486    No  Greater -1.36206112      Yes     Yes        Yes        Yes
## 488    No  Greater  3.58586507      Yes     Yes        Yes        Yes
## 490   Yes     Same  7.05704271      Yes     Yes        Yes        Yes
## 491    No     Less  2.81953428      Yes      No         No         No
## 493    No     Same  7.50239320      Yes      No         No         No
## 494    No     Less  6.85702281      Yes      No         No         No
## 495    No     Same  7.25699505      Yes     Yes        Yes        Yes
## 496    No     Same  6.11402764      Yes     Yes        Yes        Yes
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## 65        Yes 70.45857  59.30130 161.4198 26.21285     Yes     Yes
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## 71         No 94.30676  76.96663 164.2928 28.86742      No      No
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## 73        Yes 75.73821  67.05063 167.3472 23.77511      No      No
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## 341        No 66.38798 102.46474 165.4121 36.27937      No      No
No

## 342        No 78.72398  87.09566 150.1880 30.51290     Yes      No
Yes

## 349        No 64.50271  49.18944 156.7449 20.50738      No      No
No

## 359        No 62.52292 100.54627 168.0699 33.58132      No      No
No

## 365       Yes 68.18063  85.95007 165.6682 37.97065     Yes      No
Yes

## 367       Yes 72.52505  97.96208 152.4930 37.26589     Yes      No
Yes

## 369        No 67.34689  65.91308 163.2653 25.11595     Yes      No
No

## 370       Yes 63.98056  73.45444 159.9504 27.70143      No      No
No

## 371       Yes 71.63868  74.34485 162.4793 26.20660      No      No
No

## 373        No 70.19248  72.27677 165.9720 30.46132     Yes      No
Yes

## 386        No 79.95486  60.95334 156.5589 14.74609      No      No
No

## 394        No 60.60432  64.59239 162.0505 24.72927      No     Yes
No

## 401       Yes 99.97096  47.86834 171.0649 23.08673      No      No
Yes

## 402       Yes 80.66986  68.95356 158.2671 31.79764      No      No
No
```

```
## 405       Yes 59.76877 122.84484 155.6821 39.88175      No      No
Yes
## 408        No 62.55655  59.38388 164.8489 27.68278     Yes     Yes
No
## 409        No 73.22676  92.32035 174.4349 30.46722      No     Yes
Yes
## 410        No 77.68708  70.42943 160.2517 23.56759      No      No
Yes
## 414       Yes 51.68563  69.47707 161.5326 29.98921     Yes      No
Yes
## 417        No 75.47389  27.31324 151.2068 19.29066      No      No
No
## 419        No 65.74147  81.52171 161.2190 38.76250      No      No
Yes
## 422        No 74.52953  66.90172 172.3640 20.99491      No     Yes
No
## 425        No 73.35627  94.81187 158.9571 33.82040      No      No
Yes
## 427        No 69.15467  61.52779 159.7849 21.95372     Yes      No
No
## 442        No 75.25126 104.18491 155.5045 33.70470      No      No
No
## 464        No 58.21749 104.17692 167.9707 34.91109     Yes      No
Yes
## 466       Yes 57.71115  96.67726 158.2258 30.39015      No      No
Yes
## 467       Yes 65.05855  75.58737 158.4736 36.12302     Yes      No
Yes
## 470        No 61.56829  41.91596 160.0358 28.06184      No      No
No
## 472        No 71.79234  45.30784 154.5072 23.55765      No      No
No
## 475       Yes 81.15663  83.93356 148.8370 37.00882      No      No
Yes
## 485        No 69.52256  55.82314 150.2678 31.46179     Yes      No
Yes
## 492       Yes 70.63612  84.79887 153.6015 27.97732      No      No
Yes
## 498        No 63.21837  78.27270 160.4743 34.01245     Yes      No
No
## 499       Yes 98.02976  45.41424 171.3021 19.35205      No      No
No
##     smoke raterisk  fracscore fracture bonemed bonemed_fu bonetreat
```

```
##     2      No     Less  1.1545226       No      No         No        No
##     3      No     Same  5.4329275       No      No         No        No
##    12      No     Same  2.5240105       No      No         No        No
##    15      No  Greater  2.2639318       No     Yes        Yes       Yes
##    18      No     Less  0.3632298       No      No         No        No
##    19      No  Greater  5.1172785       No     Yes        Yes       Yes
##    27      No     Less  1.9584144       No      No         No        No
##    28      No     Same  0.4305433       No      No         No        No
##    31      No  Greater  7.0736960       No      No        Yes        No
##    47      No     Same -0.6562039       No      No         No        No
##    56      No     Same  1.1351559       No      No         No        No
##    62      No  Greater  3.3393347       No      No         No        No
##    65      No     Same  5.1773926       No      No         No        No
##    71      No     Less  6.7914767       No      No         No        No
##    73      No  Greater  4.5702854       No     Yes        Yes       Yes
##    95      No  Greater  5.1219625       No      No         No        No
##    96      No     Less  1.5611527       No     Yes        Yes       Yes
##   101      No  Greater  1.5349583       No      No         No        No
##   114      No     Less  1.0402130       No      No         No        No
##   115     Yes  Greater  2.9905508       No      No         No        No
##   119      No  Greater  5.1722506       No     Yes        Yes       Yes
##   123      No     Less -1.0183783       No      No         No        No
##   125      No     Same  0.5921612       No     Yes        Yes       Yes
##   129      No     Same  1.7059026       No     Yes        Yes       Yes
##   130      No     Less  6.5049889       No      No         No        No
##   131      No     Less  2.7109491       No      No         No        No
##   132      No     Less  3.4291074       No      No         No        No
##   133     Yes     Less  0.5244556       No      No         No        No
##   134      No     Same  3.2446350       No      No         No        No
##   147      No     Less  2.1135076       No      No         No        No
##   149      No     Same -0.6414349       No      No         No        No
##   152      No     Less  3.3065610       No      No         No        No
##   154      No     Same  4.2138586       No     Yes        Yes       Yes
##   167      No     Same  2.7417315       No      No         No        No
```

```
## 171    No     Less  6.5812280       No      No         No        No
## 173    No     Less -1.6904375       No      No         No        No
## 174    No  Greater  5.7206517       No     Yes        Yes       Yes
## 178    No     Same  4.6750500       No      No         No        No
## 181    No     Same  9.6754326       No     Yes        Yes       Yes
## 183   Yes     Same  2.6116172       No      No         No        No
## 191    No     Same  1.0365044       No      No         No        No
## 192    No     Same  1.5778644       No      No         No        No
## 193    No     Same  7.1317797       No      No         No        No
## 194    No     Less  0.2023886       No      No         No        No
## 196    No     Less  2.5068103       No      No         No        No
## 202    No  Greater  7.4145642       No      No        Yes        No
## 206    No  Greater  6.8293497       No      No         No        No
## 212    No     Less  7.2992465       No     Yes        Yes       Yes
## 215    No     Less  5.4297358       No     Yes        Yes       Yes
## 216    No     Less  0.3320230       No      No         No        No
## 245    No  Greater  5.4965278       No     Yes        Yes       Yes
## 251    No     Less  2.2718340       No      No         No        No
## 255   Yes     Less  1.5496948       No      No         No        No
## 268    No     Less  2.3754443       No      No         No        No
## 271    No     Same  1.8226215      Yes     Yes        Yes       Yes
## 287    No     Less  7.8515610      Yes      No         No        No
## 304    No     Same  6.6671755      Yes     Yes        Yes       Yes
## 307    No     Same  0.7229242      Yes      No         No        No
## 308    No     Less  8.0477422      Yes      No         No        No
## 316    No     Same  5.5676163      Yes     Yes        Yes       Yes
## 322    No     Same  5.3158170      Yes      No         No        No
## 324    No     Same  3.9349309      Yes     Yes        Yes       Yes
## 328    No  Greater  7.5961813      Yes      No         No        No
## 332    No  Greater  5.8693506      Yes      No         No        No
## 338    No  Greater  8.5224982      Yes      No         No        No
## 341    No  Greater  1.7254001      Yes     Yes        Yes       Yes
## 342    No     Less  3.2335355      Yes     Yes        Yes       Yes
## 349    No     Same  2.5541324      Yes     Yes        Yes       Yes
```

```
## 359    No  Greater  3.1301876      Yes     Yes        Yes       Yes
## 365    No  Greater  6.9395759      Yes      No         No        No
## 367    No  Greater  7.3925026      Yes      No         No        No
## 369    No  Greater  4.1782532      Yes     Yes        Yes       Yes
## 370    No     Less  2.4080565      Yes      No         No        No
## 371    No  Greater  6.5985888      Yes      No        Yes        No
## 373    No     Same  2.3974792      Yes      No         No        No
## 386    No     Less  3.4108887      Yes     Yes         No        No
## 394    No     Same  2.1137251      Yes      No         No        No
## 401    No  Greater 10.4291243      Yes      No         No        No
## 402    No     Same  5.7535958      Yes     Yes        Yes       Yes
## 405    No  Greater  3.5563597      Yes     Yes        Yes       Yes
## 408    No     Same  3.0922428      Yes      No         No        No
## 409    No     Less  3.5029658      Yes      No         No        No
## 410    No     Same  7.6589157      Yes     Yes        Yes       Yes
## 414    No  Greater  4.5321059      Yes      No         No        No
## 417    No  Greater  5.1845967      Yes     Yes        Yes       Yes
## 419    No     Less  6.2047670      Yes      No         No        No
## 422    No     Same  0.1605734      Yes      No         No        No
## 425    No     Less  3.7065073      Yes      No         No        No
## 427    No  Greater  3.9457952      Yes     Yes        Yes       Yes
## 442    No     Less -0.5697186      Yes      No         No        No
## 464   Yes     Same  3.9231870      Yes      No         No        No
## 466    No     Same  6.1457104      Yes      No         No        No
## 467    No  Greater  6.6828235      Yes      No         No        No
## 470    No     Same  5.0400135      Yes     Yes        Yes       Yes
## 472    No     Same  4.8106546      Yes     Yes        Yes       Yes
## 475    No     Same  7.5611009      Yes      No         No        No
## 485    No     Same  3.1057034      Yes     Yes        Yes       Yes
## 492    No  Greater  5.9810467      Yes     Yes        Yes       Yes
## 498    No  Greater  1.4036609      Yes      No         No        No
## 499    No     Less  9.6447381      Yes     Yes         No        No
##
## $results
```

```
##
## Recursive feature selection
##
## Outer resampling method: Cross-Validated (10 fold)
##
## Resampling performance over subset size:
##
##  Variables Accuracy Kappa AccuracySD KappaSD Selected
##          1        1     1          0       0        *
##          2        1     1          0       0
##          3        1     1          0       0
##          4        1     1          0       0
##          5        1     1          0       0
##         14        1     1          0       0
##
## The top 1 variables (out of 1):
##    fracture
##
##
## $control
## $control$functions
## $control$functions$summary
## function (data, lev = NULL, model = NULL)
## {
##     if (is.character(data$obs))
##         data$obs <- factor(data$obs, levels = lev)
##     postResample(data[, "pred"], data[, "obs"])
## }
## <bytecode: 0x000002190a4e0df8>
## <environment: namespace:caret>
##
## $control$functions$fit
## function (x, y, first, last, ...)
## {
```

```
##     loadNamespace("randomForest")
##     randomForest::randomForest(x, y, importance = TRUE, ...)
## }
## <bytecode: 0x000002190a4e00d8>
## <environment: namespace:caret>
##
## $control$functions$pred
## function (object, x)
## {
##     tmp <- predict(object, x)
##     if (is.factor(object$y)) {
##         out <- cbind(data.frame(pred = tmp), as.data.frame(predict(object,
##             x, type = "prob"), stringsAsFactors = TRUE))
##     }
##     else out <- tmp
##     out
## }
## <bytecode: 0x000002190a4dfc08>
## <environment: namespace:caret>
##
## $control$functions$rank
## function (object, x, y)
## {
##     vimp <- varImp(object)
##     if (is.factor(y)) {
##         if (all(levels(y) %in% colnames(vimp))) {
##             avImp <- apply(vimp[, levels(y), drop = TRUE], 1,
##                 mean)
##             vimp$Overall <- avImp
##         }
##     }
##     vimp <- vimp[order(vimp$Overall, decreasing = TRUE), , drop = FALSE]
##     if (ncol(x) == 1) {
##         vimp$var <- colnames(x)
```

```
##     }
##     else vimp$var <- rownames(vimp)
##     vimp
## }
## <bytecode: 0x000002190a4e2d60>
## <environment: namespace:caret>
##
## $control$functions$selectSize
## function (x, metric, maximize)
## {
##     best <- if (maximize)
##         which.max(x[, metric])
##     else which.min(x[, metric])
##     min(x[best, "Variables"])
## }
## <bytecode: 0x000002190a4e4980>
## <environment: namespace:caret>
##
## $control$functions$selectVar
## function (y, size)
## {
##     finalImp <- ddply(y[, c("Overall", "var")], .(var), function(x)
mean(x$Overall,
##         na.rm = TRUE))
##     names(finalImp)[2] <- "Overall"
##     finalImp <- finalImp[order(finalImp$Overall, decreasing = TRUE),
##         ]
##     as.character(finalImp$var[1:size])
## }
## <bytecode: 0x000002190a4e4248>
## <environment: namespace:caret>
##
##
## $control$rerank
## [1] FALSE
```

```
##
## $control$method
## [1] "cv"
##
## $control$saveDetails
## [1] TRUE
##
## $control$number
## [1] 10
##
## $control$repeats
## [1] 1
##
## $control$returnResamp
## [1] "all"
##
## $control$verbose
## [1] FALSE
##
## $control$p
## [1] 0.75
##
## $control$index
## NULL
##
## $control$indexOut
## NULL
##
## $control$timingSamps
## [1] 0
##
## $control$seeds
## [1] NA
##
```

```
## $control$allowParallel

## [1] TRUE
```

```
# Set up parallel processing

library(doParallel)

cl <- makeCluster(detectCores() - 1)  # Use one less than the total number of cores

registerDoParallel(cl)


# Suppress warnings to clean up model training output

options(warn = -1)


# Train models

rf_model <- train(fracture ~ ., data = train_set, method = "rf", trControl = fit_control)
```

```
## Aggregating results

## Selecting tuning parameters

## Fitting mtry = 2 on full training set
```

```
knn_model <- train(fracture ~ ., data = train_set, method = "knn", trControl = fit_control)
```

```
## Aggregating results

## Selecting tuning parameters

## Fitting k = 7 on full training set
```

```
tree_model <- train(fracture ~ ., data = train_set, method = "rpart", trControl = fit_control)
```

```
## Aggregating results

## Selecting tuning parameters

## Fitting cp = 0.0473 on full training set
```

```
# Train XGBoost model with a comprehensive tuning grid

xgb_model <- train(

    fracture ~ .,

    data = train_set,

    method = "xgbTree",

    trControl = fit_control,

    tuneGrid = expand.grid(

        nrounds = 100,

        max_depth = c(3, 6, 9),
```

```
        eta = c(0.01, 0.1, 0.3),
        gamma = c(0, 0.1, 0.2),
        colsample_bytree = c(0.5, 0.75, 1),
        min_child_weight = c(1, 3, 5),
        subsample = c(0.5, 0.75, 1)
    ),
    verbose = FALSE
)
## Aggregating results
## Selecting tuning parameters
## Fitting nrounds = 100, max_depth = 9, eta = 0.01, gamma = 0.1,
colsample_bytree = 0.75, min_child_weight = 1, subsample = 1 on full training
set
# Stop parallel processing and reset options
stopCluster(cl)
registerDoSEQ()
options(warn = 0)  # Reset warning level
# Define function to extract and print model metrics
extract_metrics <- function(model, data, outcome_col) {
  predictions <- predict(model, newdata = data)
  prob_predictions <- predict(model, newdata = data, type = "prob")
  confusion <- confusionMatrix(predictions, data[[outcome_col]])
  roc_result <- roc(response = data[[outcome_col]], predictor =
prob_predictions[,2])

  list(
    Sensitivity = confusion$byClass['Sensitivity'],
    Specificity = confusion$byClass['Specificity'],
    PPV = confusion$byClass['Pos Pred Value'],
    NPV = confusion$byClass['Neg Pred Value'],
    Accuracy = confusion$overall['Accuracy'],
    AUROC = auc(roc_result)
  )
}

# Evaluate models
```

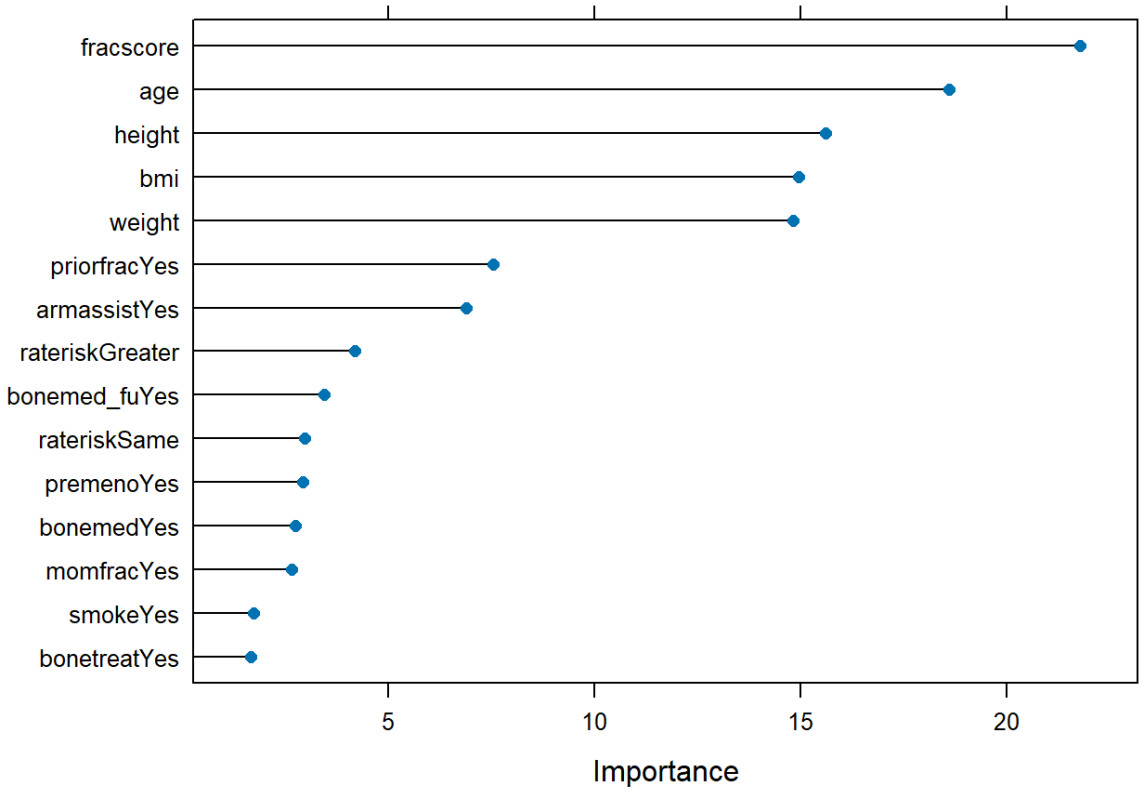
```
rf_metrics <- extract_metrics(rf_model, validation_set, "fracture")
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
knn_metrics <- extract_metrics(knn_model, validation_set, "fracture")
## Setting levels: control = No, case = Yes
## Setting direction: controls > cases
tree_metrics <- extract_metrics(tree_model, validation_set, "fracture")
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
xgb_metrics <- extract_metrics(xgb_model, validation_set, "fracture")
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
# Print metrics
print("Random Forest Metrics:")
## [1] "Random Forest Metrics:"
print(rf_metrics)
## $Sensitivity
## Sensitivity
##   0.7209302
##
## $Specificity
## Specificity
##   0.6388889
##
## $PPV
## Pos Pred Value
##      0.7045455
##
## $NPV
## Neg Pred Value
##      0.6571429
##
## $Accuracy
##  Accuracy
```

```
## 0.6835443
##
## $AUROC
## Area under the curve: 0.7574
print("KNN Metrics:")
## [1] "KNN Metrics:"
print(knn_metrics)
## $Sensitivity
## Sensitivity
##   0.6744186
##
## $Specificity
## Specificity
##   0.2222222
##
## $PPV
## Pos Pred Value
##      0.5087719
##
## $NPV
## Neg Pred Value
##      0.3636364
##
## $Accuracy
##  Accuracy
## 0.4683544
##
## $AUROC
## Area under the curve: 0.5252
print("Decision Tree Metrics:")
## [1] "Decision Tree Metrics:"
print(tree_metrics)
## $Sensitivity
## Sensitivity
```

```
##   0.6744186
##
## $Specificity
## Specificity
##   0.6111111
##
## $PPV
## Pos Pred Value
##      0.6744186
##
## $NPV
## Neg Pred Value
##      0.6111111
##
## $Accuracy
##  Accuracy
## 0.6455696
##
## $AUROC
## Area under the curve: 0.6376
print("XGBoost Metrics:")
## [1] "XGBoost Metrics:"
print(xgb_metrics)
## $Sensitivity
## Sensitivity
##   0.7209302
##
## $Specificity
## Specificity
##   0.5277778
##
## $PPV
## Pos Pred Value
##      0.6458333
```

```
##
## $NPV
## Neg Pred Value
##      0.6129032
##
## $Accuracy
##  Accuracy
## 0.6329114
##
## $AUROC
## Area under the curve: 0.6789
```

```r
# Feature Importance Plot for Random Forest
importance <- varImp(rf_model, scale = FALSE)
plot(importance)
```




```r
# Correlation matrix of the model predictions to compare model agreement
```

```r
predictions_rf <- predict(rf_model, validation_set, type = "prob")
predictions_knn <- predict(knn_model, validation_set, type = "prob")
predictions_tree <- predict(tree_model, validation_set, type = "prob")
predictions_xgb <- predict(xgb_model, validation_set, type = "prob")


# Assuming binary classification and interested in positive class probabilities
cor_matrix <- cor(cbind(predictions_rf[,2], predictions_knn[,2], predictions_tree[,2], predictions_xgb[,2]),
                  method = "pearson")
print(cor_matrix)
```

```
##           [,1]      [,2]      [,3]      [,4]
## [1,] 1.0000000 0.4698662 0.8070576 0.8628819
## [2,] 0.4698662 1.0000000 0.5212532 0.4023063
## [3,] 0.8070576 0.5212532 1.0000000 0.6969978
## [4,] 0.8628819 0.4023063 0.6969978 1.0000000
```

```r
# Evaluate models on the test set using the metrics already defined
test_metrics_rf <- extract_metrics(rf_model, test_set, "fracture")
```

```
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
```

```r
test_metrics_knn <- extract_metrics(knn_model, test_set, "fracture")
```

```
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
```

```r
test_metrics_tree <- extract_metrics(tree_model, test_set, "fracture")
```

```
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
```

```r
test_metrics_xgb <- extract_metrics(xgb_model, test_set, "fracture")
```

```
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
```

```r
# Print test metrics for each model
print("Test Metrics - Random Forest:")
```

```
## [1] "Test Metrics - Random Forest:"
```

```r
print(test_metrics_rf)
```

```
## $Sensitivity
## Sensitivity
```

```
##   0.6851852
##
## $Specificity
## Specificity
##   0.5652174
##
## $PPV
## Pos Pred Value
##      0.6491228
##
## $NPV
## Neg Pred Value
##      0.6046512
##
## $Accuracy
## Accuracy
##     0.63
##
## $AUROC
## Area under the curve: 0.7206
print("Test Metrics - KNN:")
## [1] "Test Metrics - KNN:"
print(test_metrics_knn)
## $Sensitivity
## Sensitivity
##   0.7037037
##
## $Specificity
## Specificity
##   0.3043478
##
## $PPV
## Pos Pred Value
##      0.5428571
```

```
##
## $NPV
## Neg Pred Value
##      0.4666667
##
## $Accuracy
## Accuracy
##     0.52
##
## $AUROC
## Area under the curve: 0.5215
print("Test Metrics - Decision Tree:")
## [1] "Test Metrics - Decision Tree:"
print(test_metrics_tree)
## $Sensitivity
## Sensitivity
##   0.6851852
##
## $Specificity
## Specificity
##   0.4565217
##
## $PPV
## Pos Pred Value
##      0.5967742
##
## $NPV
## Neg Pred Value
##      0.5526316
##
## $Accuracy
## Accuracy
##     0.58
##
```

```
## $AUROC
## Area under the curve: 0.5773
```

```
print("Test Metrics - XGBoost:")
```

```
## [1] "Test Metrics - XGBoost:"
```

```
print(test_metrics_xgb)
```

```
## $Sensitivity
## Sensitivity
##   0.6666667
##
## $Specificity
## Specificity
##   0.4565217
##
## $PPV
## Pos Pred Value
##      0.5901639
##
## $NPV
## Neg Pred Value
##      0.5384615
##
## $Accuracy
## Accuracy
##     0.57
##
## $AUROC
## Area under the curve: 0.6135
```

```
# Plot ROC curves for each model using the test set predictions
library(pROC)
roc_rf <- roc(response = test_set$fracture, predictor = predict(rf_model,
test_set, type = "prob")[,2])
```

```
## Setting levels: control = No, case = Yes
## Setting direction: controls < cases
```

```
roc_knn <- roc(response = test_set$fracture, predictor = predict(knn_model,
test_set, type = "prob")[,2])
```

```
## Setting levels: control = No, case = Yes

## Setting direction: controls < cases
```

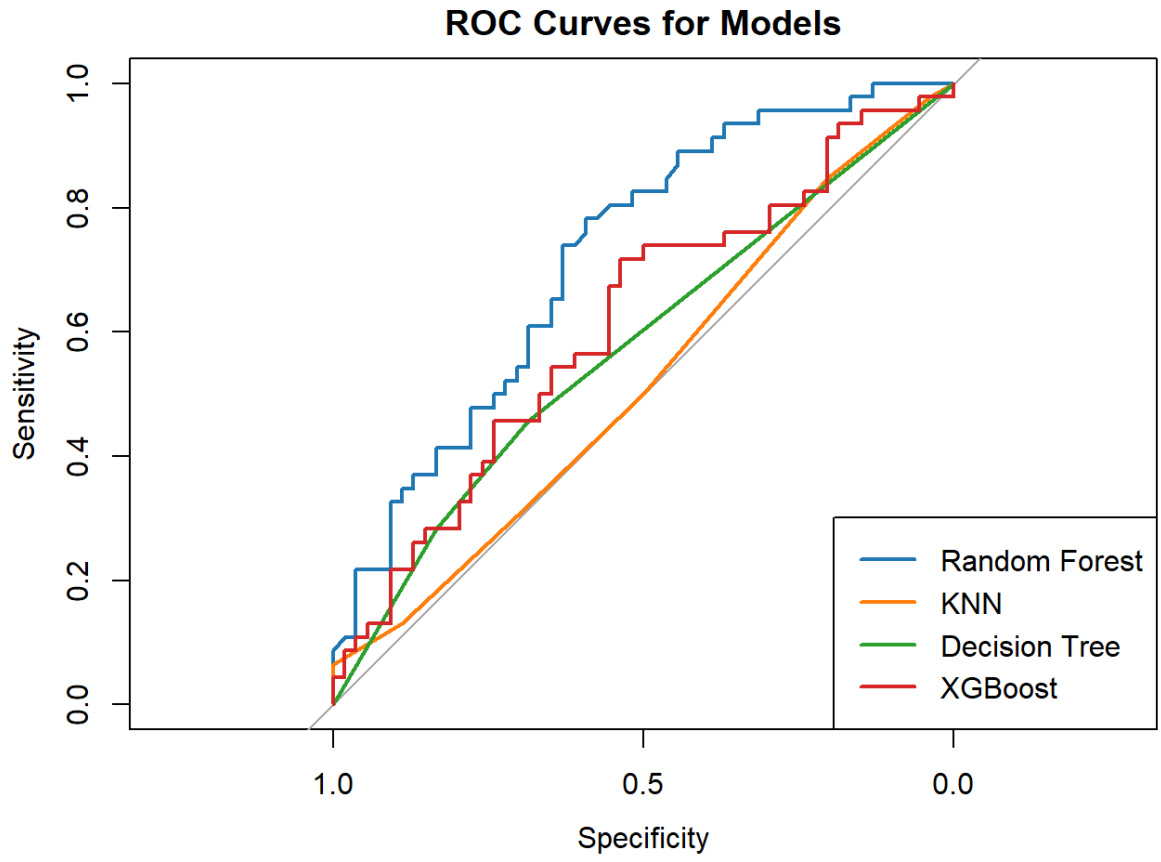
```
roc_tree <- roc(response = test_set$fracture, predictor = predict(tree_model,
test_set, type = "prob")[,2])
```

```
## Setting levels: control = No, case = Yes

## Setting direction: controls < cases
```

```
roc_xgb <- roc(response = test_set$fracture, predictor = predict(xgb_model,
test_set, type = "prob")[,2])
```

```
## Setting levels: control = No, case = Yes

## Setting direction: controls < cases
```

```
plot(roc_rf, col="#1F77B4", lwd=2, main="ROC Curves for Models")

plot(roc_knn, col="#FF7F0E", lwd=2, add=TRUE)

plot(roc_tree, col="#2CA02C", lwd=2, add=TRUE)

plot(roc_xgb, col="#D62728", lwd=2, add=TRUE)

legend("bottomright", legend=c("Random Forest", "KNN", "Decision Tree",
"XGBoost"),

       col=c("#1F77B4", "#FF7F0E", "#2CA02C", "#D62728"), lwd=2)
```



```{compare-and-analyze, cache=TRUE} # Comparison visualization and analysis # Combine AUC and other metrics into a single data frame for comparison aucs <- data.frame( Model = c("Random Forest", "KNN", "Decision Tree", "XGBoost"), AUC = c(auc(roc_rf), auc(roc_knn), auc(roc_tree), auc(roc_xgb)), Accuracy = c(test_metrics_rfAccuracy,testmetricsknn$Accuracy$,testmetricsknnAccuracy, test_metrics_treeAccuracy,testmetricsxgb$Accuracy$,testmetricsxgbAccuracy) )

# Bar plot of AUCs using ggplot2

library(ggplot2) ggplot(aucs, aes(x=Model, y=AUC, fill=Model)) + geom_bar(stat="identity", color="black") + theme_minimal() + labs(title="Comparison of Model AUCs", x="Model", y="AUC Value") + scale_fill_brewer(palette="Set1")

```