MA 679 Final Report

Group 7

2021/5/4

Introduction

After having some initial exploration of SEER data, we decided to see whether there is a bias between the doctor's decision and the treatment guideline in terms of each observation's race and gender. The treatment guideline is based on the TNM cancer stage, we only have information about the AJCC cancer stage, which means we cannot match all cancer types with their guidelines. Therefore, we only chose cancer on Salivary Gland to do further exploration since its treatment matches well with the data.

Data Processing

In the data processing step, we first selected all the Salivary Gland Cancer. In the 'NCCN Guidelines' file, there is no treatment guideline information for stage 'IVC' and 'IVNOS' of cancer Salivary Gland. We removed observations of the 'IVNOS' stage since there are only 6 observations and this amount is trivial compared with the whole dataset. As for the 'IVC' stage, according to the information provided in 'head-and-neck.pdf' page 87, there is no preferred treatment, and the treatment should be individualized based on patient characteristics. Thus, we removed all observations of the 'IVC' stage because we could not decide whether the given therapy follows the guideline or not. Other than these two stages, based on the `NCCN Guidelines`, we found that only stage 'IVB' has a different preferred number one therapy from others, its therapy1 is Radiation while other stages are recommended to have Surgery. Depending on this information, we create a binary column to indicate whether each individual is given treatment following the guideline or not, in this case, '0' means the treatment does not follow the guideline, '1' means the treatment follows the guideline. Meanwhile, we replace all the blank space and symbols in column names for convenience.

Also, we created some new variables based on the EDA: 1. Insurance2: This is a categorical variable with levels 0,1,2. We find that people in the "Insured" class have the lowest rate of being given treatment not following the guideline, while people in the "Uninsured" class have the highest rate of that. "1" indicates the "Insured" class, "2" indicates the "Uninsured" class, and "0" indicates all others.

2. Subsites2: This is a categorical variable with two levels 0 and 1. We find that in the subsite class "C08.1-Sublingual gland", all the observations are given treatment following the guideline. "1" indicates an individual is in this class, "0" indicates all others.

The specific plots and other results from EDA will be shown in the next part.

Because we decided to use machine learning, we also separate the data into training data and test data and guarantee that the proportion of 0 and 1 responses in both two samples are similar.

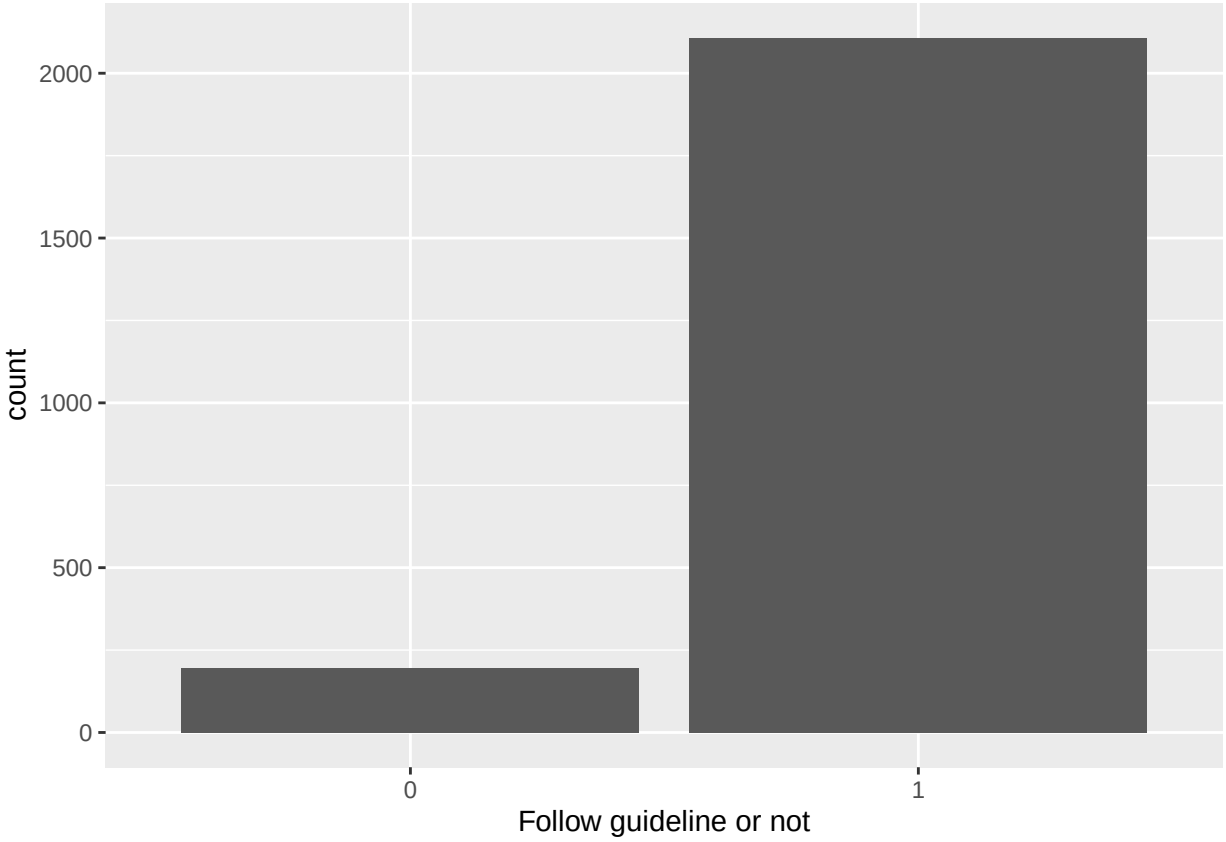
EDA

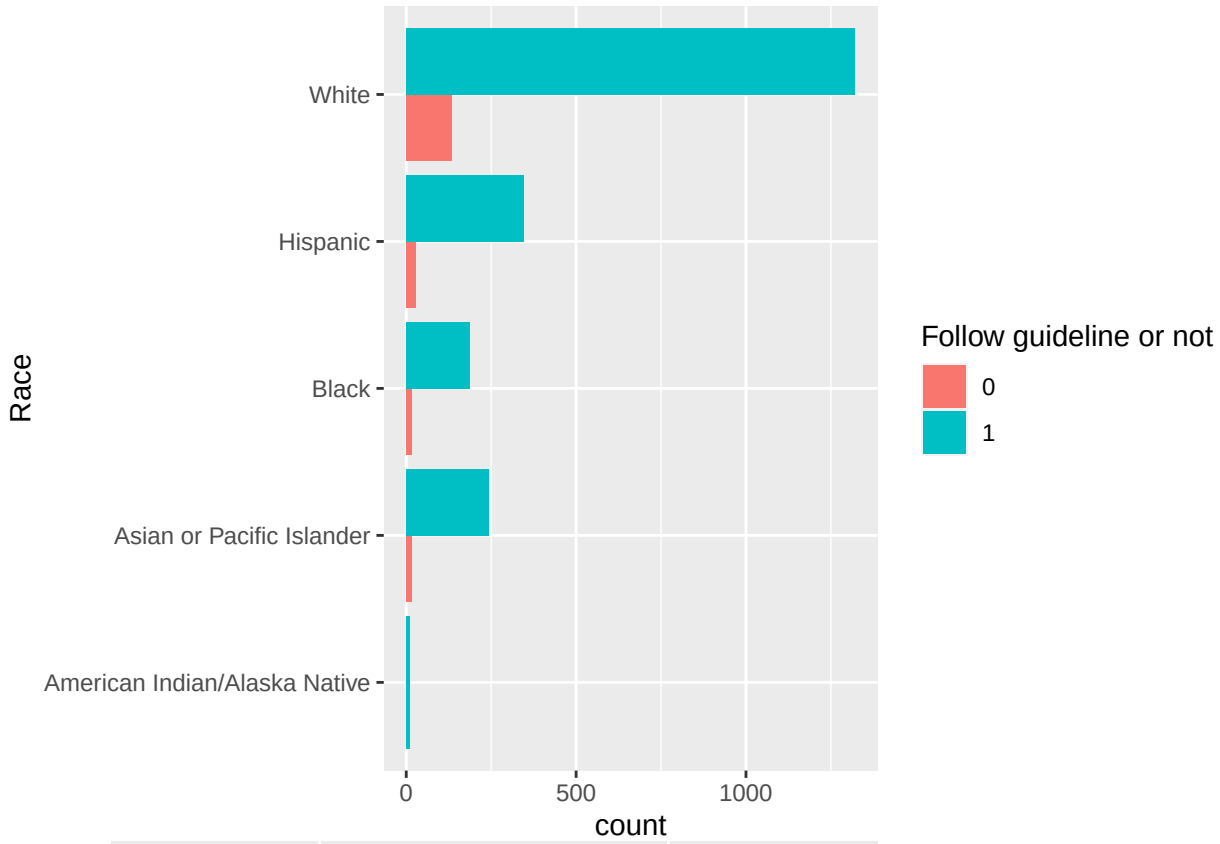
From the bar plots, we observed that this data is imbalanced in terms of Race, Gender, AJCC stage, and Insurance type, etc.

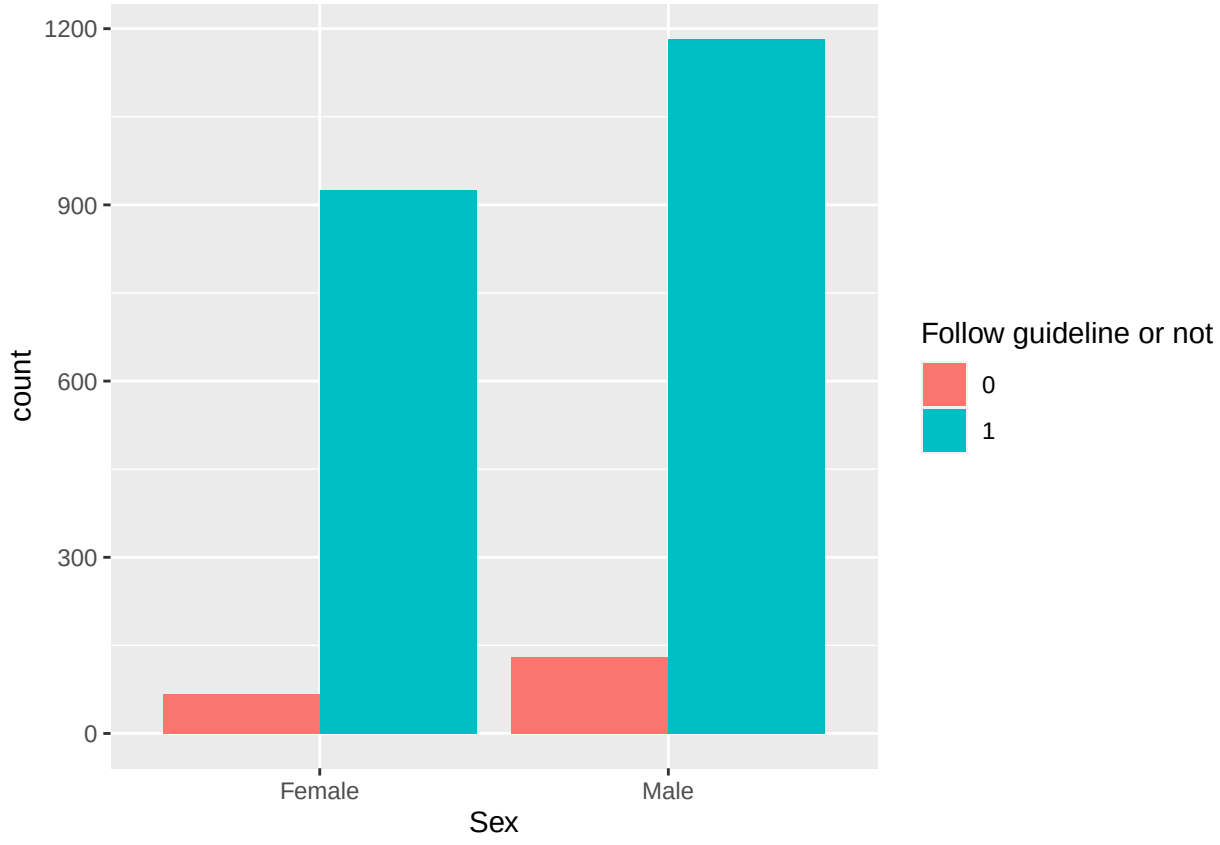
Besides this, it's notable that there are only 197 observations in class 0 (the treatment did not follow the guideline) while 2108 observations in class 1 (the treatment followed the guideline), so we also have extremely imbalanced classes in our outcome. (plots)

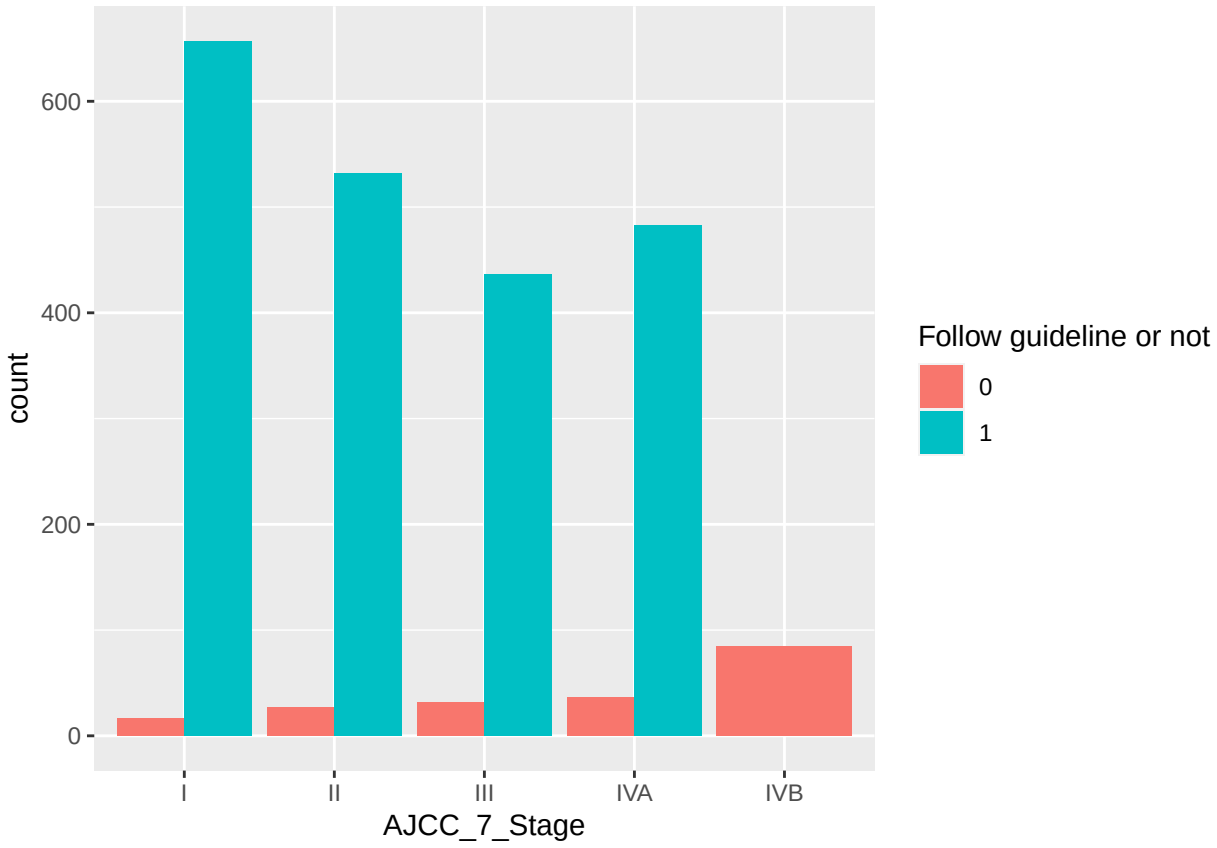
From the correlation matrix, we also noticed that, variables like education, including 9th grade, High school and bachelor are highly correlated. So we exclude them from modeling.

Other plots from our EDA are in the Appendix section.




White
Hispanic
Black
Asian or Pacific Islander
American Indian/Alaska Native
Race
0
500
1000
count
Follow guideline or not
0
1


1200
900
600
300
0
count
Female
Male
Sex
Follow guideline or not
0
1



Modeling

We tried the logistic regression and multilevel logistic regression as our baselines, and then we moved to the classification tree, SVM, and random forest to see if they could return better results.

Since we have very imbalanced classes, we chose not to use the accuracy from the confusion matrix as a standard to compare the model performances because it is misleading in this case. For example, the model could classify half of the 0s wrong, but 99% of 1s correct, but since we have only 197 zeros but 2108 ones in the data frame, the accuracy from the confusion matrix would still be super high. However, we hope our model can perform equally well for each class. What we decided to use for comparing models are:

1. the confusion matrix result, how many 0s and 1s are misclassified
2. AUC

We used 0.5 as the threshold and classified a probability greater than 0.5 as class1 and others as class0. The AUC results from logistic regression and multilevel regression are 0.72 and 0.754. Random forest with stratified sampling returns an AUC of about 0.8. For all other models, the accuracy of predicting class1 is higher than 90%, but the accuracy of predicting class0 is only about 50% while that of the random forest model with stratified sampling is over 70%.

Based on those two criteria, we decided to use the random forest model for the following analysis.

Random Forest

We first fitted a normal randomForest model and tuned the hyperparameters mtry and ntree. We got maximum AUC at 0.725 for mtry = 7 and ntree = 600.

Next, to deal with the imbalanced classes problem, we tried the stratified sampling method in randomForest with different ratios of class 0s and class 1s. We tuned the partition of the sample size and used 2:3 (60 for

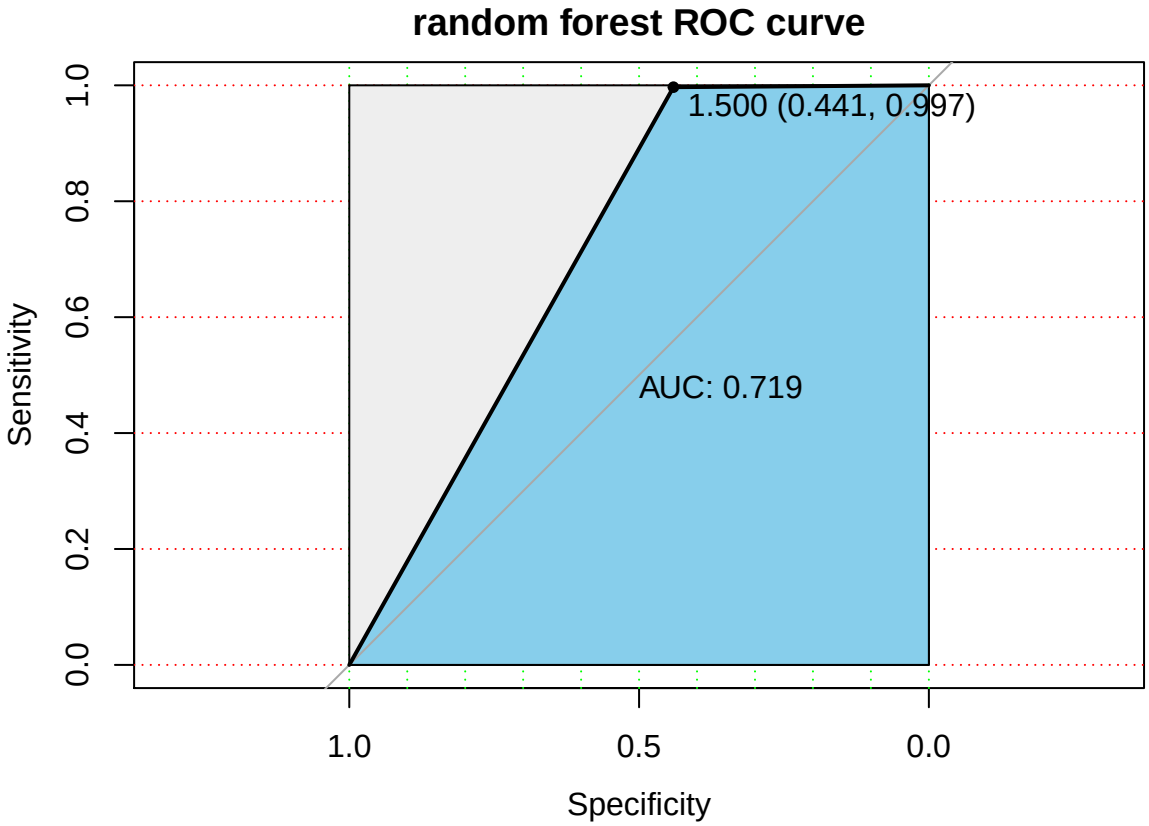
class0 and 90 for class1) which returned the maximum AUC. We also tuned mtry and ntree, and the values that returned the largest AUC are mtry = 5 and ntree = 3000.

We drew the variable importance plot using the mean decrease Gini. In both models, AJCC_7_Stage, Age_at_Diagnosis, and Year_of_Diagnosis contribute most to whether the patient followed the guidelines. For the bias that we are considering about, it seems that race, gender, and insurance tend to have a small influence.

```
##
## pred_forest   0   1
##           0  26   2
##           1  33 630
```

```
## Setting levels: control = 0, case = 1
```

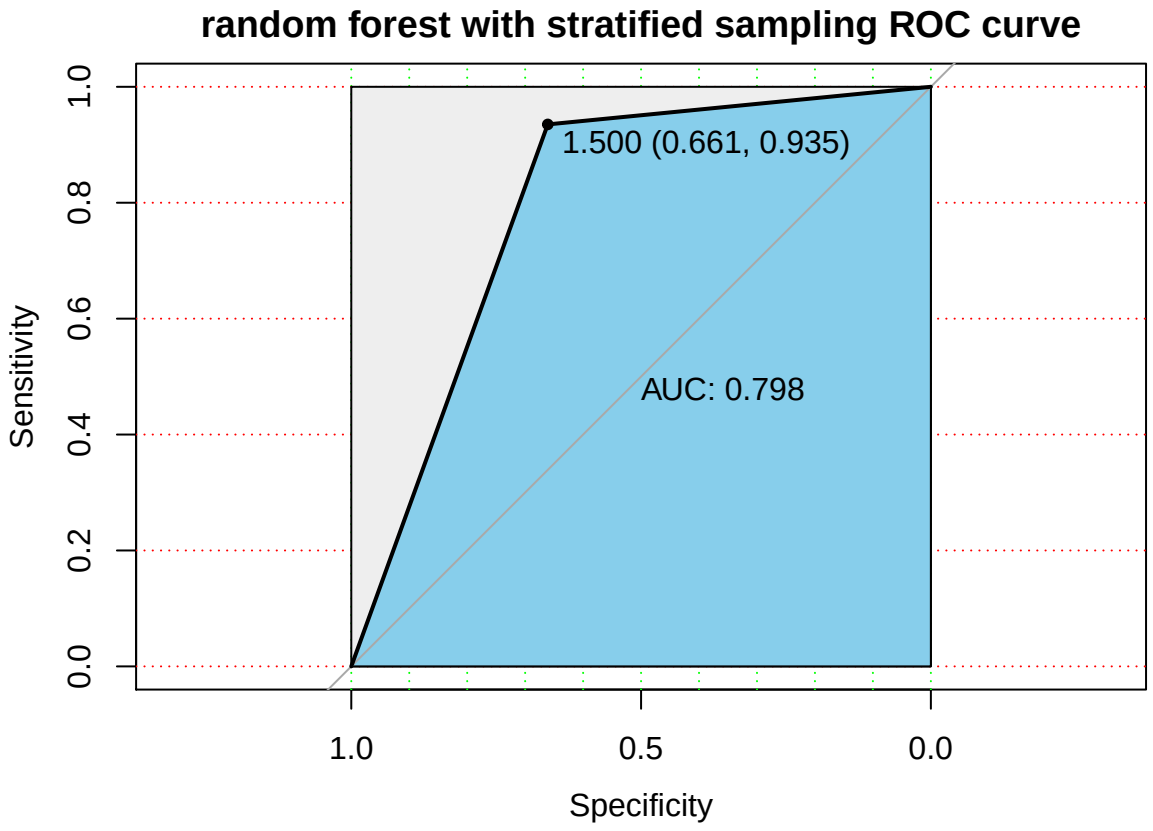
```
## Setting direction: controls < cases
```

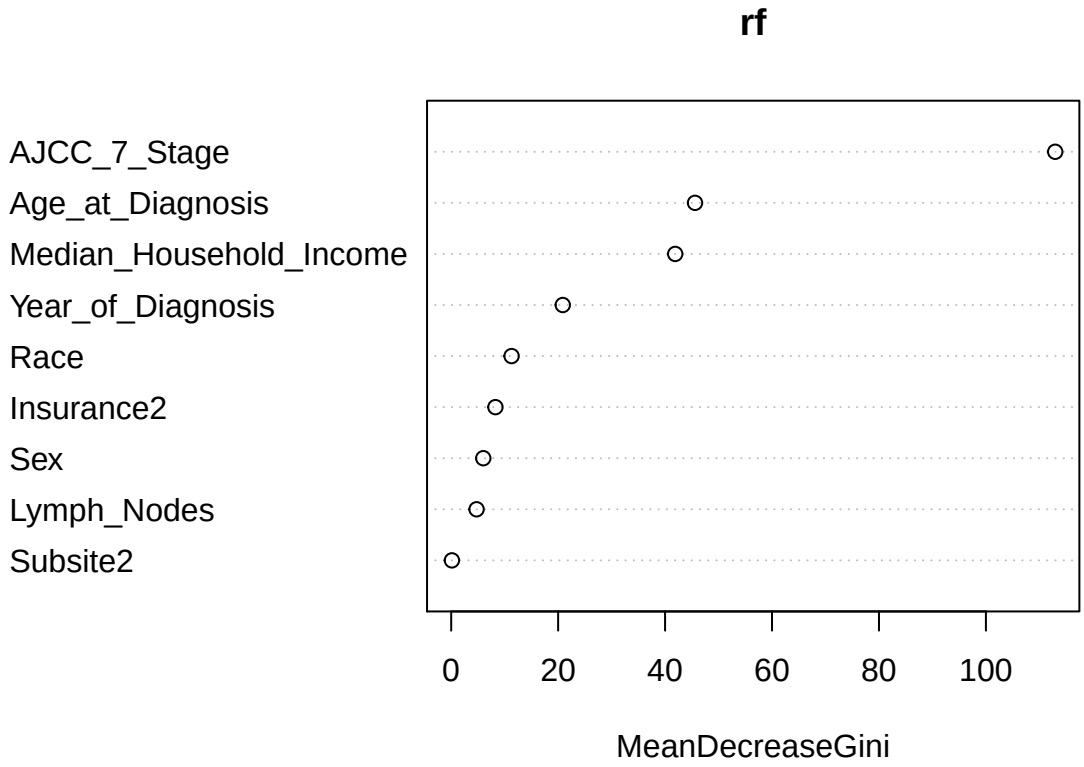



```
##
## pred_forest2   0   1
##            0  39  41
##            1  20 591
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```


random forest with stratified sampling ROC curve
1.500 (0.661, 0.935)
AUC: 0.798
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
1.0
0.5
0.0
Specificity


rf
AJCC_7_Stage
Age_at_Diagnosis
Median_Household_Income
Year_of_Diagnosis
Race
Insurance2
Sex
Lymph_Nodes
Subsite2
0
20
40
60
80
100
MeanDecreaseGini

Result

To see if there is bias, we compared two models where one of them contains Race and Gender as predictors and the other does not. If we can find an obvious difference in the prediction, then there might be some bias. We still used the confusion matrix result and AUC as standards to compare the model results.

For the random forest model without stratified sampling method, we found the model without Race and Gender as predictors had a slightly worse prediction, to be specific, this exclusion resulted in the model misclassified about 4 more observations in class1 to class0, and this causes the AUC fluctuated around 0.3% - 0.5%.

For the random forest model with the stratified sampling method, the result is very similar. The model without Race and Gender as predictors misclassified 9 more observations in class1 to class0 compared with the model with Race and Gender, and its AUC fluctuated around 0.2% .

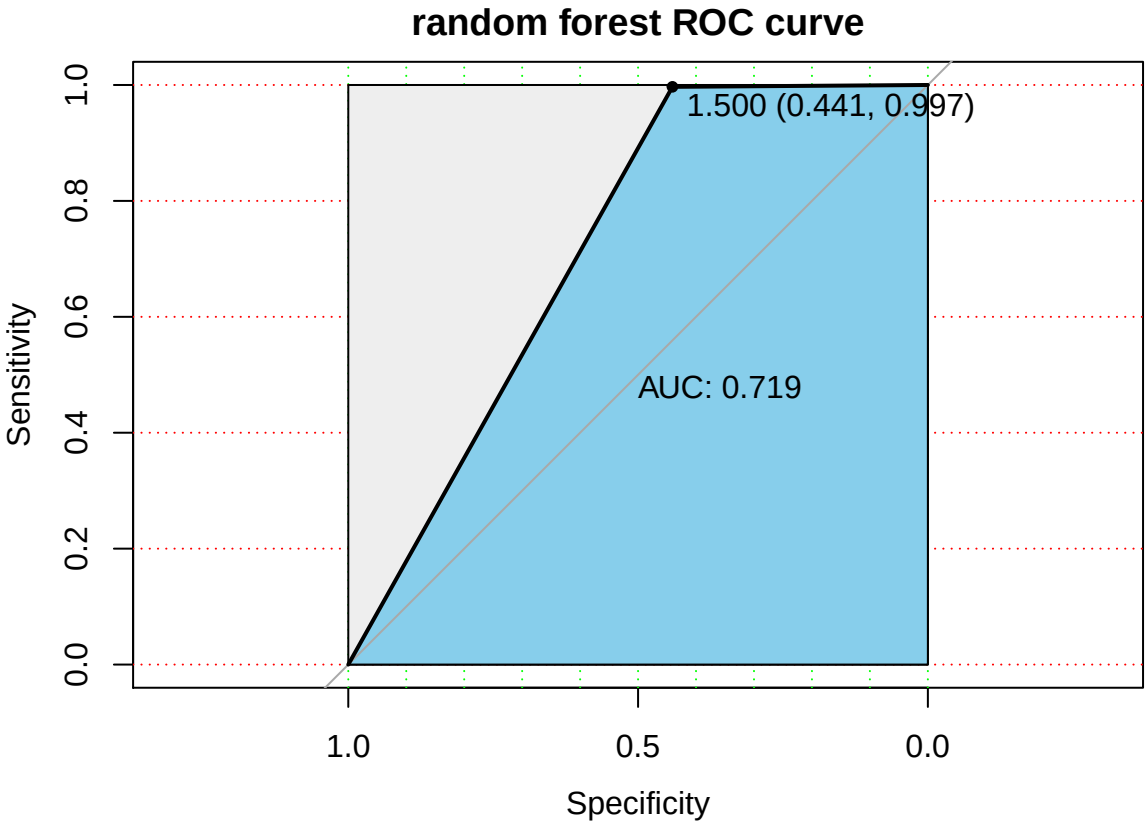
From what we got from the results, since there was no obvious difference in the prediction, we cannot conclude the existence of bias in either race or gender.

```
##
## pred_forest   0   1
##           0  26   2
##           1  33 630
```

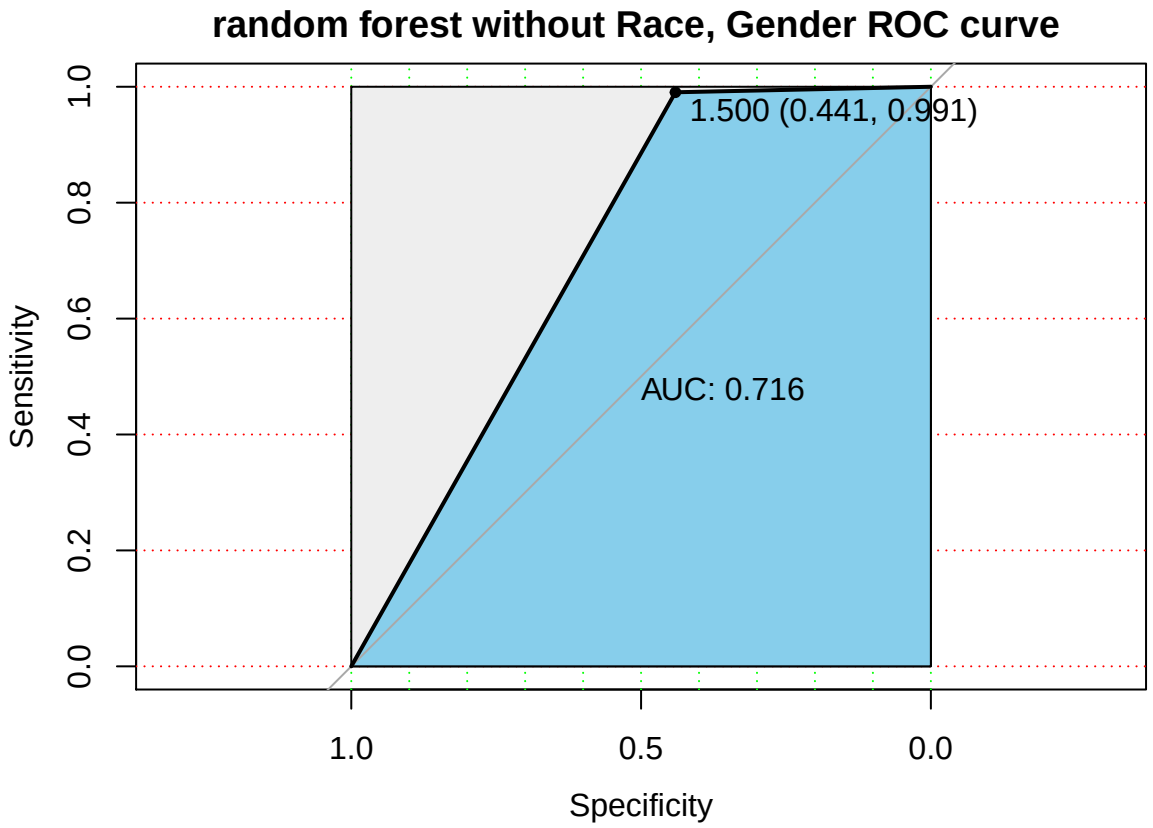
```
##
## pred_forest1_2   0   1
##              0  26   6
##              1  33 626
```

```
## Setting levels: control = 0, case = 1
```

```
## Setting direction: controls < cases
```



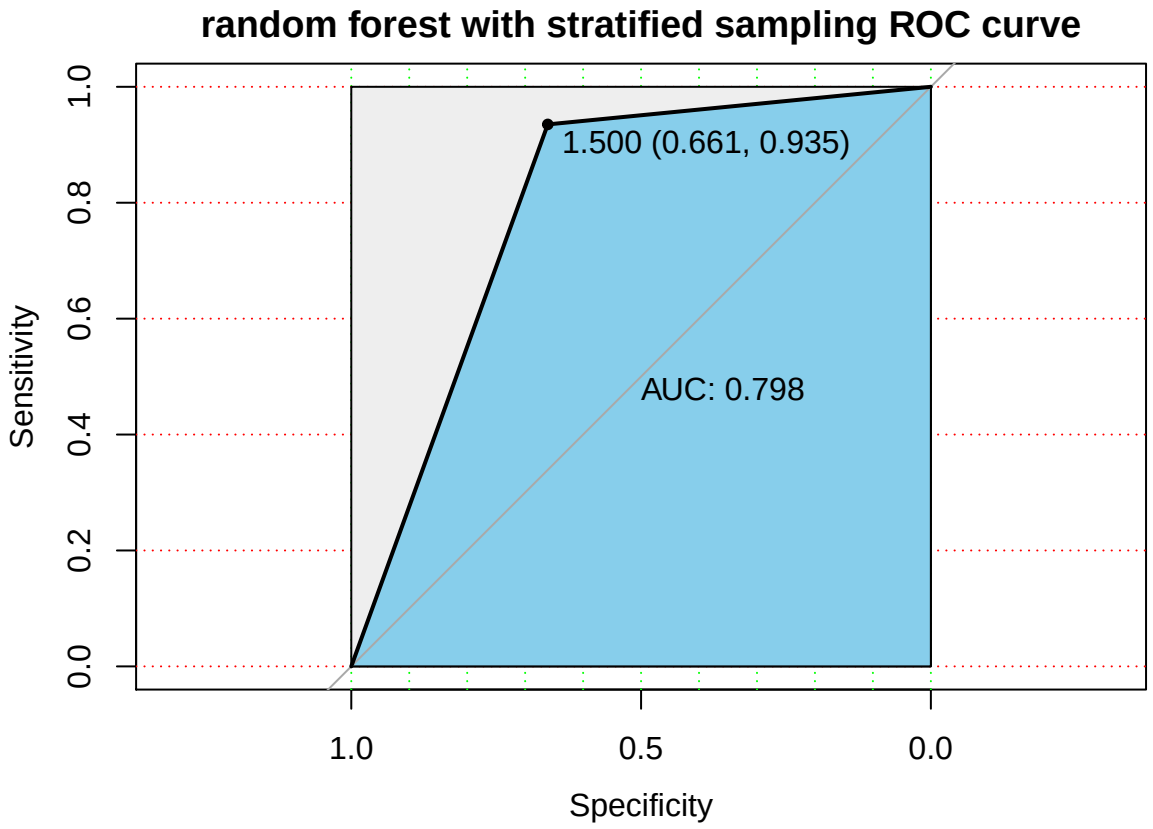
```
## Setting levels: control = 0, case = 1
## Setting direction: controls < cases
```



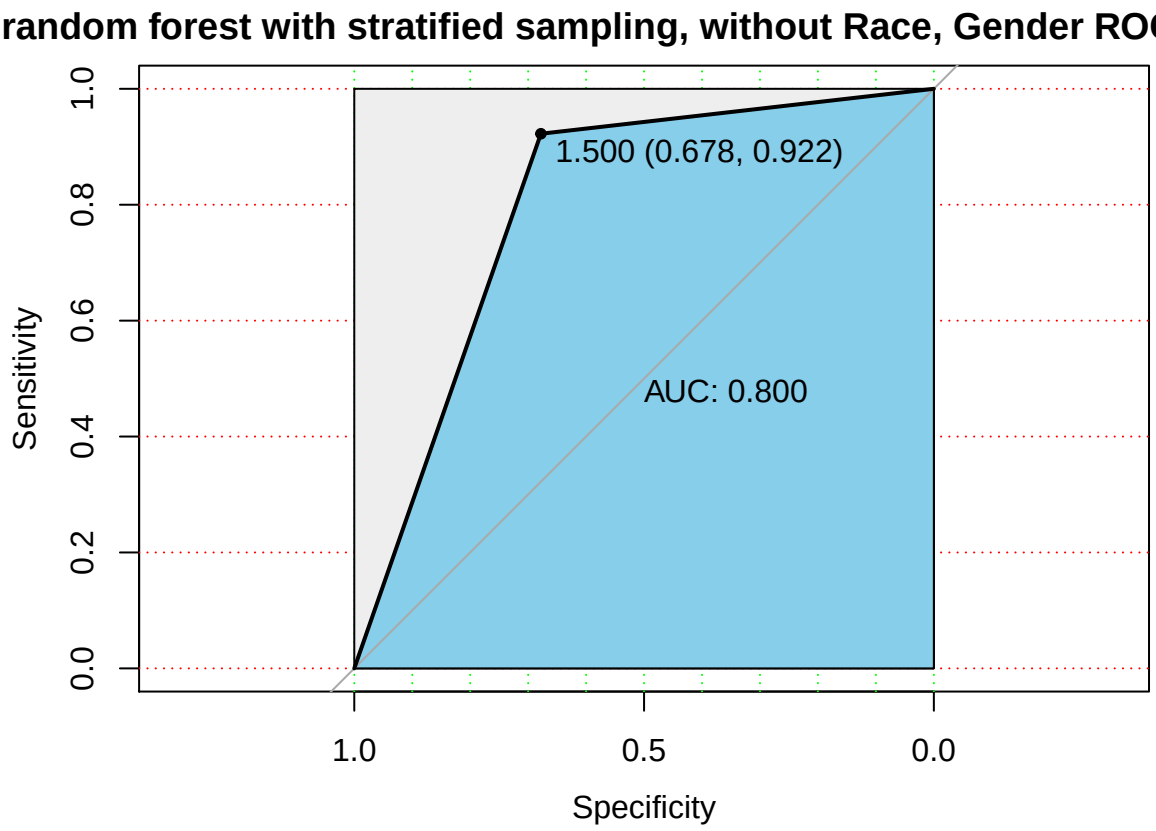

```
##
## pred_forest2   0   1
##            0  39  41
##            1  20 591
```

```
##
## pred_forest2_2   0   1
##              0  40  49
##              1  19 583
```

```
## Setting levels: control = 0, case = 1
## Setting direction: controls < cases
```




```
## Setting levels: control = 0, case = 1
## Setting direction: controls < cases
```



Discussion

Because we do not have information like TNM stage, so we cannot match treatment guidelines with all head and neck cancer. Therefore, we only choose one site here, and the conclusions we made are all based on that certain site. Once we get to the TNM stage, we can do that on all the data, and it will give us a broader view of bias.

We do our best to fit a model performing well on both class 1 and class 0, as you can see the model is not perfect due to the limitation of data imbalance. This is a question that often can be seen in machine learning since in the real world those imbalance things always happen. Our model here is only a reference to give a sense of what and how this bias will happen, and due to the accuracy of the model, we cannot assert that it must or it must not have bias.

Appendix

We found some methods on this website, and the Jupyter notebook .ipynb file is uploaded in the Appendix folder on our github. The performance of these models are close to our random forest model.

Citation

```
## [[1]]
##
## To cite package 'Metrics' in publications use:
##
##   Ben Hamner and Michael Frasco (2018). Metrics: Evaluation Metrics for
##   Machine Learning. R package version 0.1.4.
```

```
##   https://CRAN.R-project.org/package=Metrics
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {Metrics: Evaluation Metrics for Machine Learning},
##     author = {Ben Hamner and Michael Frasco},
##     year = {2018},
##     note = {R package version 0.1.4},
##     url = {https://CRAN.R-project.org/package=Metrics},
##   }
##
##
## [[2]]
##
## To cite the ROSE package in publications use:
##
##   Nicola Lunardon, Giovanna Menardi, and Nicola Torelli (2014). ROSE: a
##   Package for Binary Imbalanced Learning. R Journal, 6(1), 82-92.
##
## A BibTeX entry for LaTeX users is
##
##   @Article{,
##     title = {{ROSE}: a {P}ackage for {B}inary {I}mbalanced {L}earning},
##     author = {Nicola Lunardon and Giovanna Menardi and Nicola Torelli},
##     journal = {{R} Journal},
##     year = {2014},
##     volume = {6},
##     number = {1},
##     pages = {82--92},
##   }
##
##
## [[3]]
##
## If you use pROC in published research, please cite the following paper:
##
##   Xavier Robin, Natacha Turck, Alexandre Hainard, Natalia Tiberti,
##   Frédérique Lisacek, Jean-Charles Sanchez and Markus Müller (2011).
##   pROC: an open-source package for R and S+ to analyze and compare ROC
##   curves. BMC Bioinformatics, 12, p. 77.  DOI: 10.1186/1471-2105-12-77
##   <http://www.biomedcentral.com/1471-2105/12/77/>
##
## A BibTeX entry for LaTeX users is
##
##   @Article{,
##     title = {pROC: an open-source package for R and S+ to analyze and compare ROC curves},
##     author = {Xavier Robin and Natacha Turck and Alexandre Hainard and Natalia Tiberti and Frédérique
##     year = {2011},
##     journal = {BMC Bioinformatics},
##     volume = {12},
##     pages = {77},
##   }
##
```

```
##
## [[4]]
##
## To cite package 'e1071' in publications use:
##
##   David Meyer, Evgenia Dimitriadou, Kurt Hornik, Andreas Weingessel and
##   Friedrich Leisch (2020). e1071: Misc Functions of the Department of
##   Statistics, Probability Theory Group (Formerly: E1071), TU Wien. R
##   package version 1.7-4. https://CRAN.R-project.org/package=e1071
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {e1071: Misc Functions of the Department of Statistics, Probability
## Theory Group (Formerly: E1071), TU Wien},
##     author = {David Meyer and Evgenia Dimitriadou and Kurt Hornik and Andreas Weingessel and Friedri
##     year = {2020},
##     note = {R package version 1.7-4},
##     url = {https://CRAN.R-project.org/package=e1071},
##   }
##
##
## [[5]]
##
## To cite randomForest in publications use:
##
##   A. Liaw and M. Wiener (2002). Classification and Regression by
##   randomForest. R News 2(3), 18--22.
##
## A BibTeX entry for LaTeX users is
##
##   @Article{,
##     title = {Classification and Regression by randomForest},
##     author = {Andy Liaw and Matthew Wiener},
##     journal = {R News},
##     year = {2002},
##     volume = {2},
##     number = {3},
##     pages = {18-22},
##     url = {https://CRAN.R-project.org/doc/Rnews/},
##   }
##
##
## [[6]]
##
## To cite package 'caret' in publications use:
##
##   Max Kuhn (2020). caret: Classification and Regression Training. R
##   package version 6.0-86. https://CRAN.R-project.org/package=caret
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {caret: Classification and Regression Training},
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```
##     author = {Max Kuhn},
##     year = {2020},
##     note = {R package version 6.0-86},
##     url = {https://CRAN.R-project.org/package=caret},
##   }
##
##
## [[7]]
##
## To cite the lattice package in publications use:
##
##   Sarkar, Deepayan (2008) Lattice: Multivariate Data Visualization with
##   R. Springer, New York. ISBN 978-0-387-75968-5
##
## A BibTeX entry for LaTeX users is
##
##   @Book{,
##     title = {Lattice: Multivariate Data Visualization with R},
##     author = {Deepayan Sarkar},
##     publisher = {Springer},
##     address = {New York},
##     year = {2008},
##     note = {ISBN 978-0-387-75968-5},
##     url = {http://lmdvr.r-forge.r-project.org},
##   }
##
##
## [[8]]
##
## To cite package 'readxl' in publications use:
##
##   Hadley Wickham and Jennifer Bryan (2019). readxl: Read Excel Files. R
##   package version 1.3.1. https://CRAN.R-project.org/package=readxl
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {readxl: Read Excel Files},
##     author = {Hadley Wickham and Jennifer Bryan},
##     year = {2019},
##     note = {R package version 1.3.1},
##     url = {https://CRAN.R-project.org/package=readxl},
##   }
##
##
## [[9]]
##
## To cite package 'forcats' in publications use:
##
##   Hadley Wickham (2021). forcats: Tools for Working with Categorical
##   Variables (Factors). R package version 0.5.1.
##   https://CRAN.R-project.org/package=forcats
##
## A BibTeX entry for LaTeX users is
```

```
##
##   @Manual{,
##     title = {forcats: Tools for Working with Categorical Variables (Factors)},
##     author = {Hadley Wickham},
##     year = {2021},
##     note = {R package version 0.5.1},
##     url = {https://CRAN.R-project.org/package=forcats},
##   }
##
##
## [[10]]
##
## To cite package 'stringr' in publications use:
##
##   Hadley Wickham (2019). stringr: Simple, Consistent Wrappers for
##   Common String Operations. R package version 1.4.0.
##   https://CRAN.R-project.org/package=stringr
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {stringr: Simple, Consistent Wrappers for Common String Operations},
##     author = {Hadley Wickham},
##     year = {2019},
##     note = {R package version 1.4.0},
##     url = {https://CRAN.R-project.org/package=stringr},
##   }
##
##
## [[11]]
##
## To cite package 'dplyr' in publications use:
##
##   Hadley Wickham, Romain François, Lionel Henry and Kirill Müller
##   (2021). dplyr: A Grammar of Data Manipulation. R package version
##   1.0.5. https://CRAN.R-project.org/package=dplyr
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {dplyr: A Grammar of Data Manipulation},
##     author = {Hadley Wickham and Romain François and Lionel Henry and Kirill Müller},
##     year = {2021},
##     note = {R package version 1.0.5},
##     url = {https://CRAN.R-project.org/package=dplyr},
##   }
##
##
## [[12]]
##
## To cite package 'purrr' in publications use:
##
##   Lionel Henry and Hadley Wickham (2020). purrr: Functional Programming
##   Tools. R package version 0.3.4.
```

```
##   https://CRAN.R-project.org/package=purrr
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {purrr: Functional Programming Tools},
##     author = {Lionel Henry and Hadley Wickham},
##     year = {2020},
##     note = {R package version 0.3.4},
##     url = {https://CRAN.R-project.org/package=purrr},
##   }
##
##
## [[13]]
##
## To cite package 'readr' in publications use:
##
##   Hadley Wickham and Jim Hester (2020). readr: Read Rectangular Text
##   Data. R package version 1.4.0.
##   https://CRAN.R-project.org/package=readr
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {readr: Read Rectangular Text Data},
##     author = {Hadley Wickham and Jim Hester},
##     year = {2020},
##     note = {R package version 1.4.0},
##     url = {https://CRAN.R-project.org/package=readr},
##   }
##
##
## [[14]]
##
## To cite package 'tidyr' in publications use:
##
##   Hadley Wickham (2021). tidyr: Tidy Messy Data. R package version
##   1.1.3. https://CRAN.R-project.org/package=tidyr
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {tidyr: Tidy Messy Data},
##     author = {Hadley Wickham},
##     year = {2021},
##     note = {R package version 1.1.3},
##     url = {https://CRAN.R-project.org/package=tidyr},
##   }
##
##
## [[15]]
##
## To cite package 'tibble' in publications use:
##
```

```
##   Kirill Müller and Hadley Wickham (2021). tibble: Simple Data Frames.
##   R package version 3.1.1. https://CRAN.R-project.org/package=tibble
##
## A BibTeX entry for LaTeX users is
##
##   @Manual{,
##     title = {tibble: Simple Data Frames},
##     author = {Kirill Müller and Hadley Wickham},
##     year = {2021},
##     note = {R package version 3.1.1},
##     url = {https://CRAN.R-project.org/package=tibble},
##   }
##
##
## [[16]]
##
## To cite ggplot2 in publications, please use:
##
##   H. Wickham. ggplot2: Elegant Graphics for Data Analysis.
##   Springer-Verlag New York, 2016.
##
## A BibTeX entry for LaTeX users is
##
##   @Book{,
##     author = {Hadley Wickham},
##     title = {ggplot2: Elegant Graphics for Data Analysis},
##     publisher = {Springer-Verlag New York},
##     year = {2016},
##     isbn = {978-3-319-24277-4},
##     url = {https://ggplot2.tidyverse.org},
##   }
##
##
## [[17]]
##
##   Wickham et al., (2019). Welcome to the tidyverse. Journal of Open
##   Source Software, 4(43), 1686, https://doi.org/10.21105/joss.01686
##
## A BibTeX entry for LaTeX users is
##
##   @Article{,
##     title = {Welcome to the {tidyverse}},
##     author = {Hadley Wickham and Mara Averick and Jennifer Bryan and Winston Chang and Lucy D'Agostin
##     year = {2019},
##     journal = {Journal of Open Source Software},
##     volume = {4},
##     number = {43},
##     pages = {1686},
##     doi = {10.21105/joss.01686},
##   }
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