Telco Predicting Customer Churn

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```
library("dplyr")
```

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

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

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

```
library(ggplot2)
library(dplyr)
library(scales)
library(patchwork)
library(glmnet)
```

```
## Loading required package: Matrix

## Loaded glmnet 4.1-8
```

```
library(caret)
```

```
## 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(ROSE)
```

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

```
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
```

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

```
library(car)
```

```
## Loading required package: carData
```

```
##
## Attaching package: 'car'
```

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

```
head(telco_chrun)
```

```
##   customerID gender SeniorCitizen Partner Dependents tenure PhoneService
## 1 7590-VHVEG Female             0     Yes         No      1           No
## 2 5575-GNVDE   Male             0      No         No     34          Yes
## 3 3668-QPYBK   Male             0      No         No      2          Yes
## 4 7795-CFOCW   Male             0      No         No     45           No
## 5 9237-HQITU Female             0      No         No      2          Yes
## 6 9305-CDSKC Female             0      No         No      8          Yes
##      MultipleLines InternetService OnlineSecurity OnlineBackup DeviceProtection
## 1 No phone service             DSL             No          Yes               No
## 2               No             DSL            Yes           No              Yes
## 3               No             DSL            Yes          Yes               No
## 4 No phone service             DSL            Yes           No              Yes
## 5               No     Fiber optic             No           No               No
## 6              Yes     Fiber optic             No           No              Yes
##   TechSupport StreamingTV StreamingMovies       Contract PaperlessBilling
## 1          No          No              No Month-to-month              Yes
## 2          No          No              No       One year               No
## 3          No          No              No Month-to-month              Yes
## 4         Yes          No              No       One year               No
## 5          No          No              No Month-to-month              Yes
## 6          No         Yes             Yes Month-to-month              Yes
##               PaymentMethod MonthlyCharges TotalCharges Churn
## 1          Electronic check          29.85        29.85    No
## 2              Mailed check          56.95      1889.50    No
## 3              Mailed check          53.85       108.15   Yes
## 4 Bank transfer (automatic)          42.30      1840.75    No
## 5          Electronic check          70.70       151.65   Yes
## 6          Electronic check          99.65       820.50   Yes
```

#Understanding the nature of the variables (appropiate data types)

```
summary(telco_chrun)
```

```
##   customerID           gender          SeniorCitizen      Partner         
##  Length:7043        Length:7043        Min.   :0.0000   Length:7043       
##  Class :character   Class :character   1st Qu.:0.0000   Class :character  
##  Mode  :character   Mode  :character   Median :0.0000   Mode  :character  
##                                        Mean   :0.1621                     
##                                        3rd Qu.:0.0000                     
##                                        Max.   :1.0000                     
##                                                                           
##   Dependents            tenure      PhoneService       MultipleLines     
##  Length:7043        Min.   : 0.00   Length:7043        Length:7043       
##  Class :character   1st Qu.: 9.00   Class :character   Class :character  
##  Mode  :character   Median :29.00   Mode  :character   Mode  :character  
##                     Mean   :32.37                                        
##                     3rd Qu.:55.00                                        
##                     Max.   :72.00                                        
##                                                                           
##  InternetService    OnlineSecurity     OnlineBackup       DeviceProtection  
##  Length:7043        Length:7043        Length:7043        Length:7043       
##  Class :character   Class :character   Class :character   Class :character  
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character  
##                                                                             
##                                                                             
##                                                                             
##                                                                             
##  TechSupport        StreamingTV        StreamingMovies      Contract        
##  Length:7043        Length:7043        Length:7043        Length:7043       
##  Class :character   Class :character   Class :character   Class :character  
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character  
##                                                                             
##                                                                             
##                                                                             
##                                                                             
##  PaperlessBilling   PaymentMethod      MonthlyCharges    TotalCharges   
##  Length:7043        Length:7043        Min.   : 18.25   Min.   :  18.8  
##  Class :character   Class :character   1st Qu.: 35.50   1st Qu.: 401.4  
##  Mode  :character   Mode  :character   Median : 70.35   Median :1397.5
##                                         Mean   : 64.76   Mean   :2283.3
##                                         3rd Qu.: 89.85   3rd Qu.:3794.7
##                                         Max.   :118.75   Max.   :8684.8
##                                                          NA’s   :11
##     Churn
##  Length:7043
##  Class :character
##  Mode  :character
##
##
##
##
```

```
telco_chrun$gender <- as.factor(telco_chrun$gender)
telco_chrun$SeniorCitizen <- as.factor(telco_chrun$SeniorCitizen)
telco_chrun$Partner  <- as.factor(telco_chrun$Partner)
telco_chrun$Dependents  <- as.factor(telco_chrun$Dependents)
telco_chrun$PhoneService  <- as.factor(telco_chrun$PhoneService)
telco_chrun$MultipleLines  <- as.factor(telco_chrun$MultipleLines)
telco_chrun$InternetService  <- as.factor(telco_chrun$InternetService)
telco_chrun$OnlineSecurity   <- as.factor(telco_chrun$OnlineSecurity)
telco_chrun$DeviceProtection  <- as.factor(telco_chrun$DeviceProtection)
telco_chrun$OnlineBackup <- as.factor(telco_chrun$OnlineBackup)
telco_chrun$TechSupport  <- as.factor(telco_chrun$TechSupport)
telco_chrun$StreamingTV  <- as.factor(telco_chrun$StreamingTV)
telco_chrun$StreamingMovies  <- as.factor(telco_chrun$StreamingMovies)
telco_chrun$Contract  <- as.factor(telco_chrun$Contract)
telco_chrun$PaperlessBilling  <- as.factor(telco_chrun$PaperlessBilling)
telco_chrun$PaymentMethod  <- as.factor(telco_chrun$PaymentMethod)
telco_chrun$Churn  <- as.factor(telco_chrun$Churn)

summary(telco_chrun)
```

```
##   customerID           gender     SeniorCitizen Partner    Dependents
##  Length:7043        Female:3488   0:5901        No :3641   No :4933
##  Class :character   Male  :3555   1:1142        Yes:3402   Yes:2110
##  Mode  :character
##
##
##
##
##      tenure      PhoneService          MultipleLines     InternetService
##  Min.   : 0.00   No : 682     No              :3390   DSL        :2421
##  1st Qu.: 9.00   Yes:6361     No phone service: 682   Fiber optic:3096
##  Median :29.00                Yes             :2971   No         :1526
##  Mean   :32.37
##  3rd Qu.:55.00
##  Max.   :72.00
##
##               OnlineSecurity              OnlineBackup
##  No                 :3498   No                 :3088
##  No internet service:1526   No internet service:1526
##  Yes                :2019   Yes                :2429
```

```
##
##
##
##
##             DeviceProtection              TechSupport
##  No                 :3095    No                 :3473
##  No internet service:1526    No internet service:1526
##  Yes                :2422    Yes                :2044
##
##
##
##
##               StreamingTV              StreamingMovies           Contract
##  No                 :2810   No                 :2785   Month-to-month:3875
##  No internet service:1526   No internet service:1526   One year      :1473
##  Yes                :2707   Yes                :2732   Two year      :1695
##
##
##
##
##  PaperlessBilling                   PaymentMethod  MonthlyCharges
##  No :2872         Bank transfer (automatic):1544   Min.   : 18.25
##  Yes:4171         Credit card (automatic)  :1522   1st Qu.: 35.50
##                   Electronic check         :2365   Median : 70.35
##                   Mailed check             :1612   Mean   : 64.76
##                                                    3rd Qu.: 89.85
##                                                    Max.   :118.75
##
##   TotalCharges    Churn
##  Min.   :  18.8   No :5174
##  1st Qu.: 401.4   Yes:1869
##  Median :1397.5
##  Mean   :2283.3
##  3rd Qu.:3794.7
##  Max.   :8684.8
##  NA's   :11
```

```
telco_chrun_clean <- telco_chrun %>%
  select(-customerID) %>%

  mutate(MultipleLines = case_when(
    MultipleLines %in% c("No phone service", "No") ~ "No",
    TRUE ~ "Yes"
  )) %>%

  mutate(InternetService = case_when(
    InternetService == "Fiber optic" ~ "FiberOptic",
    InternetService == "DSL" ~ "DSL",
    TRUE ~ "No"
  )) %>%

  mutate(across(c(OnlineSecurity, OnlineBackup, DeviceProtection, TechSupport, StreamingTV, StreamingMo
              ~ case_when(
                . %in% c("No internet service", "No") ~ "No",
                  TRUE ~ "Yes"
                ))) %>%

  mutate(PaymentMethod = case_when(
    PaymentMethod == "Bank transfer (automatic)" ~ "BankTransferAuto",
    PaymentMethod == "Credit card (automatic)" ~ "CreditCardAuto",
    PaymentMethod == "Electronic check" ~ "ECheck",
    TRUE ~ "MailedCheck"
  )) %>%

  mutate(across(where(is.character), as.factor))

summary(telco_chrun_clean)
```

```
##     gender     SeniorCitizen Partner    Dependents     tenure      PhoneService
##  Female:3488   0:5901        No :3641   No :4933   Min.   : 0.00   No : 682
##  Male  :3555   1:1142        Yes:3402   Yes:2110   1st Qu.: 9.00   Yes:6361
##                                                    Median :29.00
##                                                    Mean   :32.37
##                                                    3rd Qu.:55.00
##                                                    Max.   :72.00
##
##  MultipleLines   InternetService OnlineSecurity OnlineBackup DeviceProtection
##  No :4072      DSL        :2421   No :5024       No :4614     No :4621
##  Yes:2971      FiberOptic:3096   Yes:2019       Yes:2429     Yes:2422
##                No         :1526
##
##
##
##
##  TechSupport StreamingTV StreamingMovies           Contract    PaperlessBilling
##  No :4999    No :4336    No :4311        Month-to-month:3875   No :2872
##  Yes:2044    Yes:2707    Yes:2732        One year      :1473   Yes:4171
##                                          Two year      :1695
##
##
##
##
##          PaymentMethod  MonthlyCharges    TotalCharges    Churn
##  BankTransferAuto:1544   Min.   : 18.25   Min.   :  18.8   No :5174
##  CreditCardAuto  :1522   1st Qu.: 35.50   1st Qu.: 401.4   Yes:1869
##  ECheck          :2365   Median : 70.35   Median :1397.5
##  MailedCheck     :1612   Mean   : 64.76   Mean   :2283.3
##                          3rd Qu.: 89.85   3rd Qu.:3794.7
##                          Max.   :118.75   Max.   :8684.8
##                                           NA's   :11
```

#Handling NA Values

```
telco_chrun_clean <- na.omit(telco_chrun_clean)
```

```r
dim(telco_chrun_clean)
```

```
## [1] 7032   20
```

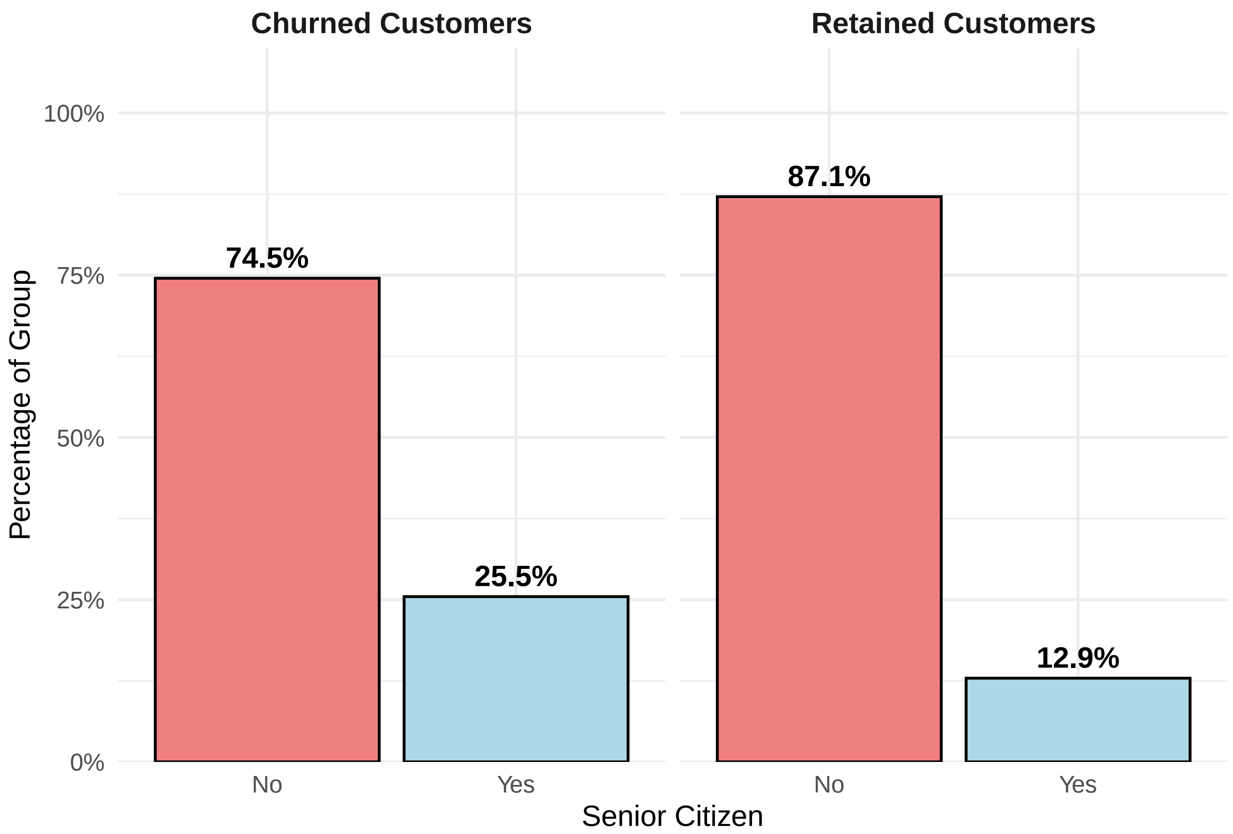
#Preliminary Relationship With Chrun Plot Function

For variables with yes/no responses

```r
create_churn_plot <- function(variable_name, data = telco_chrun_clean) {

  plot_data <- data %>%
    count(Churn, !!sym(variable_name)) %>%
    group_by(Churn) %>%
    mutate(percentage = n / sum(n)) %>%
    ungroup()

  plot <- ggplot(plot_data, aes(x = factor(!!sym(variable_name)),
                     y = percentage,
                     fill = factor(!!sym(variable_name)))) +
    geom_col(color = "black", show.legend = FALSE) +
    geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
              vjust = -0.5, size = 4, fontface = "bold") +
    facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                        labels = c("Churned Customers", "Retained Customers")),
               nrow = 1) +
    scale_y_continuous(labels = scales::percent_format(),
                       limits = c(0, 1),
                       expand = expansion(mult = c(0, 0.1))) +
    scale_fill_manual(values = c("Yes" = "lightblue", "No" = "lightcoral")) +
    labs(x = gsub("_", " ", variable_name),
         y = "Percentage of Group") +
    theme_minimal() +
    theme(strip.text = element_text(face = "bold", size = 11))

  return(list(plot_data = plot_data, plot = plot))
}
```

#EDA for demographic variables

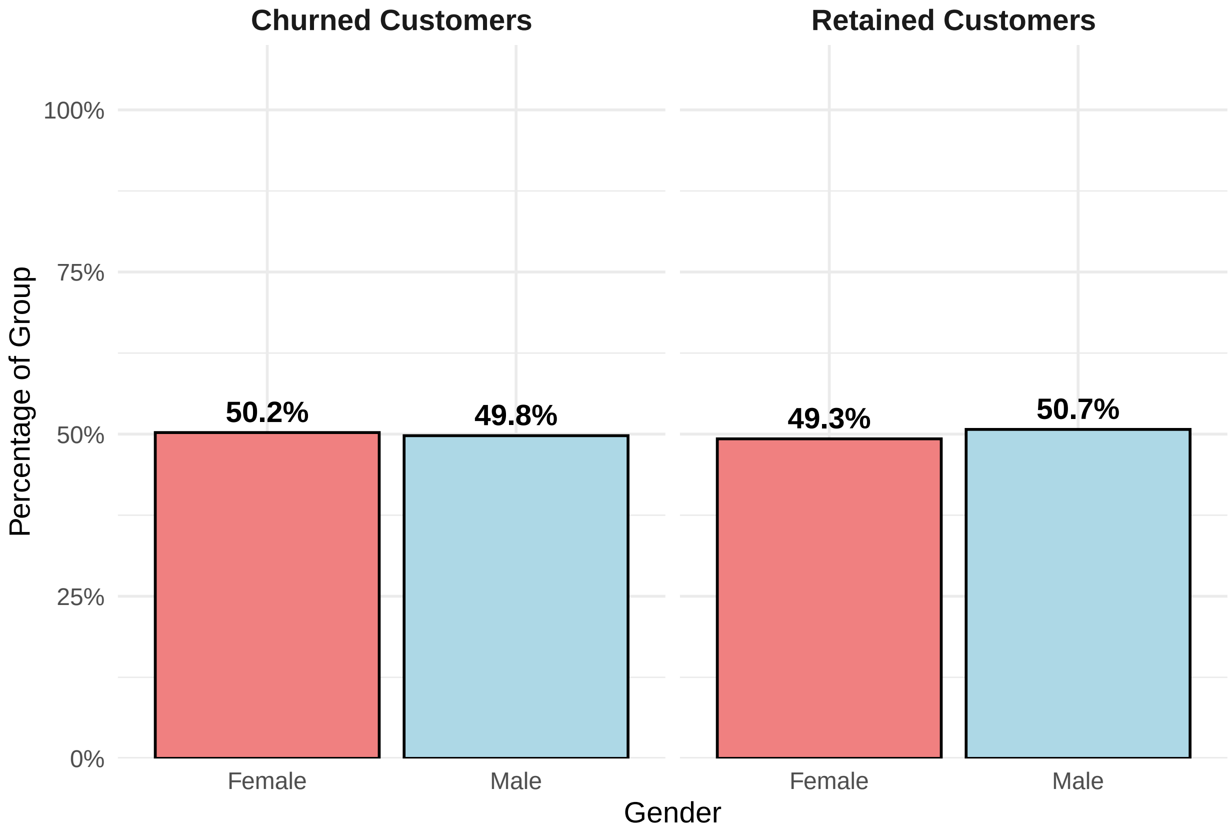
```r
Senior_plot_data <- telco_chrun_clean %>%
  count(Churn, SeniorCitizen) %>%
  group_by(Churn) %>%
  mutate(percentage = n / sum(n)) %>%
  ungroup()

Senior_plot <- ggplot(Senior_plot_data, aes(x = factor(SeniorCitizen, labels = c("No", "Yes")),
                     y = percentage,
                     fill = factor(SeniorCitizen, labels = c("No", "Yes")))) +
  geom_col(color = "black", show.legend = FALSE) +  # Bars with black outline, hide legend
  geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
            vjust = -0.5, size = 4, fontface = "bold") +
  facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                     labels = c("Churned Customers", "Retained Customers")),
             nrow = 1) +  # Put facets in one row, Churned first (left)
  scale_y_continuous(labels = scales::percent_format(),
                     limits = c(0, 1),  # Set y-axis from 0% to 100%
                     expand = expansion(mult = c(0, 0.1))) +
  scale_fill_manual(values = c("Yes" = "lightblue", "No" = "lightcoral")) +  # Light colors
  labs(
      x = "Senior Citizen",
      y = "Percentage of Group") +
  theme_minimal() +
  theme(strip.text = element_text(face = "bold", size = 11))

Senior_plot
```



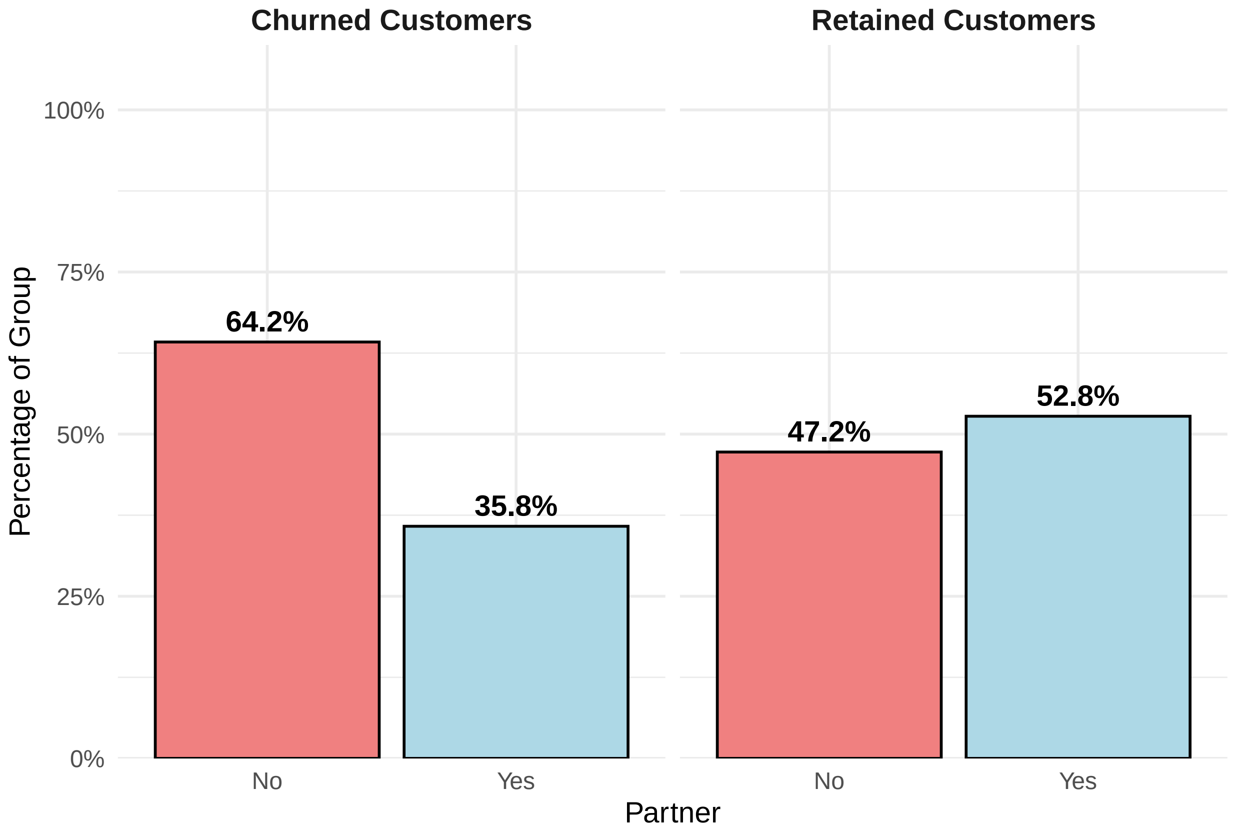
```
Gender_plot_data <- telco_chrun_clean %>%
  count(Churn, gender) %>%
  group_by(Churn) %>%
  mutate(percentage = n / sum(n)) %>%
  ungroup()
head(telco_chrun_clean)
```

```
##   gender SeniorCitizen Partner Dependents tenure PhoneService MultipleLines
## 1 Female             0     Yes         No      1           No            No
## 2   Male             0      No         No     34          Yes            No
## 3   Male             0      No         No      2          Yes            No
## 4   Male             0      No         No     45           No            No
## 5 Female             0      No          No      2          Yes            No
## 6 Female             0      No          No      8          Yes           Yes
##   InternetService OnlineSecurity OnlineBackup DeviceProtection TechSupport
## 1             DSL             No          Yes               No          No
## 2             DSL            Yes           No              Yes          No
## 3             DSL            Yes          Yes               No          No
## 4             DSL            Yes           No              Yes         Yes
## 5      FiberOptic             No           No               No          No
## 6      FiberOptic             No           No              Yes          No
##   StreamingTV StreamingMovies       Contract PaperlessBilling    PaymentMethod
## 1          No              No Month-to-month              Yes           ECheck
## 2          No              No       One year               No      MailedCheck
## 3          No              No Month-to-month              Yes      MailedCheck
## 4          No              No       One year               No BankTransferAuto
## 5          No              No Month-to-month              Yes           ECheck
## 6         Yes             Yes Month-to-month              Yes           ECheck
##   MonthlyCharges TotalCharges Churn
## 1          29.85        29.85    No
## 2          56.95      1889.50    No
## 3          53.85       108.15   Yes
## 4          42.30      1840.75    No
## 5          70.70       151.65   Yes
## 6          99.65       820.50   Yes
```

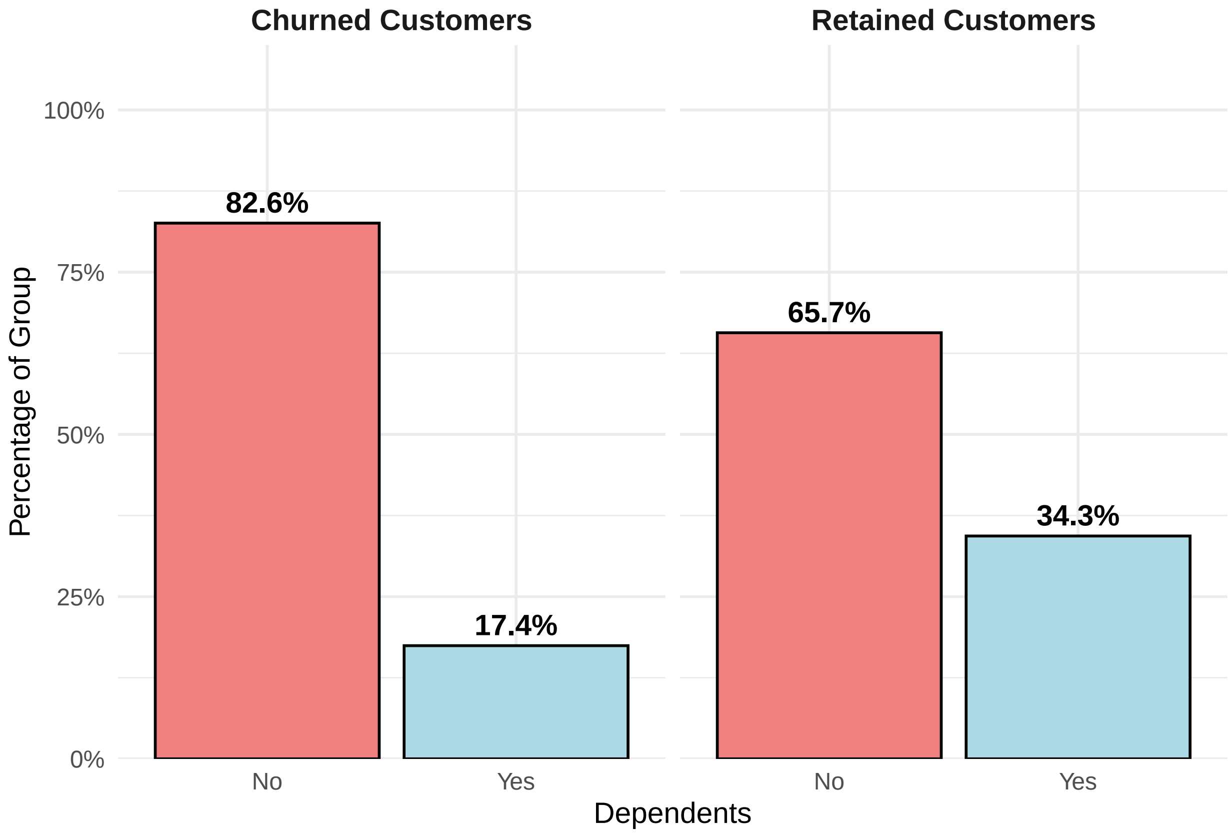
```r
Gender_plot <- ggplot(Gender_plot_data, aes(x = factor(gender),
                     y = percentage,
                     fill = factor(gender))) +
  geom_col(color = "black", show.legend = FALSE) +
  geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
            vjust = -0.5, size = 4, fontface = "bold") +
  facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                     labels = c("Churned Customers", "Retained Customers")),
             nrow = 1) +
  scale_y_continuous(labels = scales::percent_format(),
                     limits = c(0, 1),
                     expand = expansion(mult = c(0, 0.1))) +
  scale_fill_manual(values = c("Male" = "lightblue", "Female" = "lightcoral")) +
  labs(
       x = "Gender",
       y = "Percentage of Group") +
  theme_minimal() +
  theme(strip.text = element_text(face = "bold", size = 11))

Gender_plot
```



```
Partner_results <- create_churn_plot("Partner")
Partner_plot_data <- Partner_results$plot_data
Partner_plot <- Partner_results$plot

Partner_plot
```

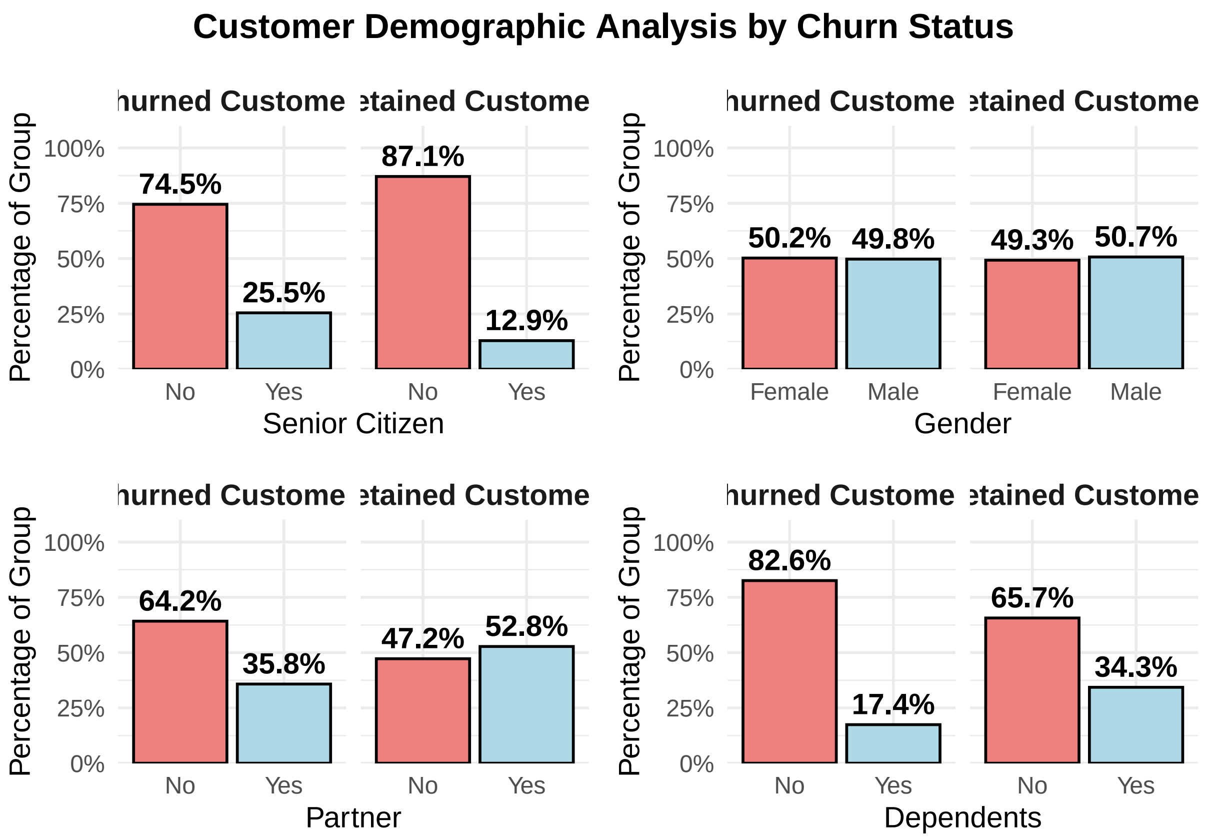


```
Dependents_results <- create_churn_plot("Dependents")
Dependents_plot_data <- Dependents_results$plot_data
Dependents_plot <- Dependents_results$plot

Dependents_plot
```



##Plot for Report

```
combined_analysis_demographics <- (Senior_plot + Gender_plot) /
                      (Partner_plot + Dependents_plot)

combined_analysis_demographics + plot_annotation(
  title = "Customer Demographic Analysis by Churn Status",
  theme = theme(plot.title = element_text(hjust = 0.5, face = "bold"))
)
```

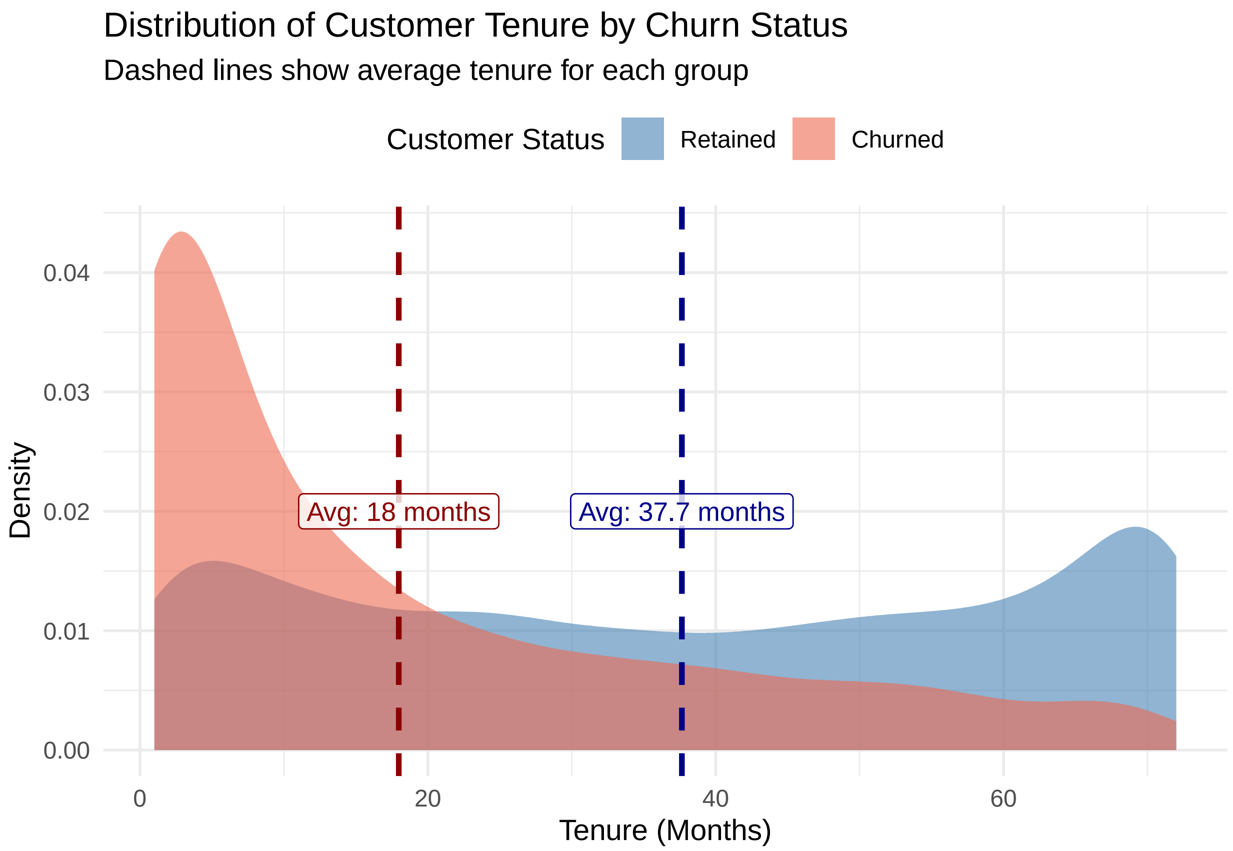


#EDA for Account Information

```
avg_tenure <- telco_chrun_clean %>%
  group_by(Churn) %>%
  summarise(avg_tenure = mean(tenure))

tenure_density_plot <- ggplot(telco_chrun_clean, aes(x = tenure, fill = Churn)) +
  geom_density(alpha = 0.6, color = NA) +
  geom_vline(data = avg_tenure,
             aes(xintercept = avg_tenure, color = Churn),
             linetype = "dashed", size = 1, show.legend = FALSE) +
  geom_label(data = avg_tenure,
             aes(x = avg_tenure, y = 0.02,
                 label = paste("Avg:", round(avg_tenure, 1), "months"),
                 color = Churn),
             fill = "white", alpha = 0.8, size = 3.5,
             show.legend = FALSE) +
  scale_fill_manual(values = c("No" = "steelblue", "Yes" = "coral2"),
                    labels = c("No" = "Retained", "Yes" = "Churned")) +
  scale_color_manual(values = c("No" = "darkblue", "Yes" = "darkred")) +
  labs(title = "Distribution of Customer Tenure by Churn Status",
       subtitle = "Dashed lines show average tenure for each group",
       x = "Tenure (Months)",
       y = "Density",
       fill = "Customer Status") +
  theme_minimal() +
  theme(legend.position = "top")
```

```
## Warning: Using `size` aesthetic for lines was deprecated in ggplot2 3.4.0.
## i Please use `linewidth` instead.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```

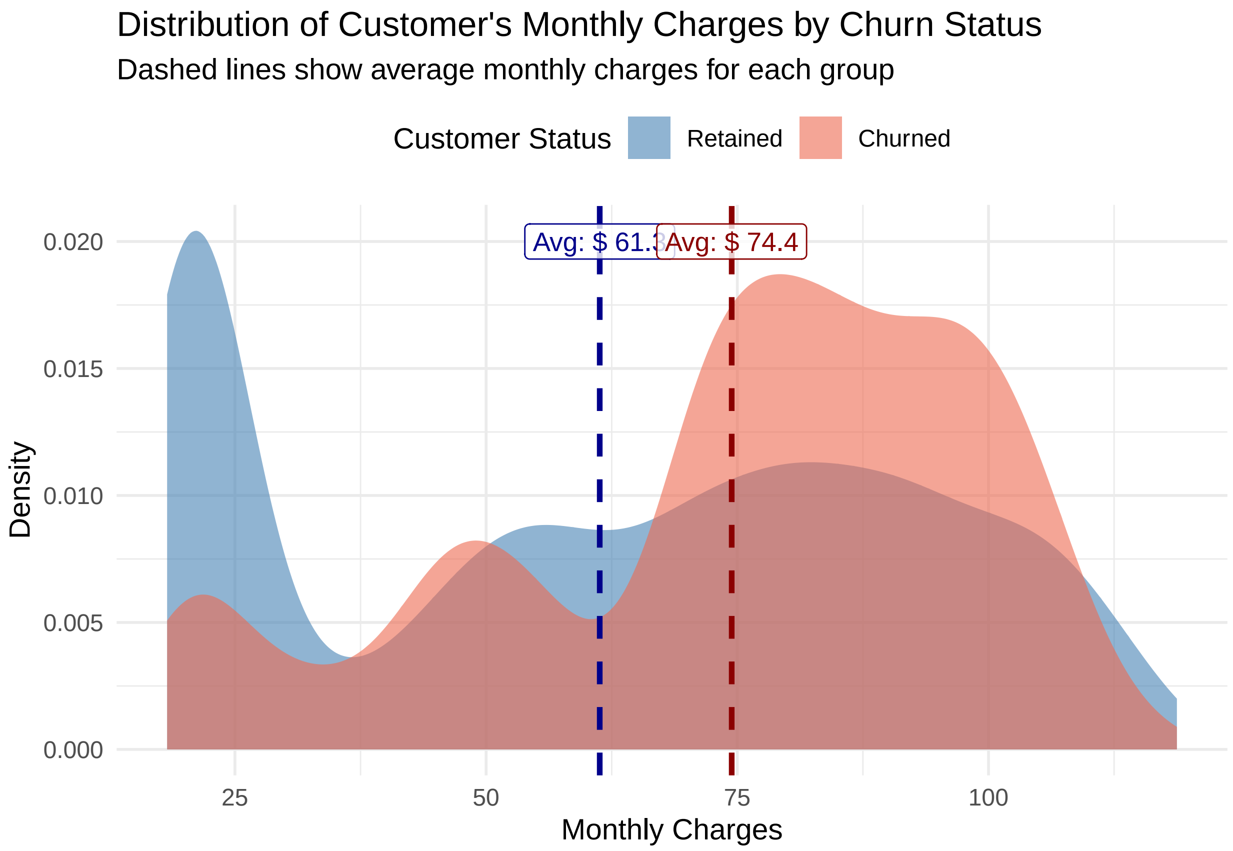
```
print(tenure_density_plot)
```



```
print(avg_tenure)
```

```
## # A tibble: 2 x 2
##   Churn avg_tenure
##   <fct>      <dbl>
## 1 No          37.7
## 2 Yes         18.0
```

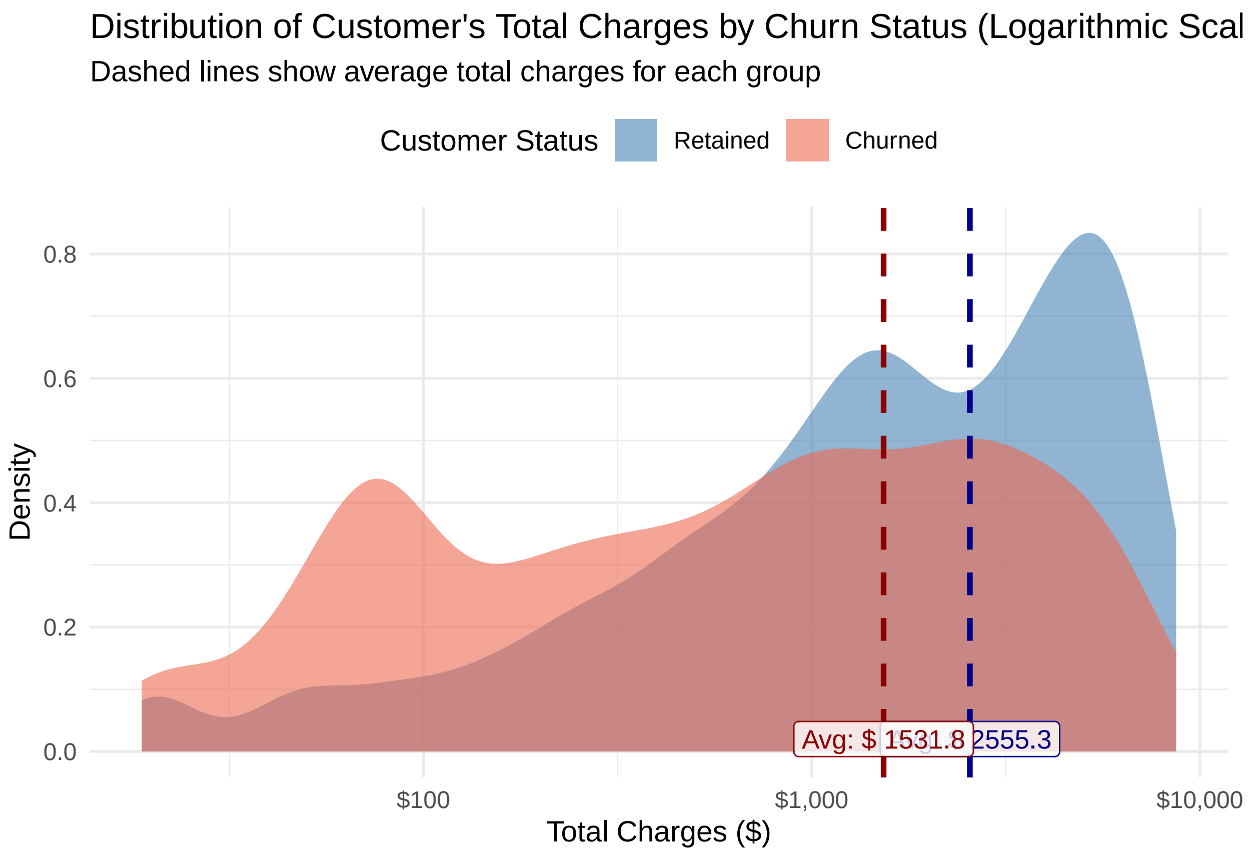
```
avg_MonthlyCharges <- telco_chrun_clean %>%
  group_by(Churn) %>%
  summarise(avg_MonthlyCharges = mean(MonthlyCharges))

MonthlyCharges_density_plot <- ggplot(telco_chrun_clean, aes(x = MonthlyCharges, fill = Churn)) +
  geom_density(alpha = 0.6, color = NA) +
  geom_vline(data = avg_MonthlyCharges,
             aes(xintercept = avg_MonthlyCharges, color = Churn),
             linetype = "dashed", size = 1, show.legend = FALSE) +
  geom_label(data = avg_MonthlyCharges,
             aes(x = avg_MonthlyCharges, y = 0.02,
                 label = paste("Avg: $", round(avg_MonthlyCharges, 1)),
                 color = Churn),
             fill = "white", alpha = 0.8, size = 3.5,
             show.legend = FALSE) +
  scale_fill_manual(values = c("No" = "steelblue", "Yes" = "coral2"),
                    labels = c("No" = "Retained", "Yes" = "Churned")) +
  scale_color_manual(values = c("No" = "darkblue", "Yes" = "darkred")) +
  labs(title = "Distribution of Customer's Monthly Charges by Churn Status",
       subtitle = "Dashed lines show average monthly charges for each group",
       x = "Monthly Charges",
       y = "Density",
       fill = "Customer Status") +
  theme_minimal() +
  theme(legend.position = "top")

print(MonthlyCharges_density_plot)
```



```
print(avg_MonthlyCharges)
```

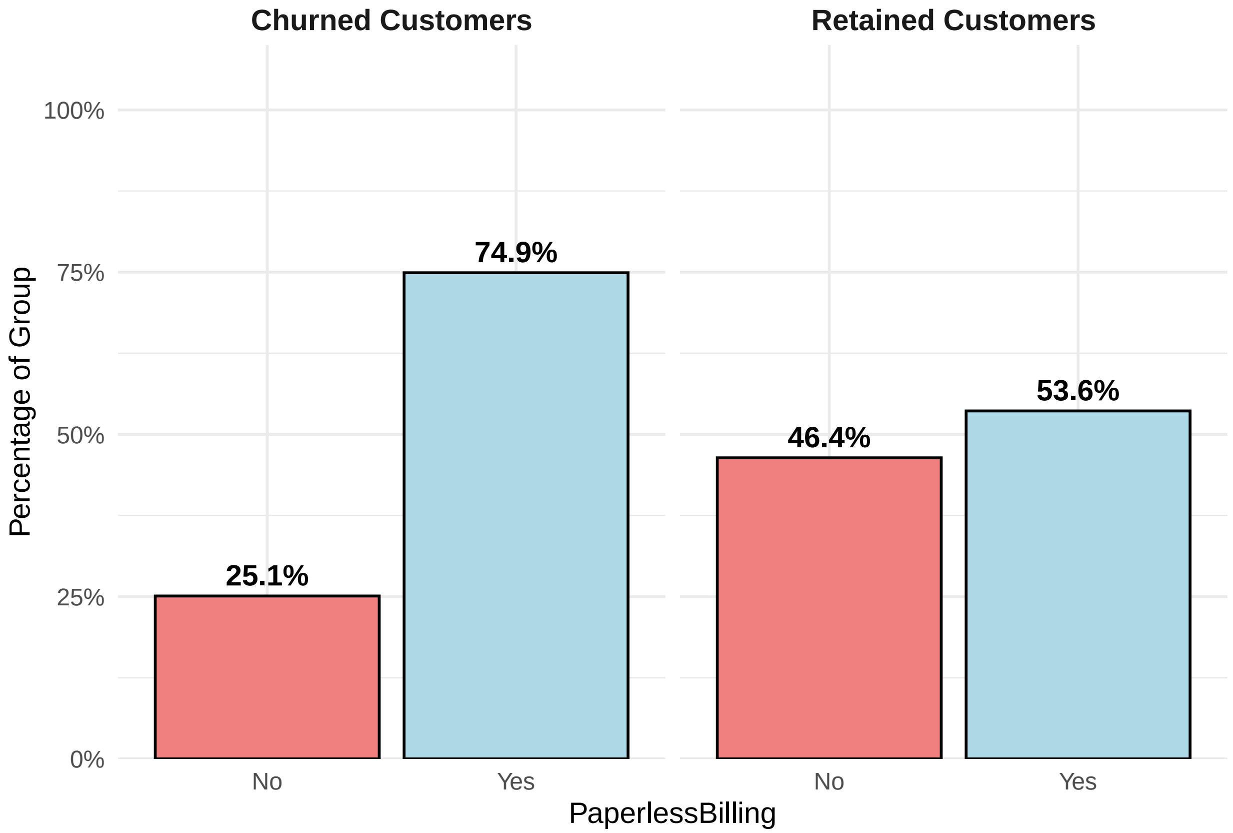
```
## # A tibble: 2 x 2
##   Churn avg_MonthlyCharges
##   <fct>              <dbl>
## 1 No                  61.3
## 2 Yes                 74.4
```

```
avg_TotalCharges <- telco_chrun_clean %>%
  group_by(Churn) %>%
  summarise(avg_TotalCharges = mean(TotalCharges))

TotalCharges_density_plot <- ggplot(telco_chrun_clean, aes(x = TotalCharges, fill = Churn)) +
  geom_density(alpha = 0.6, color = NA) +
  geom_vline(data = avg_TotalCharges,
             aes(xintercept = avg_TotalCharges, color = Churn),
             linetype = "dashed", size = 1, show.legend = FALSE) +
  geom_label(data = avg_TotalCharges,
             aes(x = avg_TotalCharges, y = 0.02,
                 label = paste("Avg: $", round(avg_TotalCharges, 1)),
                 color = Churn),
             fill = "white", alpha = 0.8, size = 3.5,
             show.legend = FALSE) +
  scale_fill_manual(values = c("No" = "steelblue", "Yes" = "coral2"),
                    labels = c("No" = "Retained", "Yes" = "Churned")) +
  scale_color_manual(values = c("No" = "darkblue", "Yes" = "darkred")) +
  labs(title = "Distribution of Customer's Total Charges by Churn Status (Logarithmic Scale)",
       subtitle = "Dashed lines show average total charges for each group",
       x = "Total Charges ($)",
       y = "Density",
       fill = "Customer Status") +
  theme_minimal() +
  theme(legend.position = "top")

TotalCharges_density_plot<- TotalCharges_density_plot +
  scale_x_log10(labels = scales::dollar)

TotalCharges_density_plot
```

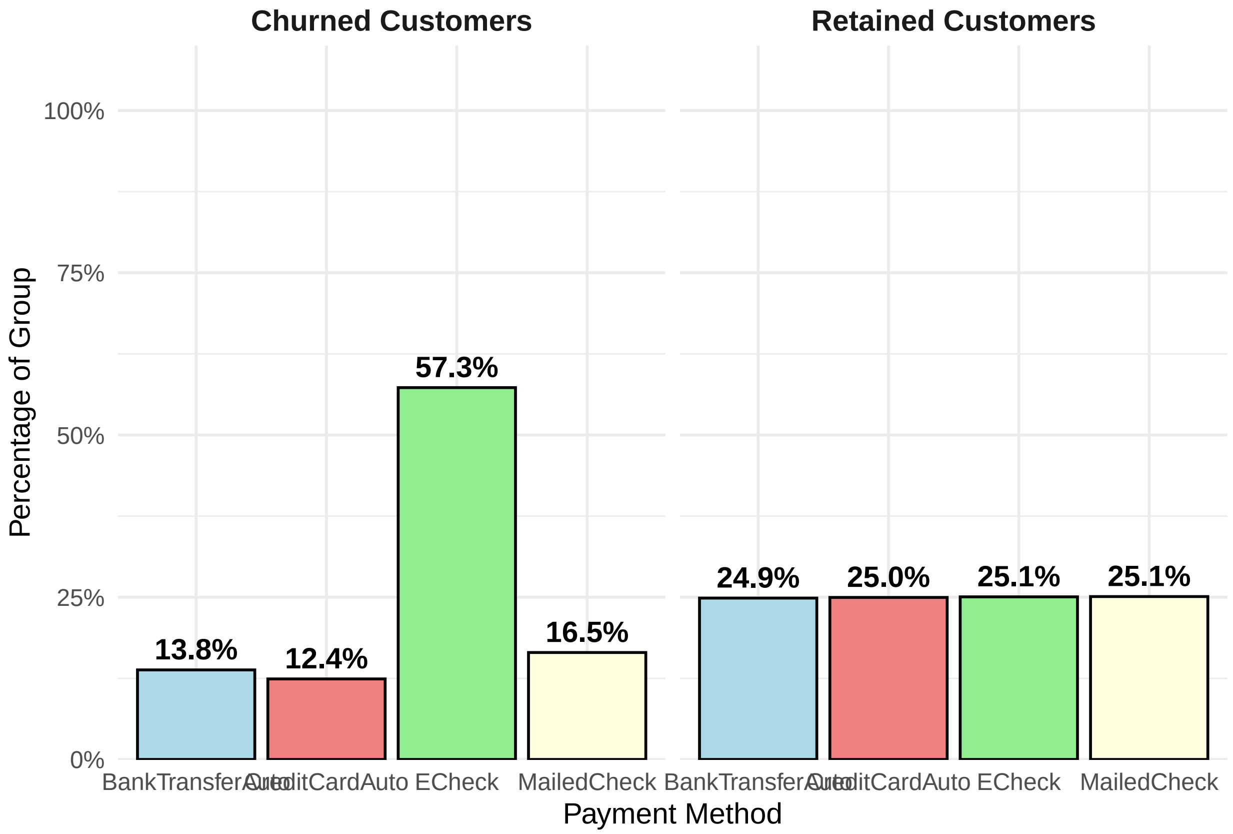


Extreme Right-Skew:

```
PaperlessBilling_results <- create_churn_plot("PaperlessBilling")
PaperlessBilling_plot_data <- PaperlessBilling_results$plot_data
PaperlessBilling_plot <- PaperlessBilling_results$plot

PaperlessBilling_plot
```

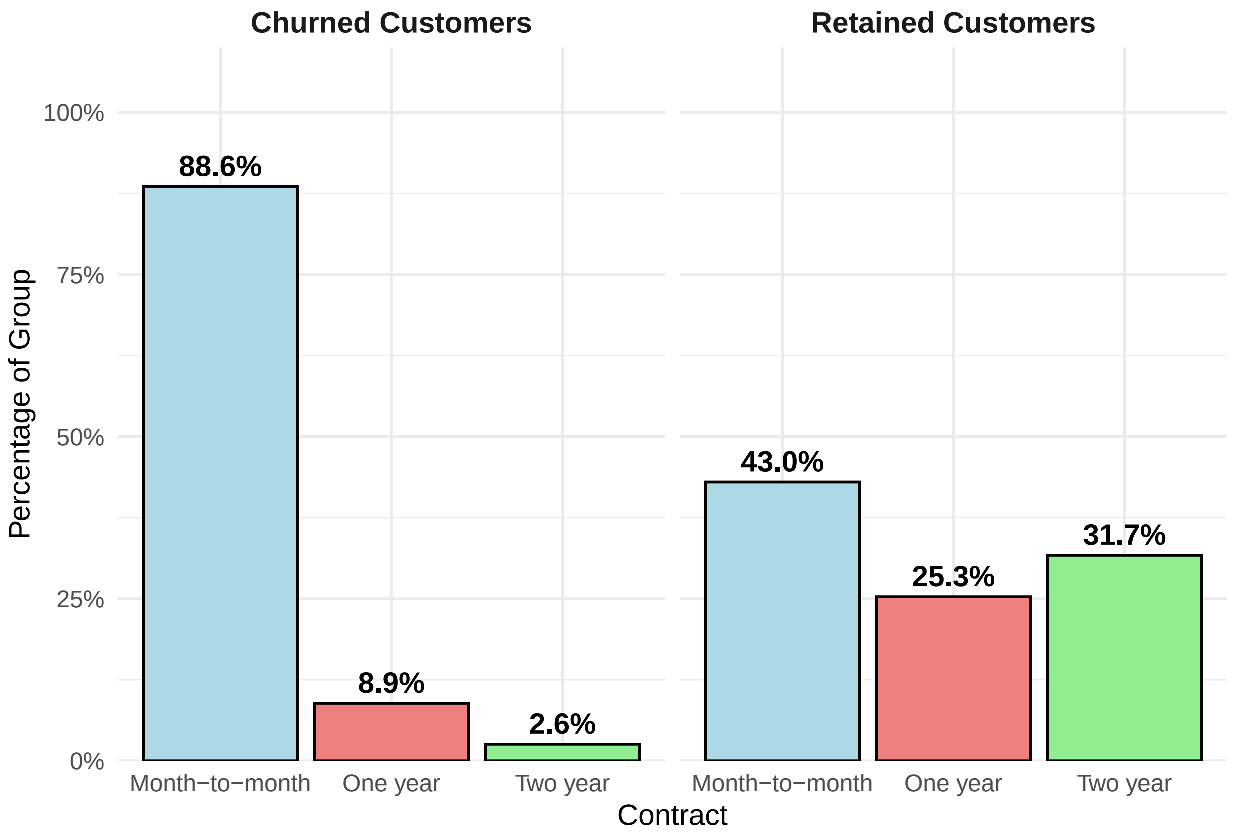


```
PaymentMethod_plot_data <- telco_chrun_clean %>%
  count(Churn, PaymentMethod) %>%
  group_by(Churn) %>%
  mutate(percentage = n / sum(n)) %>%
  ungroup()

PaymentMethod_plot <- ggplot(PaymentMethod_plot_data, aes(x = factor(PaymentMethod),
                     y = percentage,
                     fill = factor(PaymentMethod))) +
  geom_col(color = "black", show.legend = FALSE) +
  geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
            vjust = -0.5, size = 4, fontface = "bold") +
  facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                     labels = c("Churned Customers", "Retained Customers")),
             nrow = 1) +
  scale_y_continuous(labels = scales::percent_format(),
                     limits = c(0, 1),
                     expand = expansion(mult = c(0, 0.1))) +
  scale_fill_manual(values = c("BankTransferAuto" = "lightblue", "CreditCardAuto" = "lightcoral", "EChe
  labs(
       x = "Payment Method",
       y = "Percentage of Group") +
  theme_minimal() +
  theme(strip.text = element_text(face = "bold", size = 11))

PaymentMethod_plot
```



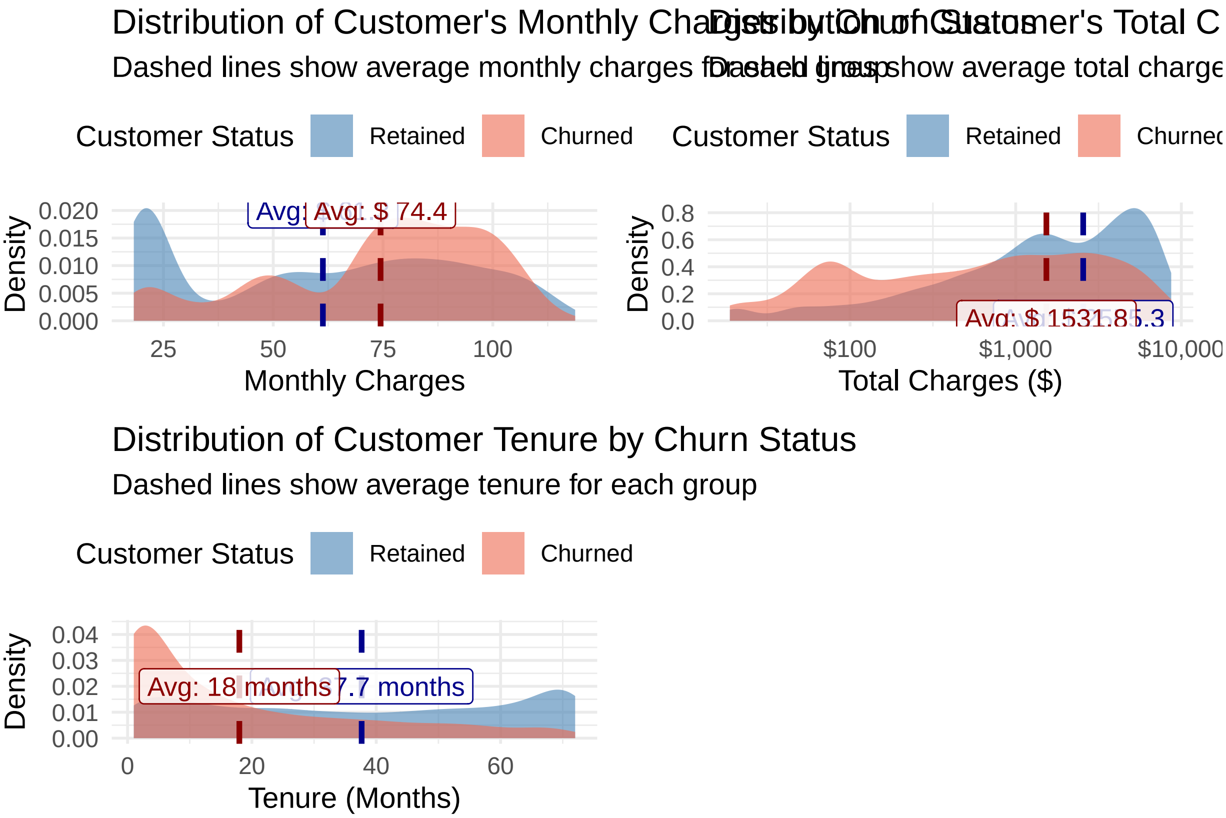
```
Contract_plot_data <- telco_chrun_clean %>%
  count(Churn, Contract) %>%
  group_by(Churn) %>%
  mutate(percentage = n / sum(n)) %>%
  ungroup()

Contract_plot <- ggplot(Contract_plot_data, aes(x = factor(Contract),
                     y = percentage,
                     fill = factor(Contract))) +
  geom_col(color = "black", show.legend = FALSE) +
  geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
            vjust = -0.5, size = 4, fontface = "bold") +
  facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                     labels = c("Churned Customers", "Retained Customers")),
             nrow = 1) +
  scale_y_continuous(labels = scales::percent_format(),
                     limits = c(0, 1),
                     expand = expansion(mult = c(0, 0.1))) +
  scale_fill_manual(values = c("Month-to-month" = "lightblue", "One year" = "lightcoral", "Two year" =
  labs(
       x = "Contract",
       y = "Percentage of Group") +
  theme_minimal() +
  theme(strip.text = element_text(face = "bold", size = 11))
```

```
Contract_plot
```

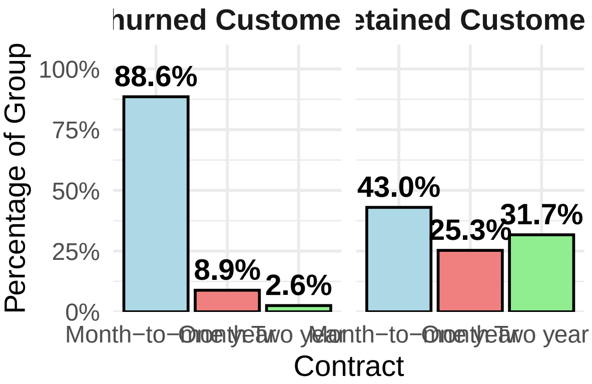


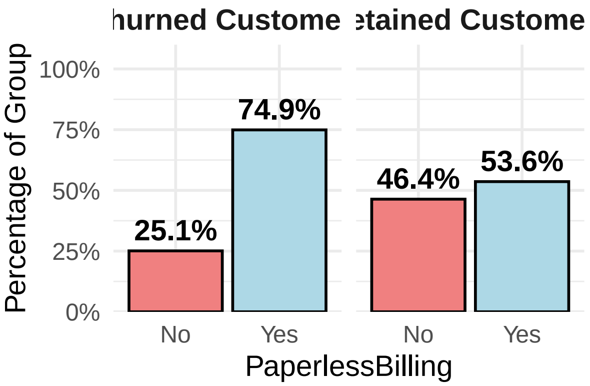
##Plots for Report

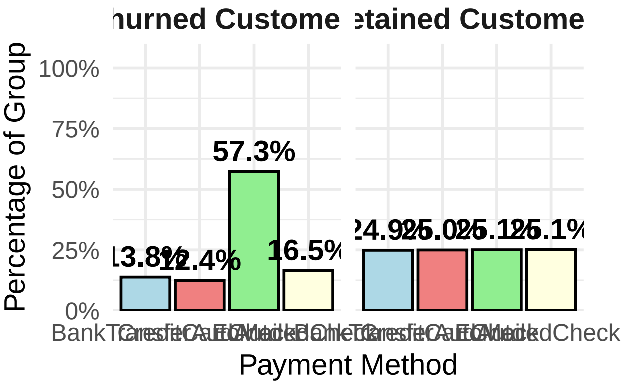
```
combined_analysis_account <- (MonthlyCharges_density_plot | TotalCharges_density_plot) /
                             (tenure_density_plot)

combined_analysis_account <- wrap_plots(
  MonthlyCharges_density_plot,
  TotalCharges_density_plot,
  tenure_density_plot,
  ncol = 2,
  nrow = 2
)

combined_analysis_account
```



```
combined_analysis_account2 <- (Contract_plot | PaperlessBilling_plot) /
                              (PaymentMethod_plot)

combined_analysis_account2 <- wrap_plots(
  Contract_plot,
  PaperlessBilling_plot,
  PaymentMethod_plot,
  ncol = 2,
  nrow = 2
)

combined_analysis_account2
```

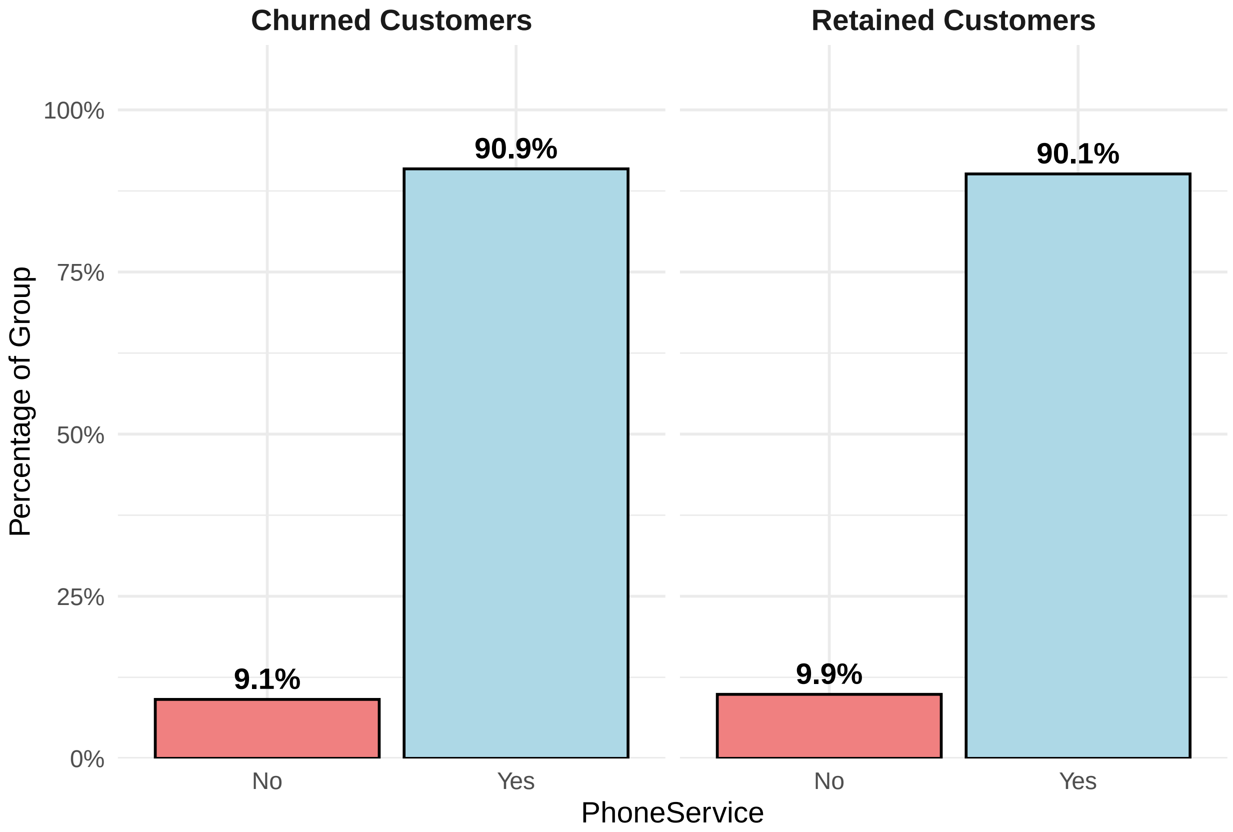




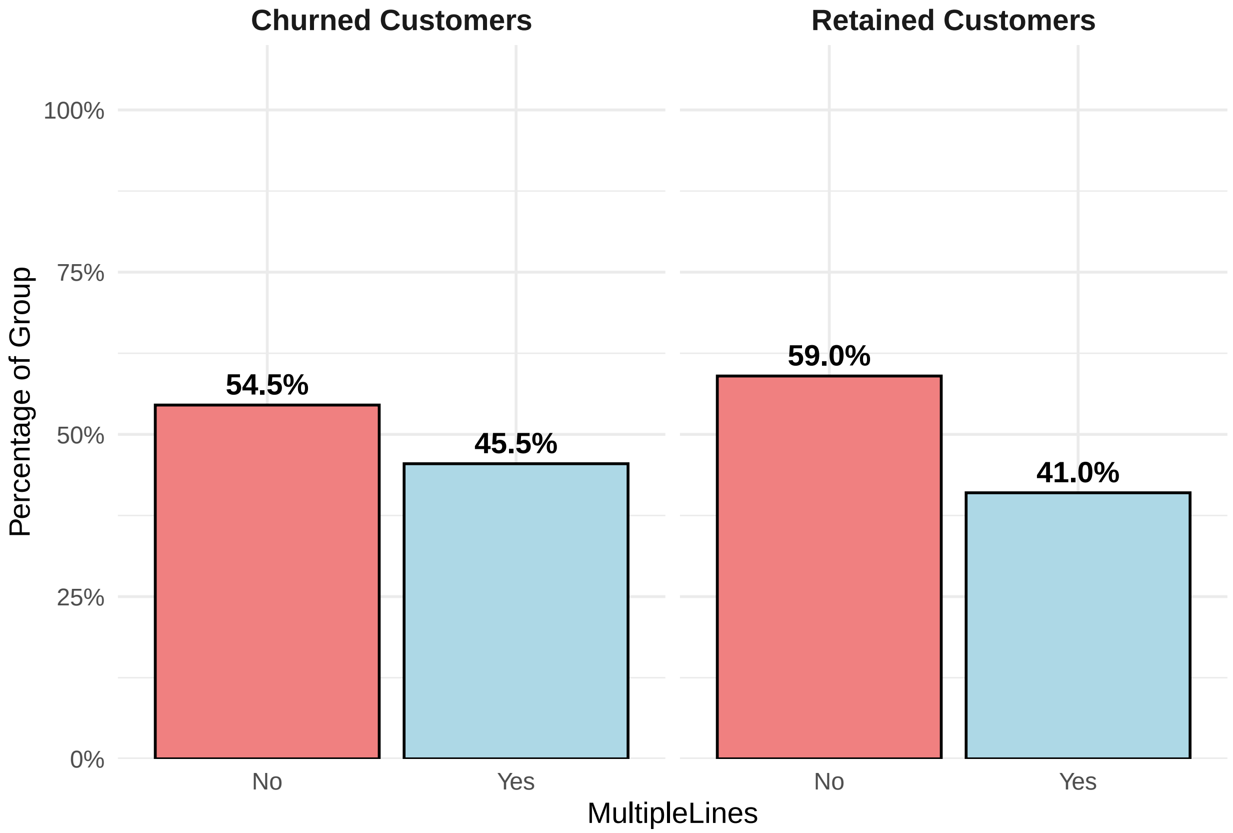


#EDA for Service Information

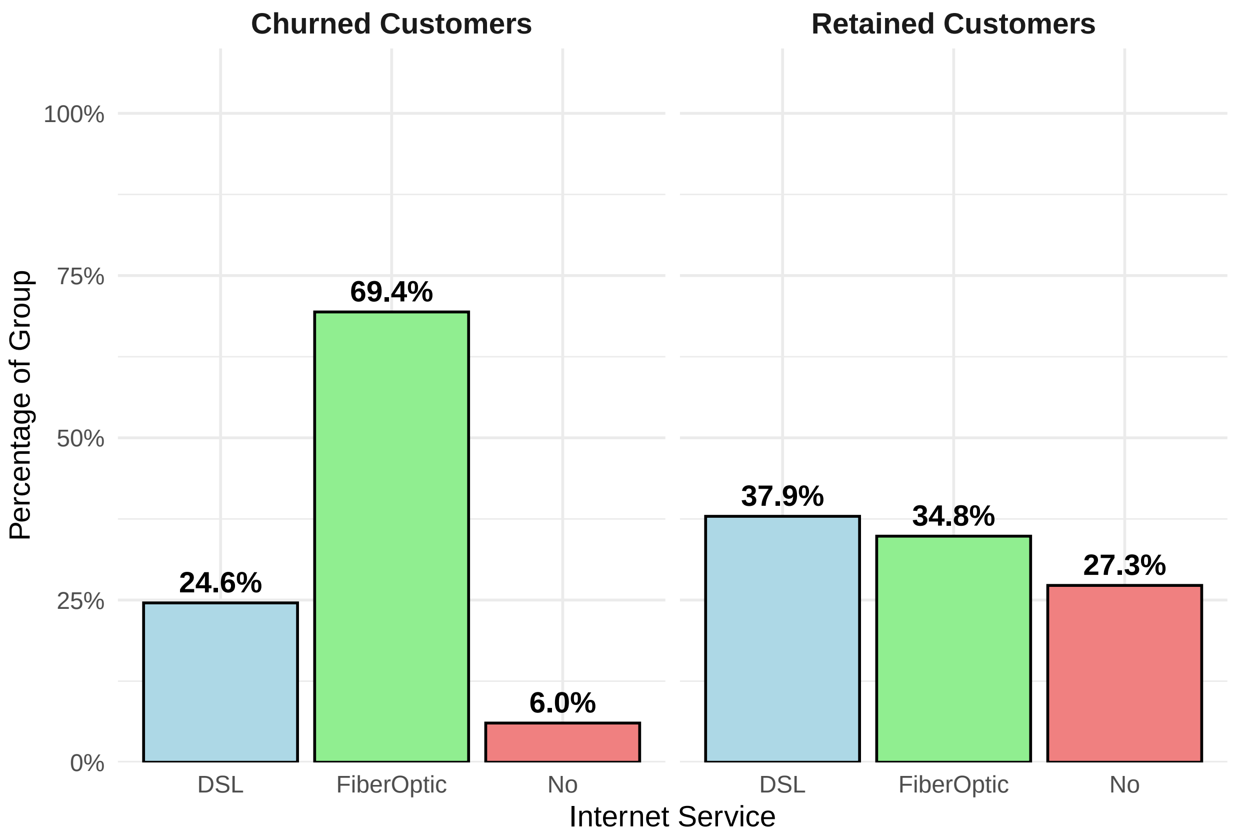
```
PhoneService_results <- create_churn_plot("PhoneService")
PhoneService_plot_data <- PhoneService_results$plot_data
PhoneService_plot <- PhoneService_results$plot

PhoneService_plot
```



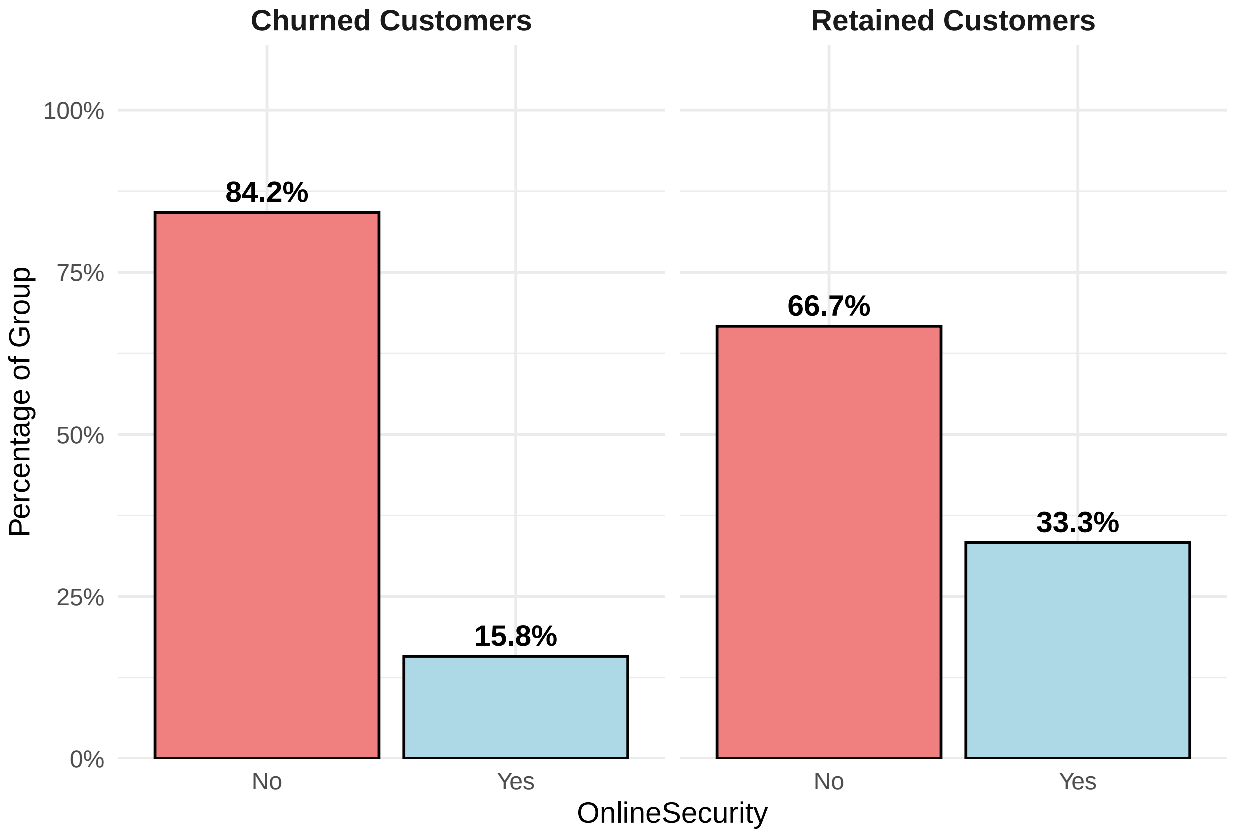
```r
MultipleLines_results <- create_churn_plot("MultipleLines")
MultipleLines_plot_data <- MultipleLines_results$plot_data
MultipleLines_plot <- MultipleLines_results$plot
MultipleLines_plot
```



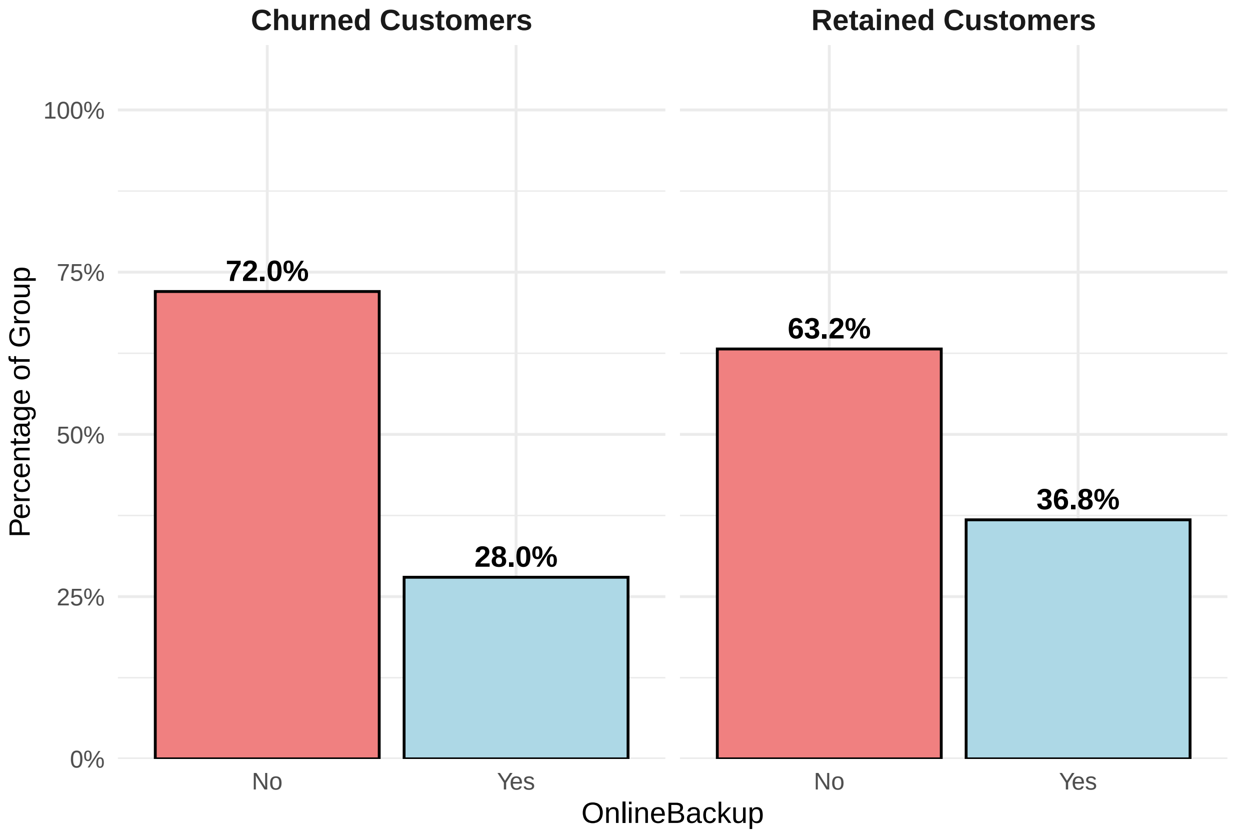
```
InternetService_plot_data <- telco_chrun_clean %>%
  count(Churn, InternetService) %>%
  group_by(Churn) %>%
  mutate(percentage = n / sum(n)) %>%
  ungroup()

InternetService_plot <- ggplot(InternetService_plot_data, aes(x = factor(InternetService),
                     y = percentage,
                     fill = factor(InternetService))) +
  geom_col(color = "black", show.legend = FALSE) +
  geom_text(aes(label = scales::percent(percentage, accuracy = 0.1)),
            vjust = -0.5, size = 4, fontface = "bold") +
  facet_wrap(~ factor(Churn, levels = c("Yes", "No"),
                     labels = c("Churned Customers", "Retained Customers")),
             nrow = 1) +
  scale_y_continuous(labels = scales::percent_format(),
                     limits = c(0, 1),
                     expand = expansion(mult = c(0, 0.1))) +
  scale_fill_manual(values = c("DSL" = "lightblue", "No" = "lightcoral", "FiberOptic" = "lightgreen"))
  labs(
       x = "Internet Service",
       y = "Percentage of Group") +
  theme_minimal() +
  theme(strip.text = element_text(face = "bold", size = 11))

InternetService_plot
```



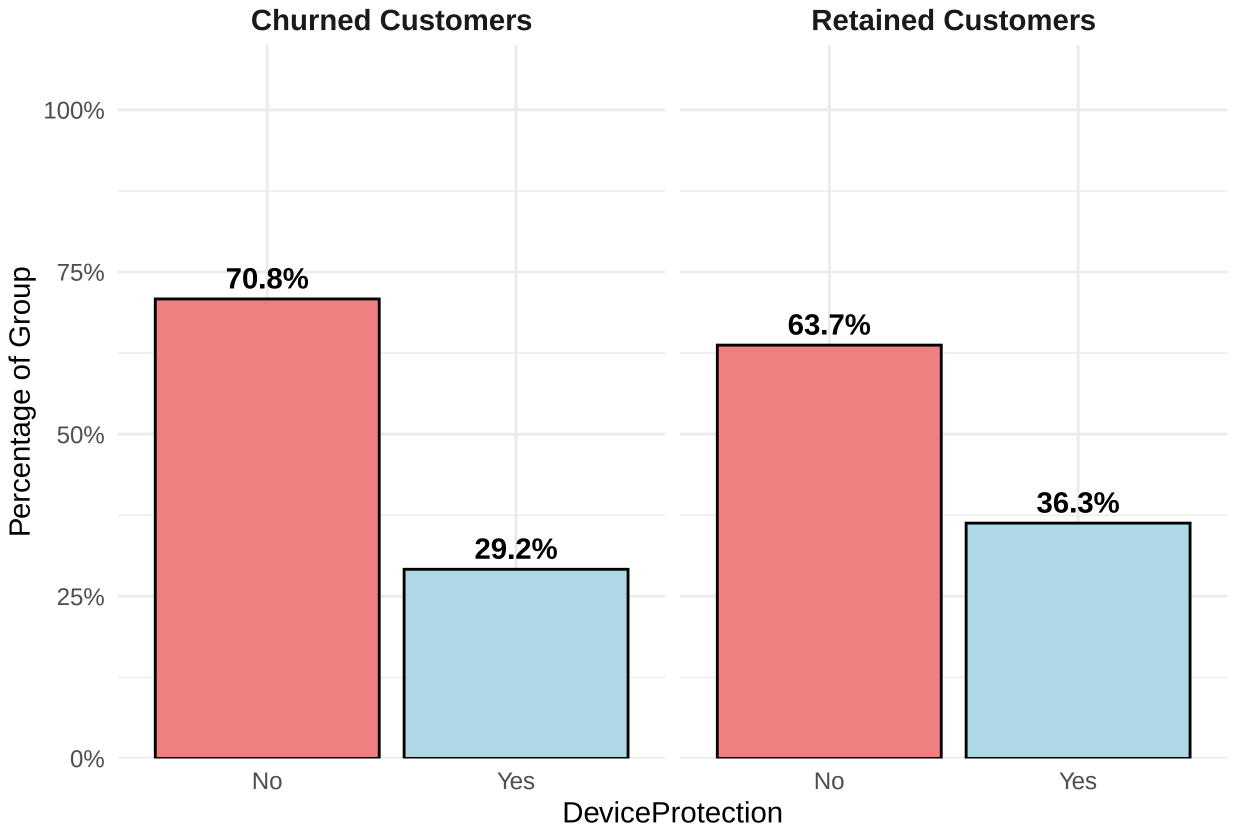
```
OnlineSecurity_results <- create_churn_plot("OnlineSecurity")
OnlineSecurity_plot_data <- OnlineSecurity_results$plot_data
OnlineSecurity_plot <- OnlineSecurity_results$plot

OnlineSecurity_plot
```



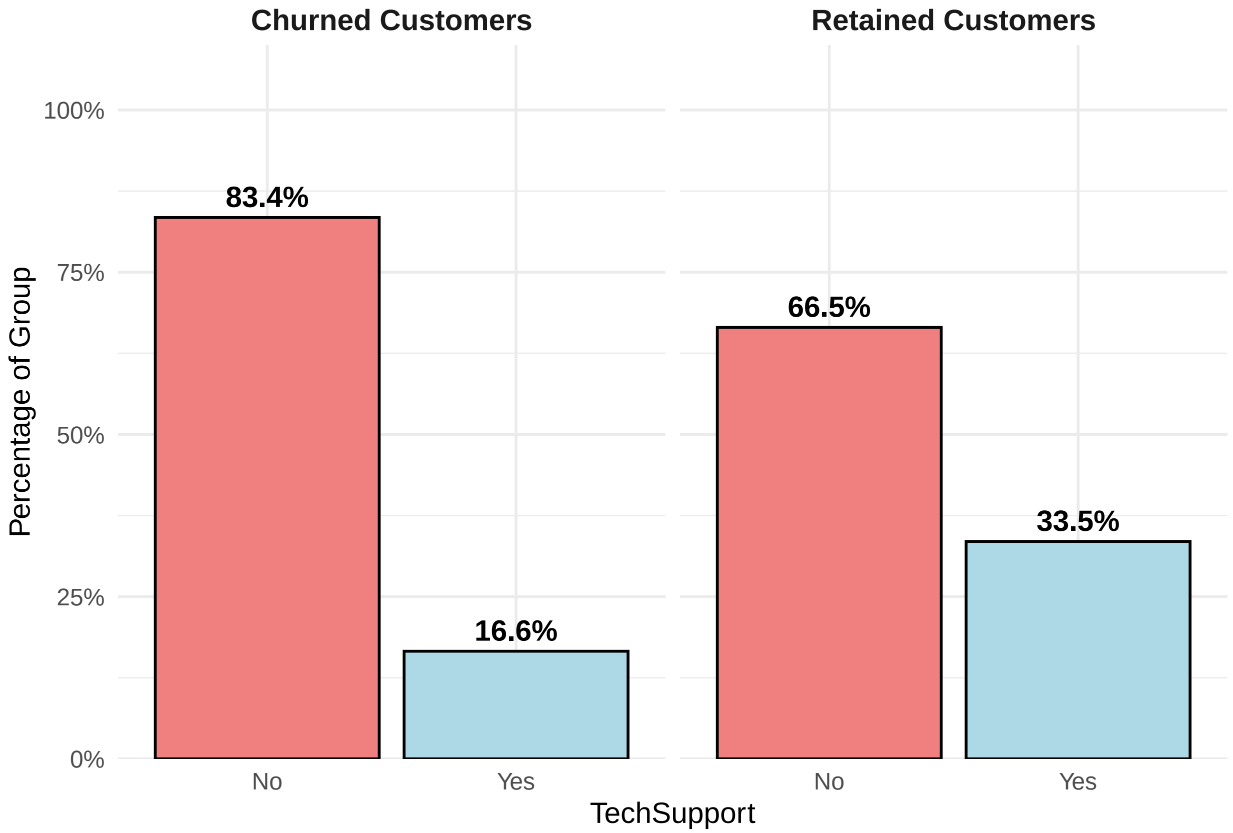
```
OnlineBackup_results <- create_churn_plot("OnlineBackup")
OnlineBackup_plot_data <- OnlineBackup_results$plot_data
OnlineBackup_plot <- OnlineBackup_results$plot

OnlineBackup_plot
```



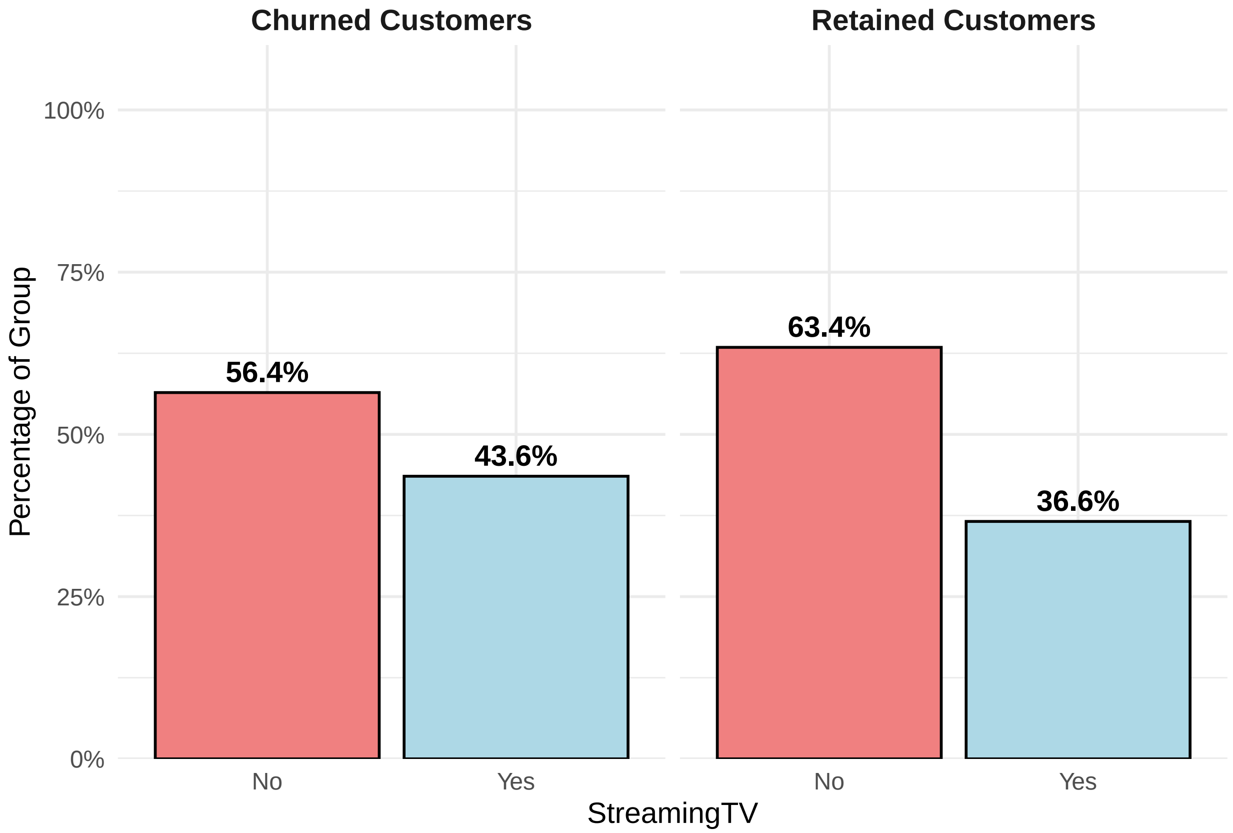
```
DeviceProtection_results <- create_churn_plot("DeviceProtection")
DeviceProtection_plot_data <- DeviceProtection_results$plot_data
DeviceProtection_plot <- DeviceProtection_results$plot

DeviceProtection_plot
```



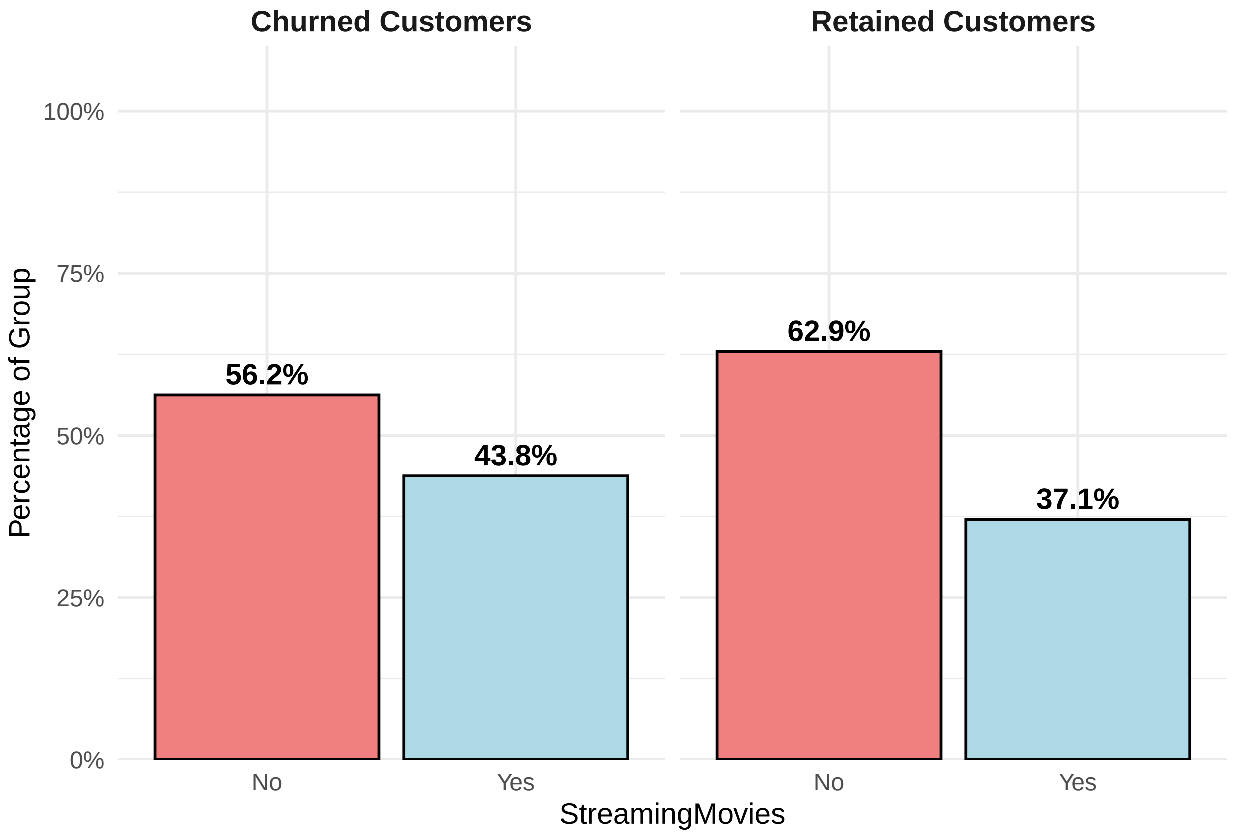
```
TechSupport_results <- create_churn_plot("TechSupport")
TechSupport_plot_data <- TechSupport_results$plot_data
TechSupport_plot <- TechSupport_results$plot
TechSupport_plot
```



```r
StreamingTV_results <- create_churn_plot("StreamingTV")
StreamingTV_plot_data <- StreamingTV_results$plot_data
StreamingTV_plot <- StreamingTV_results$plot
StreamingTV_plot
```

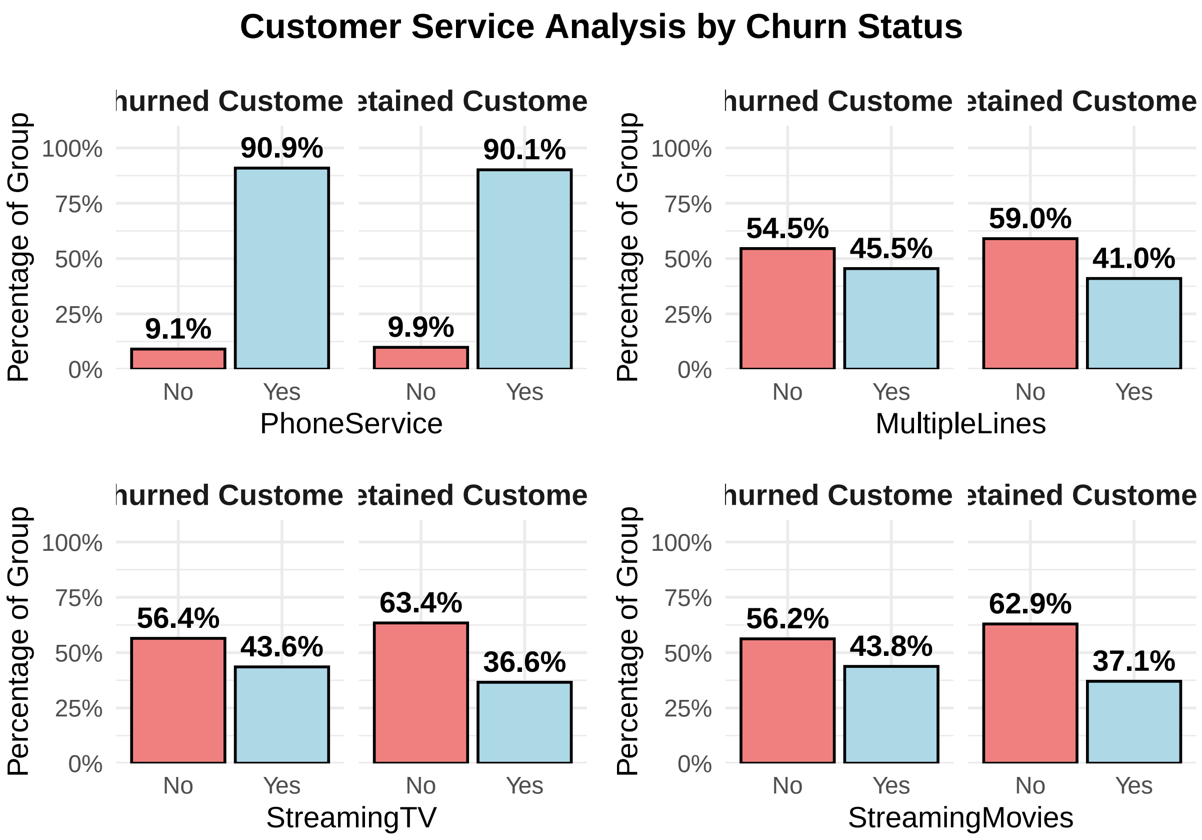


```
StreamingMovies_results <- create_churn_plot("StreamingMovies")
StreamingMovies_plot_data <- StreamingMovies_results$plot_data
StreamingMovies_plot <- StreamingMovies_results$plot
StreamingMovies_plot
```

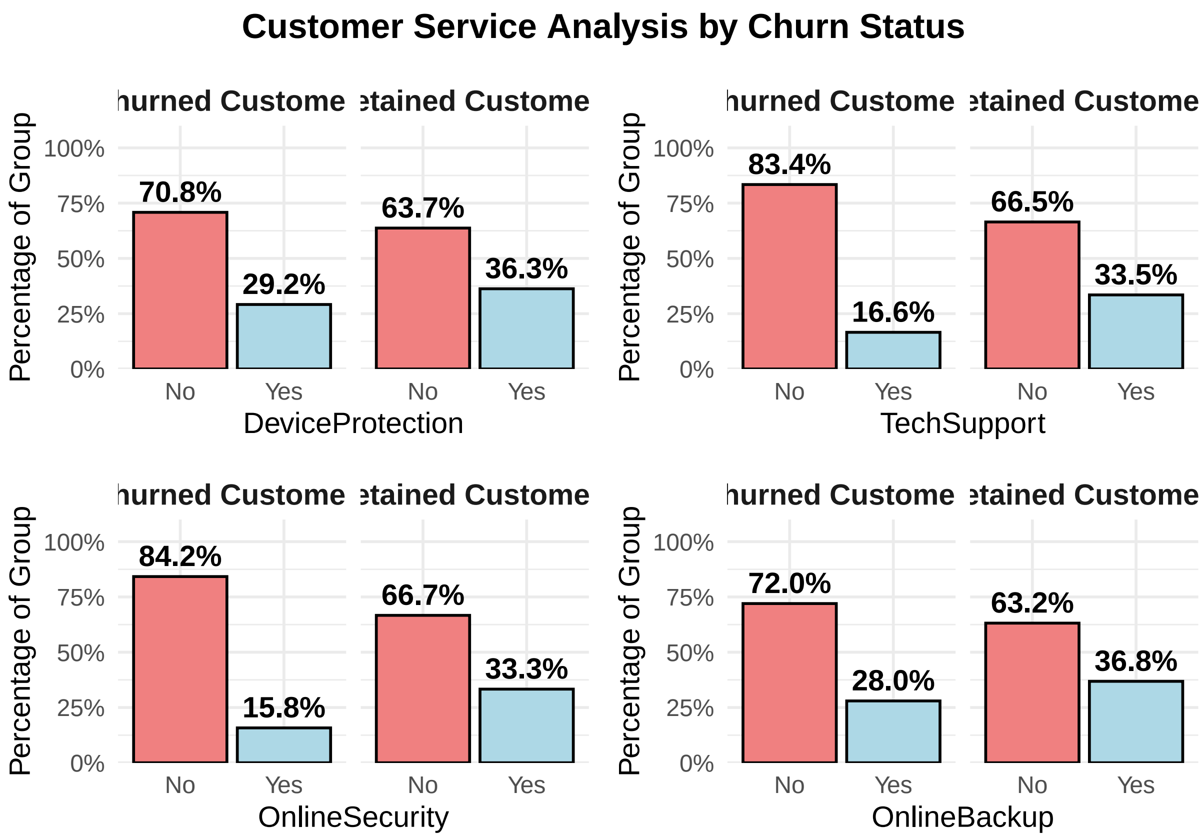


##Plots for Report

```
combined_analysis_service <- (PhoneService_plot + MultipleLines_plot) /
                         (StreamingTV_plot + StreamingMovies_plot)

combined_analysis_service + plot_annotation(
  title = "Customer Service Analysis by Churn Status",
  theme = theme(plot.title = element_text(hjust = 0.5, face = "bold"))
)
```



```r
combined_analysis_service2 <- (DeviceProtection_plot + TechSupport_plot) /
                     (OnlineSecurity_plot + OnlineBackup_plot)

combined_analysis_service2 + plot_annotation(
  title = "Customer Service Analysis by Churn Status",
  theme = theme(plot.title = element_text(hjust = 0.5, face = "bold"))
)
```



#Imbalanced Data Set addressed with Rose

```
train_index <- createDataPartition(telco_chrun_clean$Churn, p = 0.8, list = FALSE)
telco_train <- telco_chrun_clean[train_index, ]
telco_test <- telco_chrun_clean[-train_index, ]

train_balanced <- ROSE(Churn ~ ., data = telco_train, seed = 123)$data

cat("Class distribution after ROSE:\n")
```

```
## Class distribution after ROSE:
```

```
print(table(train_balanced$Churn))
```

```
##
##   No  Yes
## 2834 2793
```

```
x_train_balanced <- model.matrix(Churn ~ . -1, data = train_balanced)
x_test <- model.matrix(Churn ~ . -1, data = telco_test)

y_train_balanced <- train_balanced$Churn
y_test <- telco_test$Churn
```

#Lasso Logisitic Regression Model

Meeting the assumptions of the logisitc model

1. Logistic regression assumes linearity of independent variables and log odds of the dependent variable. Although this analysis does not require the dependent and independent variables to be related linearly, it requires that the independent variables are linearly related to the log odds of the dependent variable.

2. Logistic regression requires there to be little or no multicollinearity among the independent variables. Meaning, that the independent variables should not be too highly correlated with each other.

3. Binary logistic regression requires the dependent variable to be binary (which is true no code needed)

4. Logistic regression requires the observations to be independent of each other. (which is true no code needed)

5. Logistic regression typically requires a large sample size. (which is true no code needed)

6. No Extreme Outliers

Addressing Assumption 6: No Extreme Outlier

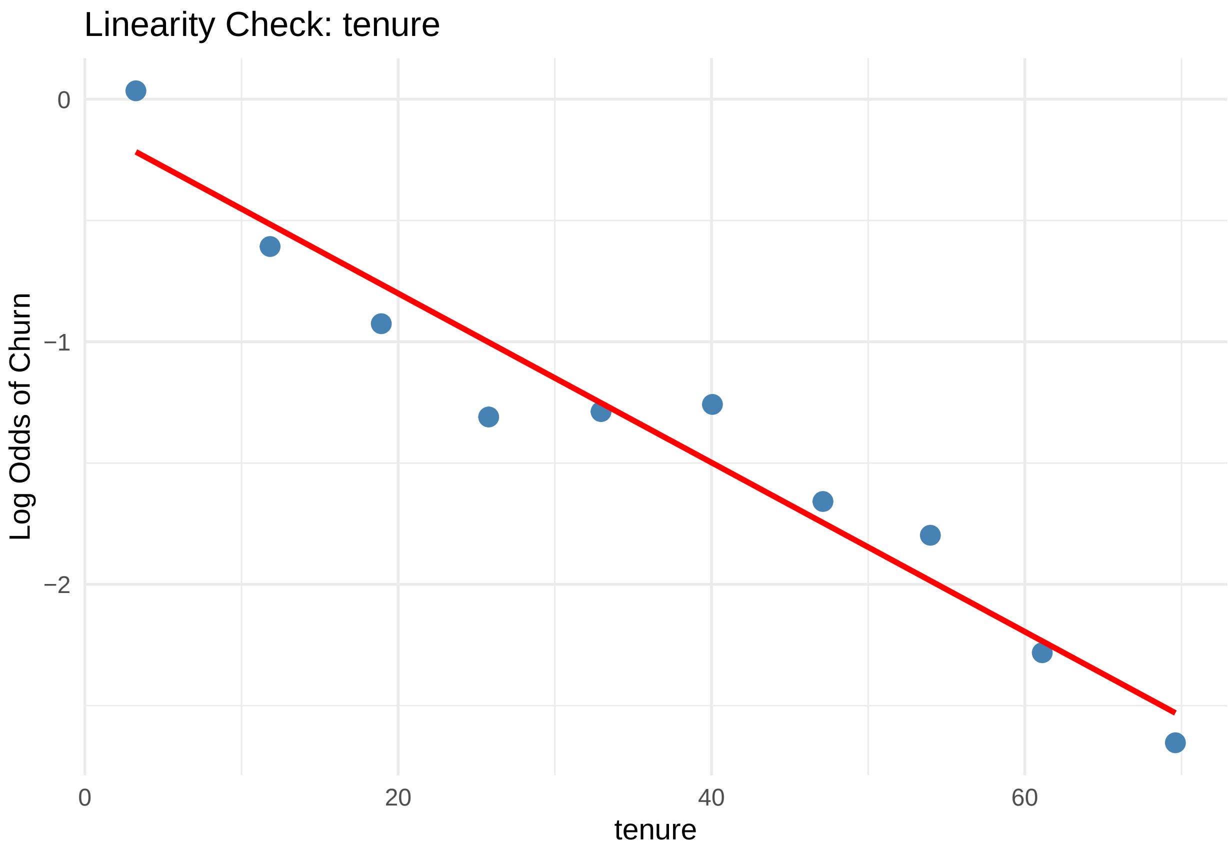
```r
check_outliers <- function(data, continuous_vars) {
  outlier_results <- list()

  for (var in continuous_vars) {
    # Calculate summary statistics
    var_data <- data[[var]]
    q1 <- quantile(var_data, 0.25, na.rm = TRUE)
    q3 <- quantile(var_data, 0.75, na.rm = TRUE)
    iqr <- q3 - q1
    lower_bound <- q1 - 1.5 * iqr
    upper_bound <- q3 + 1.5 * iqr


    outliers <- var_data[var_data < lower_bound | var_data > upper_bound]
    outlier_count <- length(outliers)
    outlier_percentage <- round((outlier_count / length(var_data)) * 100, 2)

p <- ggplot(data, aes(y = !!sym(var))) +
     geom_boxplot(fill = "lightblue", color = "darkblue") +
     labs(title = paste("Boxplot of", var),
     y = var) +
     theme_minimal()

    outlier_results[[var]] <- list(
      plot = p,
      stats = data.frame(
        Variable = var,
        Q1 = q1,
        Q3 = q3,
        IQR = iqr,
        Lower_Bound = lower_bound,
        Upper_Bound = upper_bound,
        Outlier_Count = outlier_count,
        Outlier_Percentage = outlier_percentage
      )
    )
  }

  return(outlier_results)
}

continuous_vars <- c("tenure", "MonthlyCharges", "TotalCharges")
outlier_analysis <- check_outliers(telco_chrun_clean, continuous_vars)


for (var in continuous_vars) {
  print(outlier_analysis[[var]]$stats)
}
```

```
##     Variable Q1 Q3 IQR Lower_Bound Upper_Bound Outlier_Count Outlier_Percentage
## 25%   tenure  9 55  46         -60         124             0                  0
##           Variable      Q1      Q3    IQR Lower_Bound Upper_Bound Outlier_Count
## 25% MonthlyCharges 35.5875 89.8625 54.275     -45.825     171.275             0
##     Outlier_Percentage
## 25%                  0
##         Variable     Q1       Q3      IQR Lower_Bound Upper_Bound Outlier_Count
## 25% TotalCharges 401.45 3794.738 3393.288   -4688.481    8884.669             0
##     Outlier_Percentage
## 25%                  0
```

Addressing Assumption 1: Determining the linearity of independent variables and log odds of the dependent variable.

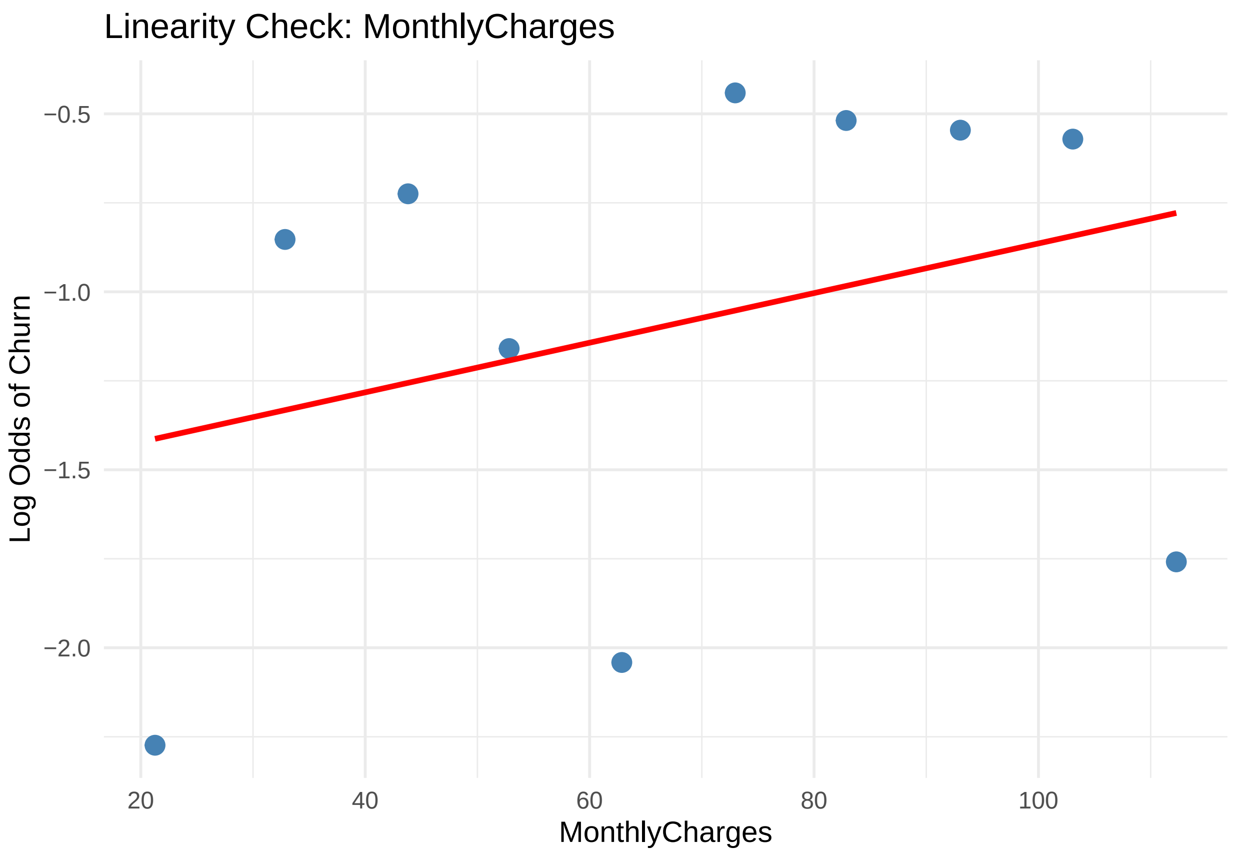
```
check_logit_linearity <- function(data, continuous_vars) {
  plots <- list()

  for (var in continuous_vars) {
    # Create bins for the continuous variable
    data_binned <- data %>%
      mutate(bin = cut(!!sym(var), breaks = 10, include.lowest = TRUE)) %>%
      group_by(bin) %>%
      summarise(
        mean_var = mean(!!sym(var)),
        churn_rate = mean(as.numeric(Churn) - 1),  # Convert to 0/1
        log_odds = log((churn_rate + 0.001) / (1 - churn_rate + 0.001))  # Avoid log(0)
      )

    # Create scatter plot
    p <- ggplot(data_binned, aes(x = mean_var, y = log_odds)) +
      geom_point(size = 3, color = "steelblue") +
      geom_smooth(method = "lm", se = FALSE, color = "red") +
      labs(title = paste("Linearity Check:", var),
           x = var, y = "Log Odds of Churn") +
      theme_minimal()

    plots[[var]] <- p
  }

  return(plots)
}

# Check linearity for continuous variables
continuous_vars <- c("tenure", "MonthlyCharges", "TotalCharges")
linearity_plots <- check_logit_linearity(telco_chrun_clean, continuous_vars)

# Display plots
linearity_plots$tenure
```

```
## 'geom_smooth()' using formula = 'y ~ x'
```



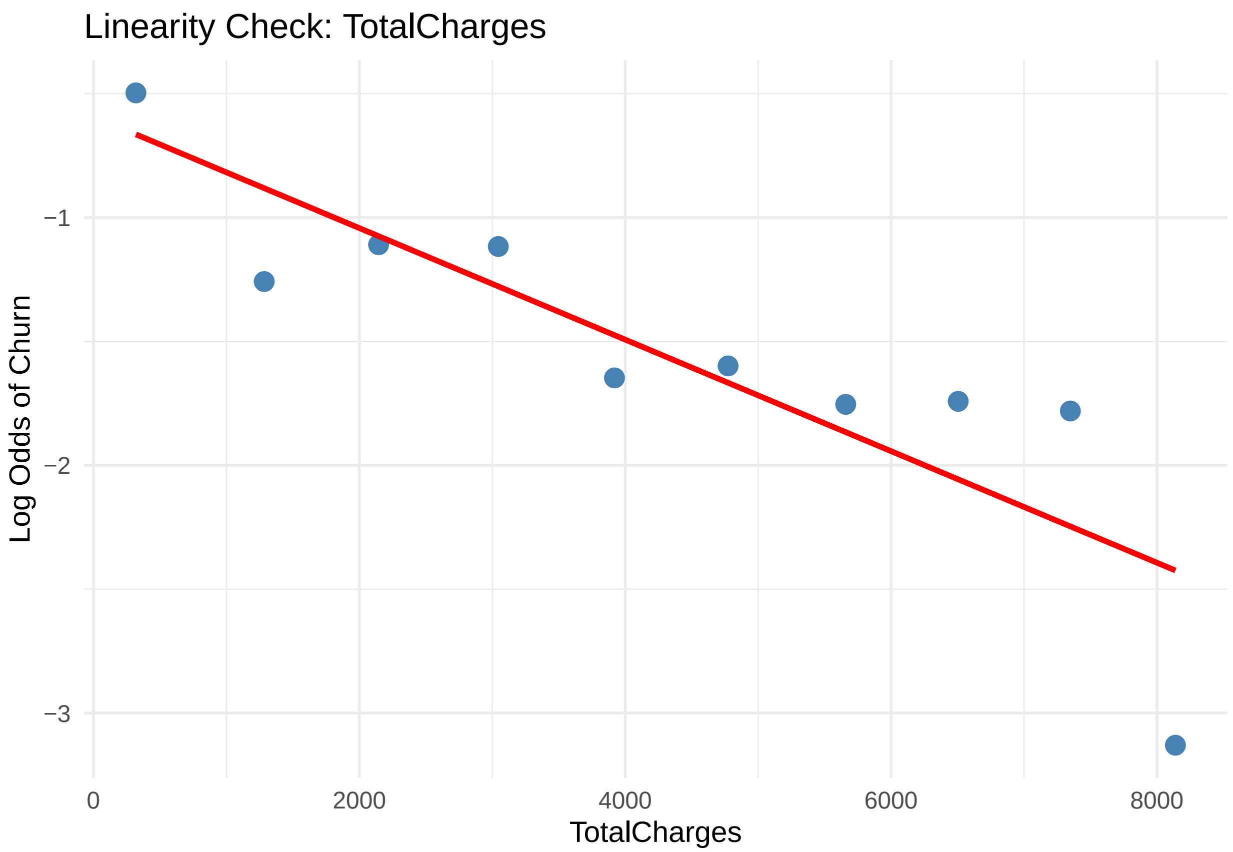
```
linearity_plots$MonthlyCharges
```

```
## 'geom_smooth()' using formula = 'y ~ x'
```



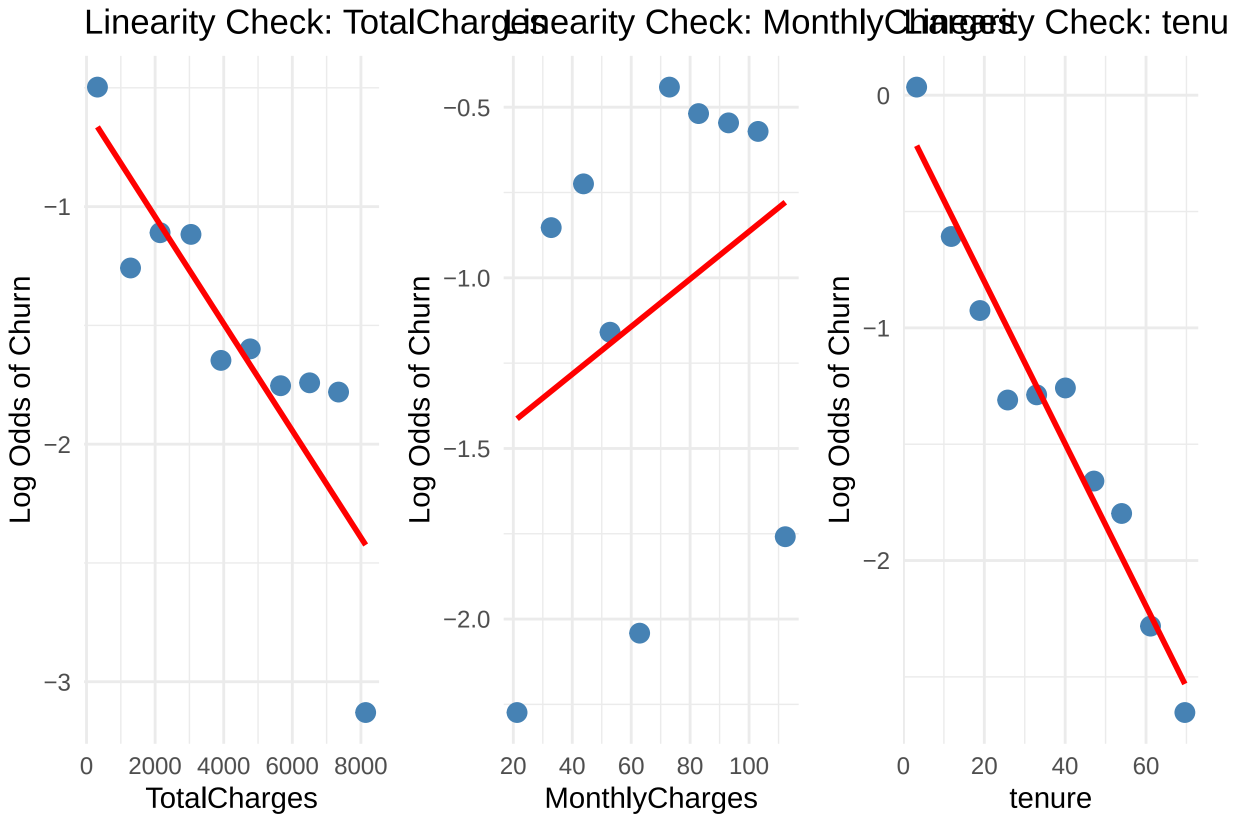
```
linearity_plots$TotalCharges
```

```
## ‘geom_smooth()‘ using formula = ’y ~ x’
```



```
combined_linearity_plots <- (linearity_plots$TotalCharges + linearity_plots$MonthlyCharges + linearity_

combined_linearity_plots
```

```
## ‘geom_smooth()‘ using formula = ’y ~ x’
## ‘geom_smooth()‘ using formula = ’y ~ x’
## ‘geom_smooth()‘ using formula = ’y ~ x’
```



Turning Monthly Charges into a categorical variable

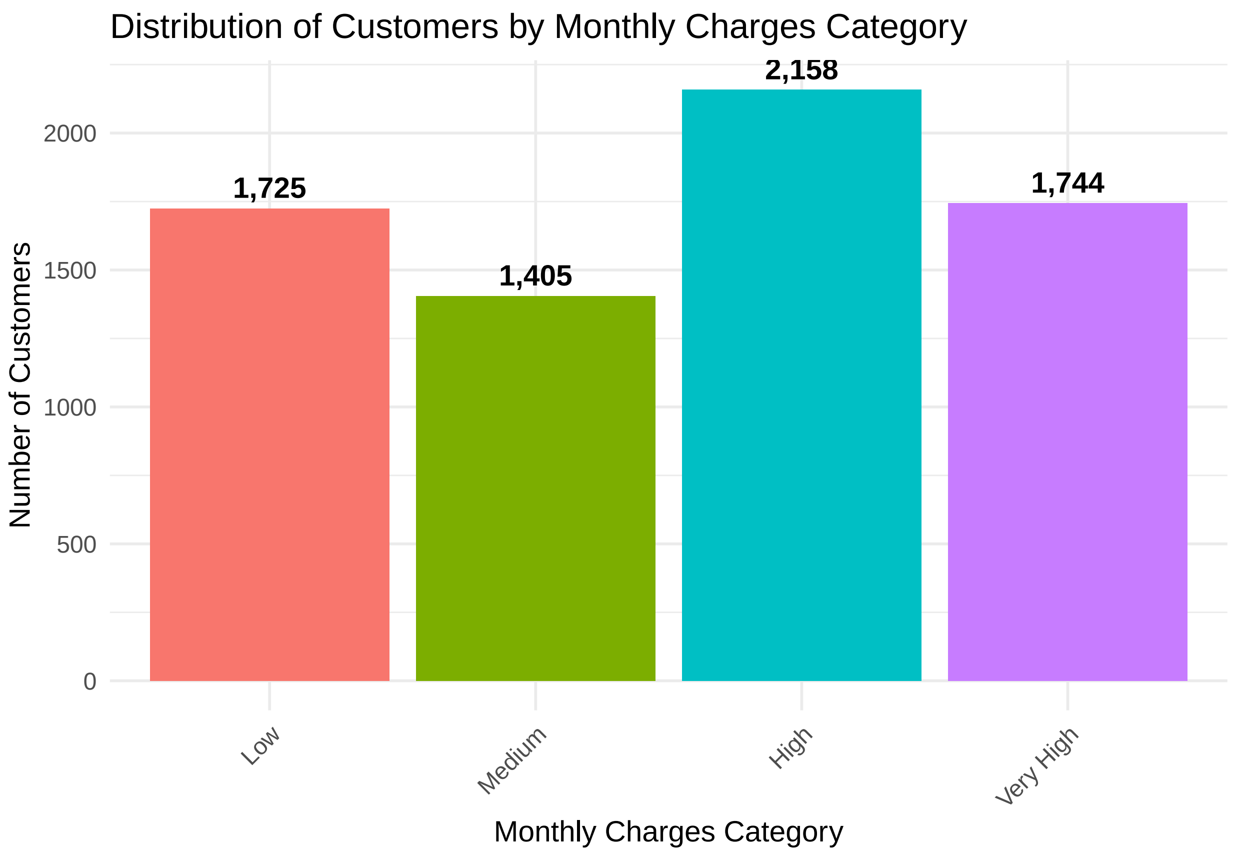
```r
telco_chrun_clean_lr <- telco_chrun_clean %>%
  mutate(
    MonthlyCharges_cat = case_when(
      MonthlyCharges < 35 ~ "Low",
      MonthlyCharges >= 35 & MonthlyCharges < 65 ~ "Medium",
      MonthlyCharges >= 65 & MonthlyCharges < 90 ~ "High",
      MonthlyCharges >= 90 ~ "Very High"
    ),
    MonthlyCharges_cat = factor(MonthlyCharges_cat,
                                levels = c("Low", "Medium",
                                           "High", "Very High"))
  )

monthly_charges_summary <- telco_chrun_clean_lr %>%
  group_by(MonthlyCharges_cat) %>%
  summarise(
    n_customers = n(),
    avg_monthly_charge = mean(MonthlyCharges),
    churn_rate = mean(Churn == "Yes"),
    .groups = 'drop'
  ) %>%
  mutate(
    percent_total = n_customers / sum(n_customers),
    churn_percent = scales::percent(churn_rate, accuracy = 0.1)
  )

print("Monthly Charges Category Summary:")
```

```
## [1] "Monthly Charges Category Summary:"
```

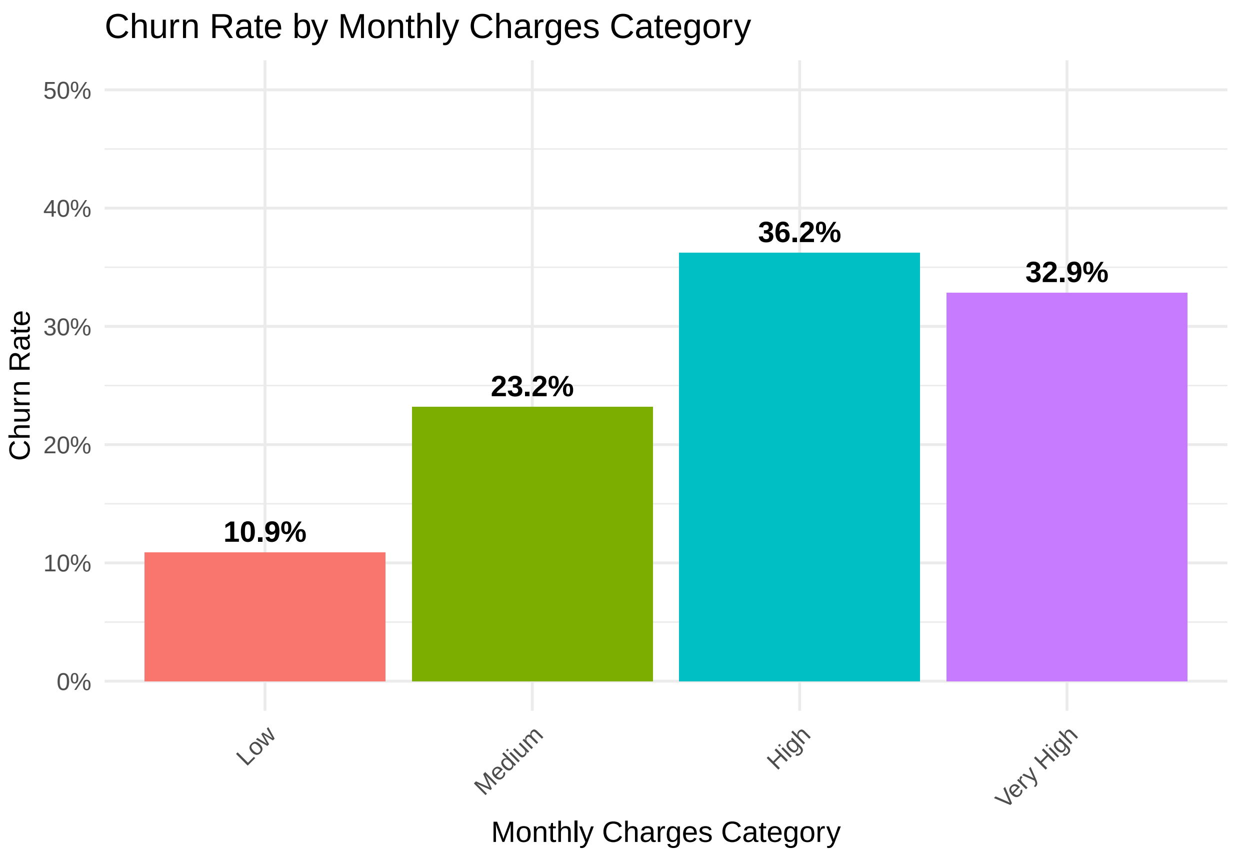
```r
print(monthly_charges_summary)
```

```
## # A tibble: 4 x 6
##   MonthlyCharges_cat n_customers avg_monthly_charge churn_rate percent_total
##   <fct>                    <int>              <dbl>      <dbl>         <dbl>
## 1 Low                       1725               22.0      0.109         0.245
## 2 Medium                    1405               51.7      0.232         0.200
## 3 High                      2158               78.3      0.362         0.307
## 4 Very High                 1744              101.       0.329         0.248
## # i 1 more variable: churn_percent <chr>
```

```r
distribution_plot <- ggplot(monthly_charges_summary, aes(x = MonthlyCharges_cat, y = n_customers, fill =
  geom_col(show.legend = FALSE) +
  geom_text(aes(label = scales::comma(n_customers)), vjust = -0.5, size = 4, fontface = "bold") +
  labs(title = "Distribution of Customers by Monthly Charges Category",
       x = "Monthly Charges Category",
       y = "Number of Customers") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

churn_plot <- ggplot(monthly_charges_summary, aes(x = MonthlyCharges_cat, y = churn_rate, fill = Monthl
  geom_col(show.legend = FALSE) +
  geom_text(aes(label = churn_percent), vjust = -0.5, size = 4, fontface = "bold") +
  scale_y_continuous(labels = scales::percent_format(), limits = c(0, 0.5)) +
  labs(title = "Churn Rate by Monthly Charges Category",
       x = "Monthly Charges Category",
       y = "Churn Rate") +
  theme_minimal() +
  theme(axis.text.x = element_text(angle = 45, hjust = 1))

distribution_plot
```

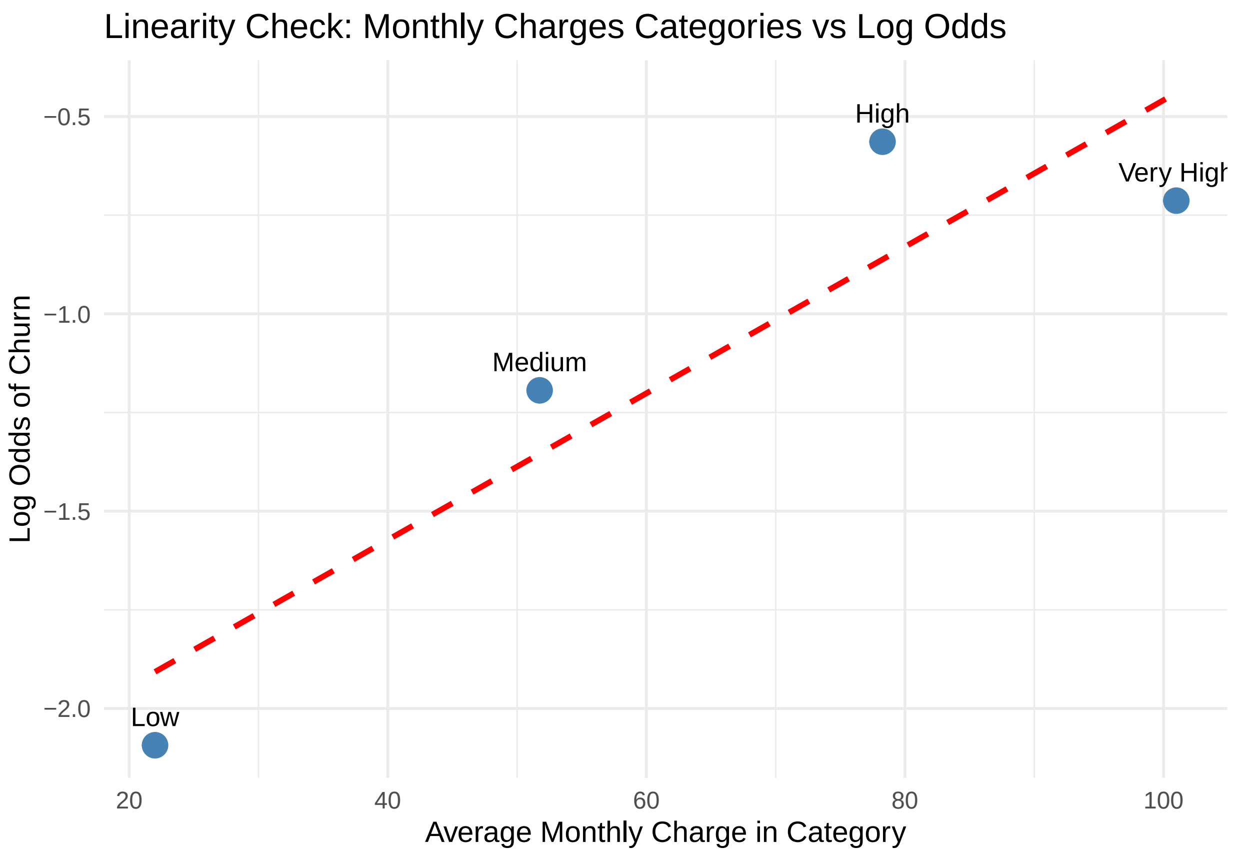

Distribution of Customers by Monthly Charges Category
Number of Customers
0
500
1000
1500
2000
1,725
1,405
2,158
1,744
Low
Medium
High
Very High
Monthly Charges Category

```
churn_plot
```



```
data_binned_cat <- telco_chrun_clean_lr %>%
  group_by(MonthlyCharges_cat) %>%
  summarise(
    avg_charge = mean(MonthlyCharges),
    churn_rate = mean(as.numeric(Churn) - 1),
    log_odds = log((churn_rate + 0.001) / (1 - churn_rate + 0.001))
  )

cat_linearity_plot <- ggplot(data_binned_cat, aes(x = avg_charge, y = log_odds)) +
  geom_point(size = 4, color = "steelblue") +
  geom_smooth(method = "lm", se = FALSE, color = "red", linetype = "dashed") +
  geom_text(aes(label = MonthlyCharges_cat), vjust = -1, size = 3.5) +
  labs(title = "Linearity Check: Monthly Charges Categories vs Log Odds",
       x = "Average Monthly Charge in Category",
       y = "Log Odds of Churn") +
  theme_minimal()

cat_linearity_plot
```

```
## `geom_smooth()` using formula = 'y ~ x'
```



```
telco_for_modeling <- telco_chrun_clean_lr %>%
  mutate(MonthlyCharges_cat = as.factor(MonthlyCharges_cat))

telco_for_modeling <- telco_chrun_clean_lr %>%
  select(-MonthlyCharges)

cat("Final dataset structure for modeling:\n")
```

```
## Final dataset structure for modeling:
```

```
str(telco_for_modeling$MonthlyCharges_cat)
```

```
##  Factor w/ 4 levels "Low","Medium",..: 1 2 2 2 3 4 3 1 4 2 ...
```

```
table(telco_for_modeling$MonthlyCharges_cat)
```

```
## 
##       Low    Medium      High Very High 
##      1725      1405      2158      1744
```

Lasso Variable Selection

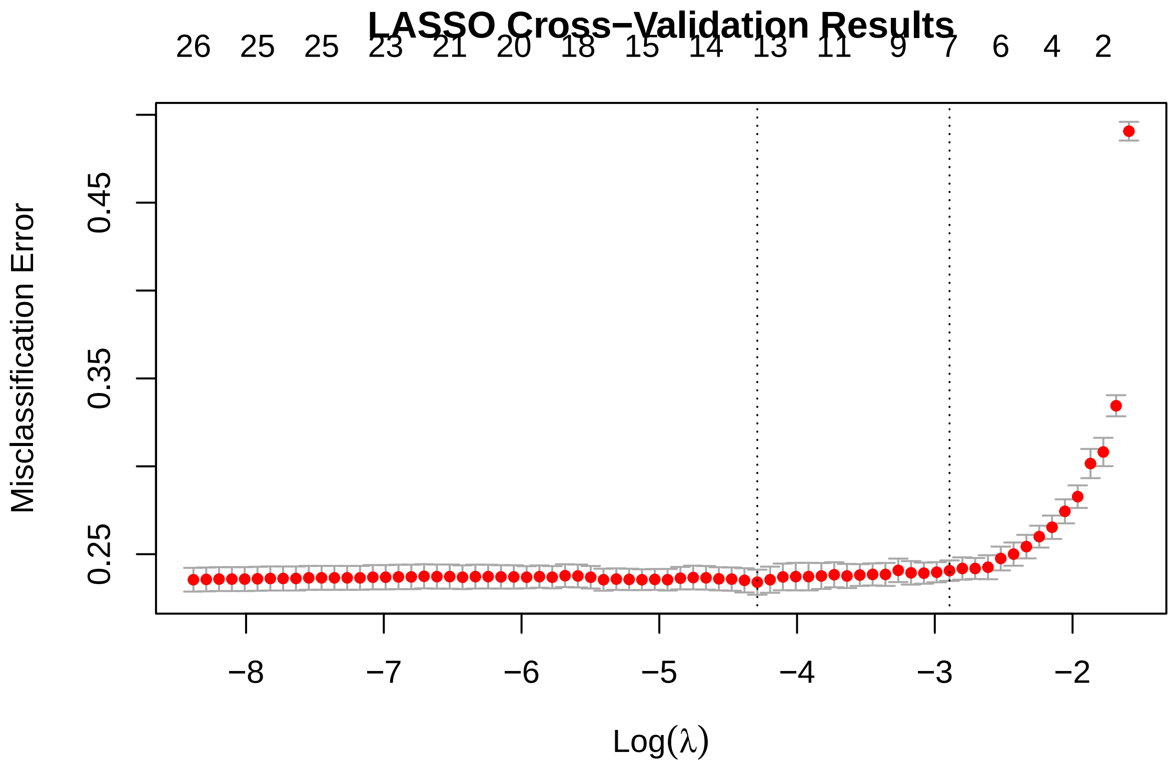
```
set.seed(123)
train_index <- createDataPartition(telco_for_modeling$Churn, p = 0.8, list = FALSE)
telco_train <- telco_for_modeling[train_index, ]
telco_test <- telco_for_modeling[-train_index, ]

train_balanced <- ROSE(Churn ~ ., data = telco_train, seed = 1)$data

cat("Class distribution after ROSE:\n")
```

```
## Class distribution after ROSE:
```

```
print(table(train_balanced$Churn))
```

```
##
##   No  Yes
## 2866 2761
```

```
x_train <- model.matrix(Churn ~ . -1, data = train_balanced)
y_train <- as.numeric(train_balanced$Churn) - 1  # Convert to 0/1

x_test <- model.matrix(Churn ~ . -1, data = telco_test)
y_test <- as.numeric(telco_test$Churn) - 1

set.seed(123)
cv_lasso <- cv.glmnet(x_train, y_train,
                     family = "binomial",
                     alpha = 1,
                     type.measure = "class",
                     nfolds = 10)

plot(cv_lasso, main = "LASSO Cross-Validation Results")
```



```
lambda_min <- cv_lasso$lambda.min
lambda_1se <- cv_lasso$lambda.1se

cat("Minimum lambda:", round(lambda_min, 4), "\n")
```

```
## Minimum lambda: 0.0137
```

```
cat("1 SE lambda:", round(lambda_1se, 4), "\n")
```

```
## 1 SE lambda: 0.0554
```

```
lasso_model <- glmnet(x_train, y_train,
                      family = "binomial",
                      alpha = 1,
                      lambda = lambda_1se)

lasso_coef <- coef(lasso_model)
print("LASSO Coefficients:")
```

```
## [1] "LASSO Coefficients:"
```

```
print(lasso_coef)
```

```
## 27 x 1 sparse Matrix of class "dgCMatrix"
##                                      s0
## (Intercept)                  0.24922638
## genderFemale                 .
## genderMale                   .
## SeniorCitizen1               .
## PartnerYes                   .
## DependentsYes                .
## tenure                      -0.01932266
## PhoneServiceYes              .
## MultipleLinesYes             .
## InternetServiceFiberOptic    0.59532195
## InternetServiceNo           -0.31157191
## OnlineSecurityYes            .
## OnlineBackupYes              .
## DeviceProtectionYes          .
## TechSupportYes               .
## StreamingTVYes               .
## StreamingMoviesYes           .
## ContractOne year            -0.26266102
## ContractTwo year            -0.77199160
## PaperlessBillingYes          0.04412032
## PaymentMethodCreditCardAuto  .
## PaymentMethodECheck          0.25277584
## PaymentMethodMailedCheck     .
## TotalCharges                 .
## MonthlyCharges_catMedium     .
## MonthlyCharges_catHigh       .
## MonthlyCharges_catVery High  .
```

```r
selected_vars <- rownames(lasso_coef)[which(lasso_coef != 0)]
selected_vars <- selected_vars[selected_vars != "(Intercept)"]
cat("\nSelected variables by LASSO:", paste(selected_vars, collapse = ", "), "\n")
```

```
##
## Selected variables by LASSO: tenure, InternetServiceFiberOptic, InternetServiceNo, ContractOne year,
```

```r
selected_summary <- data.frame(
  Variable = rownames(lasso_coef)[which(lasso_coef != 0)],
  Coefficient = lasso_coef[which(lasso_coef != 0)],
  Odds_Ratio = exp(lasso_coef[which(lasso_coef != 0)])
)
rownames(selected_summary) <- NULL

print("Selected Variables with Coefficients and Odds Ratios:")
```

```
## [1] "Selected Variables with Coefficients and Odds Ratios:"
```

```r
print(selected_summary)
```

```
##                    Variable Coefficient Odds_Ratio
## 1               (Intercept)  0.24922638  1.2830325
## 2                    tenure -0.01932266  0.9808628
## 3 InternetServiceFiberOptic  0.59532195  1.8136147
## 4         InternetServiceNo -0.31157191  0.7322949
## 5          ContractOne year -0.26266102  0.7690025
## 6          ContractTwo year -0.77199160  0.4620918
## 7       PaperlessBillingYes  0.04412032  1.0451081
## 8       PaymentMethodECheck  0.25277584  1.2875946
```

Building Logistic Regression Model

```
final_model <- glm(Churn ~ tenure + Contract + InternetService + PaperlessBilling + PaymentMethod + Seni
                  data = train_balanced,
                  family = "binomial")

cat("\nFinal Model Summary:\n")
```

```
##
## Final Model Summary:
```

```
summary(final_model)
```

```
##
## Call:
## glm(formula = Churn ~ tenure + Contract + InternetService + PaperlessBilling +
##     PaymentMethod + SeniorCitizen + OnlineSecurity, family = "binomial",
##     data = train_balanced)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -2.3464  -0.7804  -0.1832   0.7817   2.7723
##
## Coefficients:
##                              Estimate Std. Error z value Pr(>|z|)
## (Intercept)                  0.412553   0.113789   3.626 0.000288 ***
## tenure                      -0.028814   0.001983 -14.527  < 2e-16 ***
## ContractOne year            -0.771466   0.099382  -7.763 8.32e-15 ***
## ContractTwo year            -1.618989   0.155031 -10.443  < 2e-16 ***
## InternetServiceFiberOptic    0.775648   0.079590   9.746  < 2e-16 ***
## InternetServiceNo           -0.892255   0.115774  -7.707 1.29e-14 ***
## PaperlessBillingYes          0.358641   0.073916   4.852 1.22e-06 ***
## PaymentMethodCreditCardAuto  0.030231   0.112739   0.268 0.788584
## PaymentMethodECheck          0.333496   0.095442   3.494 0.000475 ***
## PaymentMethodMailedCheck    -0.147393   0.111508  -1.322 0.186231
## SeniorCitizen1               0.543213   0.088006   6.172 6.72e-10 ***
## OnlineSecurityYes           -0.377700   0.084062  -4.493 7.02e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 7798.7  on 5626  degrees of freedom
## Residual deviance: 5566.1  on 5615  degrees of freedom
## AIC: 5590.1
##
## Number of Fisher Scoring iterations: 5
```

```
odds_ratios <- exp(coef(final_model))
conf_int <- exp(confint(final_model))
```

```
## Waiting for profiling to be done...
```

```
model_summary <- data.frame(
  Variable = names(coef(final_model)),
  Coefficient = coef(final_model),
  Odds_Ratio = odds_ratios,
  CI_Lower = conf_int[,1],
  CI_Upper = conf_int[,2],
  p_value = summary(final_model)$coefficients[,4]
)

print("Model Coefficients with Odds Ratios and Confidence Intervals:")
```

```
## [1] "Model Coefficients with Odds Ratios and Confidence Intervals:"
```

```
print(model_summary, digits = 3)
```

```
##                                                Variable Coefficient Odds_Ratio
## (Intercept)                                 (Intercept)      0.4126      1.511
## tenure                                           tenure     -0.0288      0.972
## ContractOne year                       ContractOne year     -0.7715      0.462
## ContractTwo year                       ContractTwo year     -1.6190      0.198
## InternetServiceFiberOptic     InternetServiceFiberOptic      0.7756      2.172
## InternetServiceNo                     InternetServiceNo     -0.8923      0.410
## PaperlessBillingYes                 PaperlessBillingYes      0.3586      1.431
## PaymentMethodCreditCardAuto PaymentMethodCreditCardAuto      0.0302      1.031
## PaymentMethodECheck                 PaymentMethodECheck      0.3335      1.396
## PaymentMethodMailedCheck       PaymentMethodMailedCheck     -0.1474      0.863
## SeniorCitizen1                           SeniorCitizen1      0.5432      1.722
## OnlineSecurityYes                     OnlineSecurityYes     -0.3777      0.685
##                             CI_Lower CI_Upper  p_value
## (Intercept)                    1.209    1.889 2.88e-04
## tenure                         0.968    0.975 8.12e-48
## ContractOne year               0.380    0.561 8.32e-15
## ContractTwo year               0.145    0.267 1.58e-25
## InternetServiceFiberOptic      1.859    2.539 1.93e-22
## InternetServiceNo              0.326    0.514 1.29e-14
## PaperlessBillingYes            1.238    1.654 1.22e-06
## PaymentMethodCreditCardAuto    0.826    1.286 7.89e-01
## PaymentMethodECheck            1.157    1.683 4.75e-04
## PaymentMethodMailedCheck       0.694    1.074 1.86e-01
## SeniorCitizen1                 1.450    2.047 6.72e-10
## OnlineSecurityYes              0.581    0.808 7.02e-06
```

Addressing Assumption 2 by Checking Multicollinerity

```
vif_final <- vif(final_model)
print("\nVariance Inflation Factors for Final Model:")
```

```
## [1] "\nVariance Inflation Factors for Final Model:"
```

```
print(vif_final)
```

```
##                      GVIF Df GVIF^(1/(2*Df))
## tenure           1.792068  1        1.338681
## Contract         1.531658  2        1.112475
## InternetService  1.512529  2        1.108986
## PaperlessBilling 1.136897  1        1.066253
## PaymentMethod    1.374494  3        1.054445
## SeniorCitizen    1.089690  1        1.043882
## OnlineSecurity   1.162539  1        1.078211
```

```
if (all(vif_final <= 5)) {
  cat("Multicollinearity issue resolved! All VIF values <= 5\n")
} else {
  high_vif_final <- names(vif_final[vif_final > 5])
  cat("Warning: Some multicollinearity remains in:", paste(high_vif_final, collapse = ", "), "\n")
}
```

```
## Multicollinearity issue resolved! All VIF values <= 5
```

Model Evaluation

```
predictions_prob <- predict(final_model, newdata = telco_test, type = "response")
predictions_class <- ifelse(predictions_prob > 0.5, 1, 0)

conf_matrix <- table(Predicted = predictions_class, Actual = y_test)
print("Confusion Matrix:")
```

```
## [1] "Confusion Matrix:"
```

```
print(conf_matrix)
```

```
##          Actual
## Predicted   0   1
##         0 746  77
##         1 286 296
```

```
accuracy <- sum(diag(conf_matrix)) / sum(conf_matrix)
sensitivity <- conf_matrix[2,2] / sum(conf_matrix[,2])
specificity <- conf_matrix[1,1] / sum(conf_matrix[,1])
precision <- conf_matrix[2,2] / sum(conf_matrix[2,])
f1_score <- 2 * (precision * sensitivity) / (precision + sensitivity)

cat("\nModel Performance Metrics:\n")
```

```
##
## Model Performance Metrics:
```

```
cat("Accuracy:", round(accuracy, 3), "\n")
```

```
## Accuracy: 0.742
```

```
cat("Sensitivity (Recall):", round(sensitivity, 3), "\n")
```

```
## Sensitivity (Recall): 0.794
```

```
cat("Specificity:", round(specificity, 3), "\n")
```

```
## Specificity: 0.723
```

```
cat("Precision:", round(precision, 3), "\n")
```

```
## Precision: 0.509
```

```
cat("F1 Score:", round(f1_score, 3), "\n")
```

```
## F1 Score: 0.62
```

Random Forest

```
set.seed(123)

train_index <- createDataPartition(telco_chrun_clean$Churn, p = 0.8, list = FALSE)
telco_train <- telco_chrun_clean[train_index, ]
telco_test <- telco_chrun_clean[-train_index, ]

train_balanced <- ROSE(Churn ~ ., data = telco_train, seed = 123)$data

cat("Class distribution after ROSE:\n")
```

```
## Class distribution after ROSE:
```

```
print(table(train_balanced$Churn))
```

```
##
##   No  Yes
## 2834 2793
```

Variable Selection

```
set.seed(123)
rf_initial <- randomForest(Churn ~ .,
                           data = train_balanced,
                           ntree = 500,
                           importance = TRUE,
                           do.trace = 100)
```

```
## ntree      OOB      1      2
##   100:  17.22% 20.96% 13.43%
##   200:  17.10% 20.92% 13.21%
##   300:  16.78% 20.96% 12.53%
##   400:  16.87% 21.03% 12.64%
##   500:  16.95% 21.28% 12.57%
```

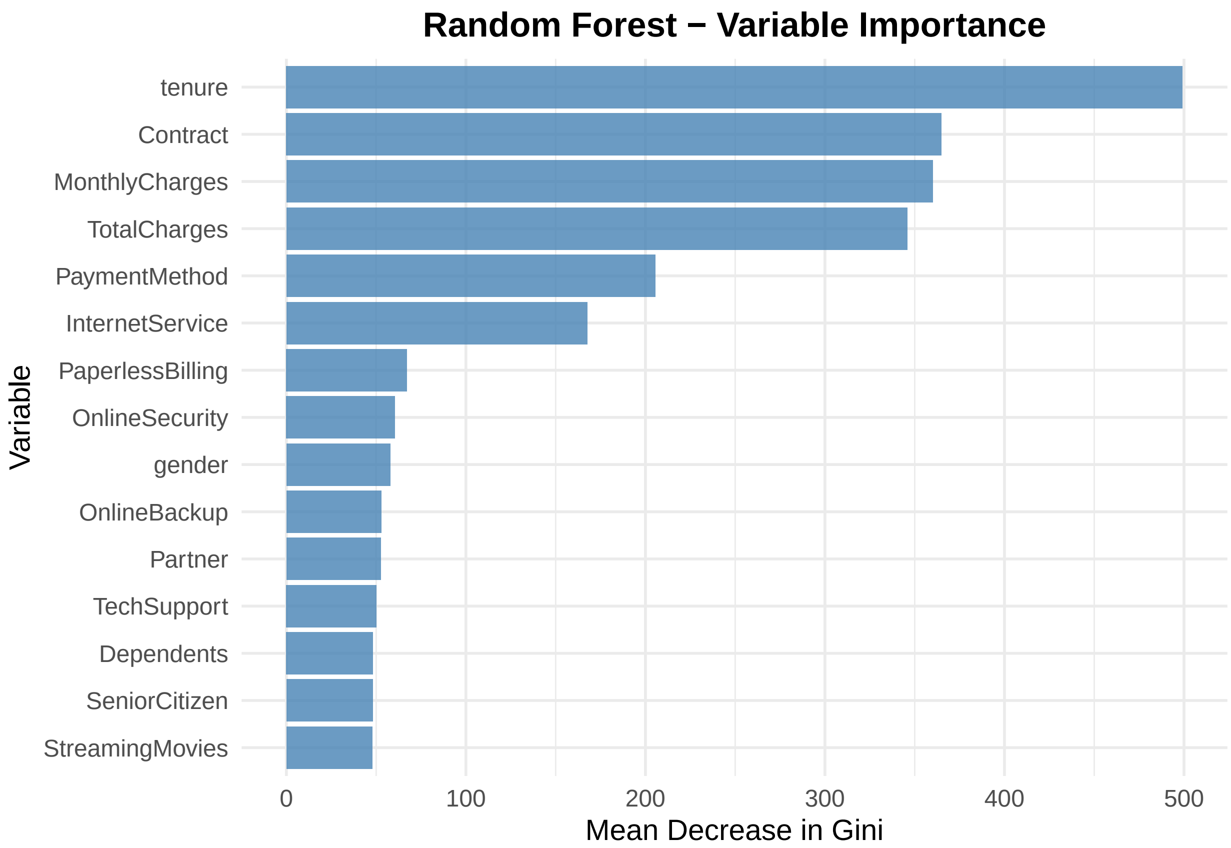
```
var_importance <- importance(rf_initial)
var_importance_df <- data.frame(
  Variable = rownames(var_importance),
  Importance = var_importance[, "MeanDecreaseGini"]
) %>%
  arrange(desc(Importance))

print("Top 15 Most Important Variables:")
```

```
## [1] "Top 15 Most Important Variables:"
```

```
print(head(var_importance_df, 15))
```

```
##                          Variable Importance
## tenure                     tenure  499.20435
## Contract                 Contract  364.92943
## MonthlyCharges     MonthlyCharges  360.05316
## TotalCharges         TotalCharges  345.81818
## PaymentMethod       PaymentMethod  205.38618
## InternetService   InternetService  167.53865
## PaperlessBilling PaperlessBilling   67.13078
## OnlineSecurity     OnlineSecurity   60.55211
## gender                     gender   57.88723
## OnlineBackup         OnlineBackup   52.91792
## Partner                   Partner   52.62060
## TechSupport           TechSupport   50.17606
## Dependents             Dependents   48.26610
## SeniorCitizen       SeniorCitizen   48.05320
## StreamingMovies   StreamingMovies   47.78629
```

```
var_imp_plot <- ggplot(head(var_importance_df, 15),
                       aes(x = reorder(Variable, Importance), y = Importance)) +
  geom_col(fill = "steelblue", alpha = 0.8) +
  coord_flip() +
  labs(title = "Random Forest - Variable Importance",
       x = "Variable",
       y = "Mean Decrease in Gini") +
  theme_minimal() +
  theme(plot.title = element_text(hjust = 0.5, face = "bold"))

print(var_imp_plot)
```



```
selected_vars_rf <- var_importance_df$Variable[1:10]  # Top 10 variables
cat("\nSelected variables for final model:", paste(selected_vars_rf, collapse = ", "), "\n")
```

```
##
## Selected variables for final model: tenure, Contract, MonthlyCharges, TotalCharges, PaymentMethod, I
```

Hypertuning Parameters

```
cat("\n=== HYPERPARAMETER TUNING ===\n")
```

```
##
## === HYPERPARAMETER TUNING ===
```

```
tune_grid <- expand.grid(
  mtry = c(2, 3, 4, 5, 6)
)

ctrl <- trainControl(
  method = "cv",
  number = 5,
  classProbs = TRUE,
  summaryFunction = twoClassSummary,
  verboseIter = TRUE,
  search = "grid"
)

formula_selected <- as.formula(paste("Churn ~", paste(selected_vars_rf, collapse = " + ")))

set.seed(123)
rf_tuned <- train(
  formula_selected,
  data = train_balanced,
  method = "rf",
  metric = "ROC",
  trControl = ctrl,
  tuneGrid = tune_grid,
  ntree = 500,
  importance = TRUE
)
```

```
## + Fold1: mtry=2
## - Fold1: mtry=2
## + Fold1: mtry=3
## - Fold1: mtry=3
## + Fold1: mtry=4
## - Fold1: mtry=4
## + Fold1: mtry=5
## - Fold1: mtry=5
## + Fold1: mtry=6
## - Fold1: mtry=6
## + Fold2: mtry=2
## - Fold2: mtry=2
## + Fold2: mtry=3
## - Fold2: mtry=3
## + Fold2: mtry=4
## - Fold2: mtry=4
## + Fold2: mtry=5
## - Fold2: mtry=5
## + Fold2: mtry=6
## - Fold2: mtry=6
## + Fold3: mtry=2
## - Fold3: mtry=2
## + Fold3: mtry=3
## - Fold3: mtry=3
## + Fold3: mtry=4
## - Fold3: mtry=4
## + Fold3: mtry=5
## - Fold3: mtry=5
## + Fold3: mtry=6
## - Fold3: mtry=6
## + Fold4: mtry=2
## - Fold4: mtry=2
## + Fold4: mtry=3
## - Fold4: mtry=3
## + Fold4: mtry=4
## - Fold4: mtry=4
## + Fold4: mtry=5
## - Fold4: mtry=5
## + Fold4: mtry=6
## - Fold4: mtry=6
## + Fold5: mtry=2
## - Fold5: mtry=2
## + Fold5: mtry=3
## - Fold5: mtry=3
## + Fold5: mtry=4
## - Fold5: mtry=4
## + Fold5: mtry=5
## - Fold5: mtry=5
## + Fold5: mtry=6
## - Fold5: mtry=6
## Aggregating results
## Selecting tuning parameters
## Fitting mtry = 4 on full training set
```

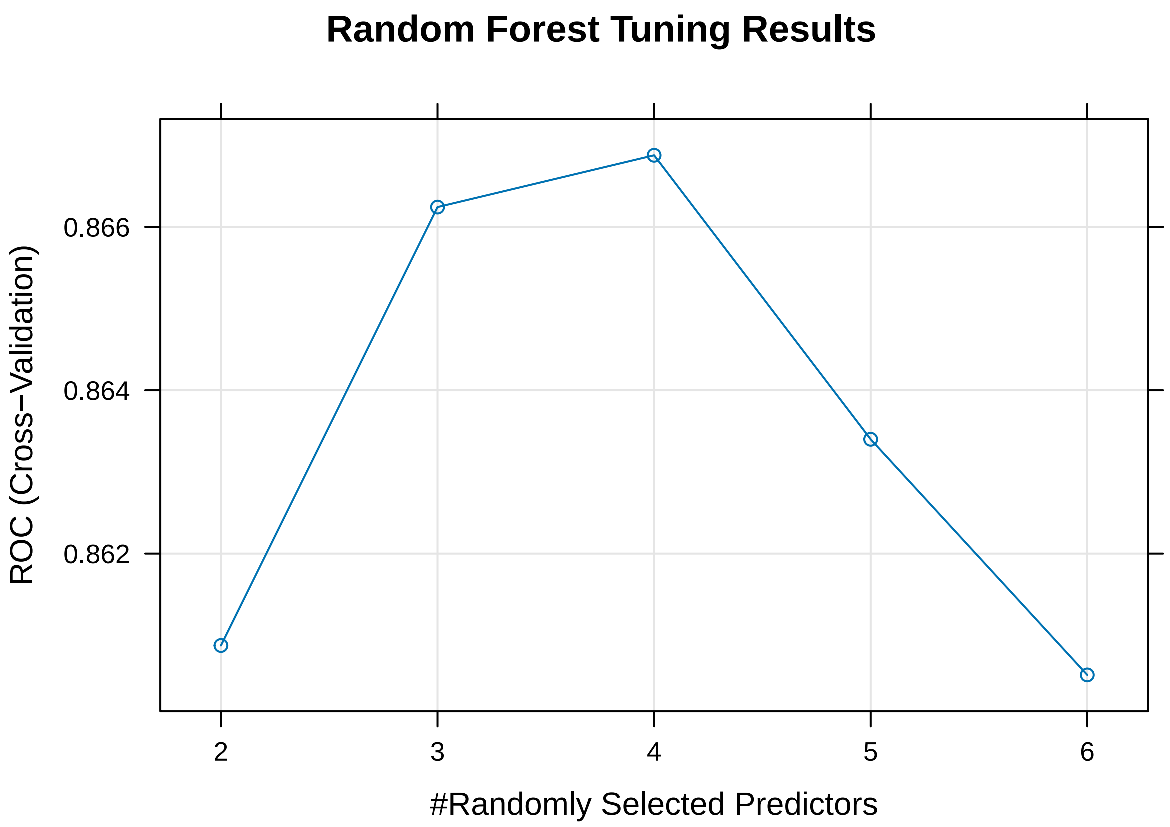
```r
cat("Best tuning parameters:\n")
```

```
## Best tuning parameters:
```

```r
print(rf_tuned$bestTune)
```

```
##   mtry
## 3    4
```

```r
plot(rf_tuned, main = "Random Forest Tuning Results")
```



## Building the Model

```
cat("\n=== FINAL RANDOM FOREST MODEL ===\n")
```

```
##
## === FINAL RANDOM FOREST MODEL ===
```

```
final_rf <- randomForest(
  formula_selected,
  data = train_balanced,
  mtry = rf_tuned$bestTune$mtry,
  nodesize = rf_tuned$bestTune$nodesize,
  importance = TRUE
)

cat("Final Random Forest Model Summary:\n")
```

```
## Final Random Forest Model Summary:
```

```
print(final_rf)
```

```
##
## Call:
##  randomForest(formula = formula_selected, data = train_balanced,      mtry = rf_tuned$bestTune$mtry,
##                Type of random forest: classification
##                       Number of trees: 500
## No. of variables tried at each split: 4
## 
##         OOB estimate of  error rate: 21.04%
## Confusion matrix:
##       No  Yes class.error
## No  2160  674   0.2378264
## Yes  510 2283   0.1825994
```

Model Evaluation

```
cat("\n=== MODEL EVALUATION ===\n")
```

```
## 
## === MODEL EVALUATION ===
```

```
predictions_prob <- predict(final_rf, newdata = telco_test, type = "prob")[, "Yes"]
predictions_class <- predict(final_rf, newdata = telco_test, type = "response")

y_test_numeric <- ifelse(telco_test$Churn == "Yes", 1, 0)
pred_class_numeric <- ifelse(predictions_class == "Yes", 1, 0)

conf_matrix <- table(Predicted = pred_class_numeric, Actual = y_test_numeric)
print("Confusion Matrix:")
```

```
## [1] "Confusion Matrix:"
```

```
print(conf_matrix)
```

```
##          Actual
## Predicted   0   1
##         0 755  92
##         1 277 281
```

```
accuracy <- sum(diag(conf_matrix)) / sum(conf_matrix)
sensitivity <- conf_matrix[2,2] / sum(conf_matrix[,2])
specificity <- conf_matrix[1,1] / sum(conf_matrix[,1])
precision <- conf_matrix[2,2] / sum(conf_matrix[2,])
f1_score <- 2 * (precision * sensitivity) / (precision + sensitivity)

roc_obj <- roc(y_test_numeric, predictions_prob)
```

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

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

```
auc_score <- auc(roc_obj)

cat("\nModel Performance Metrics:\n")
```

```
##
## Model Performance Metrics:
```

```
cat("Accuracy:", round(accuracy, 3), "\n")
```

```
## Accuracy: 0.737
```

```
cat("Sensitivity (Recall):", round(sensitivity, 3), "\n")
```

```
## Sensitivity (Recall): 0.753
```

```
cat("Specificity:", round(specificity, 3), "\n")
```

```
## Specificity: 0.732
```

```
cat("Precision:", round(precision, 3), "\n")
```

```
## Precision: 0.504
```

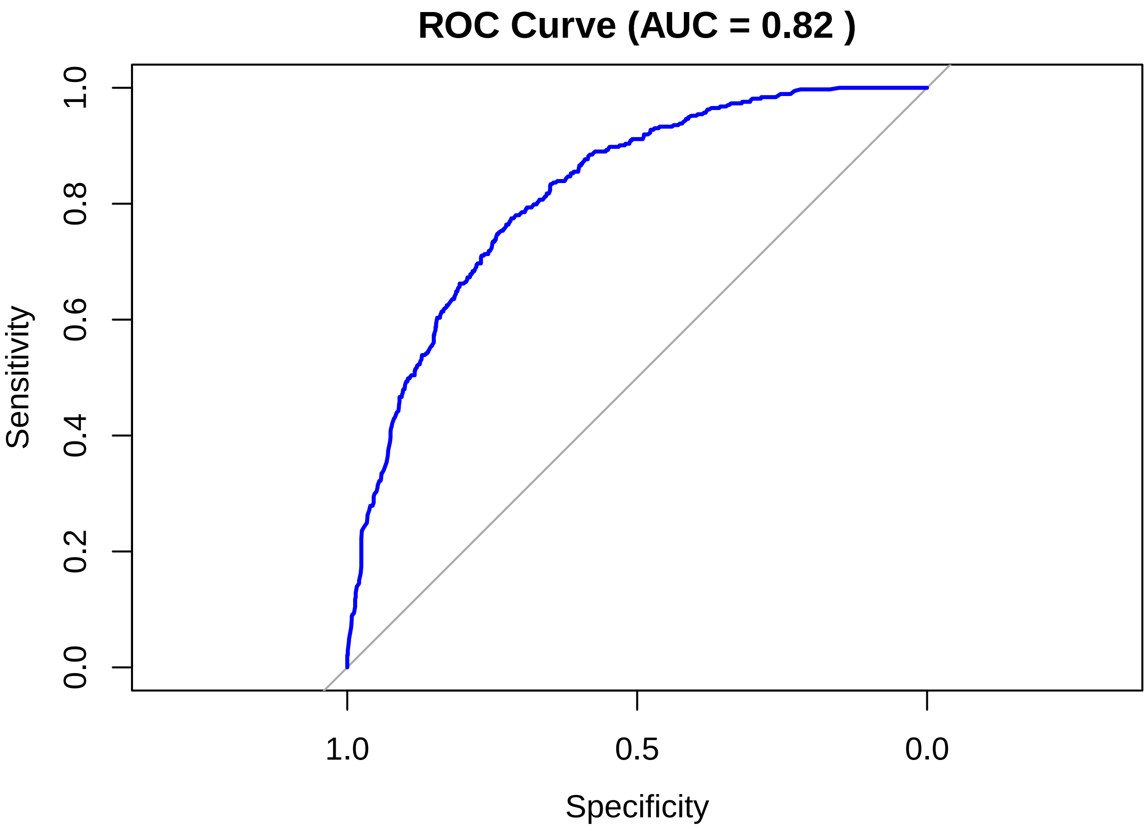
```
cat("F1 Score:", round(f1_score, 3), "\n")
```

```
## F1 Score: 0.604
```

```
cat("AUC:", round(auc_score, 3), "\n")
```

```
## AUC: 0.82
```

```
plot(roc_obj, main = paste("ROC Curve (AUC =", round(auc_score, 3), ")"),
     col = "blue", lwd = 2)
```


ROC Curve (AUC = 0.82)
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Specificity
1.0
0.5
0.0

‘‘‘