111

Dayu Tie

2024-10-02

```
data_grouped=read.csv('Artery_20.csv')
```

```
artery_data <- read.csv("Artery_20.csv")

artery_data$base_id <- sub("\\..*", "", artery_data$X)

reorder_x_column <- function(df) {
  base_id <- unique(df$base_id)[1]
  df$X <- paste0(base_id, ".", seq_len(nrow(df)))
  return(df)
}

artery_data <- do.call(rbind, lapply(split(artery_data, artery_data$base_id), reorder_x_colum
n))

artery_data$base_id <- NULL

head(artery_data)
```

```
##                  X CTE Age Arteriosclerosis Atherosclerosis CAA NAIR
## X21372.89 X21372.1   0  87                2               0   1    0
## X21372.90 X21372.2   0  87                2               0   1    0
## X21372.91 X21372.3   0  87                2               0   1    0
## X21372.92 X21372.4   0  87                2               0   1    0
## X21372.93 X21372.5   0  87                2               0   1    0
## X21372.94 X21372.6   0  87                2               0   1    0
##           CircularStretch AxialStretchRatio MediaToTotalRatio
## X21372.89               0                 0         0.4848735
## X21372.90               0                 0         0.5890345
## X21372.91               0                 0         0.5177811
## X21372.92               0                 0         0.4390967
## X21372.93               0                 0         0.4518821
## X21372.94               0                 0         0.4946289
##           RetardanceMediaMean RetardanceAdventitaMean RetardanceTotalMean
## X21372.89          0.06769936              0.09033009          0.07935707
## X21372.90          0.08130205              0.10497551          0.09103102
## X21372.91          0.07788124              0.10159885          0.08931834
## X21372.92          0.07142513              0.10509895          0.09031288
## X21372.93          0.06691258              0.09421734          0.08187880
## X21372.94          0.07391878              0.10124335          0.08772783
##           Patient_ID Arteriosclerosis_group Atherosclerosis_group
## X21372.89     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
## X21372.90     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
## X21372.91     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
## X21372.92     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
## X21372.93     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
## X21372.94     X21372   Arteriosclerosis=2,3     Atherosclerosis=0
```

```
rownames(artery_data) <- NULL

head(artery_data)
```

```
##          X CTE Age Arteriosclerosis Atherosclerosis CAA NAIR CircularStretch
## 1 X21372.1   0  87                2               0   1    0               0
## 2 X21372.2   0  87                2               0   1    0               0
## 3 X21372.3   0  87                2               0   1    0               0
## 4 X21372.4   0  87                2               0   1    0               0
## 5 X21372.5   0  87                2               0   1    0               0
## 6 X21372.6   0  87                2               0   1    0               0
##   AxialStretchRatio MediaToTotalRatio RetardanceMediaMean
## 1                 0         0.4848735          0.06769936
## 2                 0         0.5890345          0.08130205
## 3                 0         0.5177811          0.07788124
## 4                 0         0.4390967          0.07142513
## 5                 0         0.4518821          0.06691258
## 6                 0         0.4946289          0.07391878
##   RetardanceAdventitaMean RetardanceTotalMean Patient_ID Arteriosclerosis_group
## 1              0.09033009          0.07935707     X21372   Arteriosclerosis=2,3
## 2              0.10497551          0.09103102     X21372   Arteriosclerosis=2,3
## 3              0.10159885          0.08931834     X21372   Arteriosclerosis=2,3
## 4              0.10509895          0.09031288     X21372   Arteriosclerosis=2,3
## 5              0.09421734          0.08187880     X21372   Arteriosclerosis=2,3
## 6              0.10124335          0.08772783     X21372   Arteriosclerosis=2,3
##   Atherosclerosis_group
## 1     Atherosclerosis=0
## 2     Atherosclerosis=0
## 3     Atherosclerosis=0
## 4     Atherosclerosis=0
## 5     Atherosclerosis=0
## 6     Atherosclerosis=0
```

```
artery_data$Arteriosclerosis_group <- ifelse(artery_data$Arteriosclerosis_group == 0, "Arterios
clerosis=0", "Arteriosclerosis=1,2,3")
artery_data
```

```
##            X CTE Age Arteriosclerosis Atherosclerosis CAA NAIR CircularStretch
## 1   X21372.1   0  87                 2               0   1    0        0.000000
## 2   X21372.2   0  87                 2               0   1    0        0.000000
## 3   X21372.3   0  87                 2               0   1    0        0.000000
## 4   X21372.4   0  87                 2               0   1    0        0.000000
## 5   X21372.5   0  87                 2               0   1    0        0.000000
## 6   X21372.6   0  87                 2               0   1    0        0.000000
## 7   X21372.7   0  87                 2               0   1    0        0.000000
## 8   X21372.8   0  87                 2               0   1    0        0.000000
## 9   X21372.9   0  87                 2               0   1    0        0.000000
## 10 X21372.10   0  87                 2               0   1    0        0.000000
## 11 X21372.11   0  87                 2               0   1    0        0.000000
## 12   X6018.1   1  72                 1               1   3    1        0.000000
## 13   X6018.2   1  72                 1               1   3    1        0.000000
## 14   X6018.3   1  72                 1               1   3    1        0.000000
## 15   X6068.1   0  70                 2               1   2    1        1.191958
## 16   X6068.2   0  70                 2               1   2    1        1.191958
## 17   X6068.3   0  70                 2               1   2    1        1.191958
## 18   X6068.4   0  70                 2               1   2    1        1.191958
## 19   X6068.5   0  70                 2               1   2    1        1.191958
## 20   X6068.6   0  70                 2               1   2    1        1.191958
## 21   X6068.7   0  70                 2               1   2    1        1.191958
## 22   X6068.8   0  70                 2               1   2    1        1.191958
## 23   X6527.1   1  62                 1               0   1    0        0.000000
## 24   X6527.2   1  62                 1               0   1    0        0.000000
## 25   X6527.3   1  62                 1               0   1    0        0.000000
## 26   X6527.4   1  62                 1               0   1    0        0.000000
## 27   X6527.5   1  62                 1               0   1    0        0.000000
## 28   X6527.6   1  62                 1               0   1    0        0.000000
## 29   X6527.7   1  62                 1               0   1    0        0.000000
## 30   X6527.8   1  62                 1               0   1    0        0.000000
## 31   X6527.9   1  62                 1               0   1    0        0.000000
## 32  X6527.10   1  62                 1               0   1    0        0.000000
## 33  X6527.11   1  62                 1               0   1    0        0.000000
## 34  X6527.12   1  62                 1               0   1    0        0.000000
## 35  X6527.13   1  62                 1               0   1    0        0.000000
## 36  X6527.14   1  62                 1               0   1    0        0.000000
## 37  X6527.15   1  62                 1               0   1    0        0.000000
## 38  X6527.16   1  62                 1               0   1    0        0.000000
## 39  X6527.17   1  62                 1               0   1    0        0.000000
## 40   X6558.1   1  85                 2               1   0    0        1.065743
## 41   X6558.2   1  85                 2               1   0    0        1.065743
## 42   X6558.3   1  85                 2               1   0    0        1.065743
## 43   X6558.4   1  85                 2               1   0    0        1.065743
## 44   X7308.1   1  84                 1               2   1    1        1.130078
## 45   X7308.2   1  84                 1               2   1    1        1.130078
## 46   X7308.3   1  84                 1               2   1    1        1.130078
## 47   X7308.4   1  84                 1               2   1    1        1.130078
## 48   X7308.5   1  84                 1               2   1    1        1.130078
## 49   X7308.6   1  84                 1               2   1    1        1.130078
## 50   X7308.7   1  84                 1               2   1    1        1.130078
## 51   X7308.8   1  84                 1               2   1    1        1.130078
## 52   X7851.1   1  81                 2               1   0    0        1.116711
## 53   X7851.2   1  81                 2               1   0    0        1.116711
## 54   X7851.3   1  81                 2               1   0    0        1.116711
```

```
## 55   X7851.4   1  81                2                1   0    0         1.116711
## 56   X7851.5   1  81                2                1   0    0         1.116711
## 57   X7851.6   1  81                2                1   0    0         1.116711
## 58   X7851.7   1  81                2                1   0    0         1.116711
## 59   X7851.8   1  81                2                1   0    0         1.116711
## 60   X7851.9   1  81                2                1   0    0         1.116711
## 61  X7851.10   1  81                2                1   0    0         1.116711
## 62  X7851.11   1  81                2                1   0    0         1.116711
## 63   X8878.1   0  76                2                1   1    0         1.136406
## 64   X8878.2   0  76                2                1   1    0         1.136406
## 65   X8878.3   0  76                2                1   1    0         1.136406
## 66   X8878.4   0  76                2                1   1    0         1.136406
## 67   X8878.5   0  76                2                1   1    0         1.136406
## 68   X8878.6   0  76                2                1   1    0         1.136406
## 69   X8878.7   0  76                2                1   1    0         1.136406
## 70   X8878.8   0  76                2                1   1    0         1.136406
## 71   X8878.9   0  76                2                1   1    0         1.136406
## 72   X8879.1   1  56                3                1   3    1         1.167411
## 73   X8879.2   1  56                3                1   3    1         1.167411
## 74   X8879.3   1  56                3                1   3    1         1.167411
## 75   X8879.4   1  56                3                1   3    1         1.167411
## 76   X8879.5   1  56                3                1   3    1         1.167411
## 77   X8879.6   1  56                3                1   3    1         1.167411
## 78   X8879.7   1  56                3                1   3    1         1.167411
## 79   X8879.8   1  56                3                1   3    1         1.167411
## 80   X8879.9   1  56                3                1   3    1         1.167411
## 81  X8879.10   1  56                3                1   3    1         1.167411
## 82  X8879.11   1  56                3                1   3    1         1.167411
## 83   X9321.1   1  79                2                1   0    1         1.074903
## 84   X9321.2   1  79                2                1   0    1         1.074903
## 85   X9321.3   1  79                2                1   0    1         1.074903
## 86   X9321.4   1  79                2                1   0    1         1.074903
## 87   X9321.5   1  79                2                1   0    1         1.074903
## 88   X9321.6   1  79                2                1   0    1         1.074903
## 89   X9321.7   1  79                2                1   0    1         1.074903
## 90   X9321.8   1  79                2                1   0    1         1.074903
## 91   X9772.1   1  86                2                1   0    1         1.130811
## 92   X9772.2   1  86                2                1   0    1         1.130811
## 93   X9772.3   1  86                2                1   0    1         1.130811
## 94   X9772.4   1  86                2                1   0    1         1.130811
## 95   X9772.5   1  86                2                1   0    1         1.130811
## 96   X9772.6   1  86                2                1   0    1         1.130811
## 97   X9772.7   1  86                2                1   0    1         1.130811
## 98   X9772.8   1  86                2                1   0    1         1.130811
## 99   X9772.9   1  86                2                1   0    1         1.191958
##    AxialStretchRatio MediaToTotalRatio RetardanceMediaMean
## 1             0.0000         0.4848735          0.06769936
## 2             0.0000         0.5890345          0.08130205
## 3             0.0000         0.5177811          0.07788124
## 4             0.0000         0.4390967          0.07142513
## 5             0.0000         0.4518821          0.06691258
## 6             0.0000         0.4946289          0.07391878
## 7             0.0000         0.4659058          0.06743670
## 8             0.0000         0.4732283          0.06736646
## 9             0.0000         0.5030453          0.07338178
## 10            0.0000         0.4686672          0.06429975
```

```
## 11          0.0000        0.5471934        0.06594711
## 12          0.0000        0.5080565        0.00000000
## 13          0.0000        0.5839153        0.00000000
## 14          0.0000        0.5575891        0.00000000
## 15          1.0965        0.0000000        0.00000000
## 16          1.0965        0.3668933        0.05775420
## 17          1.0965        0.4861622        0.06284612
## 18          1.0965        0.3701288        0.00000000
## 19          1.0965        0.3799672        0.05816329
## 20          1.0965        0.3720109        0.06270942
## 21          1.0965        0.3466016        0.05474133
## 22          1.0965        0.3532261        0.05577871
## 23          0.0000        0.3361950        0.05393407
## 24          0.0000        0.4090557        0.05416970
## 25          0.0000        0.4869244        0.05111889
## 26          0.0000        0.5342714        0.05494594
## 27          0.0000        0.6241119        0.06019178
## 28          0.0000        0.4835967        0.05370386
## 29          0.0000        0.5999905        0.05621274
## 30          0.0000        0.5337550        0.05006687
## 31          0.0000        0.5087809        0.05601380
## 32          0.0000        0.6396090        0.05615233
## 33          0.0000        0.5415705        0.05169591
## 34          0.0000        0.6324986        0.05226379
## 35          0.0000        0.7047315        0.05776735
## 36          0.0000        0.6107977        0.05408265
## 37          0.0000        0.6528709        0.05732983
## 38          0.0000        0.6710463        0.05407904
## 39          0.0000        0.7275428        0.05678152
## 40          1.1330        0.3719515        0.04891146
## 41          1.1330        0.3347382        0.04627623
## 42          1.1330        0.0000000        0.00000000
## 43          1.1330        0.3892245        0.04777806
## 44          1.1139        0.6373232        0.07727760
## 45          1.1139        0.6058010        0.06891894
## 46          1.1139        0.5780254        0.07110833
## 47          1.1139        0.6379976        0.07238514
## 48          1.1139        0.6172913        0.07604406
## 49          1.1139        0.5889800        0.07813875
## 50          1.1139        0.5788032        0.07420155
## 51          1.1139        0.6433134        0.07574168
## 52          1.0600        0.0000000        0.00000000
## 53          1.0600        0.0000000        0.00000000
## 54          1.0600        0.0000000        0.00000000
## 55          1.0600        0.0000000        0.00000000
## 56          1.0600        0.0000000        0.00000000
## 57          1.0600        0.0000000        0.00000000
## 58          1.0600        0.0000000        0.00000000
## 59          1.0600        0.0000000        0.00000000
## 60          1.0600        0.0000000        0.00000000
## 61          1.0600        0.0000000        0.00000000
## 62          1.0600        0.0000000        0.00000000
## 63          1.1000        0.4260289        0.06230875
## 64          1.1000        0.4716014        0.07536352
## 65          1.1000        0.4900795        0.07615612
## 66          1.1000        0.4278519        0.06694058
```

```
## 67            1.1000         0.4885102          0.07334632
## 68            1.1000         0.4654797          0.06503377
## 69            1.1000         0.4777506          0.07474911
## 70            1.1000         0.4927559          0.06728793
## 71            1.1000         0.4866500          0.06242437
## 72            1.0600         0.4801036          0.06214786
## 73            1.0600         0.5096806          0.06281564
## 74            1.0600         0.3783779          0.05921093
## 75            1.0600         0.4678361          0.06196793
## 76            1.0600         0.4061642          0.06021867
## 77            1.0600         0.4520281          0.06730828
## 78            1.0600         0.4108151          0.06046426
## 79            1.0600         0.4662545          0.05649182
## 80            1.0600         0.4917221          0.07101635
## 81            1.0600         0.4612865          0.06019681
## 82            1.0600         0.5271951          0.06139871
## 83            1.0730         0.0000000          0.00000000
## 84            1.0730         0.0000000          0.00000000
## 85            1.0730         0.4006342          0.06453753
## 86            1.0730         0.3974039          0.07008047
## 87            1.0730         0.3900221          0.06818175
## 88            1.0730         0.3741729          0.07426976
## 89            1.0730         0.3994880          0.07644857
## 90            1.0730         0.4262816          0.07079942
## 91            1.0500         0.0000000          0.00000000
## 92            1.0500         0.0000000          0.00000000
## 93            1.0500         0.0000000          0.00000000
## 94            1.0500         0.4956229          0.00000000
## 95            1.0500         0.4394952          0.00000000
## 96            1.0500         0.5123032          0.06293396
## 97            1.0500         0.4707189          0.07301956
## 98            1.0500         0.4931964          0.06867403
## 99            1.0500         0.4773549          0.00000000
##    RetardanceAdventitaMean RetardanceTotalMean Patient_ID
## 1               0.09033009         0.079357073     X21372
## 2               0.10497551         0.091031022     X21372
## 3               0.10159885         0.089318343     X21372
## 4               0.10509895         0.090312883     X21372
## 5               0.09421734         0.081878796     X21372
## 6               0.10124335         0.087727830     X21372
## 7               0.09500615         0.082161374     X21372
## 8               0.09383808         0.081310950     X21372
## 9               0.08845902         0.080874503     X21372
## 10              0.09015264         0.078036241     X21372
## 11              0.07677333         0.070849314     X21372
## 12              0.00000000         0.000000000      X6018
## 13              0.00000000         0.000000000      X6018
## 14              0.00000000         0.000000000      X6018
## 15              0.11030376         0.000000000      X6068
## 16              0.06942677         0.065144166      X6068
## 17              0.08893551         0.076251857      X6068
## 18              0.06872123         0.063930824      X6068
## 19              0.07459210         0.070077069      X6068
## 20              0.07446320         0.068399452      X6068
## 21              0.07064083         0.065130048      X6068
## 22              0.06897818         0.064734548      X6068
```

```
## 23          0.05870499      0.057101022     X6527
## 24          0.05990095      0.057556543     X6527
## 25          0.05382369      0.052506663     X6527
## 26          0.05988421      0.057245832     X6527
## 27          0.05862388      0.059602436     X6527
## 28          0.05423644      0.053978886     X6527
## 29          0.05545131      0.055908155     X6527
## 30          0.05558457      0.052639466     X6527
## 31          0.05759590      0.056790963     X6527
## 32          0.05568755      0.055984825     X6527
## 33          0.05653626      0.053914864     X6527
## 34          0.05498788      0.053264905     X6527
## 35          0.05706520      0.057560030     X6527
## 36          0.05434329      0.054184098     X6527
## 37          0.05715310      0.057268482     X6527
## 38          0.05423978      0.054131914     X6527
## 39          0.05501235      0.056299496     X6527
## 40          0.05678902      0.053660851     X6558
## 41          0.05676136      0.055741251     X6558
## 42          0.00000000      0.000000000     X6558
## 43          0.05830152      0.055150446     X6558
## 44          0.09608272      0.084097758     X7308
## 45          0.08147124      0.073867045     X7308
## 46          0.08169082      0.075573899     X7308
## 47          0.08961048      0.078620754     X7308
## 48          0.08930532      0.081119269     X7308
## 49          0.09673814      0.085783489     X7308
## 50          0.09395500      0.082521610     X7308
## 51          0.09487775      0.082567252     X7308
## 52          0.00000000      0.000000000     X7851
## 53          0.00000000      0.000000000     X7851
## 54          0.00000000      0.000000000     X7851
## 55          0.00000000      0.000000000     X7851
## 56          0.00000000      0.000000000     X7851
## 57          0.00000000      0.000000000     X7851
## 58          0.00000000      0.000000000     X7851
## 59          0.00000000      0.000000000     X7851
## 60          0.00000000      0.000000000     X7851
## 61          0.00000000      0.000000000     X7851
## 62          0.00000000      0.000000000     X7851
## 63          0.08251628      0.073907308     X8878
## 64          0.09097930      0.083614863     X8878
## 65          0.08879548      0.082601182     X8878
## 66          0.08580504      0.077733830     X8878
## 67          0.09406714      0.083944812     X8878
## 68          0.08230729      0.074266799     X8878
## 69          0.08627760      0.080769882     X8878
## 70          0.08629365      0.076928467     X8878
## 71          0.07916113      0.071016185     X8878
## 72          0.06649607      0.011499470     X8879
## 73          0.08082820      0.006988864     X8879
## 74          0.07098021      0.007035360     X8879
## 75          0.07112051      0.008430291     X8879
## 76          0.07540677      0.068414010     X8879
## 77          0.07423342      0.073787585     X8879
## 78          0.08266028      0.070288688     X8879
```

```
## 79              0.07760363         0.065842062      X8879
## 80              0.06968830         0.072231404      X8879
## 81              0.07629256         0.075576149      X8879
## 82              0.06913718         0.065574214      X8879
## 83              0.00000000         0.000000000      X9321
## 84              0.00000000         0.000000000      X9321
## 85              0.06683148         0.064537518      X9321
## 86              0.07248771         0.070080467      X9321
## 87              0.07411837         0.068181738      X9321
## 88              0.08408429         0.074269772      X9321
## 89              0.08668233         0.076448567      X9321
## 90              0.07791090         0.053411908      X9321
## 91              0.00000000         0.071806155      X9772
## 92              0.00000000         0.000000000      X9772
## 93              0.07236645         0.000000000      X9772
## 94              0.00000000         0.000000000      X9772
## 95              0.10273161         0.072602883      X9772
## 96              0.08933228         0.085209064      X9772
## 97              0.09744762         0.000000000      X9772
## 98              0.09463328         0.000000000      X9772
## 99              0.08470406         0.063459605      X9772
##    Arteriosclerosis_group Atherosclerosis_group
## 1  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 2  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 3  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 4  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 5  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 6  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 7  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 8  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 9  Arteriosclerosis=1,2,3     Atherosclerosis=0
## 10 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 11 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 12 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 13 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 14 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 15 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 16 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 17 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 18 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 19 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 20 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 21 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 22 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 23 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 24 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 25 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 26 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 27 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 28 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 29 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 30 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 31 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 32 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 33 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 34 Arteriosclerosis=1,2,3     Atherosclerosis=0
```

```
## 35 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 36 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 37 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 38 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 39 Arteriosclerosis=1,2,3     Atherosclerosis=0
## 40 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 41 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 42 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 43 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 44 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 45 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 46 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 47 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 48 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 49 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 50 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 51 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 52 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 53 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 54 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 55 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 56 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 57 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 58 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 59 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 60 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 61 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 62 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 63 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 64 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 65 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 66 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 67 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 68 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 69 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 70 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 71 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 72 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 73 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 74 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 75 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 76 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 77 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 78 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 79 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 80 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 81 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 82 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 83 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 84 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 85 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 86 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 87 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 88 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 89 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 90 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
```

```
## 91 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 92 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 93 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 94 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 95 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 96 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 97 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 98 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
## 99 Arteriosclerosis=1,2,3   Atherosclerosis=1,2
```

```
#write.csv(artery_data, file = "artery_cleaned.csv", row.names = FALSE)
```

```
#use RetardanceTotalMean as response value and fit mixed linear model

library(lme4)
```

```
## 载入需要的程序包：Matrix
```

```
model <- lmer(RetardanceTotalMean ~ Age + CircularStretch + AxialStretchRatio+CTE*CAA+NAIR
*CAA+(1 | Patient_ID), data = artery_data)
summary(model)
```

```
## Linear mixed model fit by REML ['lmerMod']
## Formula: RetardanceTotalMean ~ Age + CircularStretch + AxialStretchRatio +
##     CTE * CAA + NAIR * CAA + (1 | Patient_ID)
##    Data: artery_data
##
## REML criterion at convergence: -414.6
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -2.92580 -0.09064  0.01308  0.31439  2.60233
##
## Random effects:
##  Groups     Name        Variance  Std.Dev.
##  Patient_ID (Intercept) 0.0012882 0.03589
##  Residual               0.0004095 0.02024
## Number of obs: 99, groups:  Patient_ID, 11
##
## Fixed effects:
##                    Estimate Std. Error t value
## (Intercept)       -0.384692   0.493927  -0.779
## Age                0.002806   0.003391   0.828
## CircularStretch    0.148478   0.236707   0.627
## AxialStretchRatio -0.099871   0.244521  -0.408
## CTE                0.119277   0.190748   0.625
## CAA                0.207231   0.210251   0.986
## NAIR               0.021635   0.037228   0.581
## CTE:CAA           -0.060170   0.097603  -0.616
## CAA:NAIR          -0.128059   0.097261  -1.317
##
## Correlation of Fixed Effects:
##             (Intr) Age    CrclrS AxlStR CTE    CAA    NAIR   CTE:CA
## Age         -0.969
## CrclrStrtch -0.208  0.268
## AxlStrtchRt  0.050 -0.124 -0.980
## CTE         -0.941  0.846  0.165 -0.023
## CAA         -0.961  0.870  0.123  0.033  0.976
## NAIR         0.187 -0.233 -0.292  0.260 -0.205 -0.112
## CTE:CAA      0.883 -0.776 -0.113 -0.011 -0.974 -0.943  0.199
## CAA:NAIR     0.905 -0.814 -0.109 -0.053 -0.884 -0.952 -0.074  0.813
```

```
AIC(model)
```

```
## [1] -392.5971
```

```
#install.packages("MCMCglmm")
#library(MCMCglmm)


#formula <- cbind(RetardanceMediaMean, RetardanceAdventitaMean, RetardanceTotalMean) ~
           #Age + CircularStretch + AxialStretchRatio + CTE * CAA + NAIR * CAA


#model <- MCMCglmm(
#  formula,
 # random = ~ us(1 + Age):Patient_ID,
  #rcov = ~ idh(trait):units,
  #data = artery_data,
  #family = c("gaussian", "gaussian", "gaussian")
#)


#summary(model)
```

```
library(lme4)

# use cte as response value and fit mixed logestic
model <- glmer(CTE ~ Age +RetardanceTotalMean +
               MediaToTotalRatio + RetardanceMediaMean + RetardanceAdventitaMean +
               (1 | Patient_ID),
               data = artery_data,
               family = binomial(link = "logit"))
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge with max|grad| = 0.289358 (tol = 0.002, component 1)
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, : Model is near
ly unidentifiable: large eigenvalue ratio
##  - Rescale variables?
```

```
summary(model)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula:
## CTE ~ Age + RetardanceTotalMean + MediaToTotalRatio + RetardanceMediaMean +
##     RetardanceAdventitaMean + (1 | Patient_ID)
##    Data: artery_data
##
##      AIC      BIC   logLik deviance df.resid
##     26.0     44.1     -6.0     12.0       92
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -0.18099 -0.05842  0.00308  0.00827  0.02037
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  Patient_ID (Intercept) 187.3    13.69
## Number of obs: 99, groups:  Patient_ID, 11
##
## Fixed effects:
##                          Estimate Std. Error z value Pr(>|z|)
## (Intercept)              13.46752   16.36707   0.823    0.411
## Age                      -0.02372    0.19984  -0.119    0.906
## RetardanceTotalMean     -27.41277   94.08435  -0.291    0.771
## MediaToTotalRatio         7.08350   17.64622   0.401    0.688
## RetardanceMediaMean     -24.16044   87.21176  -0.277    0.782
## RetardanceAdventitaMean -34.18721   96.10858  -0.356    0.722
##
## Correlation of Fixed Effects:
##             (Intr) Age    RtrdTM MdTTtR RtrdMM
## Age         -0.915
## RtrdncTtlMn -0.033 -0.041
## MediaTTtlRt -0.147  0.092 -0.437
## RetrdncMdMn -0.101  0.096 -0.128 -0.374
## RtrdncAdvnM -0.036 -0.163 -0.085 -0.314 -0.182
## optimizer (Nelder_Mead) convergence code: 0 (OK)
## Model failed to converge with max|grad| = 0.289358 (tol = 0.002, component 1)
## Model is nearly unidentifiable: large eigenvalue ratio
##  - Rescale variables?
```

```
AIC(model)
```

```
## [1] 25.97899
```

```
library(lme4)
artery_data$Age <- scale(artery_data$Age)
artery_data$RetardanceTotalMean <- scale(artery_data$RetardanceTotalMean)
artery_data$MediaToTotalRatio <- scale(artery_data$MediaToTotalRatio)
artery_data$RetardanceMediaMean <- scale(artery_data$RetardanceMediaMean)
artery_data$RetardanceAdventitaMean <- scale(artery_data$RetardanceAdventitaMean)

# use standard factors
model <- glmer(CTE ~ Age + RetardanceTotalMean +
               MediaToTotalRatio + RetardanceMediaMean + RetardanceAdventitaMean +
               (1 | Patient_ID),
               data = artery_data,
               family = binomial(link = "logit"))


summary(model)
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula:
## CTE ~ Age + RetardanceTotalMean + MediaToTotalRatio + RetardanceMediaMean +
##     RetardanceAdventitaMean + (1 | Patient_ID)
##    Data: artery_data
##
##      AIC      BIC   logLik deviance df.resid
##     23.7     41.9     -4.9      9.7       92
##
## Scaled residuals:
##       Min        1Q    Median        3Q       Max
## -0.046941 -0.013518  0.000128  0.000688  0.002077
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  Patient_ID (Intercept) 4366     66.07
## Number of obs: 99, groups:  Patient_ID, 11
##
## Fixed effects:
##                        Estimate Std. Error z value Pr(>|z|)
## (Intercept)              15.2666     6.7431   2.264   0.0236 *
## Age                      -0.1122     3.9693  -0.028   0.9775
## RetardanceTotalMean      -1.8458     8.4987  -0.217   0.8281
## MediaToTotalRatio         1.8592     7.2654   0.256   0.7980
## RetardanceMediaMean      -0.2057     4.1053  -0.050   0.9600
## RetardanceAdventitaMean  -1.6996     6.7771  -0.251   0.8020
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
##             (Intr) Age    RtrdTM MdTTtR RtrdMM
## Age          0.021
## RtrdncTtlMn -0.621 -0.161
## MediaTTtlRt  0.395  0.039 -0.447
## RetrdncMdMn  0.010  0.226 -0.256 -0.242
## RtrdncAdvnM -0.423 -0.177 -0.019 -0.387  0.000
```

```
#install.packages("optimx")
library(optimx)
library(lme4)

# use BFGS Optimizer
model <- glmer(CTE ~ Age + RetardanceTotalMean +
               MediaToTotalRatio + RetardanceMediaMean + RetardanceAdventitaMean +
               (1 | Patient_ID),
               data = artery_data,
               family = binomial(link = "logit"),
               control = glmerControl(optimizer = "optimx", optCtrl = list(method = "BFGS")))
```

```
## Warning in optimx.setup(par, fn1, gr1, he1, lower, upper, method, itnmax, :
## optimx: No match to available methods
```

```
## Warning in optimx.setup(par, fn1, gr1, he1, lower, upper, method, itnmax, :
## Default method when bounds specified is L-BFGS-B to match optim()
```

```
## Warning in optimx.setup(par, fn1, gr1, he1, lower, upper, method, itnmax, :
## optimx: No match to available methods
```

```
## Warning in optimx.setup(par, fn1, gr1, he1, lower, upper, method, itnmax, :
## Default method when bounds specified is L-BFGS-B to match optim()
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## unable to evaluate scaled gradient
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge: degenerate Hessian with 1 negative eigenvalues
```

```
summary(model)
```

```
## Warning in vcov.merMod(object, use.hessian = use.hessian): variance-covariance matrix comput
ed from finite-difference Hessian is
## not positive definite or contains NA values: falling back to var-cov estimated from RX
```

```
## Warning in vcov.merMod(object, correlation = correlation, sigm = sig): variance-covariance m
atrix computed from finite-difference Hessian is
## not positive definite or contains NA values: falling back to var-cov estimated from RX
```

```
## Generalized linear mixed model fit by maximum likelihood (Laplace
##   Approximation) [glmerMod]
##  Family: binomial  ( logit )
## Formula:
## CTE ~ Age + RetardanceTotalMean + MediaToTotalRatio + RetardanceMediaMean +
##     RetardanceAdventitaMean + (1 | Patient_ID)
##    Data: artery_data
## Control: glmerControl(optimizer = "optimx", optCtrl = list(method = "BFGS"))
##
##      AIC      BIC   logLik deviance df.resid
##     23.7     41.9     -4.9      9.7       92
##
## Scaled residuals:
##       Min        1Q    Median        3Q       Max
## -0.046936 -0.013514  0.000128  0.000688  0.002076
##
## Random effects:
##  Groups     Name        Variance Std.Dev.
##  Patient_ID (Intercept) 4367     66.08
## Number of obs: 99, groups:  Patient_ID, 11
##
## Fixed effects:
##                        Estimate Std. Error z value Pr(>|z|)
## (Intercept)              15.2676    48.6687   0.314    0.754
## Age                      -0.1121    59.7169  -0.002    0.999
## RetardanceTotalMean      -1.8467    43.9794  -0.042    0.967
## MediaToTotalRatio         1.8592    51.3448   0.036    0.971
## RetardanceMediaMean      -0.2055    17.2220  -0.012    0.990
## RetardanceAdventitaMean  -1.6995    41.8726  -0.041    0.968
##
## Correlation of Fixed Effects:
##             (Intr) Age    RtrdTM MdTTtR RtrdMM
## Age         -0.233
## RtrdncTtlMn -0.296  0.154
## MediaTTtlRt  0.016 -0.296 -0.684
## RetrdncMdMn  0.151 -0.022 -0.267 -0.123
## RtrdncAdvnM -0.327 -0.255 -0.311  0.560 -0.185
## optimizer (optimx) convergence code: 0 (OK)
## unable to evaluate scaled gradient
## Model failed to converge: degenerate  Hessian with 1 negative eigenvalues
## optimx: No match to available methods
## Default method when bounds specified is L-BFGS-B to match optim()
```

```
complete_data=read.csv('ArteryProperties.csv')
complete_data
```

```
##     Number BC CTE Age Arteriosclerosis Atherosclerosis CAA Braak NAIR
## 1     6108  5   3  72                1               1   3     3    2
## 2     6108  5   3  72                1               1   3     3    2
## 3     6108  5   3  72                1               1   3     3    2
## 4     6359  0   2  63                1               2   0     0    0
## 5     6359  0   2  63                1               2   0     0    0
## 6     6359  0   2  63                1               2   0     0    0
## 7     6558  1   3  85                2               1   0     1    0
## 8     7412  6   4  84                2               1   2     3    3
## 9     7412  6   4  84                2               1   2     3    3
## 10    7412  6   4  84                2               1   2     3    3
## 11    7444  2   4  77                2               0   2     2    0
## 12    7444  2   4  77                2               0   2     2    0
## 13    7444  2   4  77                2               0   2     2    0
## 14    8304  0   0  49                0               0   0     0    0
## 15    8304  0   0  49                0               0   0     0    0
## 16    8304  0   0  49                0               0   0     0    0
## 17    8319  1   1  51                1               0   0     1    0
## 18    8319  1   1  51                1               0   0     1    0
## 19    8319  1   1  51                1               0   0     1    0
## 20    9140  2   3  59                1               0   0     2    0
## 21    9140  2   3  59                1               0   0     2    0
## 22    9140  2   3  59                1               0   0     2    0
## 23    6392  3   3  77                2               0   3     3    0
## 24    6392  3   3  77                2               0   3     3    0
## 25    6392  3   3  77                2               0   3     3    0
## 26    6392  3   3  77                2               0   3     3    0
## 27    6392  3   3  77                2               0   3     3    0
## 28    6392  3   3  77                2               0   3     3    0
## 29    7017  1   3  60                0               1   0     1    0
## 30    7017  1   3  60                0               1   0     1    0
## 31    7017  1   3  60                0               1   0     1    0
## 32    7017  1   3  60                0               1   0     1    0
## 33    7017  1   3  60                0               1   0     1    0
## 34    6018  5   3  72                1               1   3     3    2
## 35    6018  5   3  72                1               1   3     3    2
## 36    6018  5   3  72                1               1   3     3    2
## 37    7851  1   4  81                2               1   0     1    0
## 38    7851  1   4  81                2               1   0     1    0
## 39    7851  1   4  81                2               1   0     1    0
## 40    7851  1   4  81                2               1   0     1    0
## 41    7851  1   4  81                2               1   0     1    0
## 42    7851  1   4  81                2               1   0     1    0
## 43    7851  1   4  81                2               1   0     1    0
## 44    7851  1   4  81                2               1   0     1    0
## 45    7851  1   4  81                2               1   0     1    0
## 46    7851  1   4  81                2               1   0     1    0
## 47    7851  1   4  81                2               1   0     1    0
## 48    9772  3   4  86                2               1   0     2    1
## 49    9772  3   4  86                2               1   0     2    1
## 50    9772  3   4  86                2               1   0     2    1
## 51    9772  3   4  86                2               1   0     2    1
## 52    9772  3   4  86                2               1   0     2    1
## 53    9772  3   4  86                2               1   0     2    1
## 54    9772  3   4  86                2               1   0     2    1
```

```
## 55    9772  3   4  86                2                1   0    2    1
## 56    9772  3   4  86                2                1   0    2    1
## 57    6068  6   0  70                2                1   2    3    3
## 58    6068  6   0  70                2                1   2    3    3
## 59    6068  6   0  70                2                1   2    3    3
## 60    6068  6   0  70                2                1   2    3    3
## 61    6068  6   0  70                2                1   2    3    3
## 62    6068  6   0  70                2                1   2    3    3
## 63    6068  6   0  70                2                1   2    3    3
## 64    6068  6   0  70                2                1   2    3    3
## 65    9321  3   3  79                2                1   0    2    1
## 66    9321  3   3  79                2                1   0    2    1
## 67    9321  3   3  79                2                1   0    2    1
## 68    9321  3   3  79                2                1   0    2    1
## 69    9321  3   3  79                2                1   0    2    1
## 70    9321  3   3  79                2                1   0    2    1
## 71    9321  3   3  79                2                1   0    2    1
## 72    9321  3   3  79                2                1   0    2    1
## 73    6558  1   3  85                2                1   0    1    0
## 74    6558  1   3  85                2                1   0    1    0
## 75    6558  1   3  85                2                1   0    1    0
## 76    6558  1   3  85                2                1   0    1    0
## 77    7308  3   4  84                1                2   1    2    1
## 78    7308  3   4  84                1                2   1    2    1
## 79    7308  3   4  84                1                2   1    2    1
## 80    7308  3   4  84                1                2   1    2    1
## 81    7308  3   4  84                1                2   1    2    1
## 82    7308  3   4  84                1                2   1    2    1
## 83    7308  3   4  84                1                2   1    2    1
## 84    7308  3   4  84                1                2   1    2    1
## 85    8878  1   0  76                2                1   1    1    0
## 86    8878  1   0  76                2                1   1    1    0
## 87    8878  1   0  76                2                1   1    1    0
## 88    8878  1   0  76                2                1   1    1    0
## 89    8878  1   0  76                2                1   1    1    0
## 90    8878  1   0  76                2                1   1    1    0
## 91    8878  1   0  76                2                1   1    1    0
## 92    8878  1   0  76                2                1   1    1    0
## 93    8878  1   0  76                2                1   1    1    0
## 94    8879  5   3  56                3                1   3    3    2
## 95    8879  5   3  56                3                1   3    3    2
## 96    8879  5   3  56                3                1   3    3    2
## 97    8879  5   3  56                3                1   3    3    2
## 98    8879  5   3  56                3                1   3    3    2
## 99    8879  5   3  56                3                1   3    3    2
## 100   8879  5   3  56                3                1   3    3    2
## 101   8879  5   3  56                3                1   3    3    2
## 102   8879  5   3  56                3                1   3    3    2
## 103   8879  5   3  56                3                1   3    3    2
## 104   8879  5   3  56                3                1   3    3    2
## 105   6527  1   3  62                1                0   1    1    0
## 106   6527  1   3  62                1                0   1    1    0
## 107   6527  1   3  62                1                0   1    1    0
## 108   6527  1   3  62                1                0   1    1    0
## 109   6527  1   3  62                1                0   1    1    0
## 110   6527  1   3  62                1                0   1    1    0
```

```
## 111   6527  1   3  62                1                0   1     1    0
## 112   6527  1   3  62                1                0   1     1    0
## 113   6527  1   3  62                1                0   1     1    0
## 114   6527  1   3  62                1                0   1     1    0
## 115   6527  1   3  62                1                0   1     1    0
## 116   6527  1   3  62                1                0   1     1    0
## 117   6527  1   3  62                1                0   1     1    0
## 118   6527  1   3  62                1                0   1     1    0
## 119   6527  1   3  62                1                0   1     1    0
## 120   6527  1   3  62                1                0   1     1    0
## 121   6527  1   3  62                1                0   1     1    0
## 122  21372  1   0  87                2                0   1     1    0
## 123  21372  1   0  87                2                0   1     1    0
## 124  21372  1   0  87                2                0   1     1    0
## 125  21372  1   0  87                2                0   1     1    0
## 126  21372  1   0  87                2                0   1     1    0
## 127  21372  1   0  87                2                0   1     1    0
## 128  21372  1   0  87                2                0   1     1    0
## 129  21372  1   0  87                2                0   1     1    0
## 130  21372  1   0  87                2                0   1     1    0
## 131  21372  1   0  87                2                0   1     1    0
## 132  21372  1   0  87                2                0   1     1    0
##     CircularStretch AxialStretchRatio MediaToTotalRatio RetardanceMediaMean
## 1          0.000000             0.0000        0.56950203          0.00000000
## 2          0.000000             0.0000        0.94067666          0.04948925
## 3          0.000000             0.0000        0.05803236          0.05338192
## 4          1.055729             1.1000        0.86538858          0.05976310
## 5          1.055729             1.1000        0.77269293          0.05177723
## 6          1.055729             1.1000        0.46454251          0.05216220
## 7          1.065743             1.1330        0.39469372          0.05191886
## 8          1.122368             1.0800        0.26320915          0.07323910
## 9          1.122368             1.0800        0.78004006          0.05180890
## 10         1.122368             1.0800        0.25208782          0.06022062
## 11         1.159165             1.0850        0.36695457          0.05532836
## 12         1.159165             1.0850        0.29393945          0.07614329
## 13         1.159165             1.0850        0.29296090          0.05995091
## 14         1.194860             1.1300        0.56836051          0.05454245
## 15         1.194860             1.1300        0.59086113          0.05914795
## 16         1.194860             1.1300        0.11682860          0.05094889
## 17         1.121653             1.0700        0.52265741          0.05018194
## 18         1.121653             1.0700        0.55188938          0.04902876
## 19         1.121653             1.0700        0.38891021          0.05200834
## 20         1.170090             1.0800        0.50724605          0.05124159
## 21         1.170090             1.0800        0.56436626          0.05435010
## 22         1.170090             1.0800        0.48848304          0.04769684
## 23         1.053098             1.0500        0.41908611          0.14504656
## 24         1.053098             1.0500        0.45964938          0.09905053
## 25         1.053098             1.0500        0.47547637          0.09084100
## 26         1.053098             1.0500        0.50268703          0.07756291
## 27         1.053098             1.0500        0.34976810          0.08592186
## 28         1.053098             1.0500        0.62316688          0.07865974
## 29         1.105010             1.1000        0.52169787          0.09252661
## 30         1.105010             1.1000        0.58768804          0.07755256
## 31         1.105010             1.1000        0.46415152          0.12525021
## 32         1.105010             1.1000        0.66896125          0.08205076
## 33         1.105010             1.1000        0.67002620          0.14827786
```

```
## 34        0.000000        0.0000        0.50805653        0.00000000
## 35        0.000000        0.0000        0.58391527        0.00000000
## 36        0.000000        0.0000        0.55758913        0.00000000
## 37        1.116711        1.0600        0.00000000        0.00000000
## 38        1.116711        1.0600        0.00000000        0.00000000
## 39        1.116711        1.0600        0.00000000        0.00000000
## 40        1.116711        1.0600        0.00000000        0.00000000
## 41        1.116711        1.0600        0.00000000        0.00000000
## 42        1.116711        1.0600        0.00000000        0.00000000
## 43        1.116711        1.0600        0.00000000        0.00000000
## 44        1.116711        1.0600        0.00000000        0.00000000
## 45        1.116711        1.0600        0.00000000        0.00000000
## 46        1.116711        1.0600        0.00000000        0.00000000
## 47        1.116711        1.0600        0.00000000        0.00000000
## 48        1.130811        1.0500        0.00000000        0.00000000
## 49        1.130811        1.0500        0.00000000        0.00000000
## 50        1.130811        1.0500        0.00000000        0.00000000
## 51        1.130811        1.0500        0.49562294        0.00000000
## 52        1.130811        1.0500        0.43949517        0.00000000
## 53        1.130811        1.0500        0.51230320        0.06293396
## 54        1.130811        1.0500        0.47071888        0.07301956
## 55        1.130811        1.0500        0.49319635        0.06867403
## 56        1.191958        1.0500        0.47735490        0.00000000
## 57        1.191958        1.0965        0.00000000        0.00000000
## 58        1.191958        1.0965        0.36689330        0.05775420
## 59        1.191958        1.0965        0.48616222        0.06284612
## 60        1.191958        1.0965        0.37012876        0.00000000
## 61        1.191958        1.0965        0.37996724        0.05816329
## 62        1.191958        1.0965        0.37201090        0.06270942
## 63        1.191958        1.0965        0.34660158        0.05474133
## 64        1.191958        1.0965        0.35322607        0.05577871
## 65        1.074903        1.0730        0.00000000        0.00000000
## 66        1.074903        1.0730        0.00000000        0.00000000
## 67        1.074903        1.0730        0.40063416        0.06453753
## 68        1.074903        1.0730        0.39740392        0.07008047
## 69        1.074903        1.0730        0.39002212        0.06818175
## 70        1.074903        1.0730        0.37417286        0.07426976
## 71        1.074903        1.0730        0.39948798        0.07644857
## 72        1.074903        1.0730        0.42628159        0.07079942
## 73        1.065743        1.1330        0.37195152        0.04891146
## 74        1.065743        1.1330        0.33473816        0.04627623
## 75        1.065743        1.1330        0.00000000        0.00000000
## 76        1.065743        1.1330        0.38922448        0.04777806
## 77        1.130078        1.1139        0.63732318        0.07727760
## 78        1.130078        1.1139        0.60580104        0.06891894
## 79        1.130078        1.1139        0.57802540        0.07110833
## 80        1.130078        1.1139        0.63799756        0.07238514
## 81        1.130078        1.1139        0.61729133        0.07604406
## 82        1.130078        1.1139        0.58898002        0.07813875
## 83        1.130078        1.1139        0.57880316        0.07420155
## 84        1.130078        1.1139        0.64331339        0.07574168
## 85        1.136406        1.1000        0.42602887        0.06230875
## 86        1.136406        1.1000        0.47160143        0.07536352
## 87        1.136406        1.1000        0.49007945        0.07615612
## 88        1.136406        1.1000        0.42785187        0.06694058
## 89        1.136406        1.1000        0.48851024        0.07334632
```

```
## 90          1.136406            1.1000         0.46547965          0.06503377
## 91          1.136406            1.1000         0.47775058          0.07474911
## 92          1.136406            1.1000         0.49275590          0.06728793
## 93          1.136406            1.1000         0.48665000          0.06242437
## 94          1.167411            1.0600         0.48010361          0.06214786
## 95          1.167411            1.0600         0.50968060          0.06281564
## 96          1.167411            1.0600         0.37837787          0.05921093
## 97          1.167411            1.0600         0.46783612          0.06196793
## 98          1.167411            1.0600         0.40616424          0.06021867
## 99          1.167411            1.0600         0.45202812          0.06730828
## 100         1.167411            1.0600         0.41081515          0.06046426
## 101         1.167411            1.0600         0.46625449          0.05649182
## 102         1.167411            1.0600         0.49172214          0.07101635
## 103         1.167411            1.0600         0.46128649          0.06019681
## 104         1.167411            1.0600         0.52719512          0.06139871
## 105         0.000000            0.0000         0.33619498          0.05393407
## 106         0.000000            0.0000         0.40905568          0.05416970
## 107         0.000000            0.0000         0.48692440          0.05111889
## 108         0.000000            0.0000         0.53427139          0.05494594
## 109         0.000000            0.0000         0.62411189          0.06019178
## 110         0.000000            0.0000         0.48359667          0.05370386
## 111         0.000000            0.0000         0.59999050          0.05621274
## 112         0.000000            0.0000         0.53375503          0.05006687
## 113         0.000000            0.0000         0.50878086          0.05601380
## 114         0.000000            0.0000         0.63960897          0.05615233
## 115         0.000000            0.0000         0.54157055          0.05169591
## 116         0.000000            0.0000         0.63249862          0.05226379
## 117         0.000000            0.0000         0.70473148          0.05776735
## 118         0.000000            0.0000         0.61079773          0.05408265
## 119         0.000000            0.0000         0.65287087          0.05732983
## 120         0.000000            0.0000         0.67104632          0.05407904
## 121         0.000000            0.0000         0.72754285          0.05678152
## 122         0.000000            0.0000         0.48487353          0.06769936
## 123         0.000000            0.0000         0.58903447          0.08130205
## 124         0.000000            0.0000         0.51778107          0.07788124
## 125         0.000000            0.0000         0.43909669          0.07142513
## 126         0.000000            0.0000         0.45188211          0.06691258
## 127         0.000000            0.0000         0.49462886          0.07391878
## 128         0.000000            0.0000         0.46590583          0.06743670
## 129         0.000000            0.0000         0.47322832          0.06736646
## 130         0.000000            0.0000         0.50304532          0.07338178
## 131         0.000000            0.0000         0.46866722          0.06429975
## 132         0.000000            0.0000         0.54719335          0.06594711
##     RetardanceAdventitaMean RetardanceTotalMean Thickness
## 1                0.06497876         0.062093642        30
## 2                0.04944616         0.054986376        30
## 3                0.07306711         0.066679843        30
## 4                0.05452225         0.059054896        30
## 5                0.04625623         0.052055318        30
## 6                0.05719694         0.054250270        30
## 7                0.05743457         0.056694545        30
## 8                0.06571213         0.077803075        30
## 9                0.05084598         0.052442975        30
## 10               0.06807658         0.059496295        30
## 11               0.06065950         0.067628540        30
## 12               0.08321945         0.077342063        30
```

```
## 13          0.05928117     0.059422925     30
## 14          0.06390365     0.061806675     30
## 15          0.07921691     0.068059698     30
## 16          0.06482238     0.062553130     30
## 17          0.05258710     0.051711287     30
## 18          0.04924965     0.049513694     30
## 19          0.05151797     0.053228885     30
## 20          0.06656808     0.061519478     30
## 21          0.07366941     0.063145712     30
## 22          0.06430533     0.059999865     30
## 23          0.14043486     0.144735230     30
## 24          0.09727100     0.098601140     30
## 25          0.07814550     0.091828361     30
## 26          0.06999654     0.077734090     30
## 27          0.08484704     0.086621031     30
## 28          0.06763352     0.078846678     30
## 29          0.08381984     0.092692681     30
## 30          0.06681923     0.075629123     30
## 31          0.09618032     0.125115260     30
## 32          0.07266559     0.082066260     30
## 33          0.11630197     0.146835100     30
## 34          0.00000000     0.000000000     20
## 35          0.00000000     0.000000000     20
## 36          0.00000000     0.000000000     20
## 37          0.00000000     0.000000000     20
## 38          0.00000000     0.000000000     20
## 39          0.00000000     0.000000000     20
## 40          0.00000000     0.000000000     20
## 41          0.00000000     0.000000000     20
## 42          0.00000000     0.000000000     20
## 43          0.00000000     0.000000000     20
## 44          0.00000000     0.000000000     20
## 45          0.00000000     0.000000000     20
## 46          0.00000000     0.000000000     20
## 47          0.00000000     0.000000000     20
## 48          0.00000000     0.071806155     20
## 49          0.00000000     0.000000000     20
## 50          0.07236645     0.000000000     20
## 51          0.00000000     0.000000000     20
## 52          0.10273161     0.072602883     20
## 53          0.08933228     0.085209064     20
## 54          0.09744762     0.000000000     20
## 55          0.09463328     0.000000000     20
## 56          0.08470406     0.063459605     20
## 57          0.11030376     0.000000000     20
## 58          0.06942677     0.065144166     20
## 59          0.08893551     0.076251857     20
## 60          0.06872123     0.063930824     20
## 61          0.07459210     0.070077069     20
## 62          0.07446320     0.068399452     20
## 63          0.07064083     0.065130048     20
## 64          0.06897818     0.064734548     20
## 65          0.00000000     0.000000000     20
## 66          0.00000000     0.000000000     20
## 67          0.06683148     0.064537518     20
## 68          0.07248771     0.070080467     20
```

```
## 69          0.07411837     0.068181738     20
## 70          0.08408429     0.074269772     20
## 71          0.08668233     0.076448567     20
## 72          0.07791090     0.053411908     20
## 73          0.05678902     0.053660851     20
## 74          0.05676136     0.055741251     20
## 75          0.00000000     0.000000000     20
## 76          0.05830152     0.055150446     20
## 77          0.09608272     0.084097758     20
## 78          0.08147124     0.073867045     20
## 79          0.08169082     0.075573899     20
## 80          0.08961048     0.078620754     20
## 81          0.08930532     0.081119269     20
## 82          0.09673814     0.085783489     20
## 83          0.09395500     0.082521610     20
## 84          0.09487775     0.082567252     20
## 85          0.08251628     0.073907308     20
## 86          0.09097930     0.083614863     20
## 87          0.08879548     0.082601182     20
## 88          0.08580504     0.077733830     20
## 89          0.09406714     0.083944812     20
## 90          0.08230729     0.074266799     20
## 91          0.08627760     0.080769882     20
## 92          0.08629365     0.076928467     20
## 93          0.07916113     0.071016185     20
## 94          0.06649607     0.011499470     20
## 95          0.08082820     0.006988864     20
## 96          0.07098021     0.007035360     20
## 97          0.07112051     0.008430291     20
## 98          0.07540677     0.068414010     20
## 99          0.07423342     0.073787585     20
## 100         0.08266028     0.070288688     20
## 101         0.07760363     0.065842062     20
## 102         0.06968830     0.072231404     20
## 103         0.07629256     0.075576149     20
## 104         0.06913718     0.065574214     20
## 105         0.05870499     0.057101022     20
## 106         0.05990095     0.057556543     20
## 107         0.05382369     0.052506663     20
## 108         0.05988421     0.057245832     20
## 109         0.05862388     0.059602436     20
## 110         0.05423644     0.053978886     20
## 111         0.05545131     0.055908155     20
## 112         0.05558457     0.052639466     20
## 113         0.05759590     0.056790963     20
## 114         0.05568755     0.055984825     20
## 115         0.05653626     0.053914864     20
## 116         0.05498788     0.053264905     20
## 117         0.05706520     0.057560030     20
## 118         0.05434329     0.054184098     20
## 119         0.05715310     0.057268482     20
## 120         0.05423978     0.054131914     20
## 121         0.05501235     0.056299496     20
## 122         0.09033009     0.079357073     20
## 123         0.10497551     0.091031022     20
## 124         0.10159885     0.089318343     20
```

```
## 125              0.10509895         0.090312883        20
## 126              0.09421734         0.081878796        20
## 127              0.10124335         0.087727830        20
## 128              0.09500615         0.082161374        20
## 129              0.09383808         0.081310950        20
## 130              0.08845902         0.080874503        20
## 131              0.09015264         0.078036241        20
## 132              0.07677333         0.070849314        20
```

```
library(ordinal)
model <- clmm(factor(CTE) ~  Age + CircularStretch + AxialStretchRatio+RetardanceTotalMean+Medi
aToTotalRatio+RetardanceMediaMean+RetardanceAdventitaMean+(1 | Number), data = complete_data)
```

```
## Warning in update.uC(rho): Non finite negative log-likelihood
##   at iteration 383
```

```
summary(model)
```

```
## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula:
## factor(CTE) ~ Age + CircularStretch + AxialStretchRatio + RetardanceTotalMean +
##     MediaToTotalRatio + RetardanceMediaMean + RetardanceAdventitaMean +
##     (1 | Number)
## data:    complete_data
##
##  link  threshold nobs logLik AIC   niter       max.grad cond.H
##  logit flexible  132  -21.06 66.12 1420(32370) 7.03e+01 1.4e+10
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  Number (Intercept) 7773     88.17
## Number of groups:  Number 20
##
## Coefficients:
##                          Estimate Std. Error  z value Pr(>|z|)
## Age                     5.229e-01  9.651e-04    541.8   <2e-16 ***
## CircularStretch         1.823e+01  8.446e-04  21583.3   <2e-16 ***
## AxialStretchRatio      -1.780e+01  8.445e-04 -21081.7   <2e-16 ***
## RetardanceTotalMean    -1.008e+01  8.432e-04 -11959.6   <2e-16 ***
## MediaToTotalRatio       3.524e-01  8.435e-04    417.7   <2e-16 ***
## RetardanceMediaMean     3.423e+01  8.432e-04  40600.1   <2e-16 ***
## RetardanceAdventitaMean -4.941e+01  8.432e-04 -58599.3   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Threshold coefficients:
##       Estimate Std. Error   z value
## 0|1 -2.105e+01  9.963e+01    -0.211
## 1|2  1.636e+00  5.855e+00     0.279
## 2|3  1.603e+01  4.184e+00     3.831
## 3|4  5.472e+01  8.445e-04 64803.358
```

```
AIC(model)
```

```
## [1] 66.11502
```

```
library(ordinal)
model <- clmm(factor(NAIR) ~  Age + CircularStretch + AxialStretchRatio+RetardanceTotalMean+Med
iaToTotalRatio+RetardanceMediaMean      +RetardanceAdventitaMean+(1 | Number), data = complete_
data)
summary(model)
```

```
## Cumulative Link Mixed Model fitted with the Laplace approximation
##
## formula:
## factor(NAIR) ~ Age + CircularStretch + AxialStretchRatio + RetardanceTotalMean +
##     MediaToTotalRatio + RetardanceMediaMean + RetardanceAdventitaMean +
##     (1 | Number)
## data:    complete_data
##
##  link  threshold nobs logLik AIC   niter      max.grad cond.H
##  logit flexible  132  -17.97 57.94 895(19463) 6.52e+01 4.4e+07
##
## Random effects:
##  Groups Name        Variance Std.Dev.
##  Number (Intercept) 3047     55.2
## Number of groups:  Number 20
##
## Coefficients:
##                          Estimate Std. Error  z value Pr(>|z|)
## Age                     2.838e-01  9.578e-04    296.3   <2e-16 ***
## CircularStretch        -2.488e-01  9.105e-04   -273.3   <2e-16 ***
## AxialStretchRatio      -4.879e+01  9.104e-04 -53589.8   <2e-16 ***
## RetardanceTotalMean    -6.935e+00  8.758e-04  -7918.3   <2e-16 ***
## MediaToTotalRatio       5.708e+00  8.860e-04   6442.0   <2e-16 ***
## RetardanceMediaMean    -1.630e+01  8.759e-04 -18608.4   <2e-16 ***
## RetardanceAdventitaMean  1.174e+01  8.761e-04  13398.9   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Threshold coefficients:
##       Estimate Std. Error    z value
## 0|1 -1.678e+01  9.116e-04 -18409.757
## 1|2  9.791e+00  8.773e-04  11160.370
## 2|3  3.653e+01  5.773e+00      6.327
```

```
AIC(model)
```

```
## [1] 57.93763
```