```
load("synthetic_raw.Rda")
library(SmoothHOOI)
library(ggplot2)
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(tidyr)
```

This is an illustration of how to use our functions on synthetic data

```
set.seed(32123)
```

Generate synthetic data

```
#synthetic <- synthetic_data(L_tilde, R_tilde, mean_G, cov_G, E, p=207, noise_level=1, pattern="random"

synthetic <- synthetic_data(L_tilde, R_tilde, mean_G, cov_G, E, p=207, noise_level=1, pattern = "structu

synthetic_dat <- synthetic$sim_Mmiss

#save(synthetic_dat, file = "synthetic_data.Rda")
```

Make the second order difference matrix

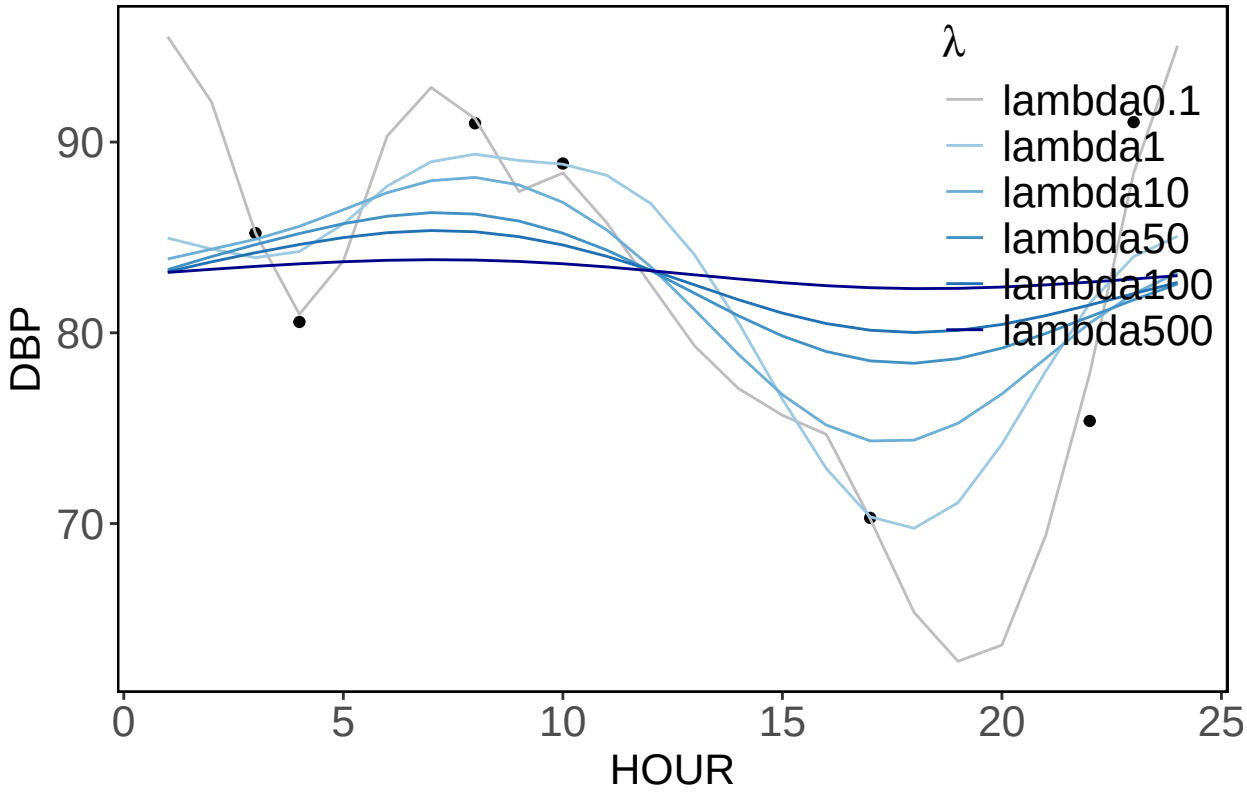
```
D2 <- SecDiffMat(24)
```

Coarse-to-fine grid search (Example)

```
original <- (synthetic_dat@data[ , 1, 180])*12+70
lambda_seq <- c(0.1, 1, 10, 50, 100, 500)
est_df <- matrix(NA, nrow=24, ncol=length(lambda_seq))
for (i in 1:length(lambda_seq)){
  lambda <- lambda_seq[i]
  res <-  mglram(tnsr = synthetic_dat@data, ranks = c(6, 3), init=0, D = D2,
                 lambda = lambda, max_iter = 500, tol = 1e-5, L0_ = NULL)
```

```
  est_df[,i] <- (res$est[,1,180])*12 +70
}
org_df <- data.frame(cbind(c(1:24), original))
est_df <- data.frame(cbind(c(1:24), est_df))
colnames(org_df) <- c("hour", "original")
colnames(est_df) <- c("hour", paste0("lambda",lambda_seq))
est_long <- pivot_longer(est_df, cols = starts_with("lambda"),
                         names_to = "lambda", values_to = "y")
est_long$lambda <- factor(est_long$lambda, levels=c("lambda0.1","lambda1","lambda10","lambda50","lambda
```

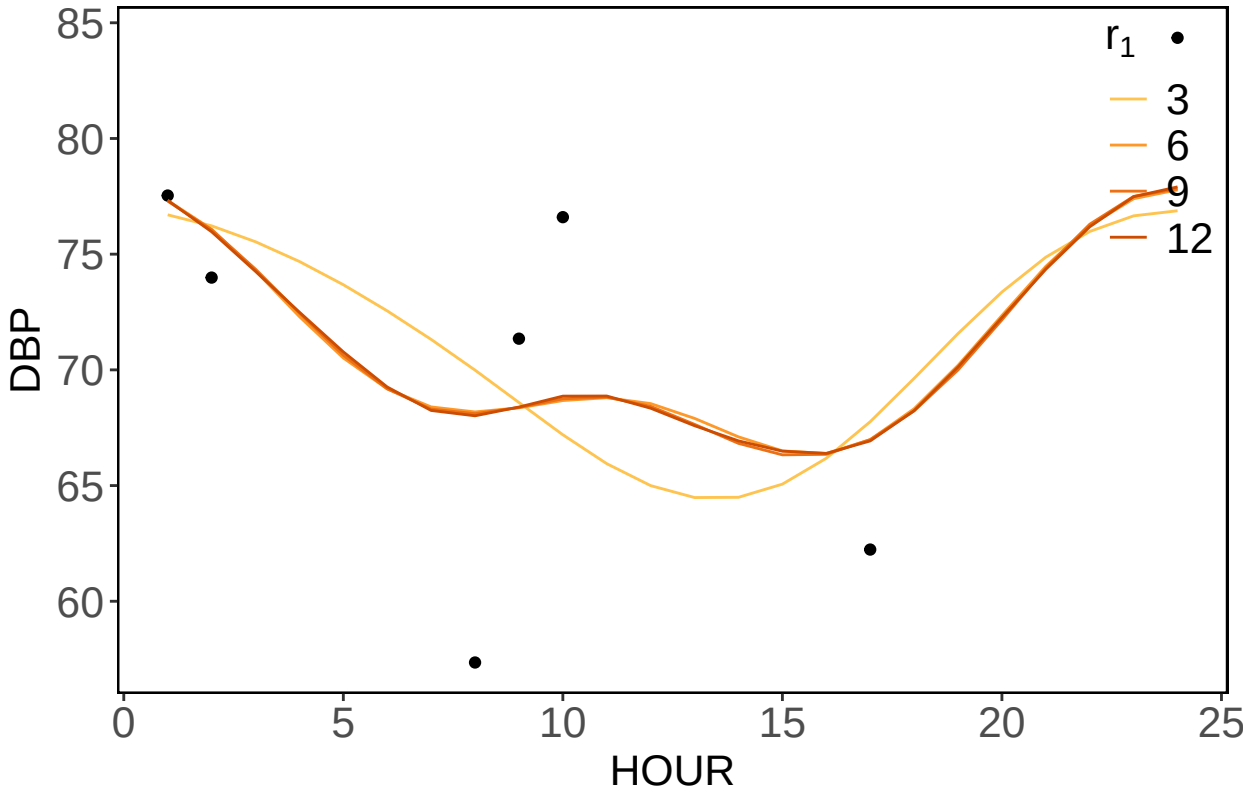
```
custom_colors <- c("grey","#9ECAE1","#6BAED6", "#4292C6", "#2171B5","darkblue")
names(custom_colors) <- levels(factor(est_long$lambda))

ggplot() +
  geom_point(data = org_df, aes(x = hour, y = original), color = "black") +  # Original data
  geom_line(data = est_long, aes(x = hour, y =y, color = lambda)) +  # Estimated curves
  labs(title = "",
       x = "HOUR", y = "DBP") +
  scale_color_manual(values = custom_colors,
                     name = expression(lambda)) +
  theme(legend.position = c(1, 1),
    legend.justification = c(1, 1),
    panel.grid = element_blank(),
    panel.background = element_blank(),
    plot.background = element_blank(),
    panel.border = element_rect(color = "black", fill = NA, linewidth = 0.8),  # add border rectangle
    axis.line = element_blank(),
    legend.background = element_blank(),  # removes the outer background & border
    legend.key = element_blank(),
    axis.text = element_text(size = 16),
    axis.title = element_text(size = 16),
    legend.text = element_text(size = 16,hjust=0),
    legend.title = element_text(size = 16)
    )
```




```
original <- (synthetic_dat@data[ , 1, 1])*12 + 70
r1_seq <- c(3,6,9,12)
est_df <- matrix(NA, nrow=24, ncol=length(r1_seq))

for (i in 1:length(r1_seq)){
  r1 <- r1_seq[i]
  res <-  mglram(tnsr = synthetic_dat@data, ranks = c(r1, 3), init=0, D = D2,
                 lambda = 10, max_iter = 500, tol = 1e-5, L0_ = NULL)
  est_df[,i] <- (res$est[,1,1])*12 + 70
}

colnames(est_df) <- paste0("r", r1_seq)
est_df <- cbind(hour = 1:24, est_df)
est_df <- data.frame(est_df)
org_df <- data.frame(hour = 1:24, original = original)
est_long <- pivot_longer(est_df, cols = starts_with("r"),
                         names_to = "r", values_to = "y")
est_long$r <- factor(est_long$r, levels = paste0("r", r1_seq))
```

```
custom_colors <- c("#FEC44F", "#FE9929","#EC7014","#CC4C02")
names(custom_colors) <- levels(factor(est_long$r))

ggplot() +
  geom_point(data = org_df, aes(x = hour, y = original), color = "black") +  # Original data
  geom_line(data = est_long, aes(x = hour, y =y, color = r)) +  # Estimated curves
  labs(title = "",
       x = "HOUR", y = "DBP") +
  scale_color_manual(values = custom_colors,
```

```
                    labels = c("r3" = 3, "r6" = 6,
                               "r9" = 9, "r12" = 12),
                    name =  expression(r[1])) +
  theme(legend.position = c(1, 1),
    legend.justification = c(1, 1),
    panel.grid = element_blank(),
    panel.background = element_blank(),
    plot.background = element_blank(),
    panel.border = element_rect(color = "black", fill = NA, linewidth = 0.8),  # add border rectangle
    axis.line = element_blank(),
    legend.background = element_blank(),  # removes the outer background & border
    legend.key = element_blank(),
    axis.text = element_text(size = 16),
    axis.title = element_text(size = 16),
    legend.text = element_text(size = 16,hjust=0),
    legend.title = element_text(size = 16)
    )
```



Find optimal hyperparameter using k-fold cross-validation

```
start_time <- Sys.time()

kcv_res <- kcv(tnsr=synthetic_dat@data, rank_grid=as.matrix(expand.grid(r1<-seq(3,6,by=1), r2<-c(2,3))),
               k=5, L0_ =NULL, D=D2, tol=0.01, max_iter=500, init=0)
```

```r
end_time <- Sys.time()

exec_time <- end_time - start_time
print(exec_time)
```

```
## Time difference of 8.100234 mins
```

```r
kcv_res
```

```
## $MSE_mat
##           [,1]      [,2]      [,3]      [,4]      [,5]      [,6]      [,7]
## [1,] 0.4942339 0.4882951 0.4848214 0.4824064 0.4805549 0.4790842 0.4778581
## [2,] 0.5172700 0.5017996 0.4934665 0.4876554 0.4834435 0.4802149 0.4776675
## [3,] 0.5397529 0.5177960 0.5060908 0.4985144 0.4931221 0.4890912 0.4859702
## [4,] 0.5447999 0.5176707 0.5047372 0.4968205 0.4913981 0.4874115 0.4843402
## [5,] 0.5646849 0.5518426 0.5443432 0.5390976 0.5351042 0.5318821 0.5292060
## [6,] 0.6075049 0.5785536 0.5635194 0.5539042 0.5470290 0.5417890 0.5377811
## [7,] 0.6315316 0.5956107 0.5765610 0.5641732 0.5552948 0.5485696 0.5432737
## [8,] 0.6228361 0.5833545 0.5645573 0.5528576 0.5447089 0.5386532 0.5339401
##           [,8]      [,9]     [,10]     [,11]     [,12]     [,13]     [,14]
## [1,] 0.4768395 0.4759561 0.4752172 0.4745559 0.4740048 0.4735143 0.4731151
## [2,] 0.4756702 0.4741165 0.4728828 0.4719019 0.4710991 0.4704462 0.4699209
## [3,] 0.4835067 0.4814981 0.4798734 0.4785218 0.4774181 0.4764862 0.4757101
## [4,] 0.4819339 0.4799920 0.4784129 0.4771001 0.4760126 0.4751024 0.4743490
## [5,] 0.5269268 0.5249520 0.5232362 0.5217300 0.5203963 0.5191894 0.5181516
## [6,] 0.5342709 0.5314099 0.5289830 0.5269053 0.5251284 0.5235871 0.5222183
## [7,] 0.5389780 0.5354016 0.5324249 0.5298842 0.5277019 0.5258031 0.5241486
## [8,] 0.5301958 0.5271173 0.5245666 0.5224184 0.5205874 0.5190082 0.5176714
##          [,15]     [,16]     [,17]     [,18]     [,19]     [,20]     [,21]
## [1,] 0.4727614 0.4724730 0.4722266 0.4720378 0.4718797 0.4717680 0.4716799
## [2,] 0.4694822 0.4691425 0.4688775 0.4686918 0.4685456 0.4684560 0.4684089
## [3,] 0.4750601 0.4745289 0.4740963 0.4737409 0.4734643 0.4732420 0.4730740
## [4,] 0.4737209 0.4731902 0.4727625 0.4724075 0.4721291 0.4719069 0.4717379
## [5,] 0.5172068 0.5163561 0.5156091 0.5149405 0.5143398 0.5138076 0.5133326
## [6,] 0.5210053 0.5199790 0.5190328 0.5181936 0.5174681 0.5168314 0.5162542
## [7,] 0.5227179 0.5214489 0.5203059 0.5193289 0.5184648 0.5176815 0.5169988
## [8,] 0.5165079 0.5154802 0.5146078 0.5138253 0.5131669 0.5125817 0.5120774
##          [,22]     [,23]     [,24]     [,25]     [,26]     [,27]     [,28]
## [1,] 0.4716344 0.4716159 0.4716135 0.4716544 0.4717160 0.4717882 0.4718977
## [2,] 0.4684047 0.4684417 0.4685007 0.4685901 0.4687281 0.4688644 0.4690402
## [3,] 0.4729560 0.4728888 0.4728515 0.4728489 0.4729012 0.4729589 0.4730520
## [4,] 0.4716161 0.4715401 0.4715022 0.4714986 0.4715397 0.4715957 0.4716776
## [5,] 0.5129286 0.5125541 0.5122236 0.5119387 0.5117244 0.5115122 0.5113530
## [6,] 0.5157543 0.5153130 0.5149354 0.5145957 0.5143002 0.5140948 0.5138977
## [7,] 0.5163957 0.5158687 0.5153975 0.5149828 0.5146329 0.5143332 0.5140763
## [8,] 0.5116609 0.5112816 0.5109749 0.5107194 0.5105068 0.5103296 0.5101900
##          [,29]     [,30]
## [1,] 0.4720135 0.4721507
## [2,] 0.4692211 0.4694247
## [3,] 0.4731735 0.4733121
## [4,] 0.4717999 0.4719271
## [5,] 0.5112157 0.5111004
## [6,] 0.5137148 0.5135921
```

```
## [7,] 0.5138644 0.5136768
## [8,] 0.5101109 0.5100463
##
## $SE_mat
##             [,1]        [,2]        [,3]        [,4]        [,5]        [,6]
## [1,] 0.005441095 0.005126904 0.004894346 0.004716007 0.004561539 0.004454061
## [2,] 0.006754331 0.006472516 0.006057254 0.005987266 0.005959665 0.005960373
## [3,] 0.010396753 0.008703820 0.007766835 0.007196275 0.006826144 0.006592351
## [4,] 0.004306314 0.005201497 0.005731699 0.006057875 0.006273192 0.006422112
## [5,] 0.009345320 0.007799071 0.006968207 0.006415920 0.005999329 0.005697511
## [6,] 0.012242430 0.010955413 0.010117427 0.009482061 0.008988382 0.008567198
## [7,] 0.011374452 0.011994112 0.012248611 0.012351412 0.012378504 0.012372032
## [8,] 0.014173052 0.013603698 0.013402407 0.013261999 0.013154587 0.013066553
##             [,7]        [,8]        [,9]       [,10]       [,11]       [,12]
## [1,] 0.004346959 0.004277600 0.004205694 0.004153980 0.004098417 0.004057039
## [2,] 0.005970609 0.005963952 0.005935055 0.005893712 0.005846181 0.005805135
## [3,] 0.006445750 0.006366711 0.006323264 0.006318900 0.006332458 0.006370691
## [4,] 0.006529540 0.006618656 0.006688559 0.006742665 0.006793293 0.006835874
## [5,] 0.005454150 0.005250234 0.005078567 0.004944907 0.004824667 0.004729986
## [6,] 0.008244075 0.007923551 0.007669462 0.007438637 0.007237974 0.007058415
## [7,] 0.012347304 0.012300821 0.012268041 0.012236323 0.012182921 0.012144148
## [8,] 0.012962491 0.012880849 0.012801890 0.012724842 0.012654687 0.012586364
##            [,13]       [,14]       [,15]       [,16]       [,17]       [,18]
## [1,] 0.004023603 0.003989926 0.003961850 0.003935295 0.003911812 0.003898461
## [2,] 0.005763585 0.005728812 0.005696210 0.005670292 0.005647141 0.005622140
## [3,] 0.006414941 0.006469192 0.006528194 0.006596789 0.006667796 0.006740017
## [4,] 0.006874762 0.006916430 0.006954355 0.006986019 0.007020100 0.007057003
## [5,] 0.004650625 0.004587723 0.004544206 0.004488279 0.004454090 0.004426432
## [6,] 0.006906551 0.006772223 0.006652168 0.006545213 0.006448524 0.006349873
## [7,] 0.012125539 0.012086745 0.012039896 0.012015330 0.011980857 0.011951720
## [8,] 0.012518977 0.012451178 0.012398279 0.012337741 0.012282895 0.012238409
##            [,19]       [,20]       [,21]       [,22]       [,23]       [,24]
## [1,] 0.003879573 0.003863083 0.003848384 0.003839564 0.003828464 0.003818733
## [2,] 0.005605447 0.005588757 0.005576635 0.005569075 0.005556522 0.005547876
## [3,] 0.006817035 0.006890816 0.006964632 0.007036660 0.007113050 0.007184965
## [4,] 0.007089335 0.007121154 0.007152379 0.007183044 0.007212852 0.007238352
## [5,] 0.004405648 0.004388994 0.004377005 0.004383072 0.004378864 0.004377760
## [6,] 0.006275971 0.006202373 0.006128582 0.006067772 0.006012284 0.005965414
## [7,] 0.011923684 0.011903483 0.011878070 0.011853694 0.011829384 0.011807197
## [8,] 0.012183953 0.012137159 0.012097969 0.012057030 0.012012792 0.011984458
##            [,25]       [,26]       [,27]       [,28]       [,29]       [,30]
## [1,] 0.003811008 0.003804056 0.003803693 0.003793513 0.003794922 0.003790193
## [2,] 0.005539264 0.005534330 0.005529614 0.005526790 0.005523814 0.005518994
## [3,] 0.007255835 0.007332035 0.007400559 0.007471283 0.007540223 0.007608221
## [4,] 0.007266965 0.007302473 0.007330102 0.007353411 0.007387143 0.007409453
## [5,] 0.004378759 0.004387074 0.004391507 0.004401499 0.004412560 0.004433647
## [6,] 0.005919235 0.005877017 0.005842843 0.005805288 0.005772975 0.005750410
## [7,] 0.011786013 0.011778638 0.011754988 0.011729259 0.011723148 0.011702856
## [8,] 0.011948201 0.011915786 0.011881696 0.011860948 0.011831561 0.011811291
##
## $opt_para
##      [,1] [,2] [,3]
## [1,]    4    2   22
```

```r
start_time <- Sys.time()

res <- mglram(tnsr = synthetic_dat@data, ranks = c(4, 2), init=0, D = D2,
       lambda = 22, max_iter = 500, tol = 1e-5, L0 = NULL)

res$conv
```

```
## [1] TRUE
```

```r
end_time <- Sys.time()

exec_time <- end_time - start_time
print(exec_time)
```

```
## Time difference of 0.872026 secs
```

```r
tilde <- MakeIdent(L=res$L, G=res$G, R=res$R)

L_tilde <- tilde$L_tilde
R_tilde <- tilde$R_tilde
G_tilde <- tilde$G_tilde

L_tilde
```

```
##             [,1]        [,2]         [,3]         [,4]
##  [1,] 0.2206883  0.20946321  0.158643221  0.269797852
##  [2,] 0.2187772  0.24325575  0.090528762  0.292051267
##  [3,] 0.2161894  0.26202757  0.019364534  0.243143273
##  [4,] 0.2130374  0.26524971 -0.050546798  0.134631456
##  [5,] 0.2095039  0.25243455 -0.115642555 -0.005384659
##  [6,] 0.2055978  0.22383800 -0.172879659 -0.142617630
##  [7,] 0.2013284  0.17987614 -0.219421420 -0.247187717
##  [8,] 0.1967475  0.12236279 -0.254377085 -0.292288616
##  [9,] 0.1921995  0.05366405 -0.276458965 -0.262515250
## [10,] 0.1884389 -0.02209773 -0.284459889 -0.162894323
## [11,] 0.1858047 -0.09939879 -0.276300504 -0.020773381
## [12,] 0.1844490 -0.17208893 -0.250363649  0.124543021
## [13,] 0.1844874 -0.23421340 -0.206411449  0.234951388
## [14,] 0.1860149 -0.28044802 -0.146359020  0.279357090
## [15,] 0.1889712 -0.30642056 -0.073847230  0.246612152
## [16,] 0.1929806 -0.30886285  0.006139336  0.137584150
## [17,] 0.1978474 -0.28777574  0.087513591 -0.014948567
## [18,] 0.2030917 -0.24552623  0.163169918 -0.164465087
## [19,] 0.2083673 -0.18687786  0.225831109 -0.265477419
## [20,] 0.2132969 -0.11760303  0.269423153 -0.284968526
## [21,] 0.2174069 -0.04294168  0.290433194 -0.223056832
## [22,] 0.2201965  0.03174587  0.287814957 -0.101597068
## [23,] 0.2215948  0.10144857  0.262841056  0.045614793
## [24,] 0.2217274  0.16163578  0.218078693  0.179645030
```

```
R_tilde
```

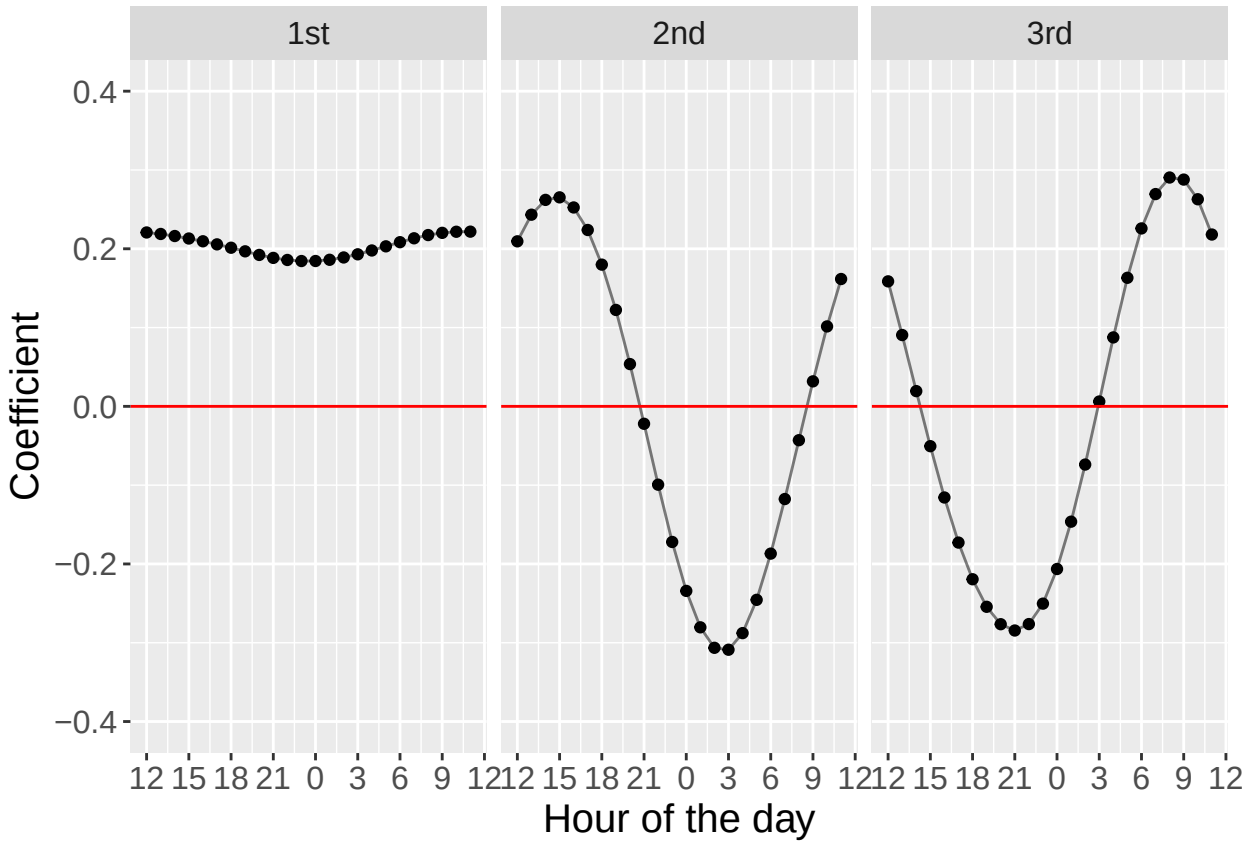
```
##            [,1]       [,2]
## [1,] -0.6216723  0.2635381
## [2,] -0.5426435  0.5341936
## [3,] -0.5648554 -0.8032340
```

```
G_tilde[ , ,1:10]
```

```
## , , 1
##
##            [,1]        [,2]
## [1,]  0.8543972 -0.27009472
## [2,] -3.9382968 -0.49928421
## [3,]  0.3196049 -0.22221670
## [4,] -0.1929465 -0.09387727
##
## , , 2
##
##            [,1]       [,2]
## [1,] -2.9304372 -8.4408757
## [2,] -0.9295727 -0.6111330
## [3,] -2.0439473  0.1805035
## [4,]  0.3369946 -0.3016741
##
## , , 3
##
##            [,1]        [,2]
## [1,] -2.8169347  1.24929896
## [2,] -2.0300129  1.47130551
## [3,]  0.2287871 -0.03819774
## [4,]  0.2270664 -0.15402923
##
## , , 4
##
##            [,1]       [,2]
## [1,]  7.5207114  4.3246232
## [2,] -3.2924600  2.1972569
## [3,]  1.1476151 -1.1450120
## [4,]  0.1924004 -0.2377452
##
## , , 5
##
##            [,1]        [,2]
## [1,]  0.3825251 -2.13316732
## [2,] -5.9460831  1.92592207
## [3,]  0.5590574  0.30098240
## [4,]  0.1117306 -0.05371549
##
## , , 6
##
##            [,1]       [,2]
## [1,] 11.3483607  3.9784182
```

```
## [2,] -3.5069147  1.0148912
## [3,]  2.7334161  0.4399401
## [4,] -0.1067417 -0.1777268
##
## , , 7
##
##             [,1]       [,2]
## [1,] -4.48656113 -2.2664087
## [2,] -1.75952691 -0.1488138
## [3,] -0.80053449  0.5398819
## [4,] -0.06260307  0.2676097
##
## , , 8
##
##           [,1]       [,2]
## [1,] 8.0009465 -3.5233689
## [2,] 0.7850699 -1.9120519
## [3,] 0.6808659 -0.0409865
## [4,] 0.0772281  0.3456544
##
## , , 9
##
##            [,1]       [,2]
## [1,]  2.9206400 -1.0945722
## [2,] -0.1765490 -0.7803076
## [3,] -0.9594006  0.3822404
## [4,]  0.3046266  0.1077564
##
## , , 10
##
##            [,1]       [,2]
## [1,]  0.9837584 -4.9662146
## [2,] -1.8047192  0.5915635
## [3,]  2.4437509  0.1677661
## [4,] -0.0353981  0.4613825
```

```
dataL = data.frame(loading = c(L_tilde[, 1], L_tilde[, 2], L_tilde[, 3]),
                   component = c(rep("1st", 24), rep("2nd", 24), rep("3rd", 24)),
                   hour = rep(12:35, 3))

pL = dataL %>%
  ggplot(aes(x = hour, y = loading)) + geom_line(alpha = 0.5) + geom_point() + geom_hline(yintercept = 0
  scale_x_continuous(breaks = c(12, 15, 18, 21, 24, 27, 30, 33, 36), labels = c(12, 15, 18, 21, 0, 3, 6
  xlab("Hour of the day") +
  facet_grid(~ component) +
  ylab("Coefficient") +
  theme(text = element_text(size = 15)) +
  scale_y_continuous(limits = c(-0.4, 0.4))

pL
```




```
R_tilde[, 1] # first component of R tilde
```

```
## [1] -0.6216723 -0.5426435 -0.5648554
```

```
R_tilde[, 2] # second component of R tilde
```

```
## [1]  0.2635381  0.5341936 -0.8032340
```

```
## 37/100 DBP + 33/50 SBP + 29/100 HR (Seem to be joint effect of the three)
R_tilde[1, 1]/sum(R_tilde[, 1]) # DBP: 37/100
```

```
## [1] 0.3595204
```

```
R_tilde[2, 1]/sum(R_tilde[, 1]) # SBP: 33/100
```

```
## [1] 0.3138171
```

```
R_tilde[3, 1]/sum(R_tilde[, 1]) # HR: 30/100 = 3/10
```

```
## [1] 0.3266625
```

```r
## -13/100 DBP - 33/100 SBP + 27/50 HR (Contrast between blood pressure and heart rate?)
R_tilde[1, 2]/sum(abs(R_tilde[, 2])) # DBP: -13/100
```

```
## [1] 0.1646119
```

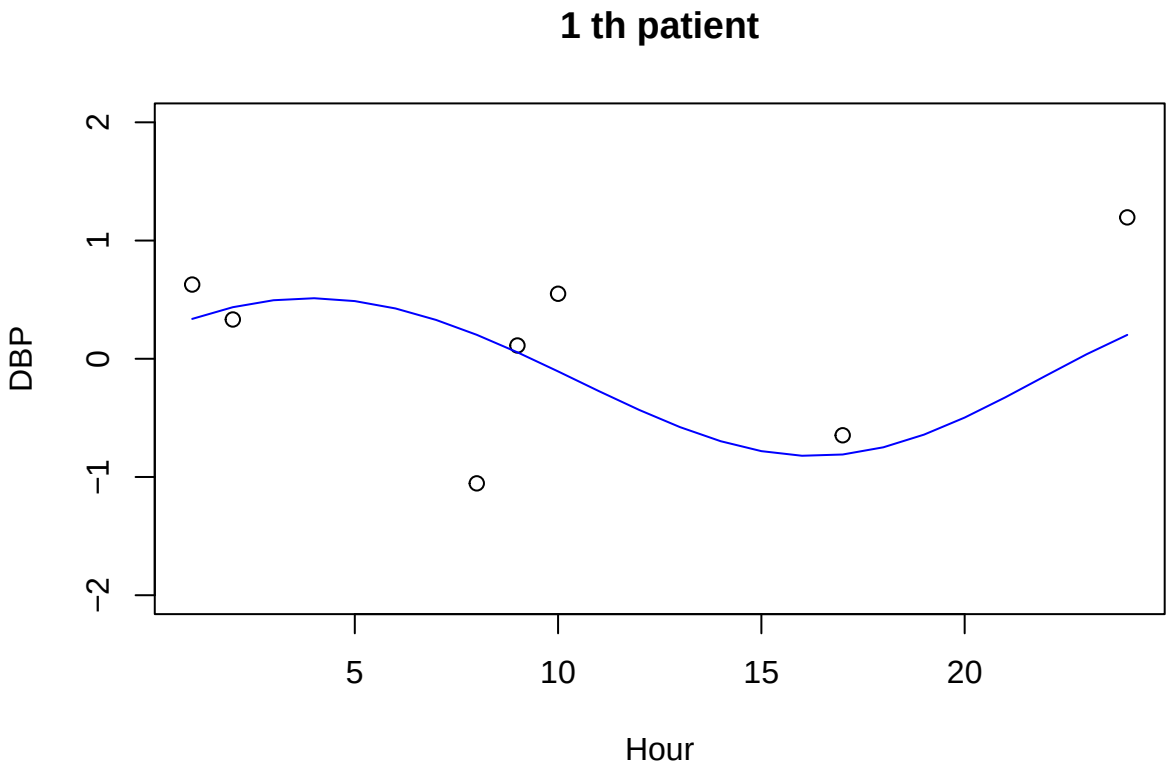
```r
R_tilde[2, 2]/sum(abs(R_tilde[, 2])) # SBP: -33/100
```

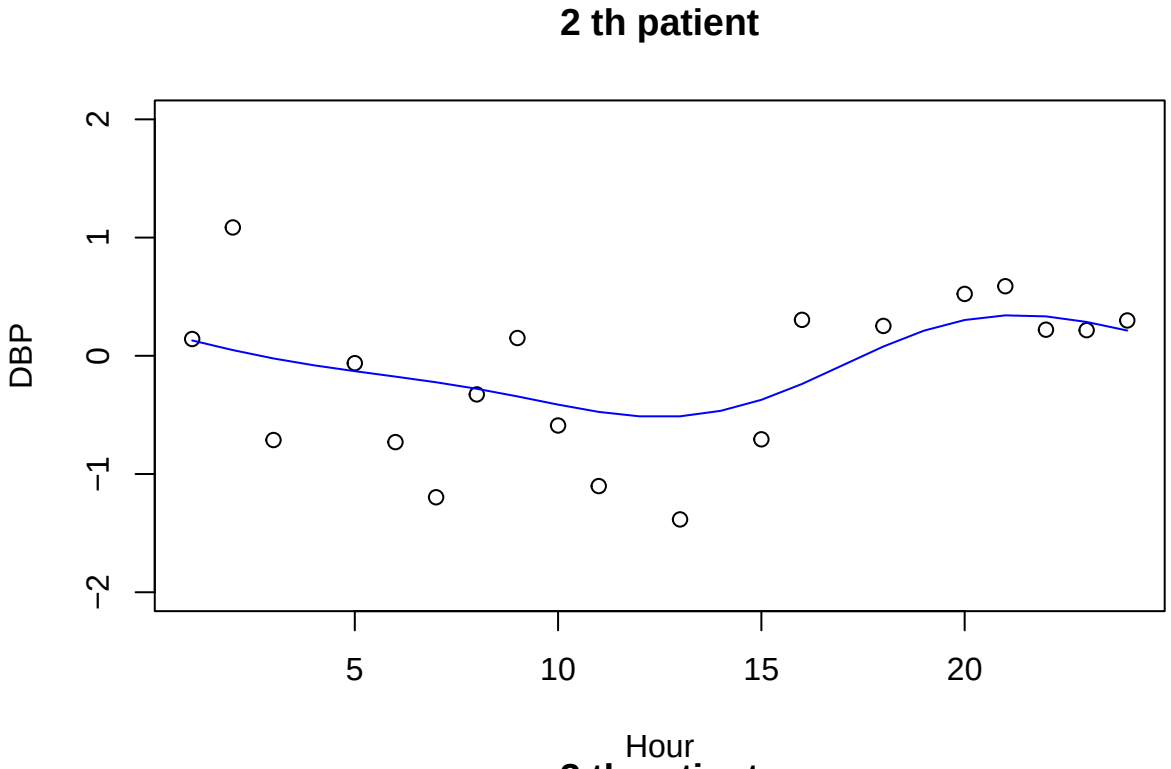
```
## [1] 0.3336696
```

```r
R_tilde[3, 2]/sum(abs(R_tilde[, 2])) # HR: 54/100 = 27/50
```

```
## [1] -0.5017184
```

```r
for (i in 1:25){
  plot(synthetic_dat@data[ , 1, i], main=paste(i,"th patient"), xlab="Hour", ylab="DBP", ylim=c(-2,2))
  lines(res$est[ , 1, i], col="blue") # estimated curve by our algorithm
}
```

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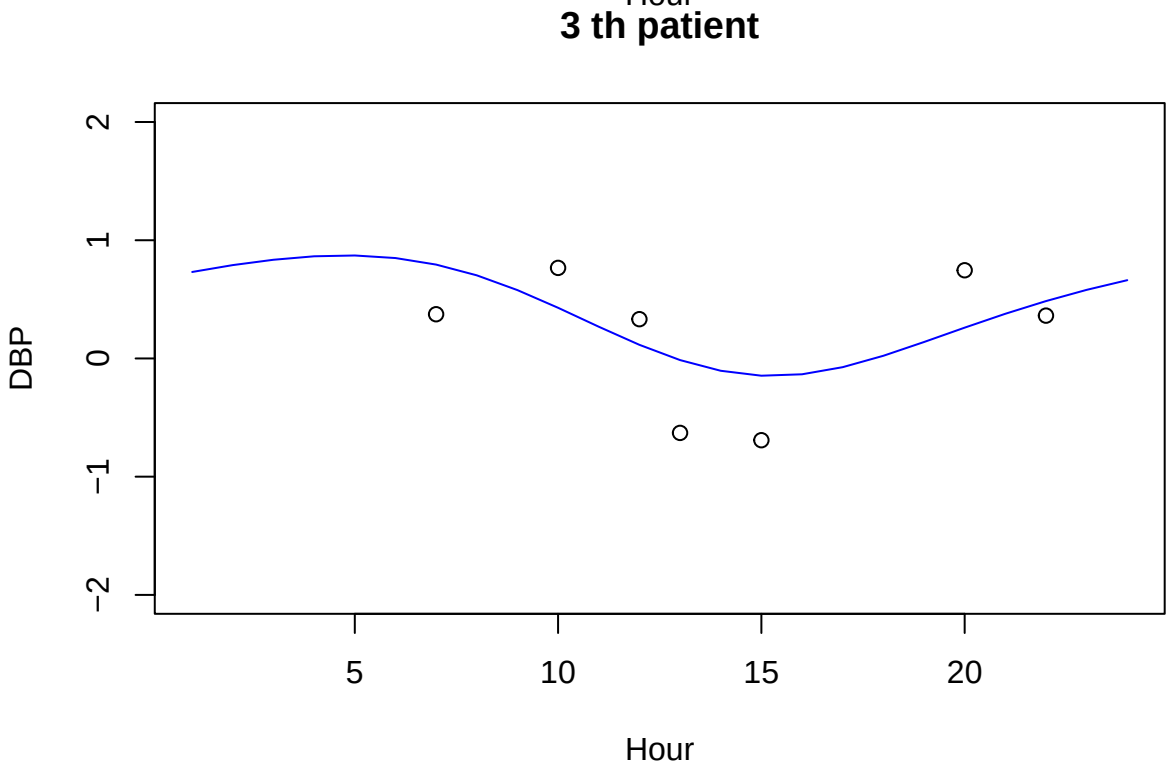
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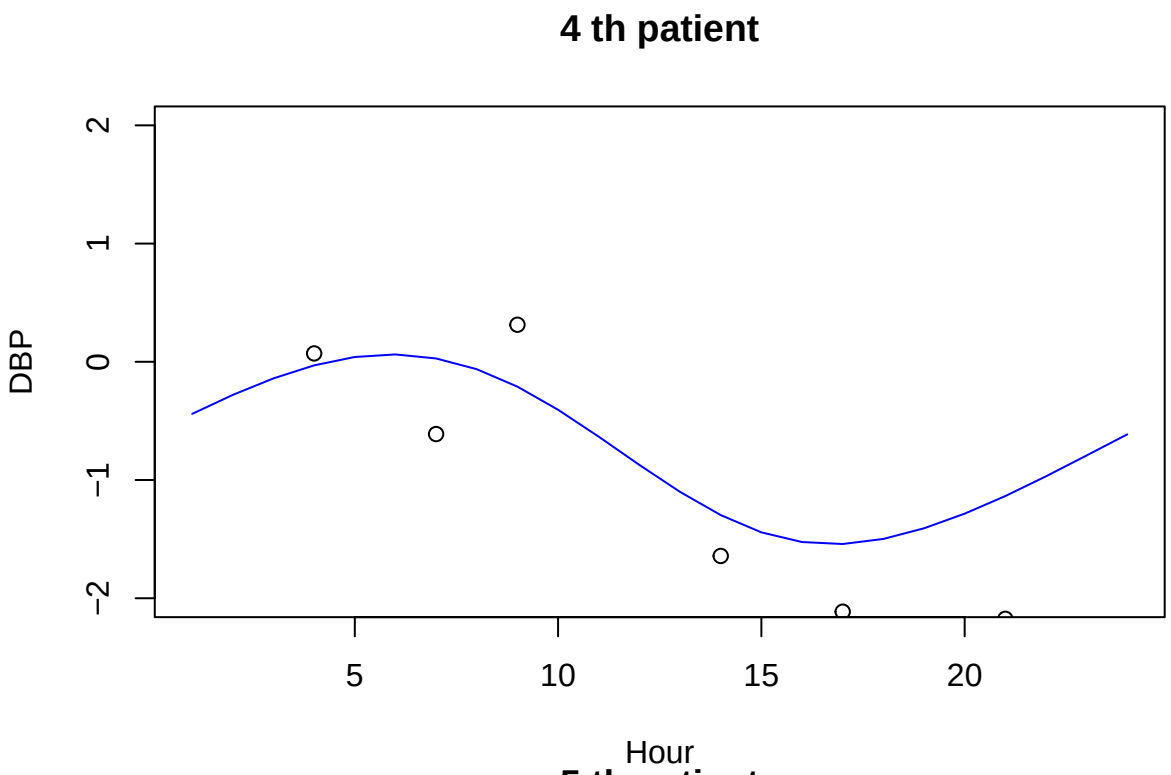
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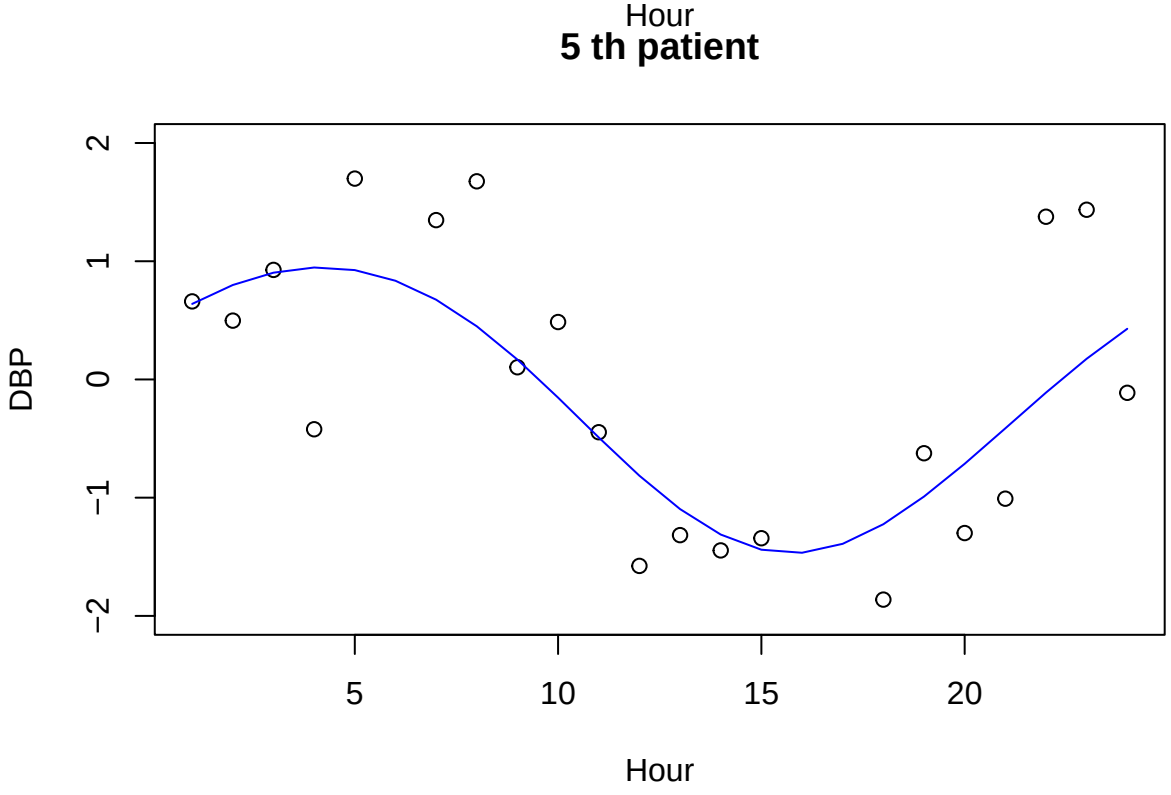
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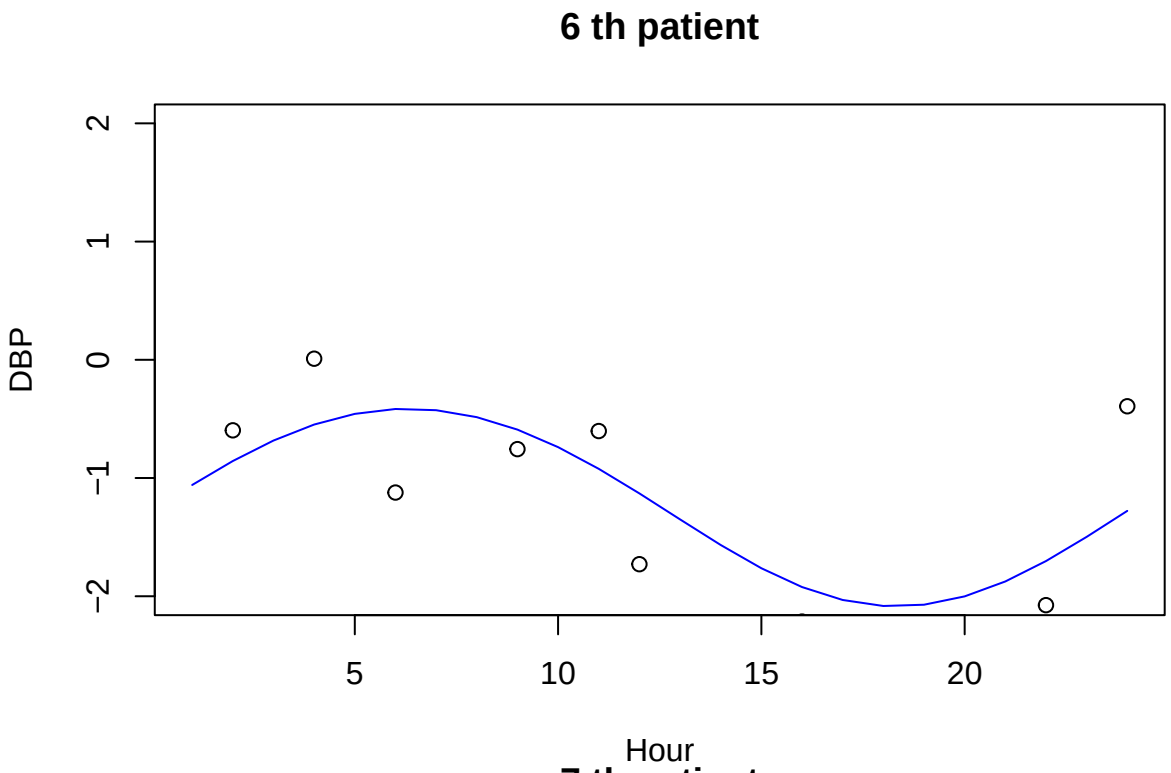
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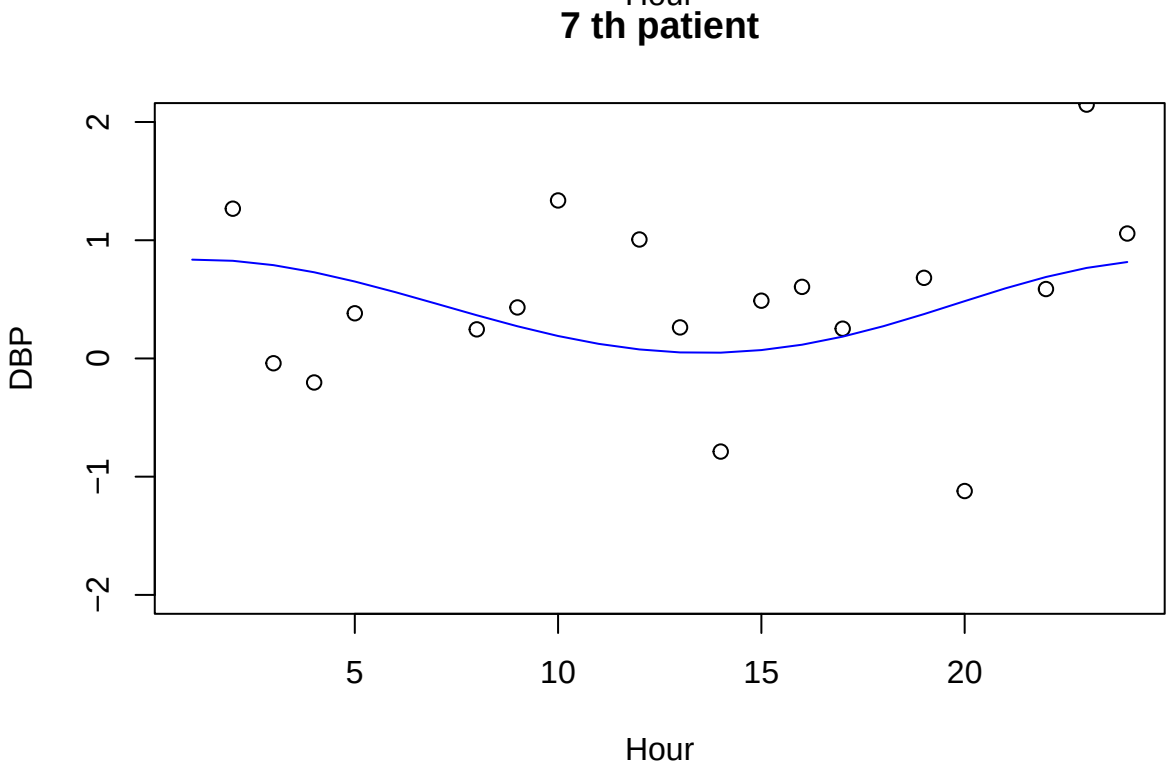
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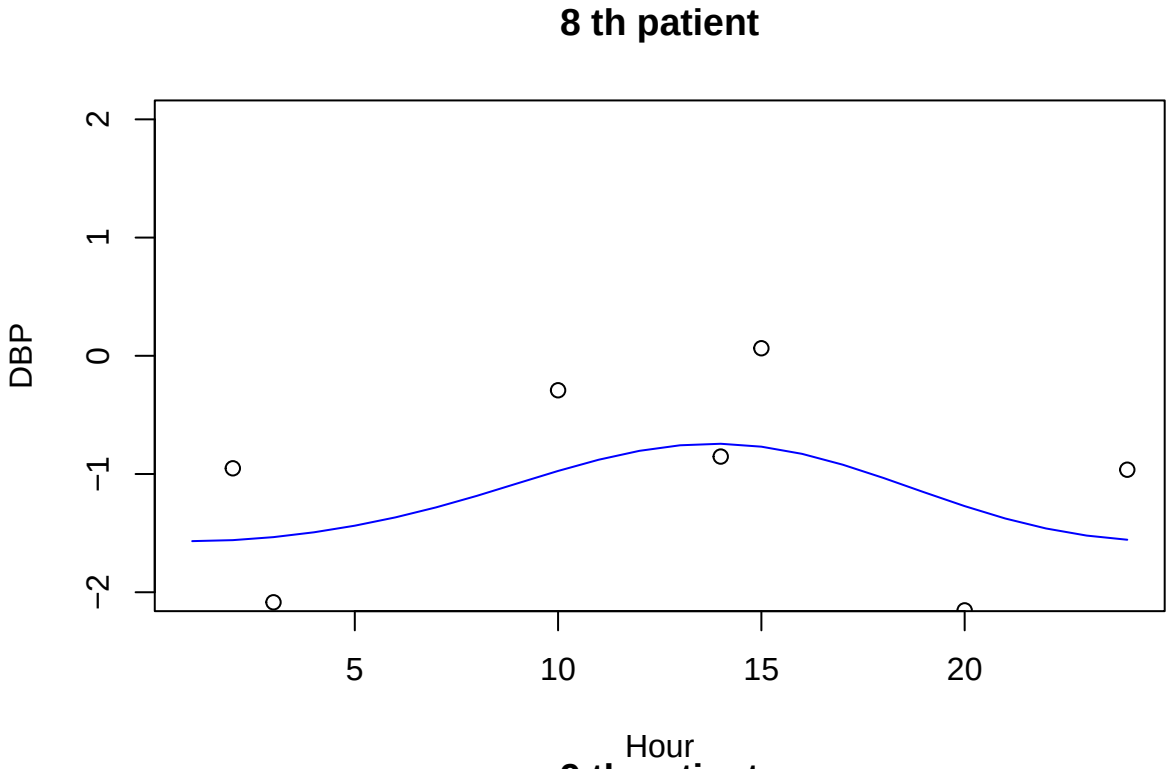
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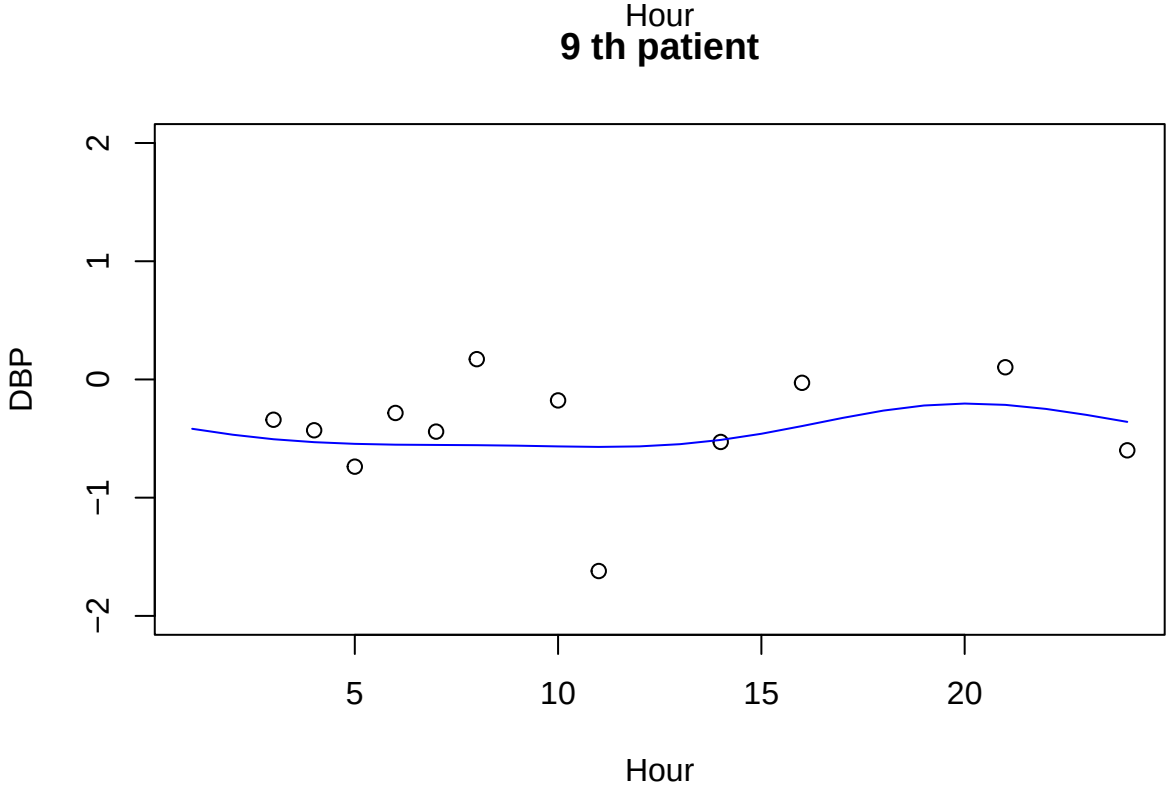
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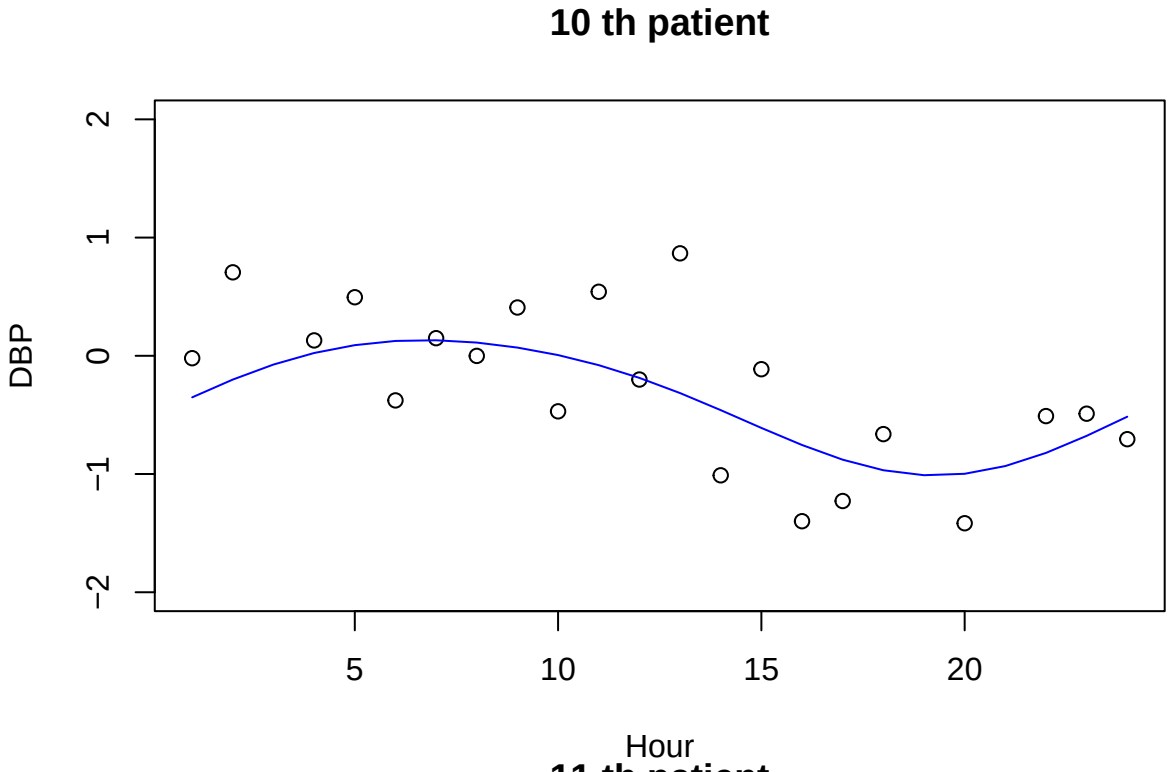
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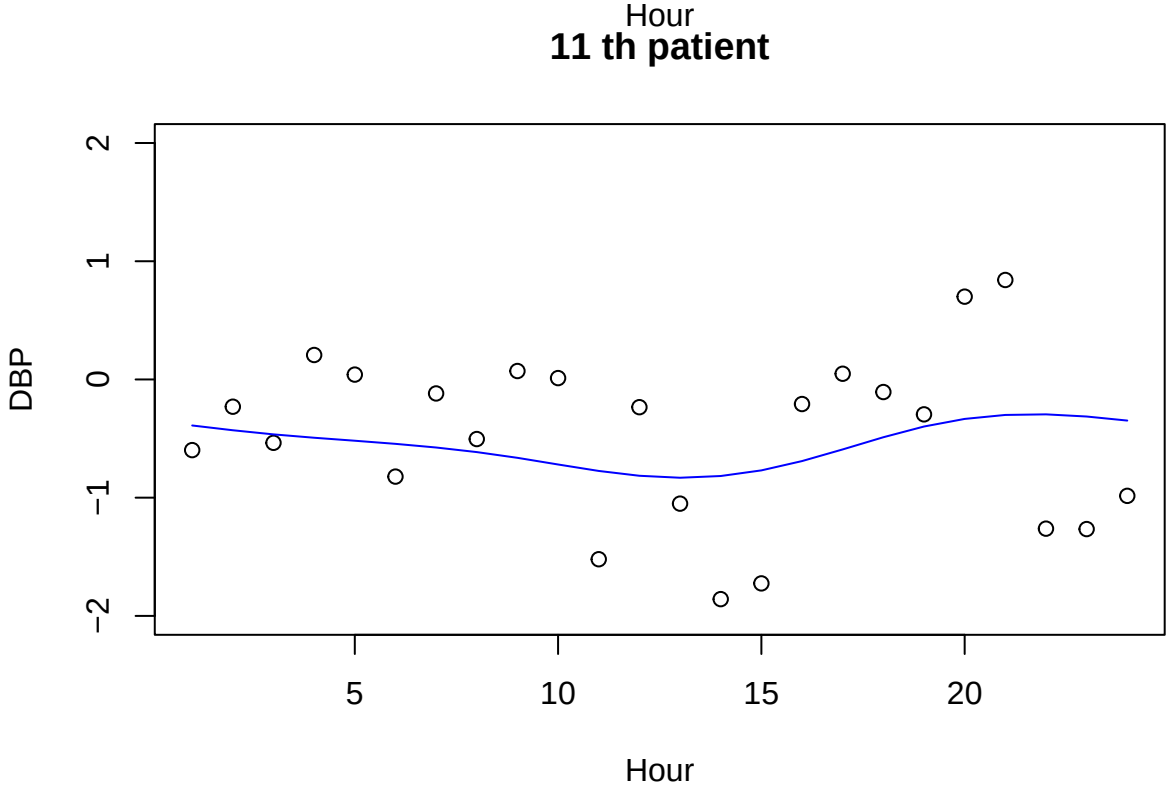
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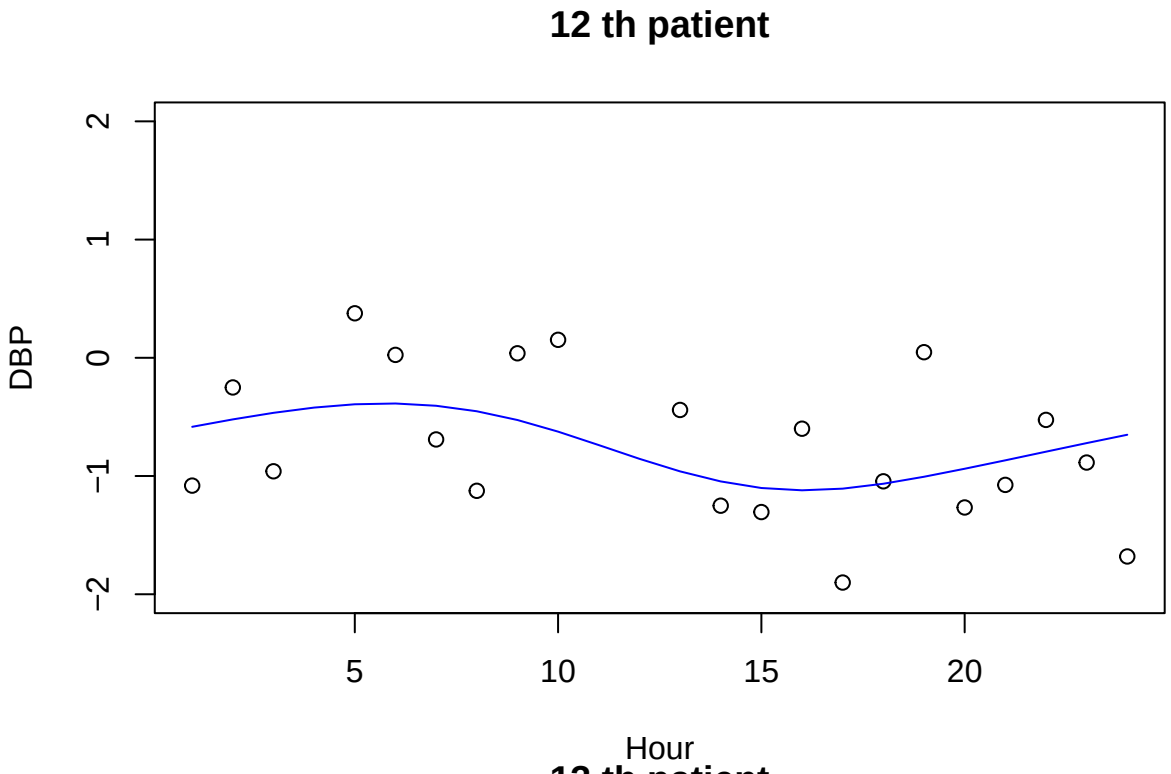
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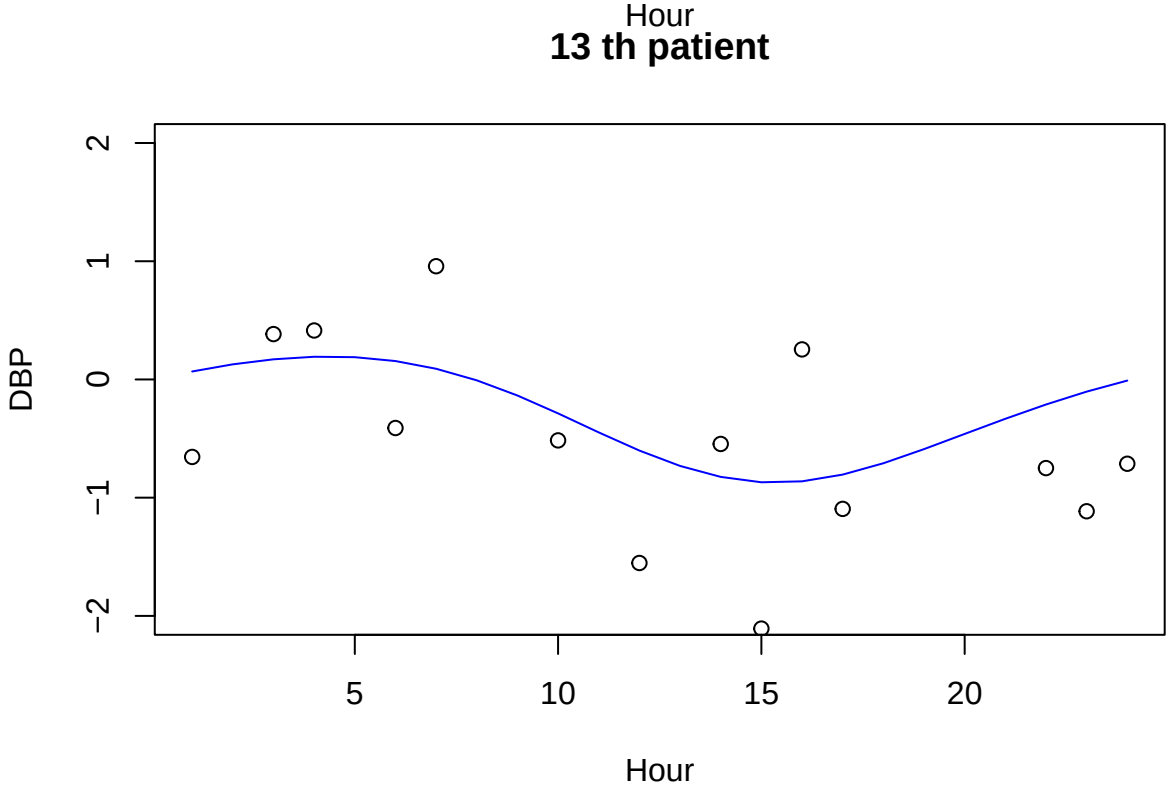
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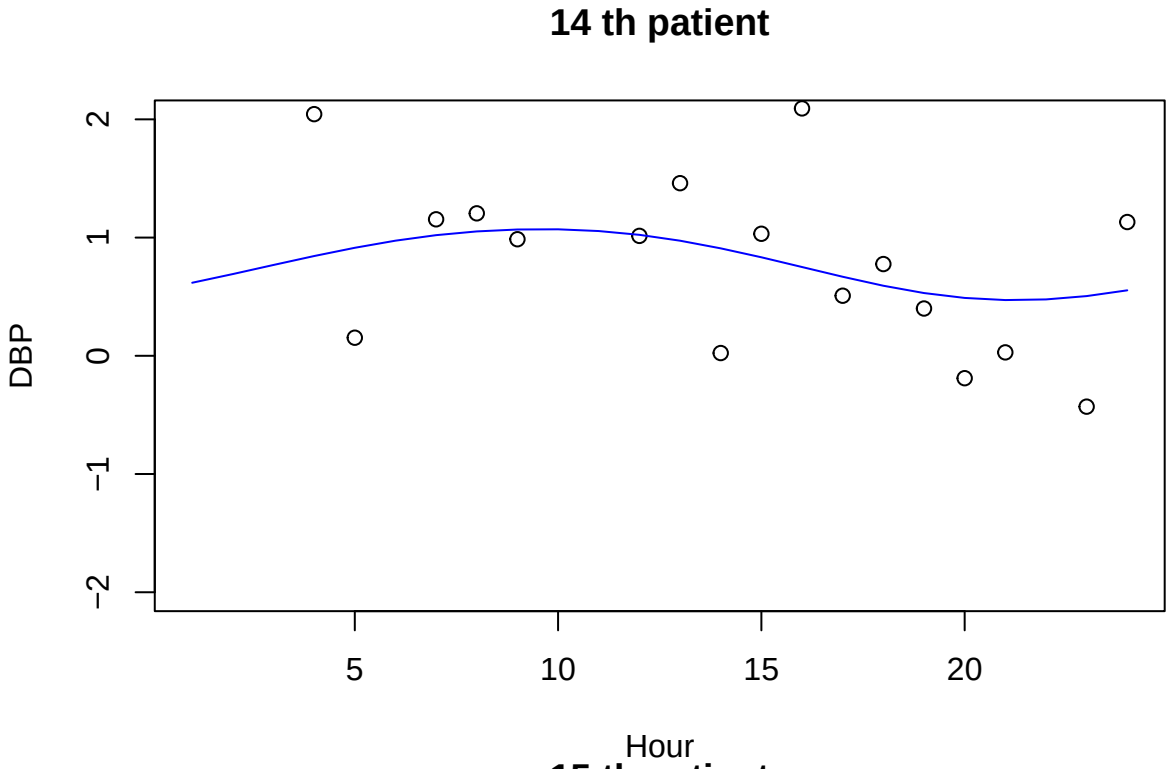
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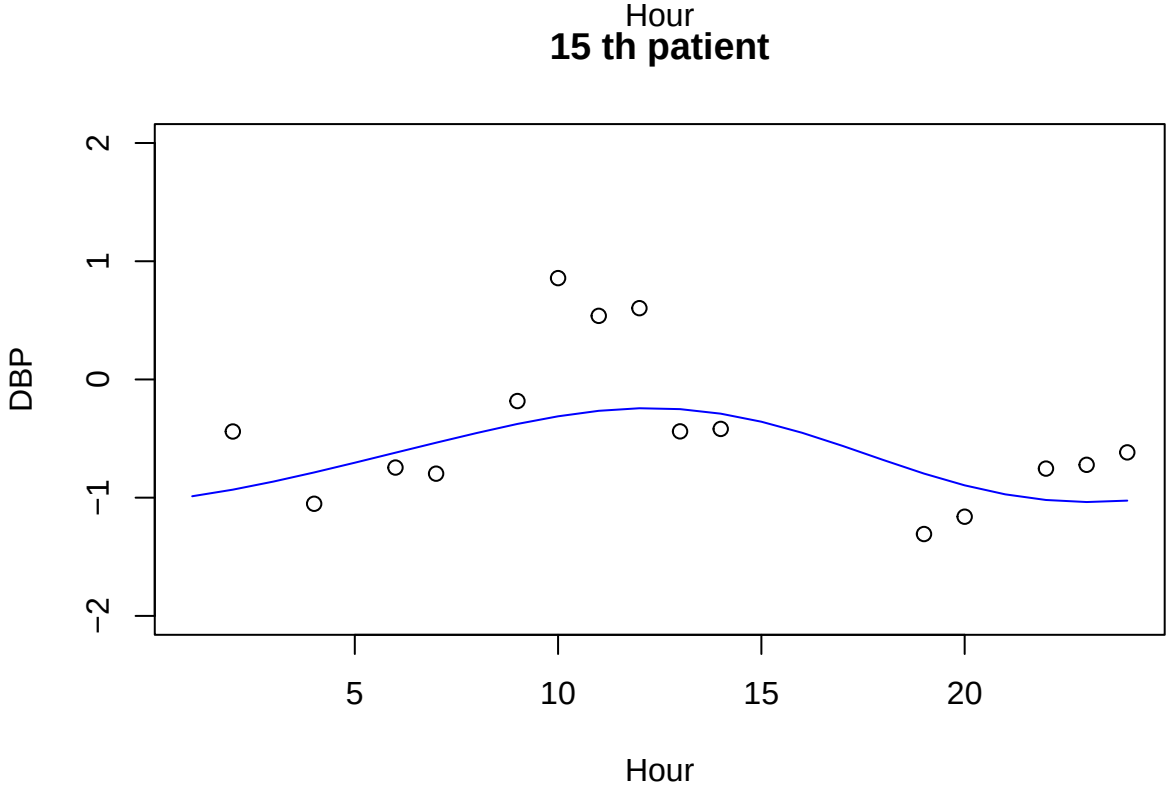
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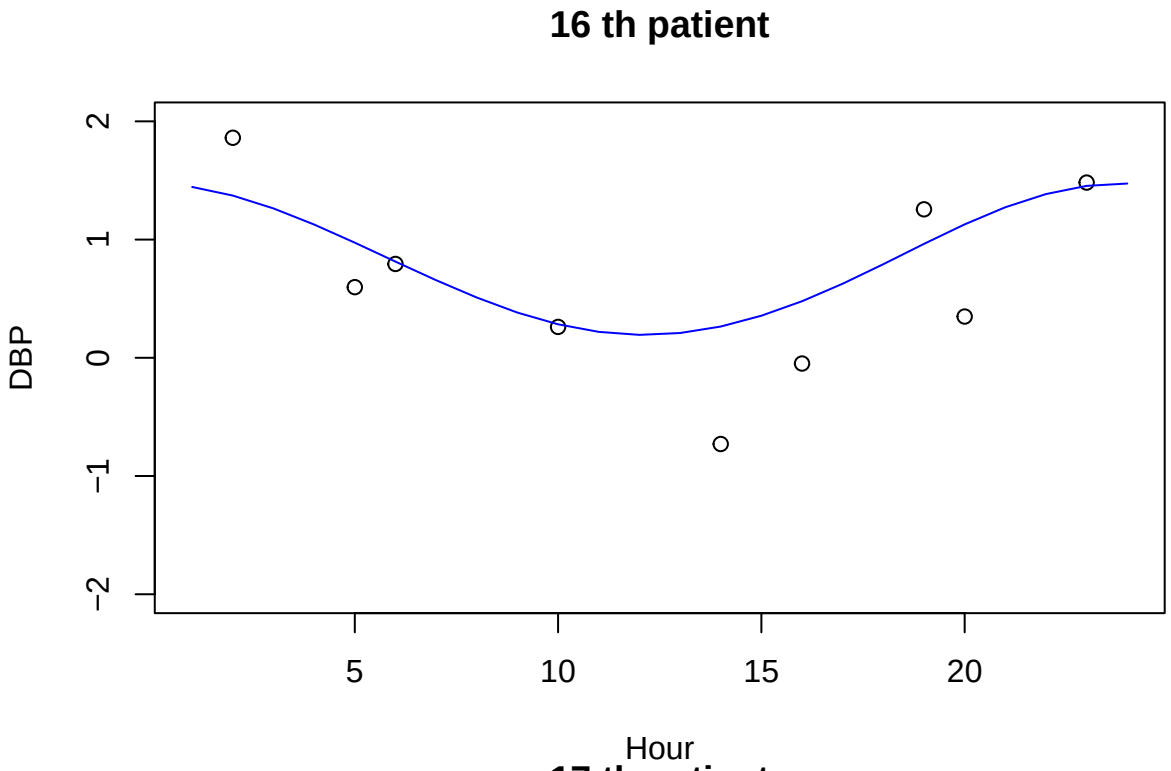
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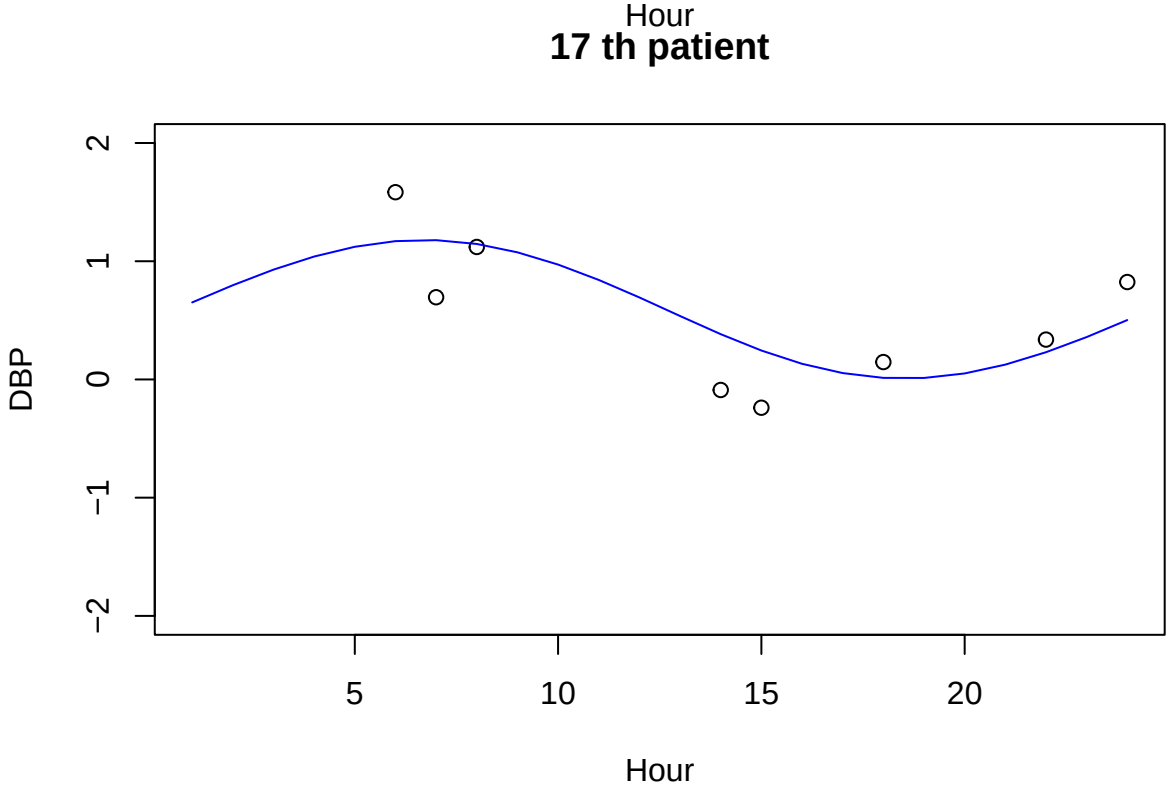
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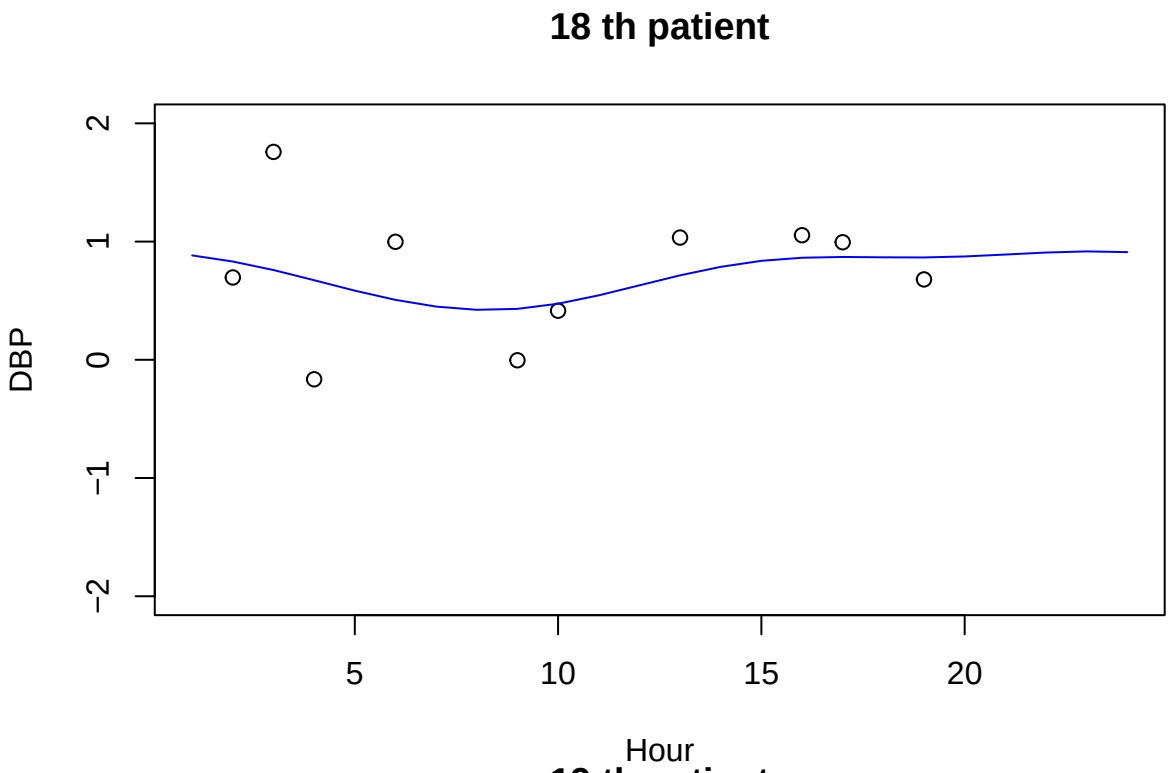
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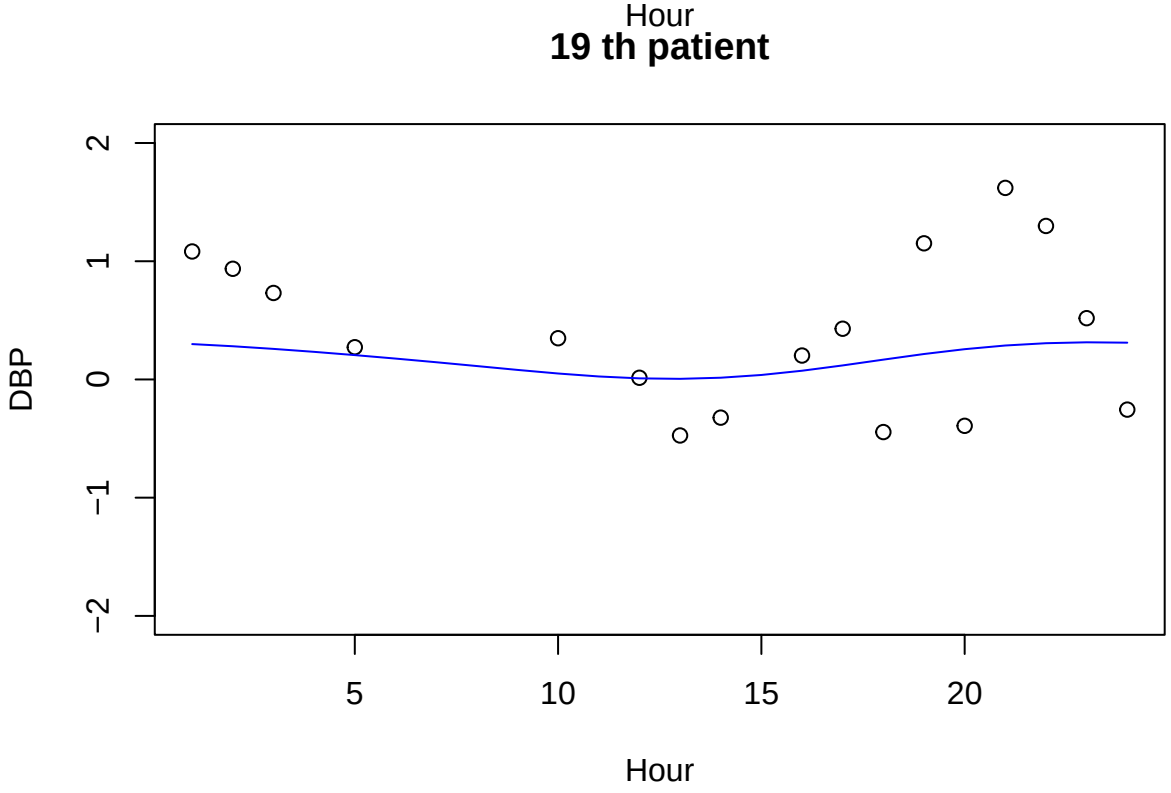
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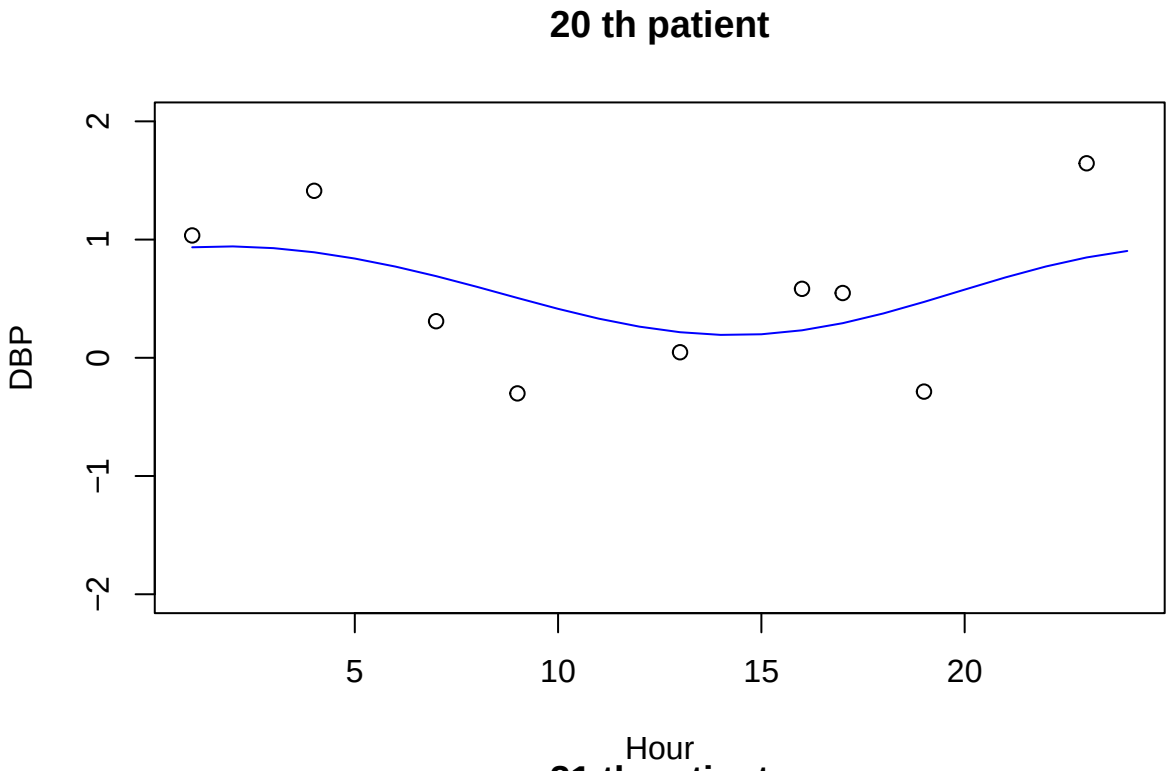
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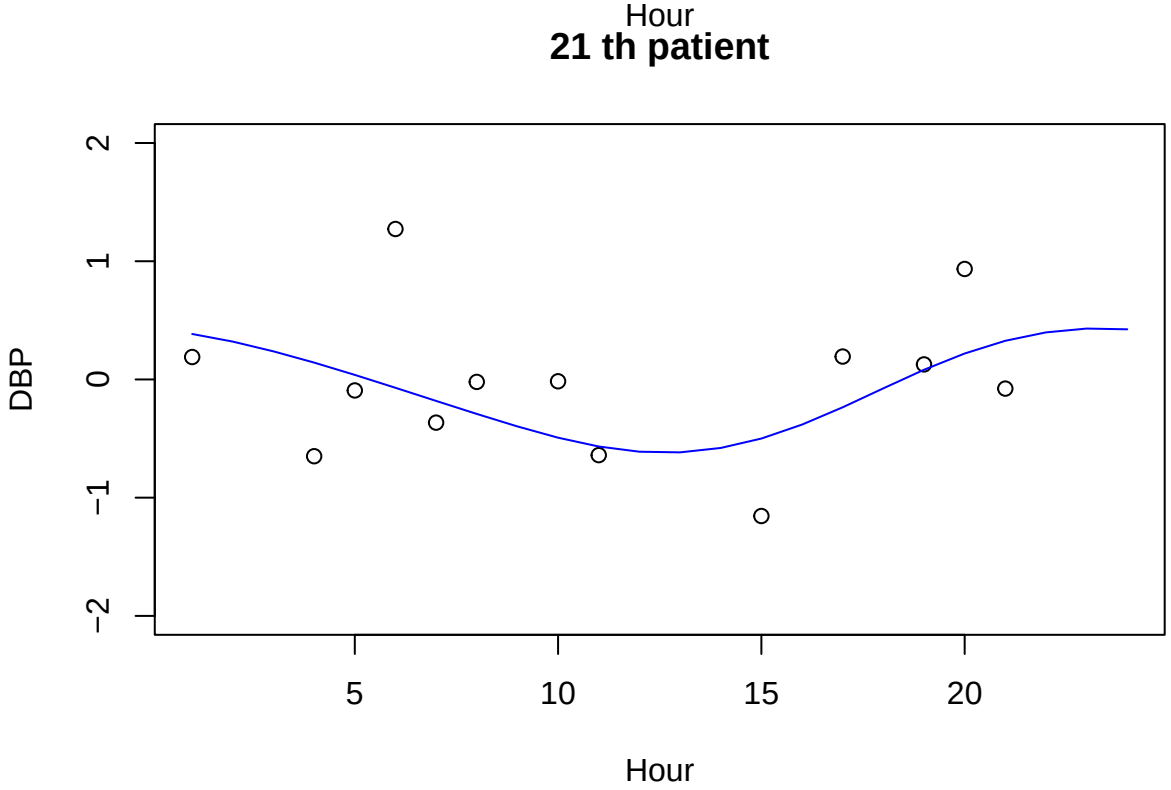
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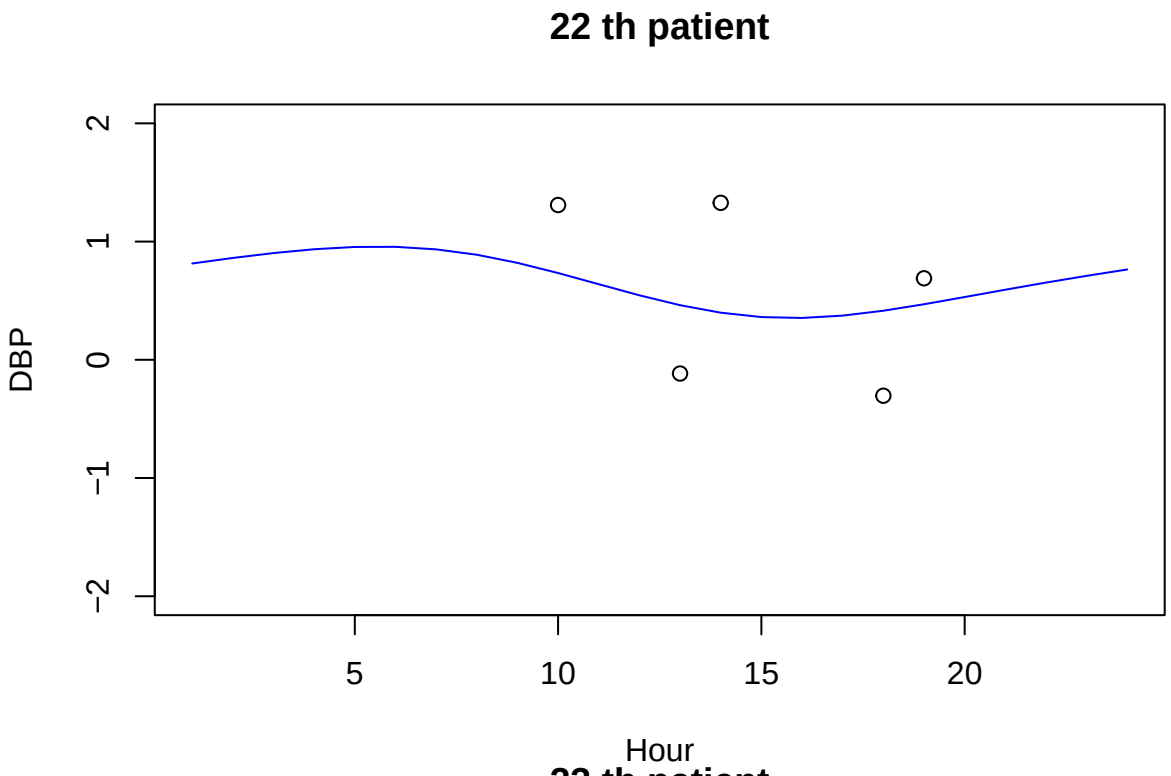
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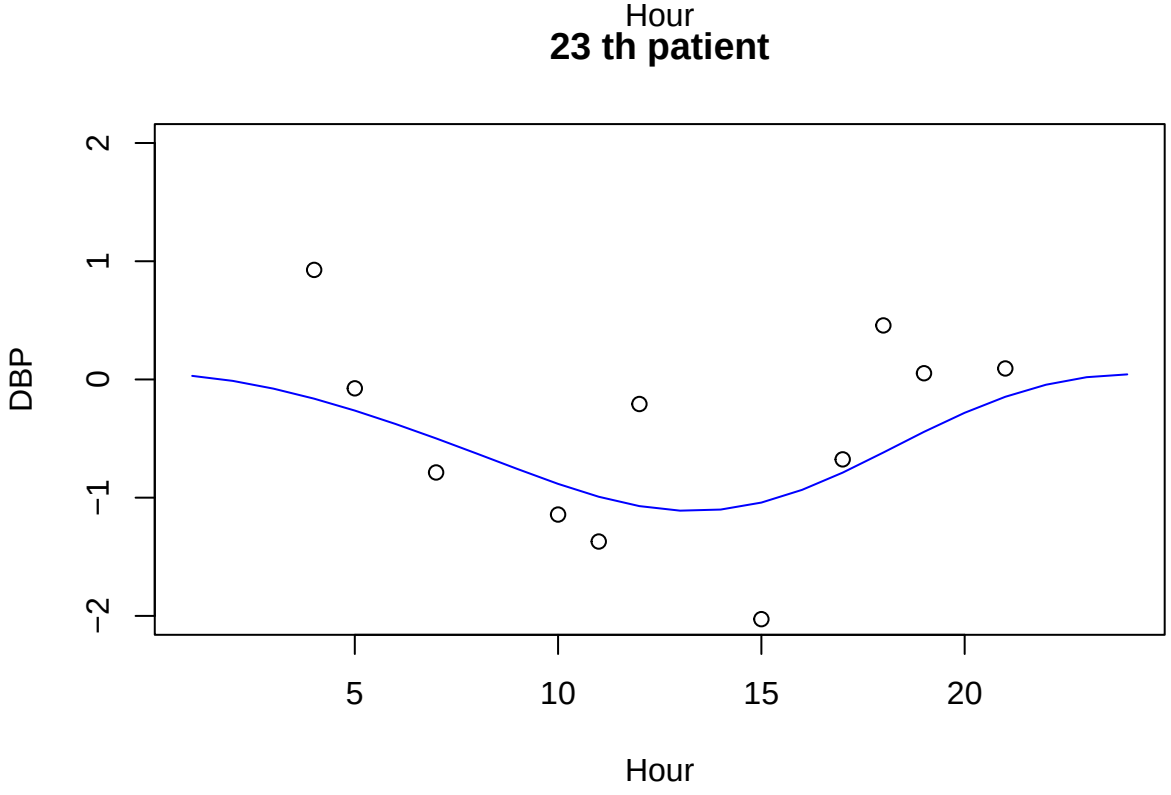
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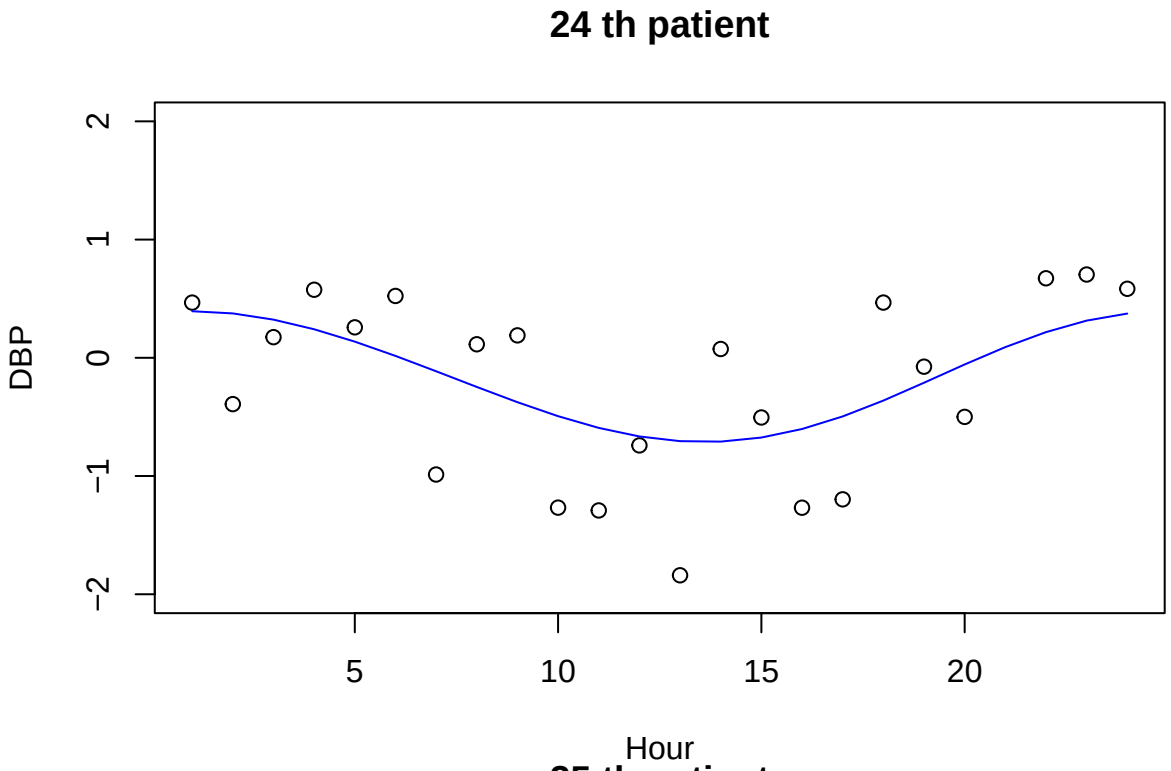
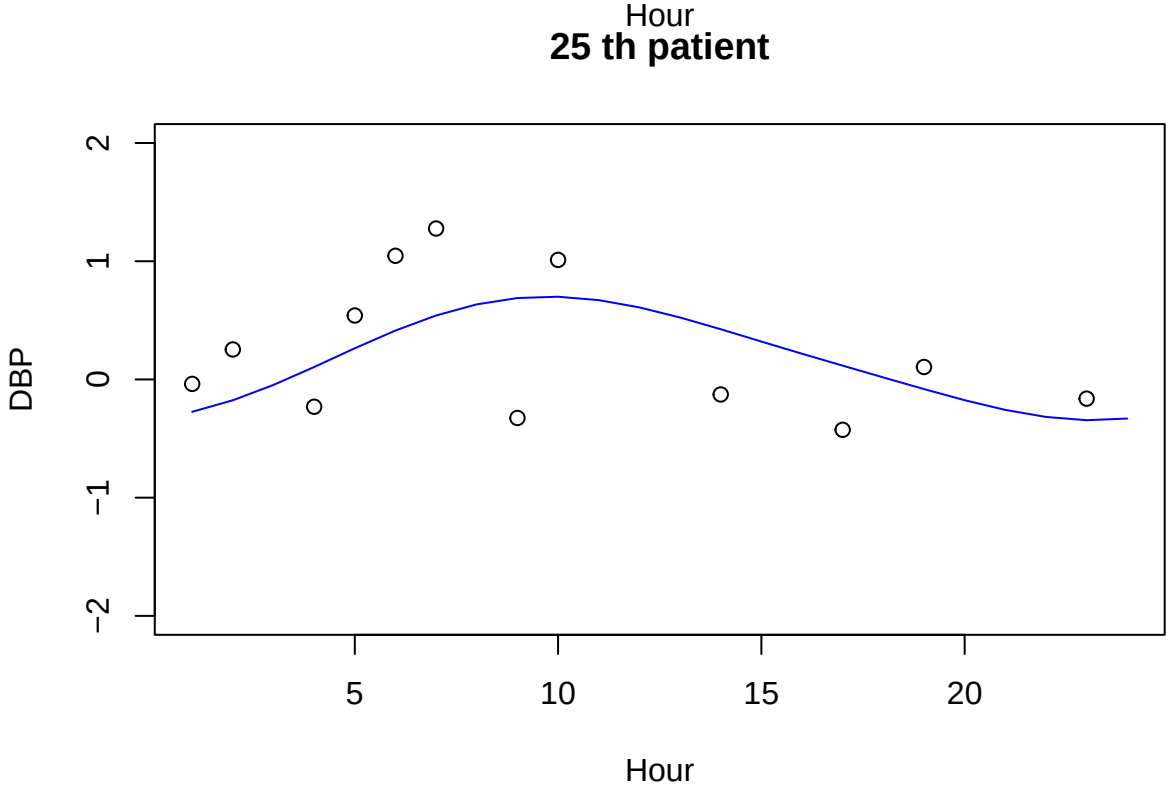
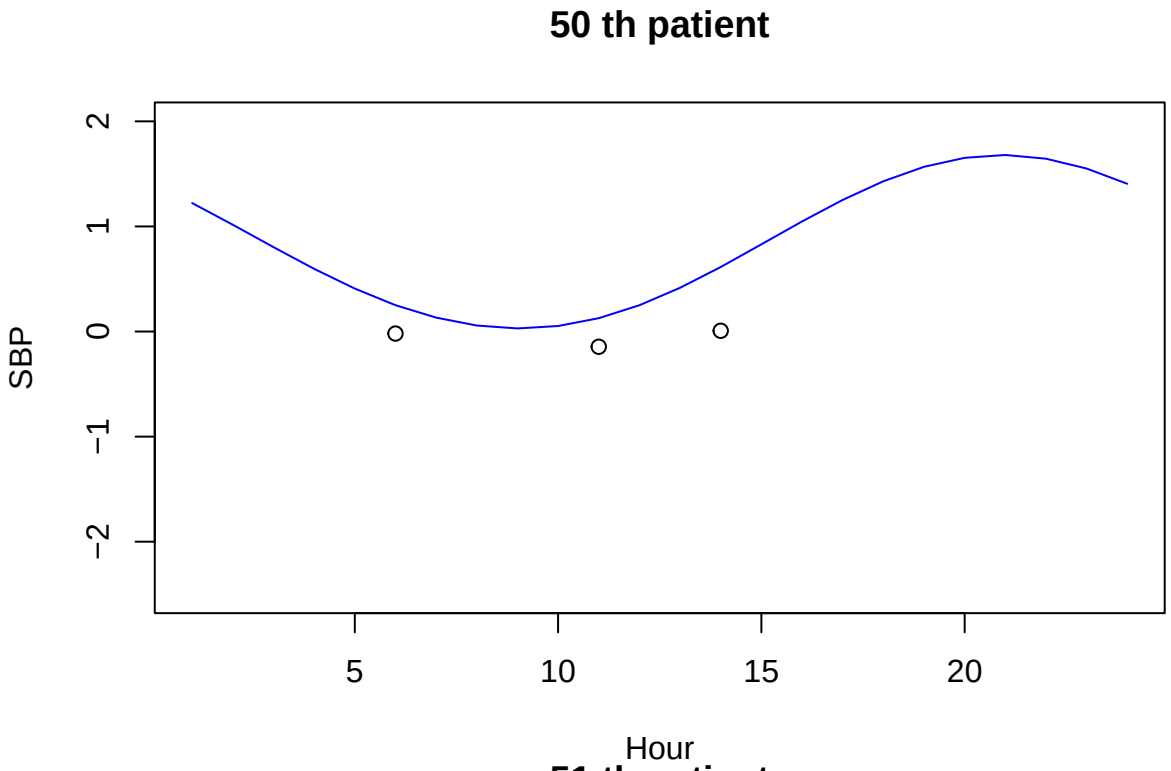





```
# Plot Estimated Curves for SBP
for (i in 50:75){
  plot(synthetic_dat@data[ , 2, i], main=paste(i,"th patient"), xlab="Hour", ylab="SBP", ylim=c(-2.5,2))
  lines(res$est[ , 2, i], col="blue")
}
```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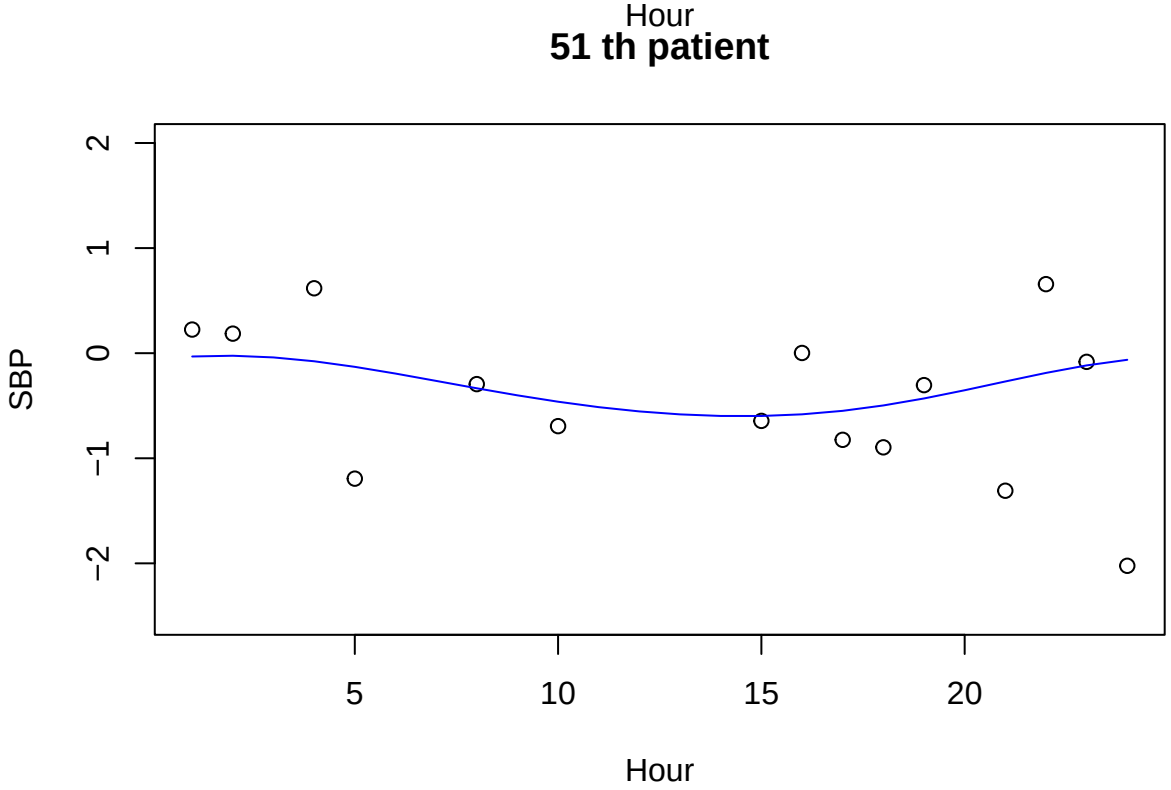
51 th patient
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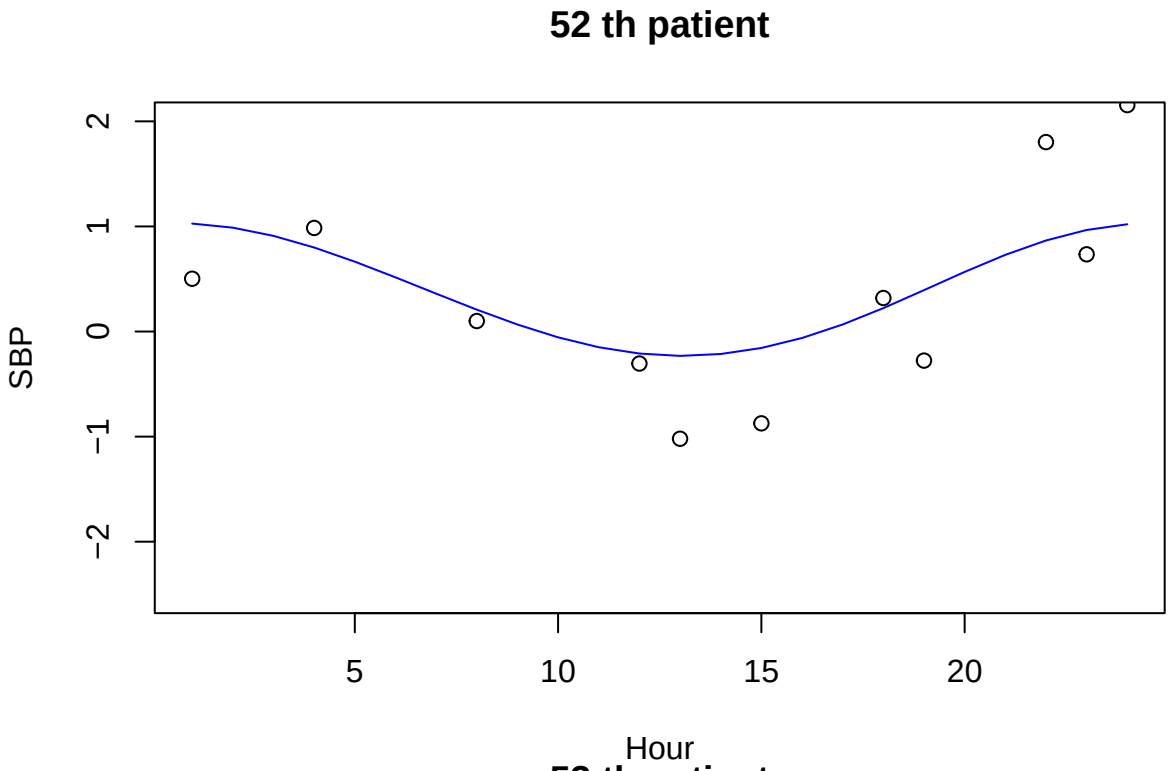
52 th patient
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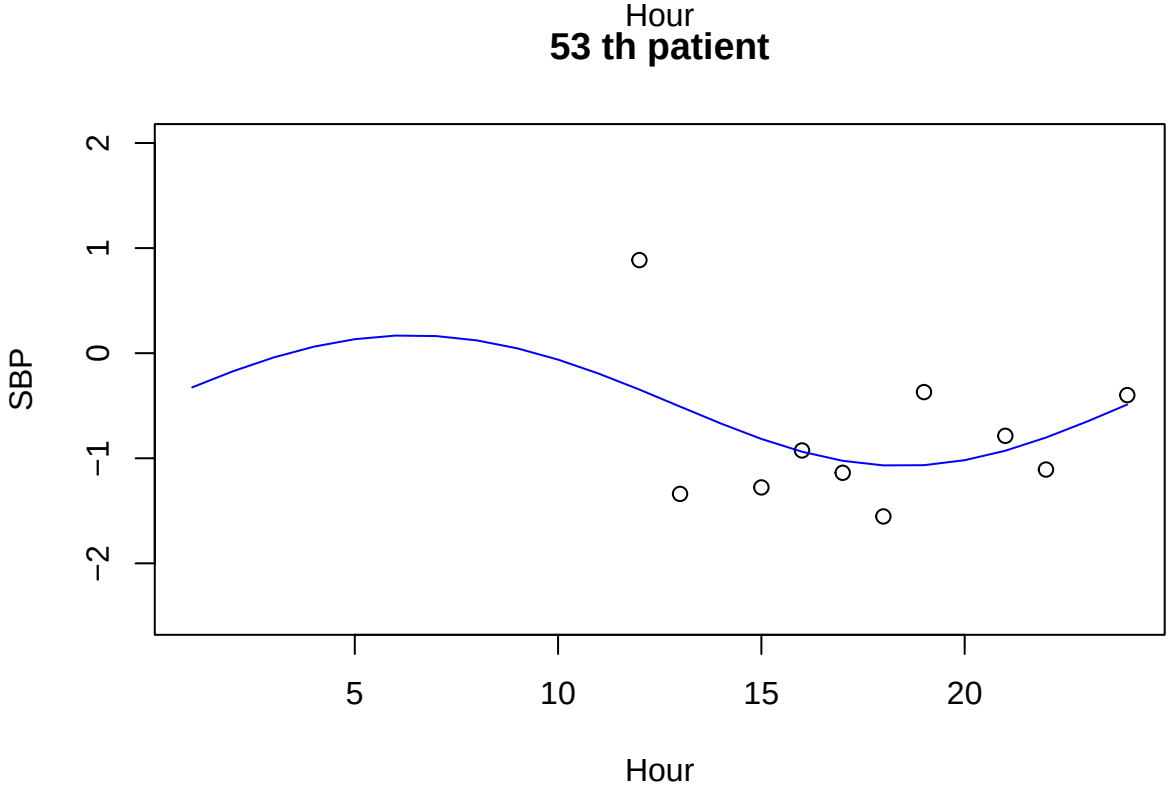
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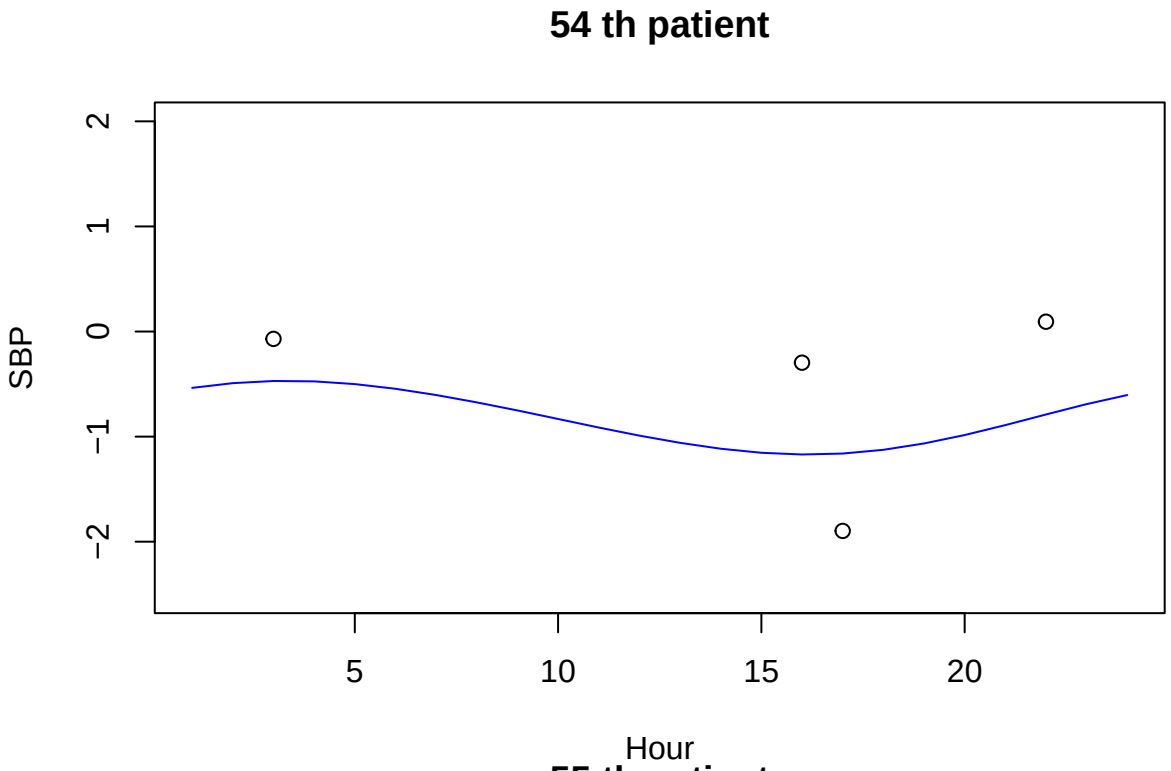
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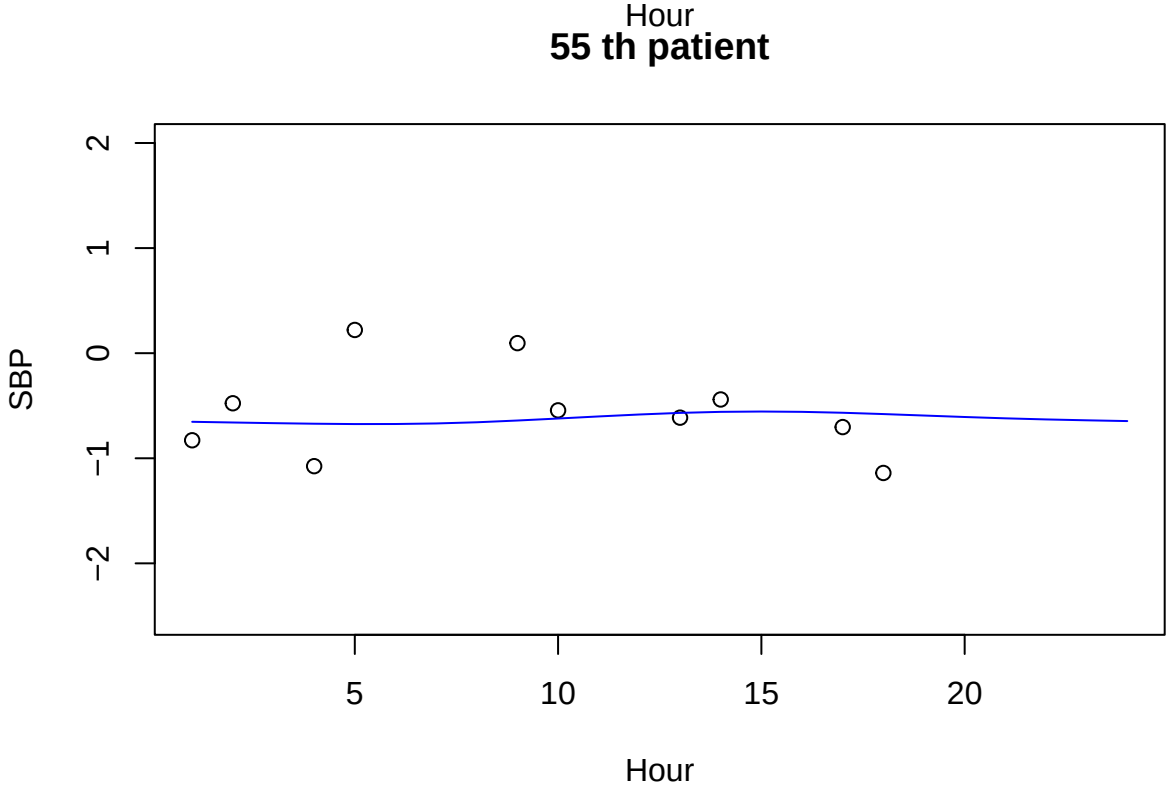
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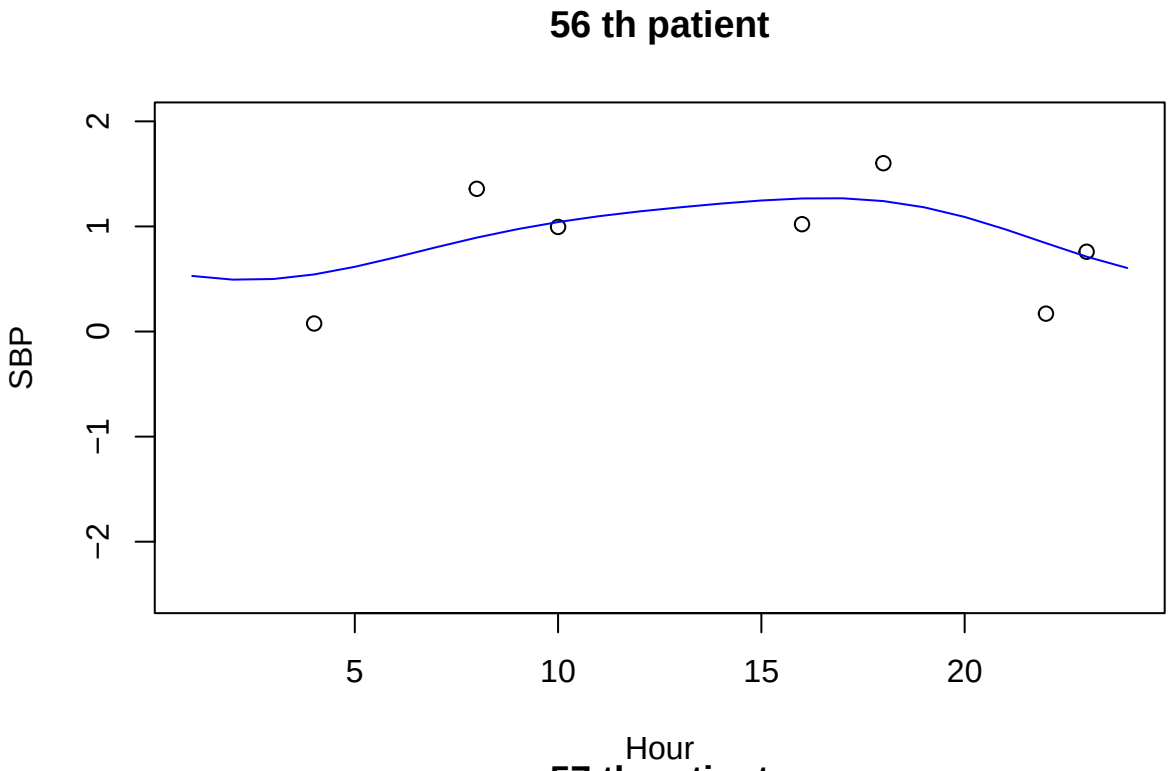
56 th patient
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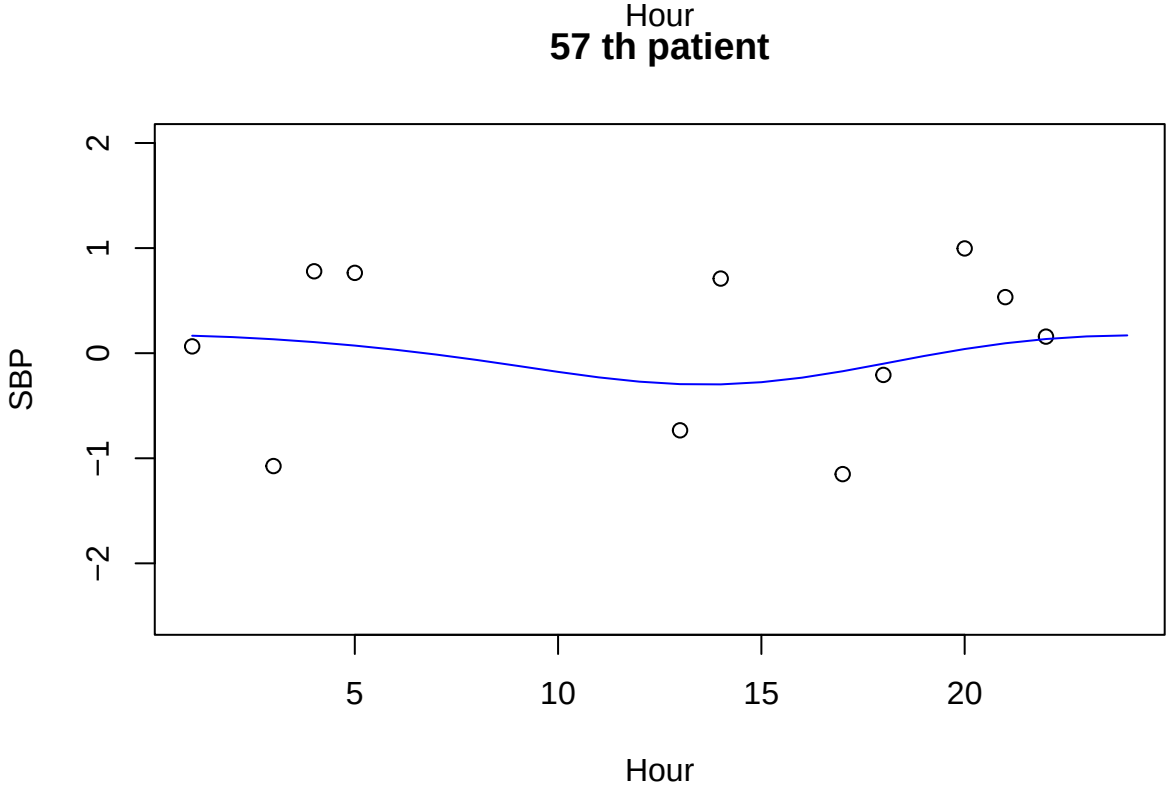
57 th patient
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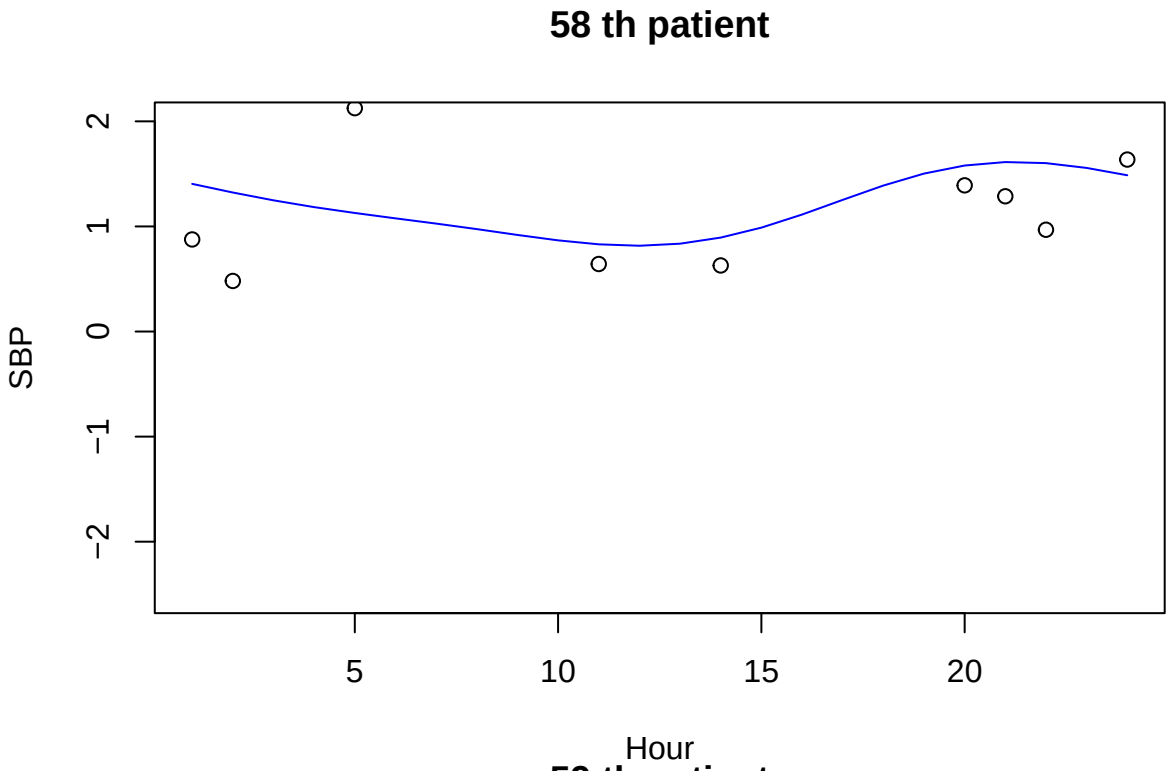
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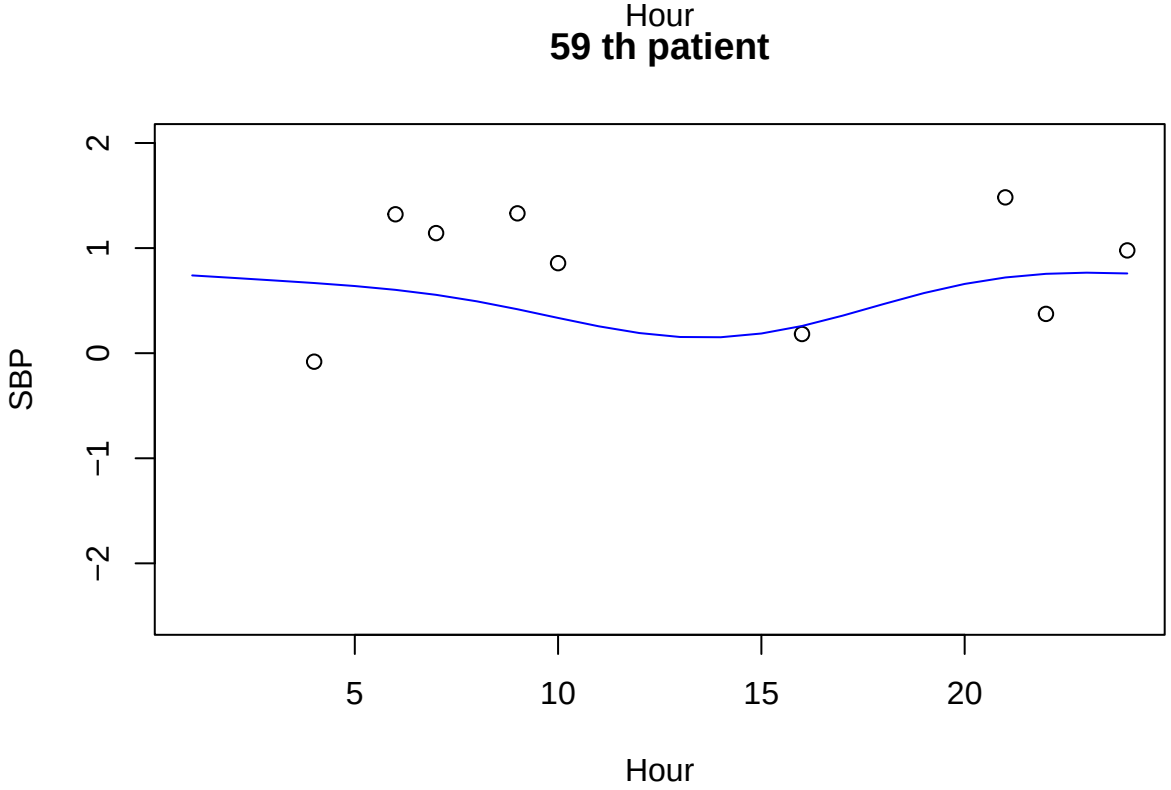
59 th patient
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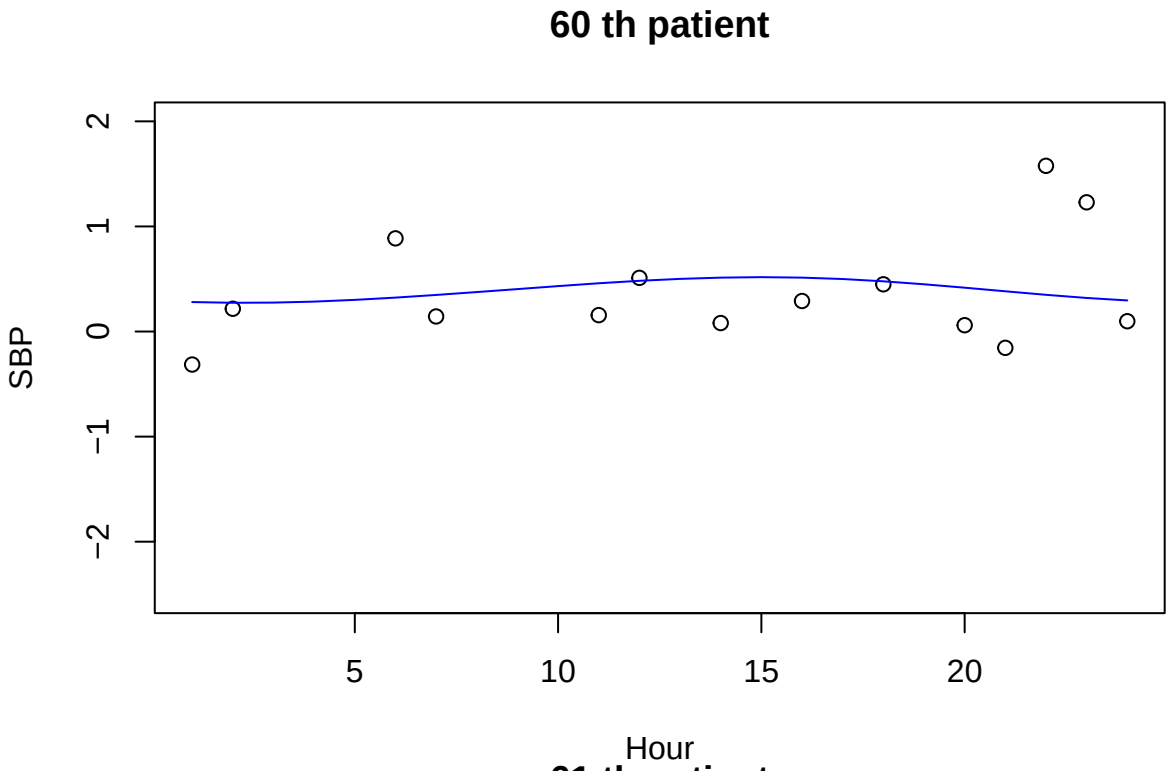
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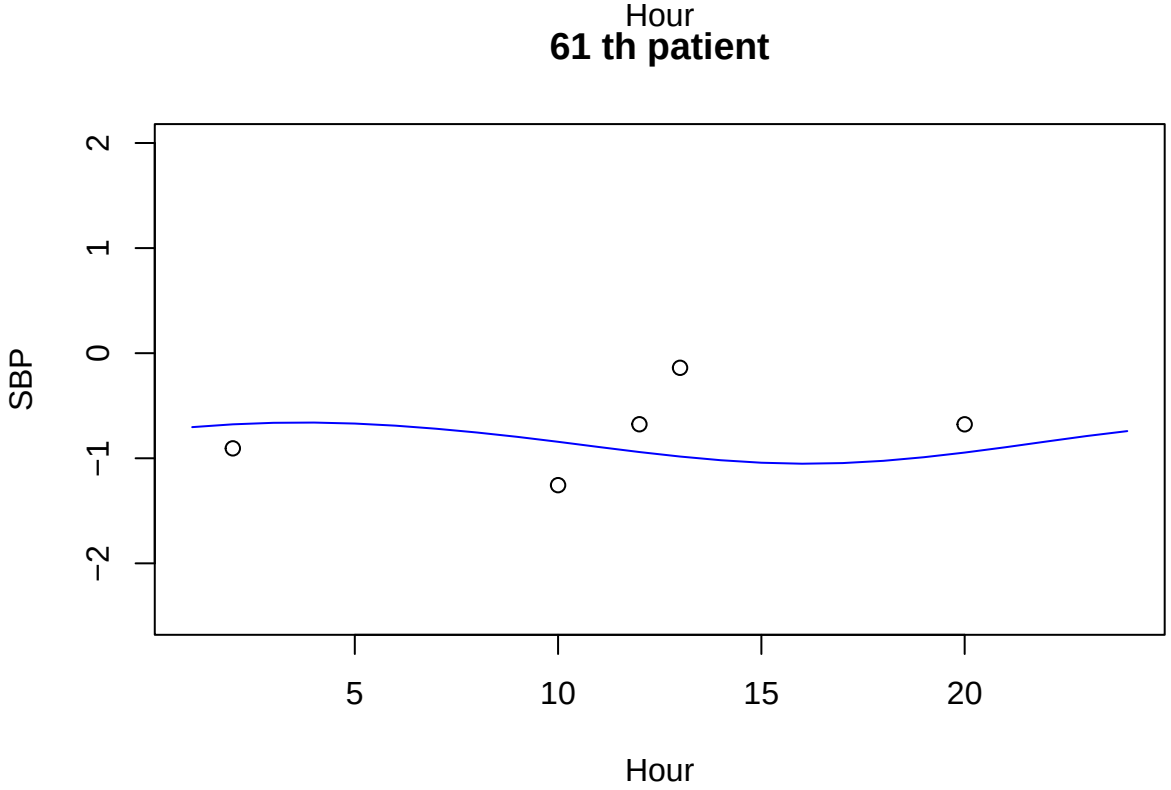
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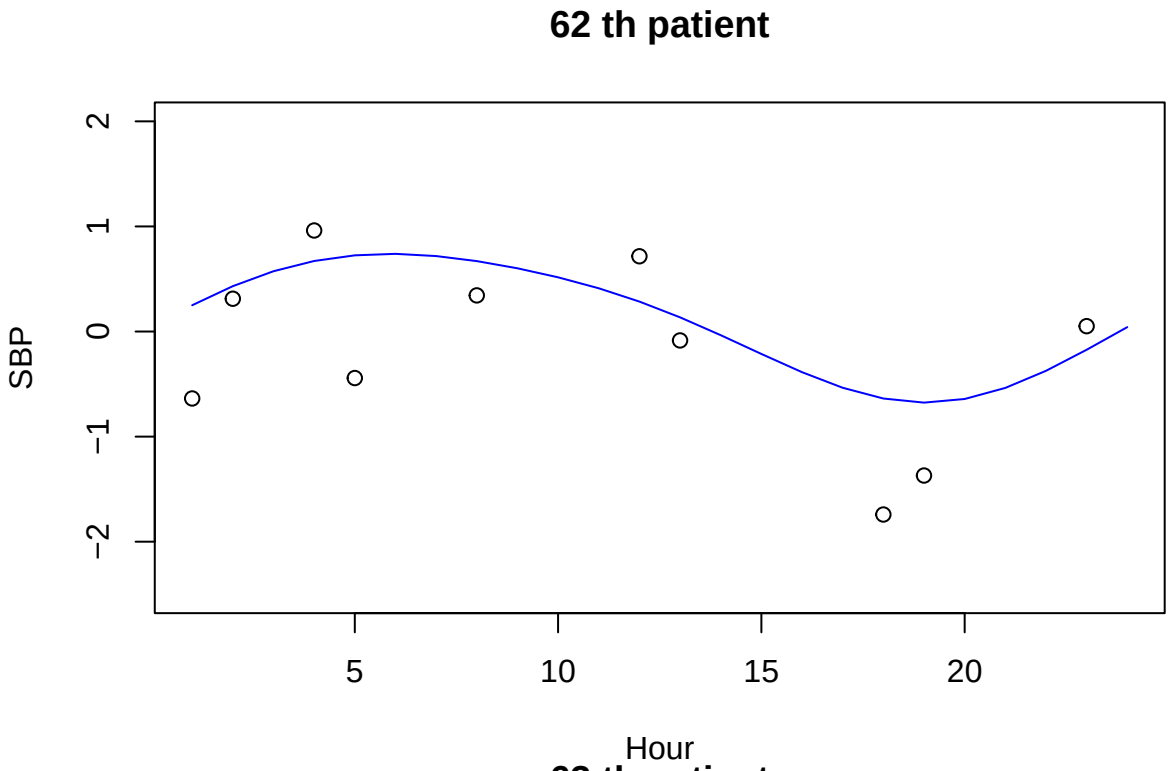
62 th patient
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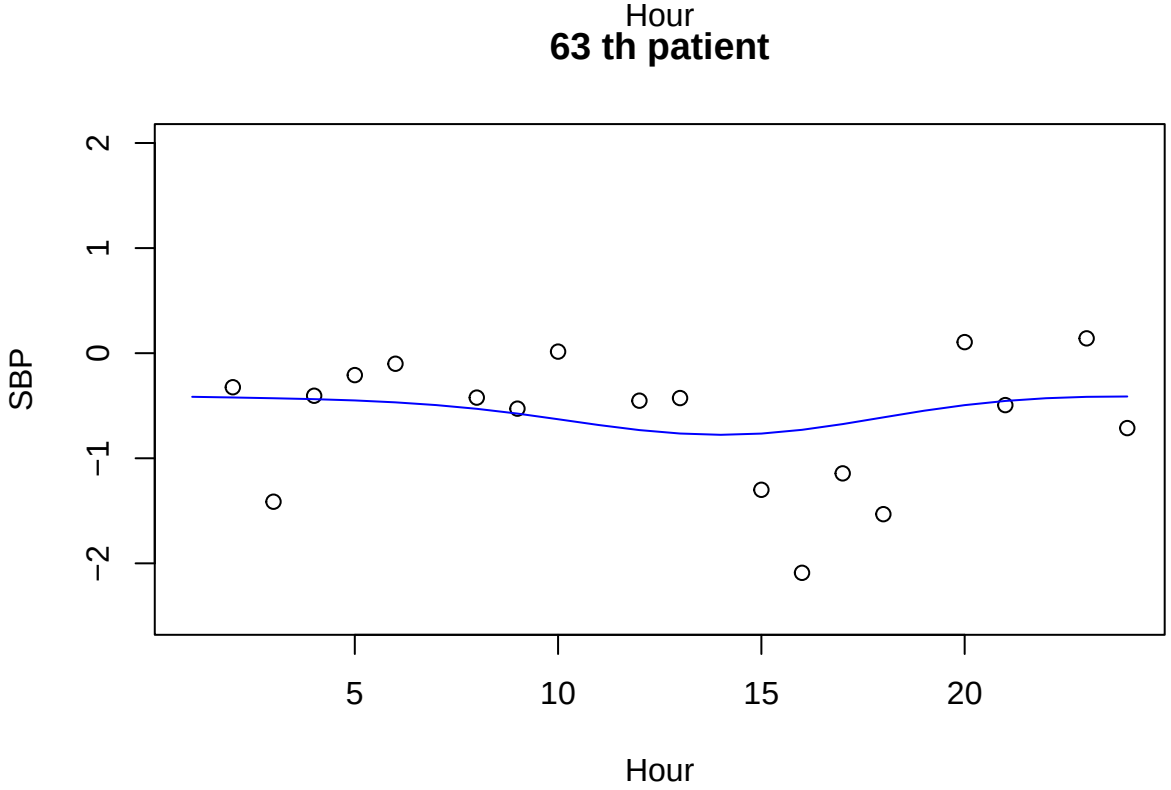
63 th patient
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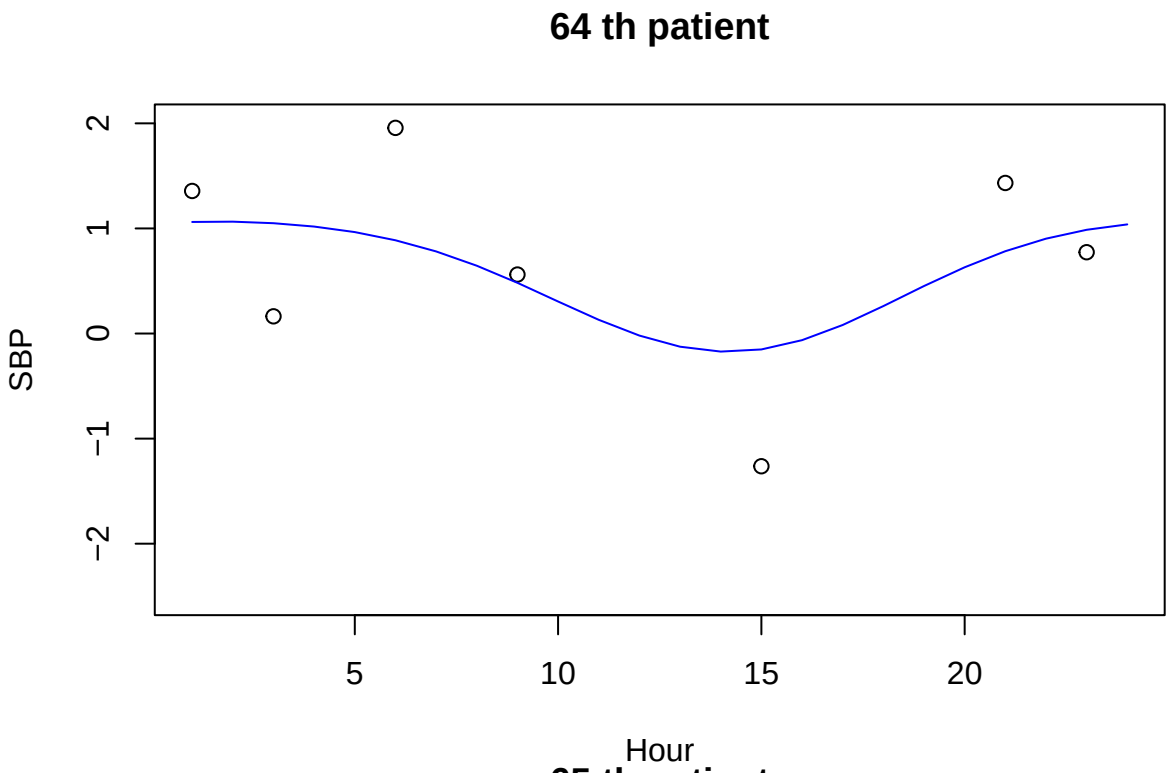
64 th patient
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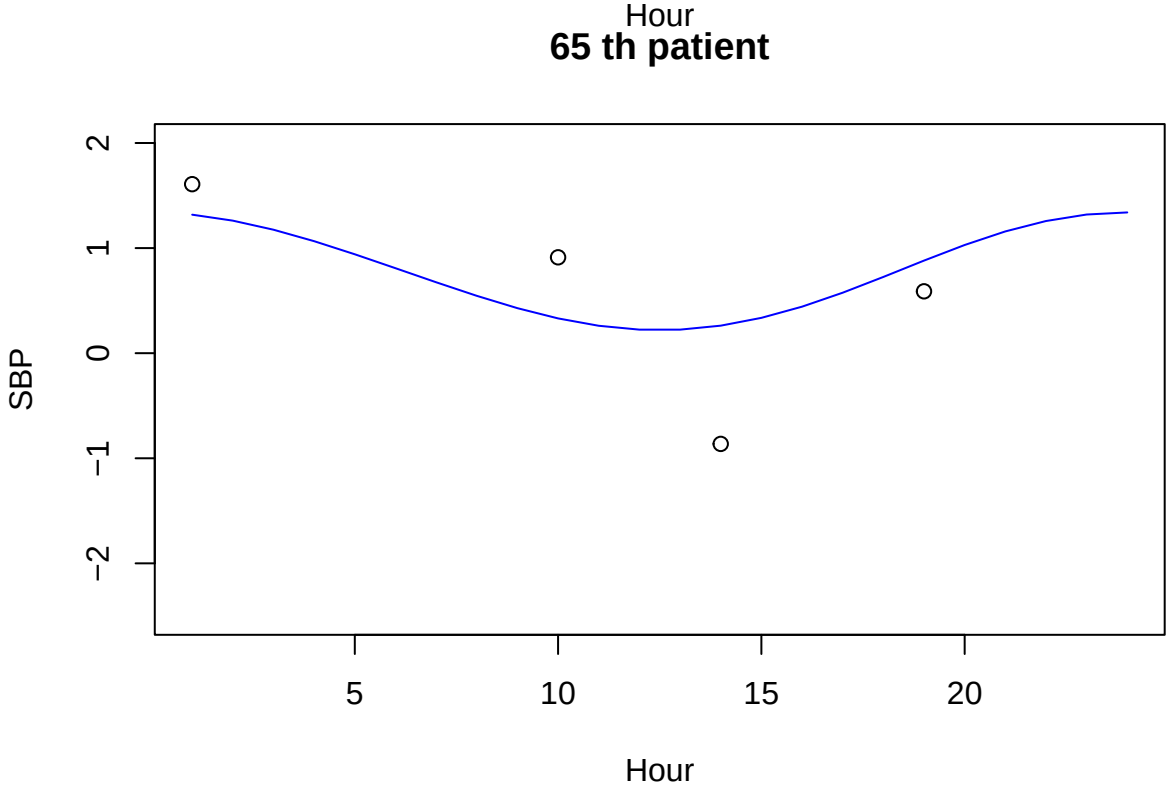
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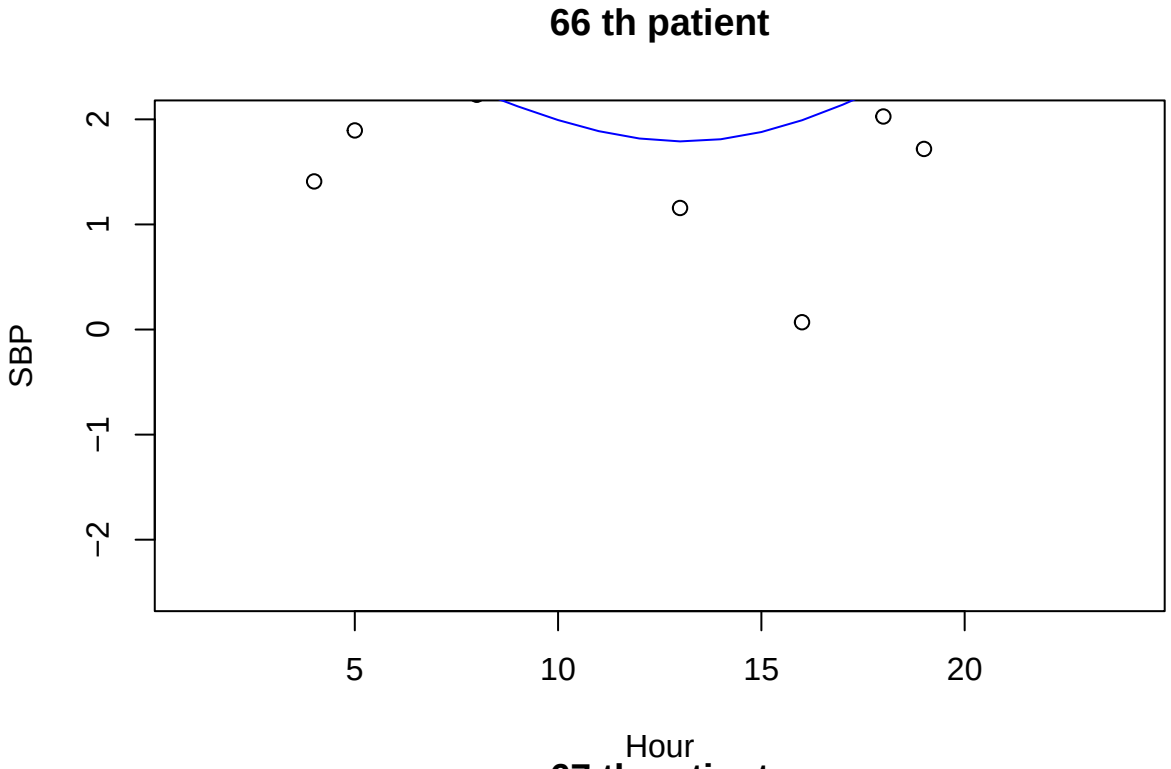
66 th patient
SBP
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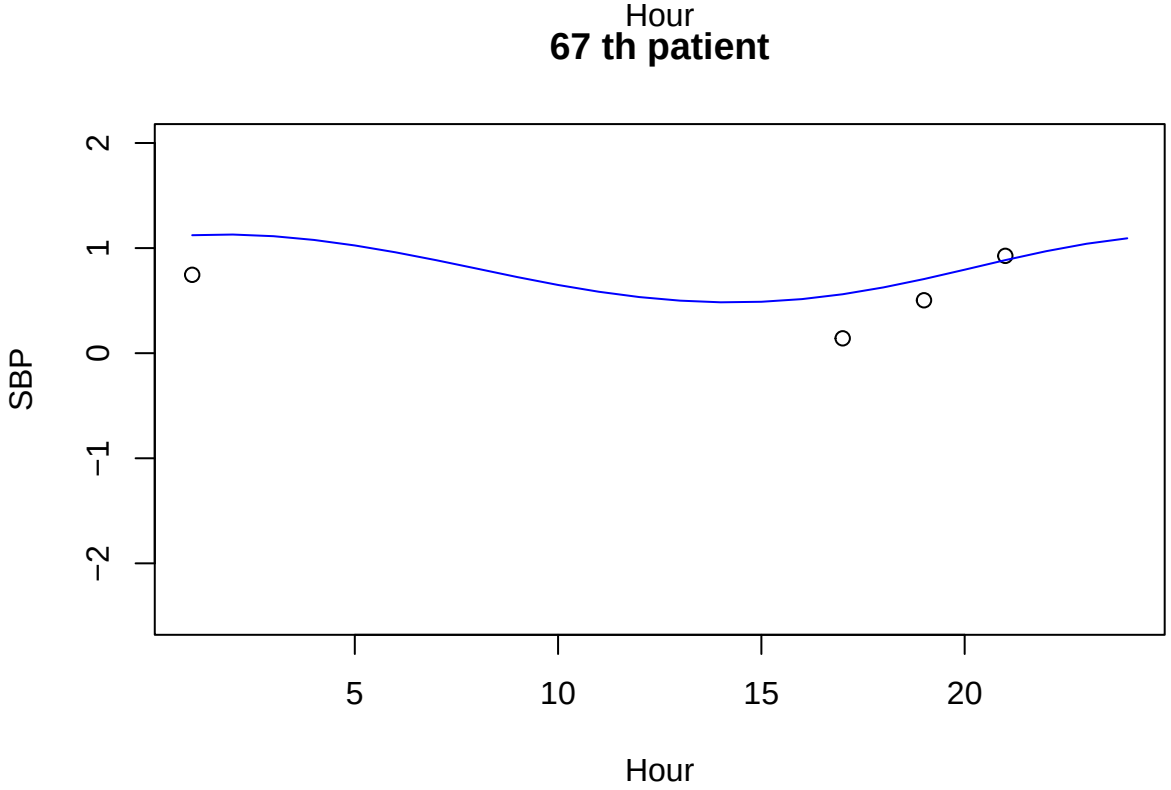
Hour


67 th patient
SBP
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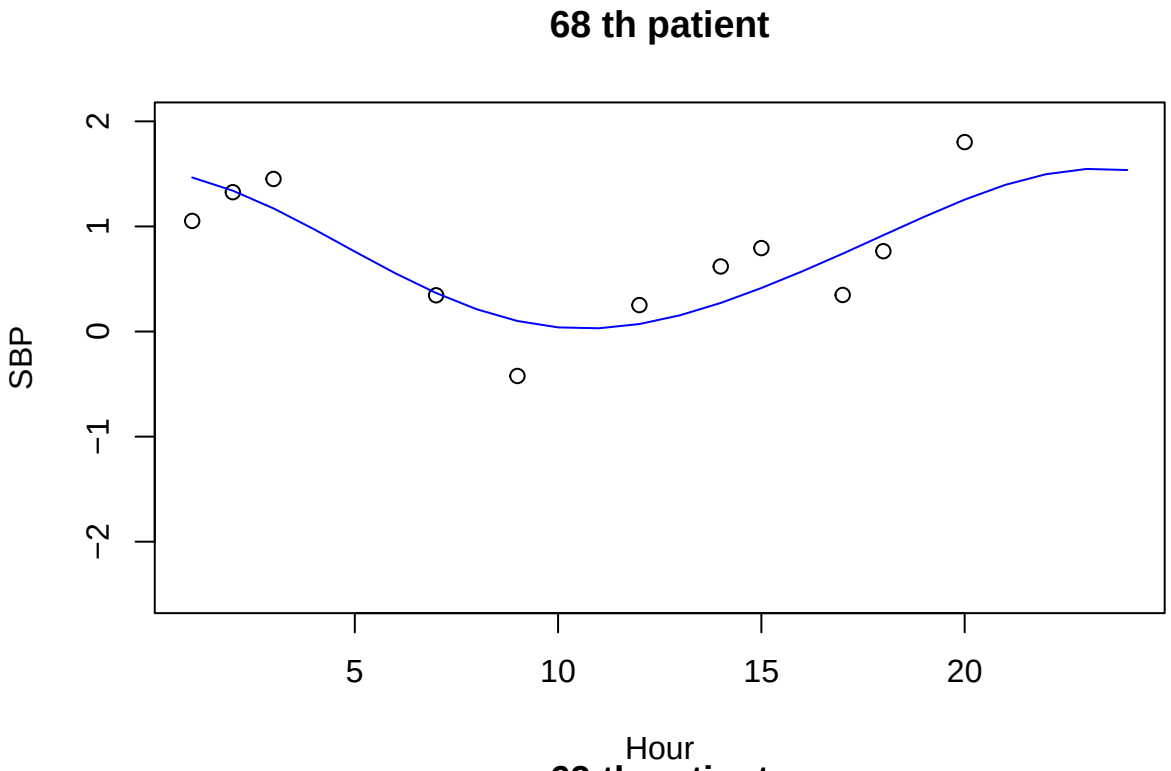
68 th patient
SBP
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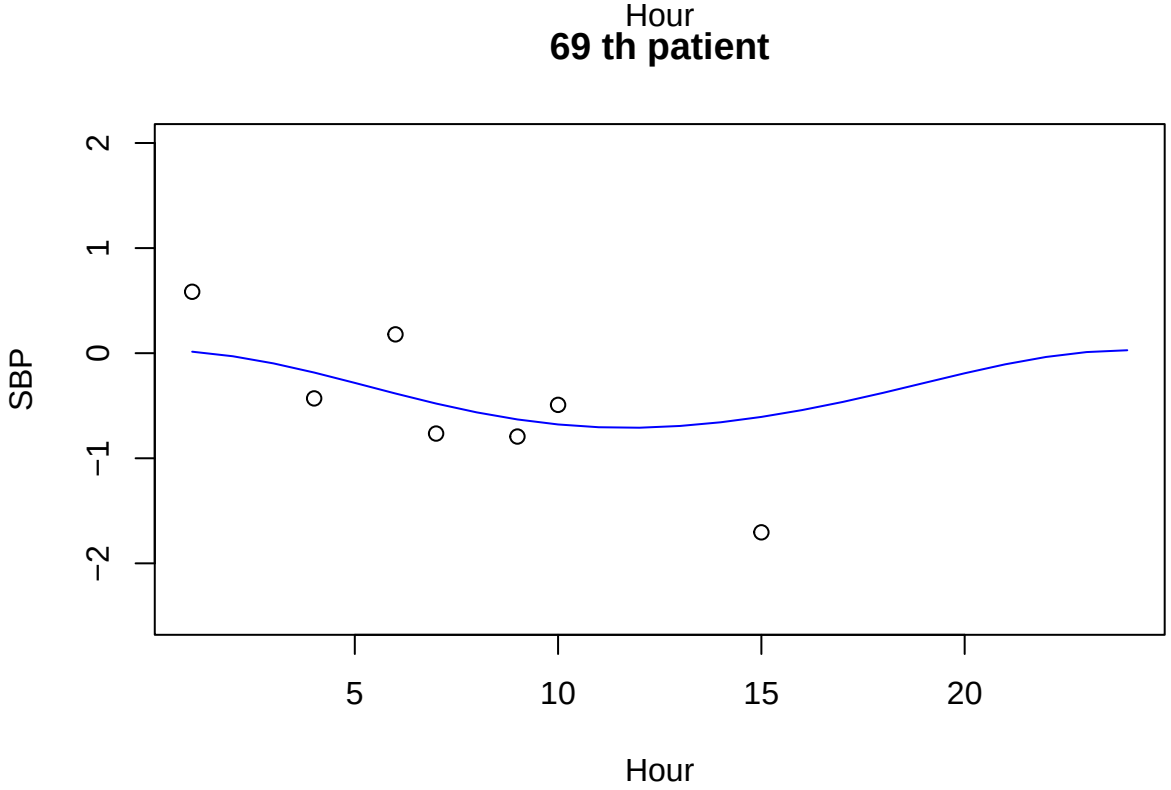
Hour


69 th patient
SBP
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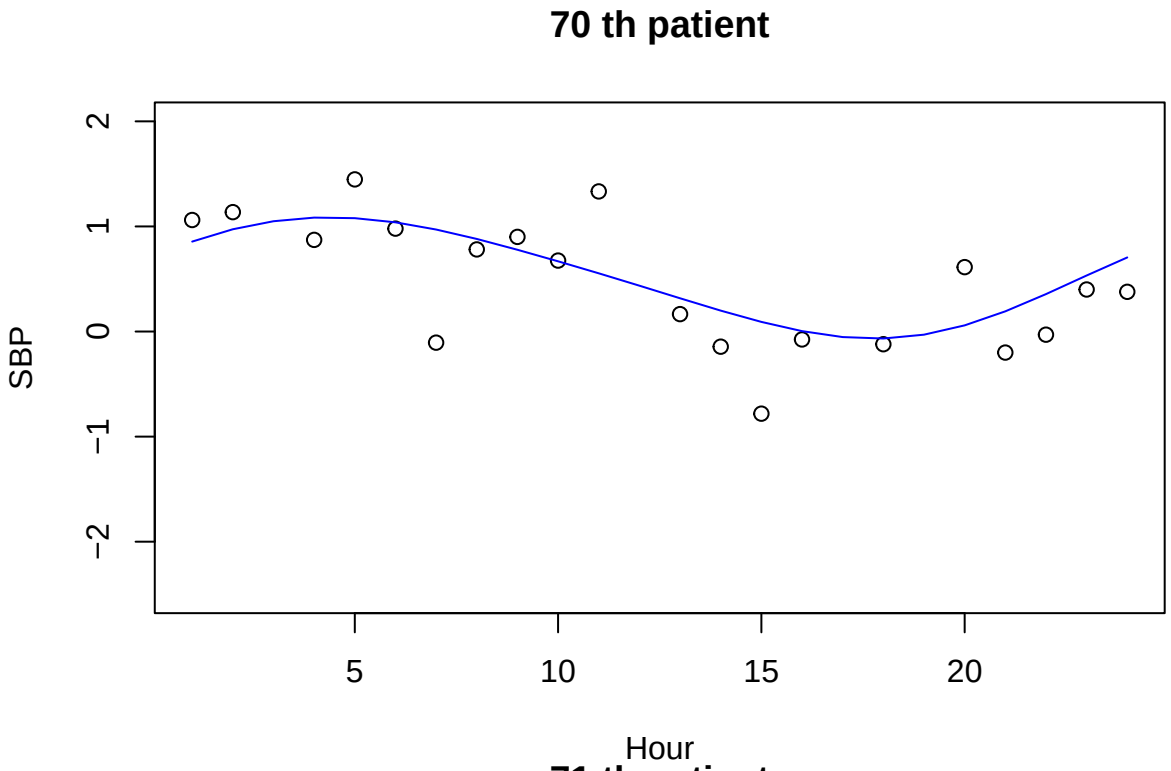
Hour


70 th patient
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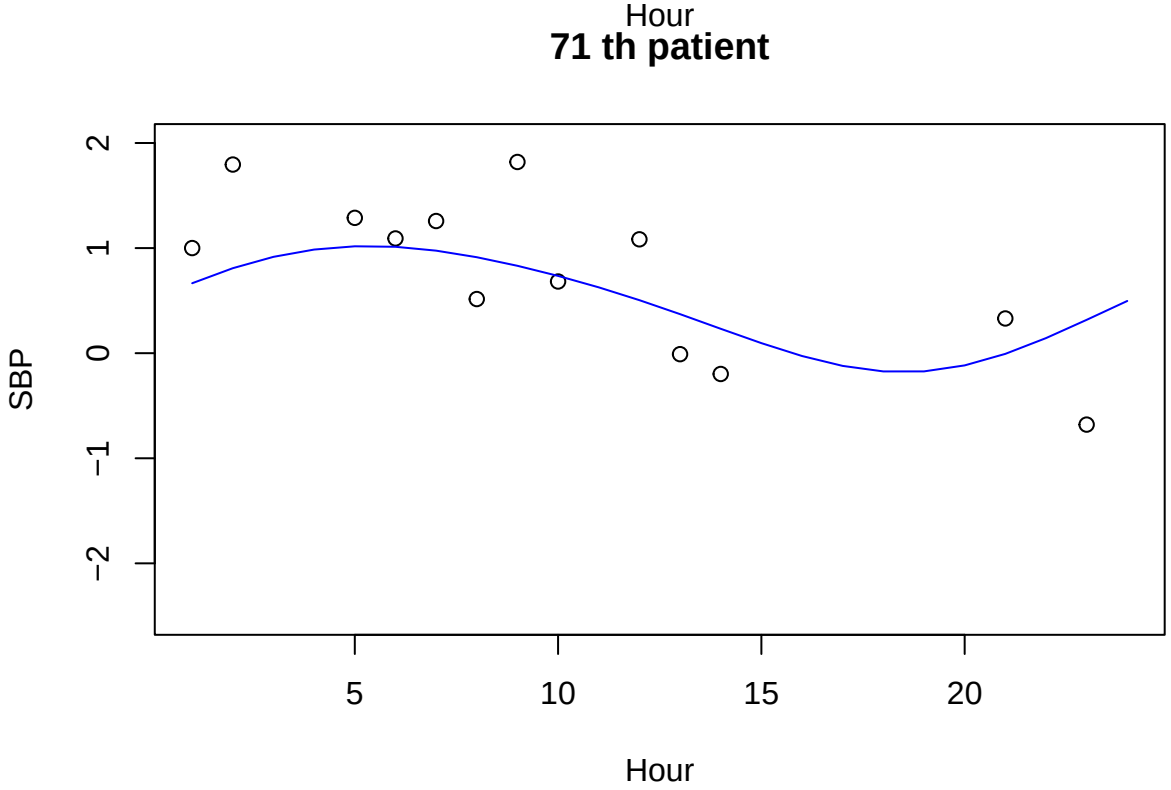
Hour


71 th patient
SBP
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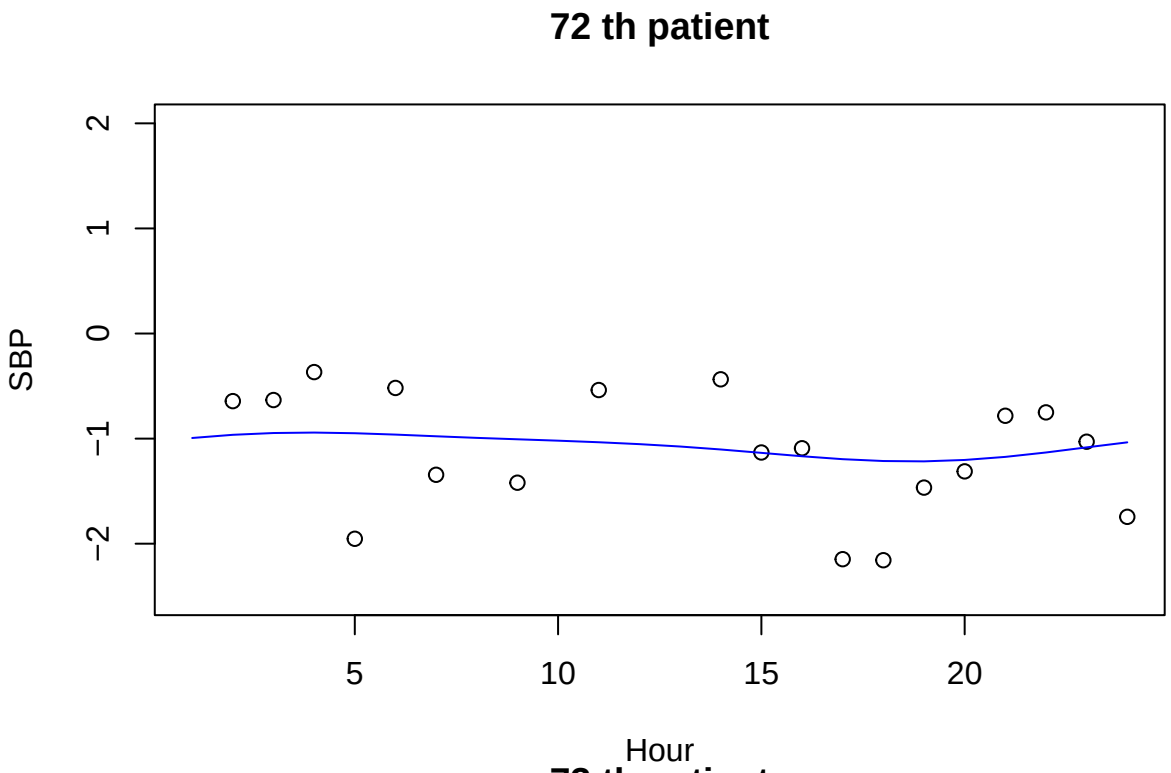
Hour


72 th patient
SBP
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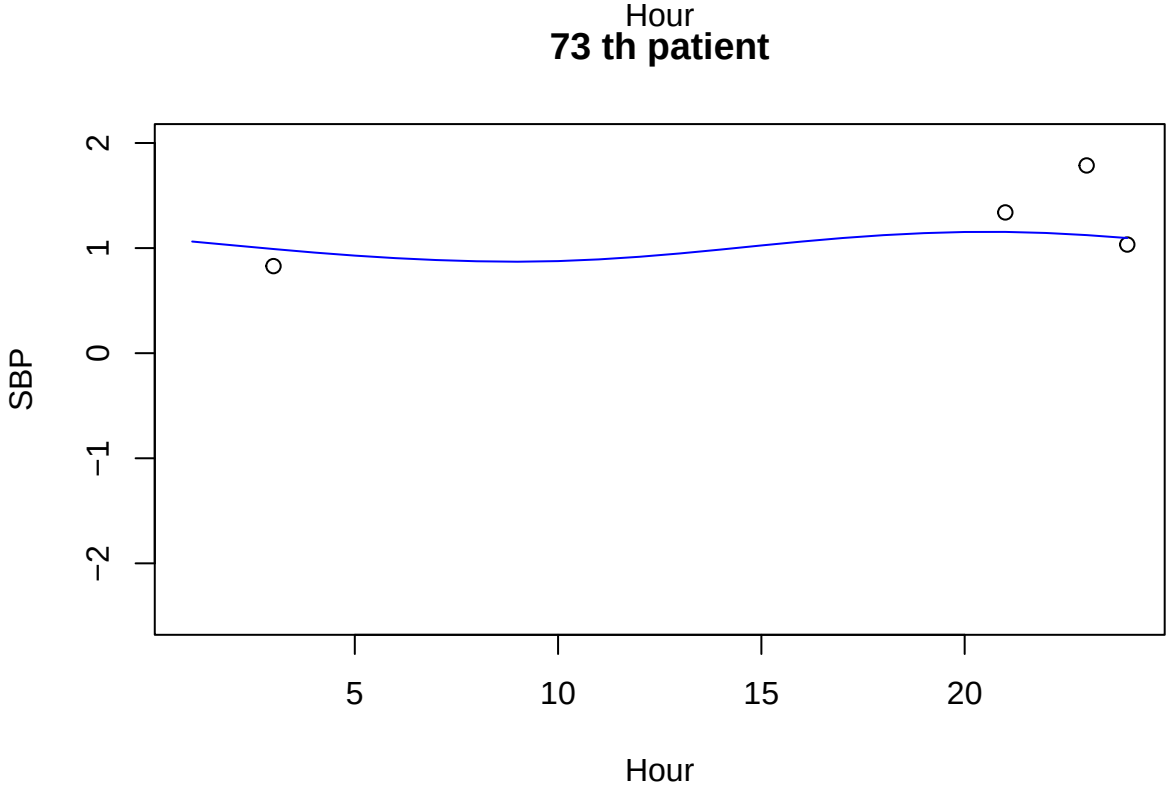
Hour


73 th patient
SBP
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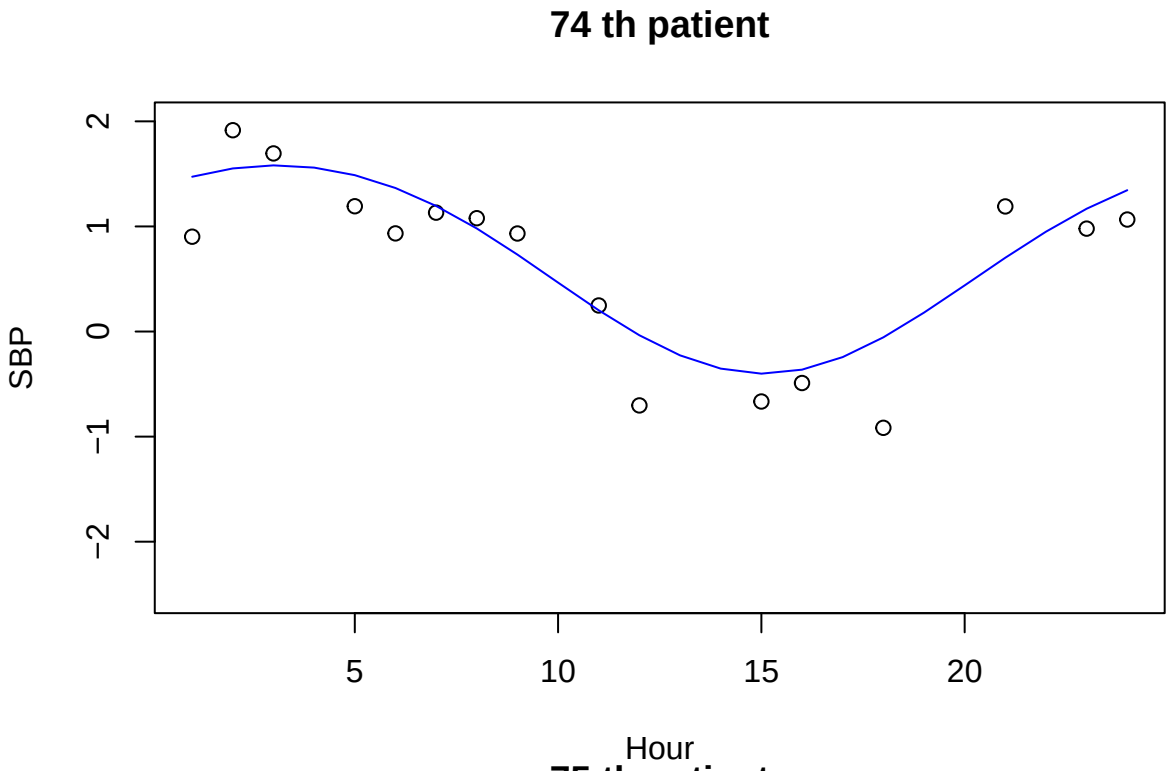
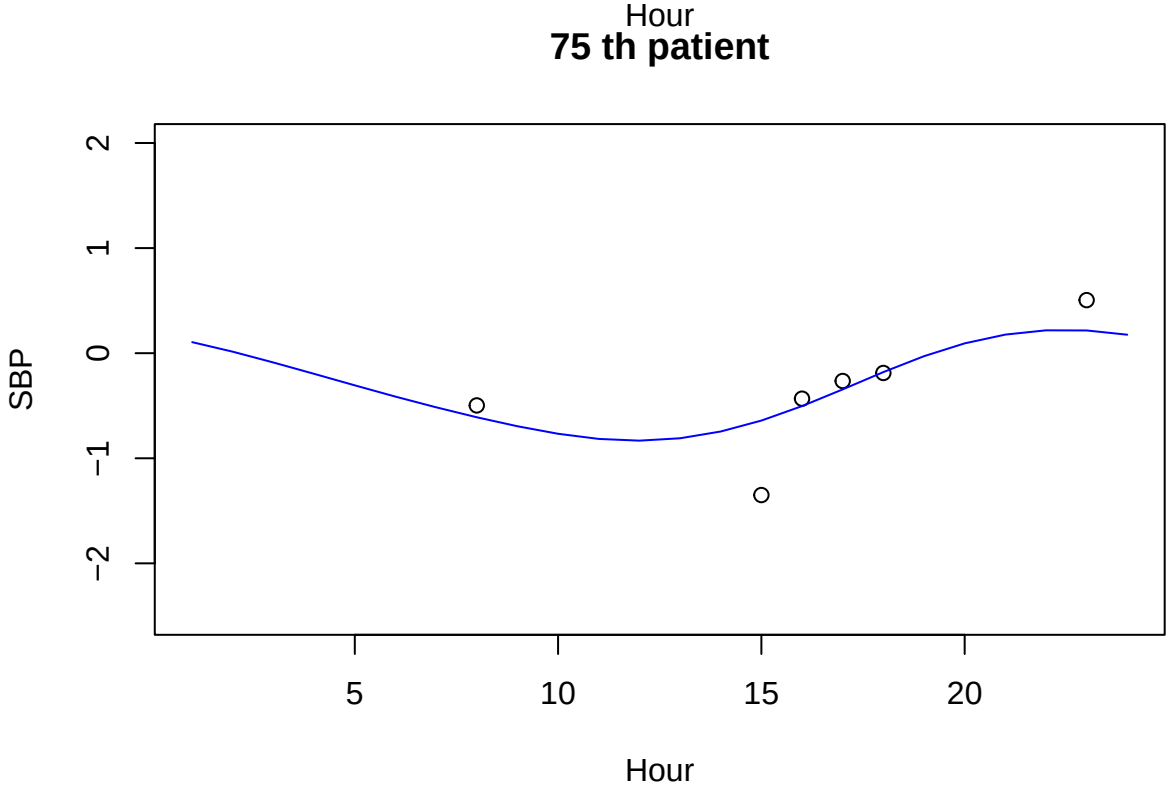
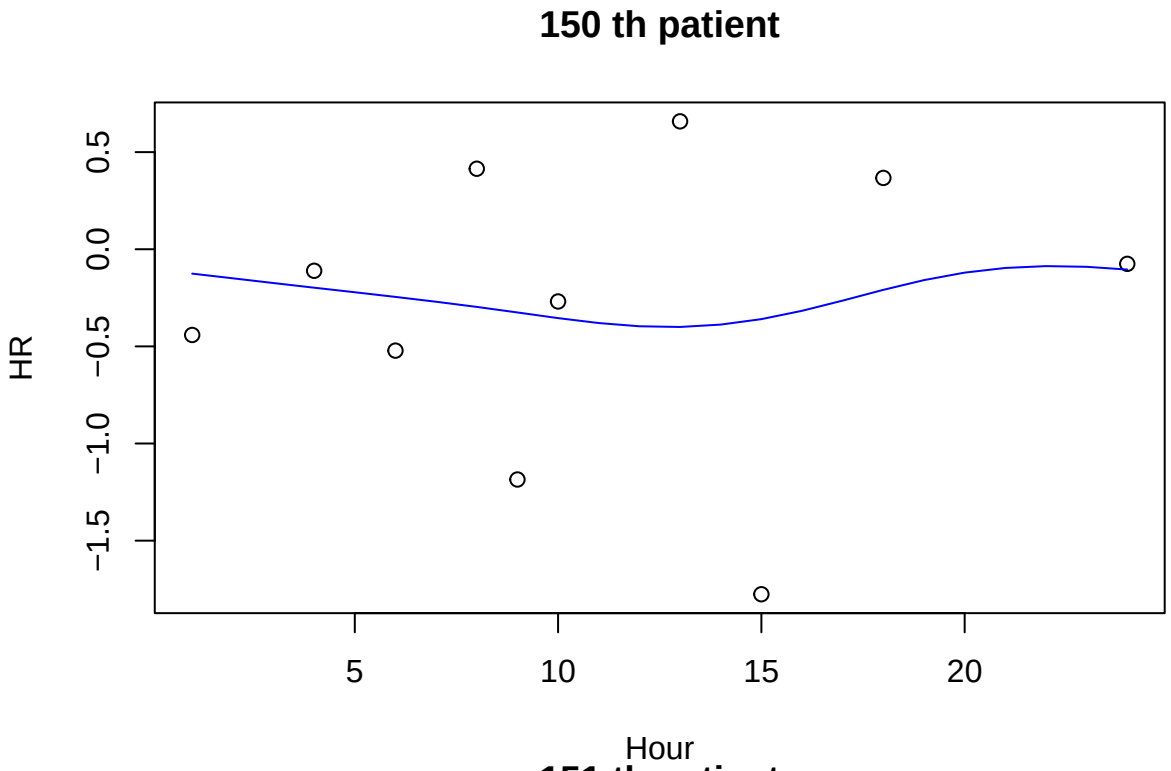
Hour






```
# Plot Estimated Curves for HR
for (i in 150:175){
  plot(synthetic_dat@data[ , 3, i], main=paste(i,"th patient"), xlab="Hour", ylab="HR")
  lines(res$est[ , 3, i], col="blue")
}
```


150 th patient
HR
0.5
0.0
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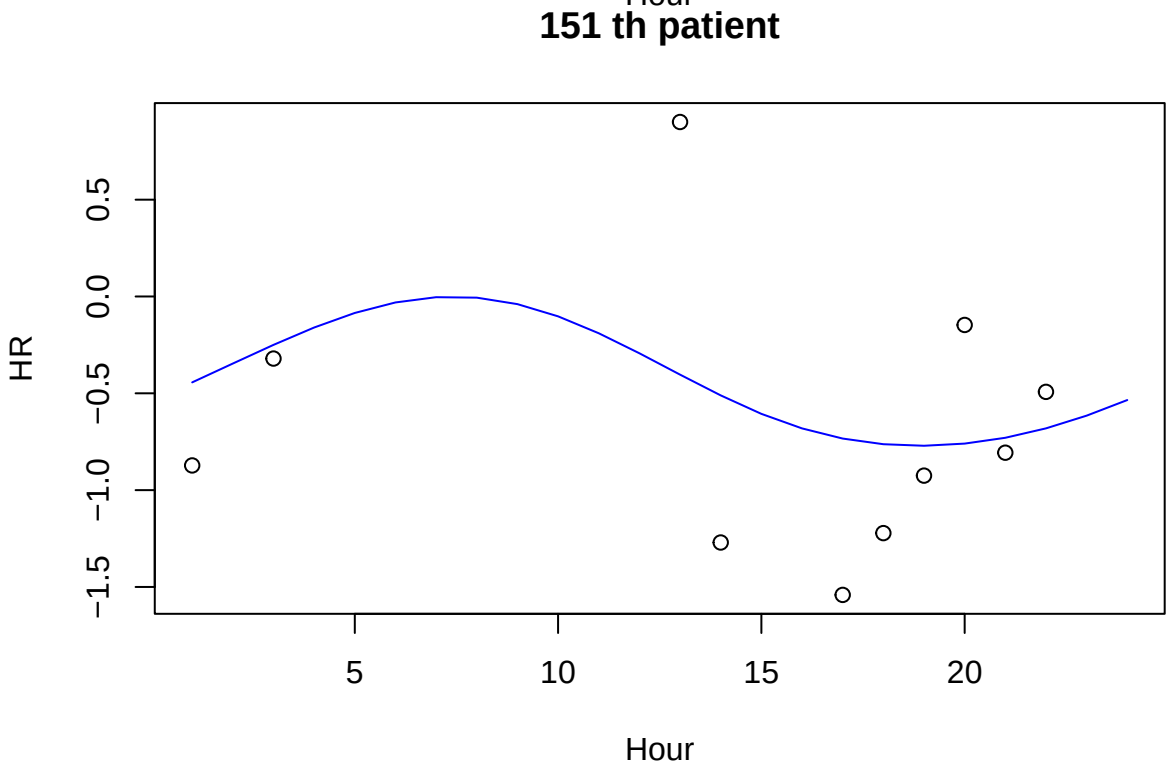
−1.0
−1.5
5
10
15
20
Hour


151 th patient
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0.5
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−0.5
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−1.5
5
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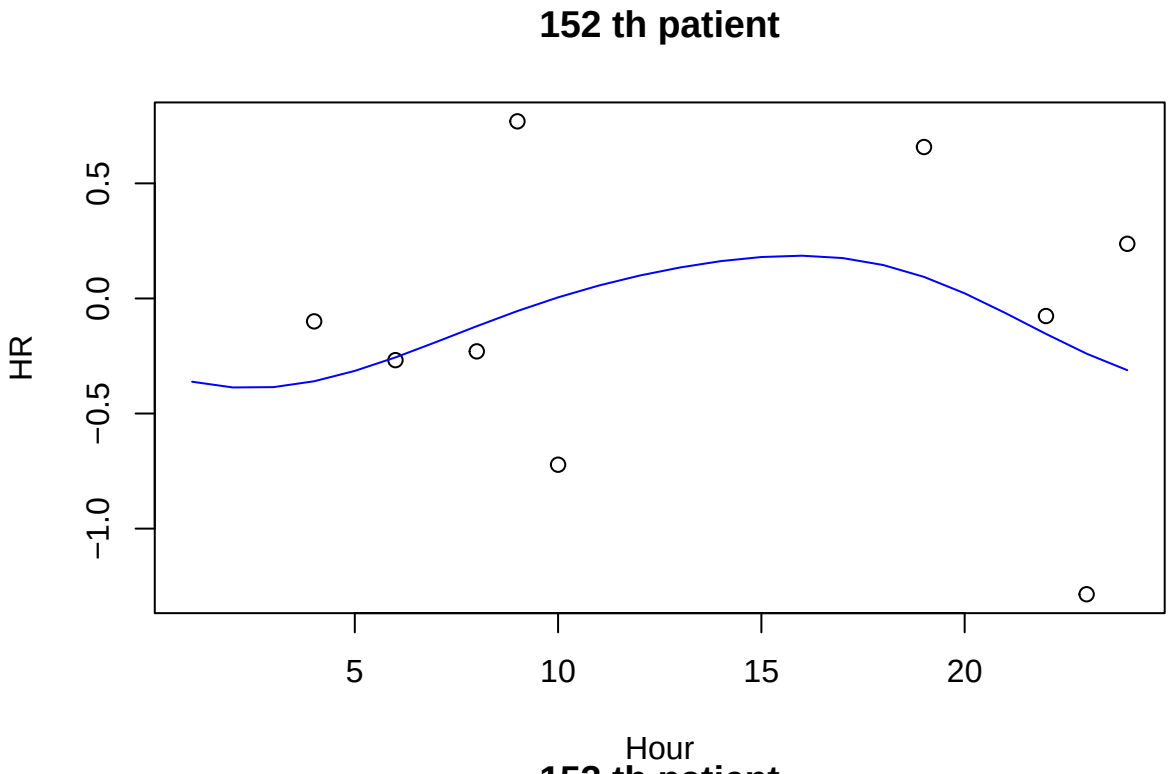
15
20
Hour


152 th patient
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0.5
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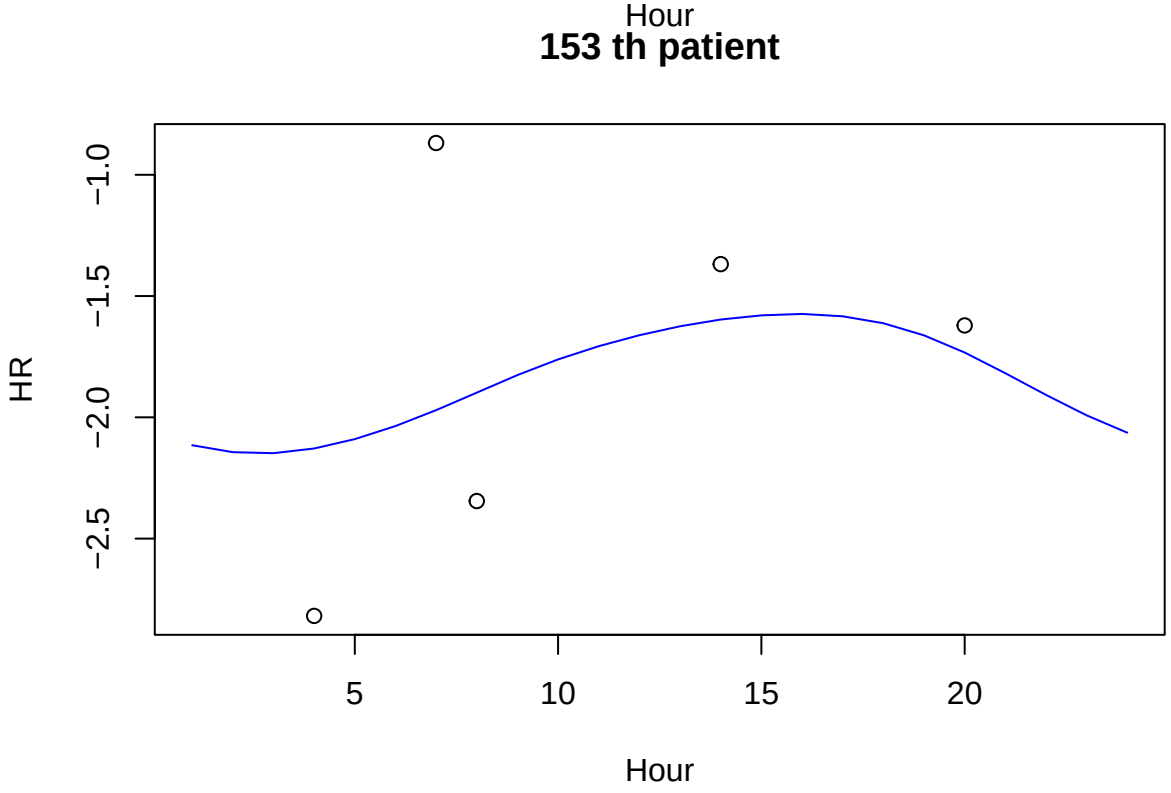
10
15
20
Hour


153 th patient
HR
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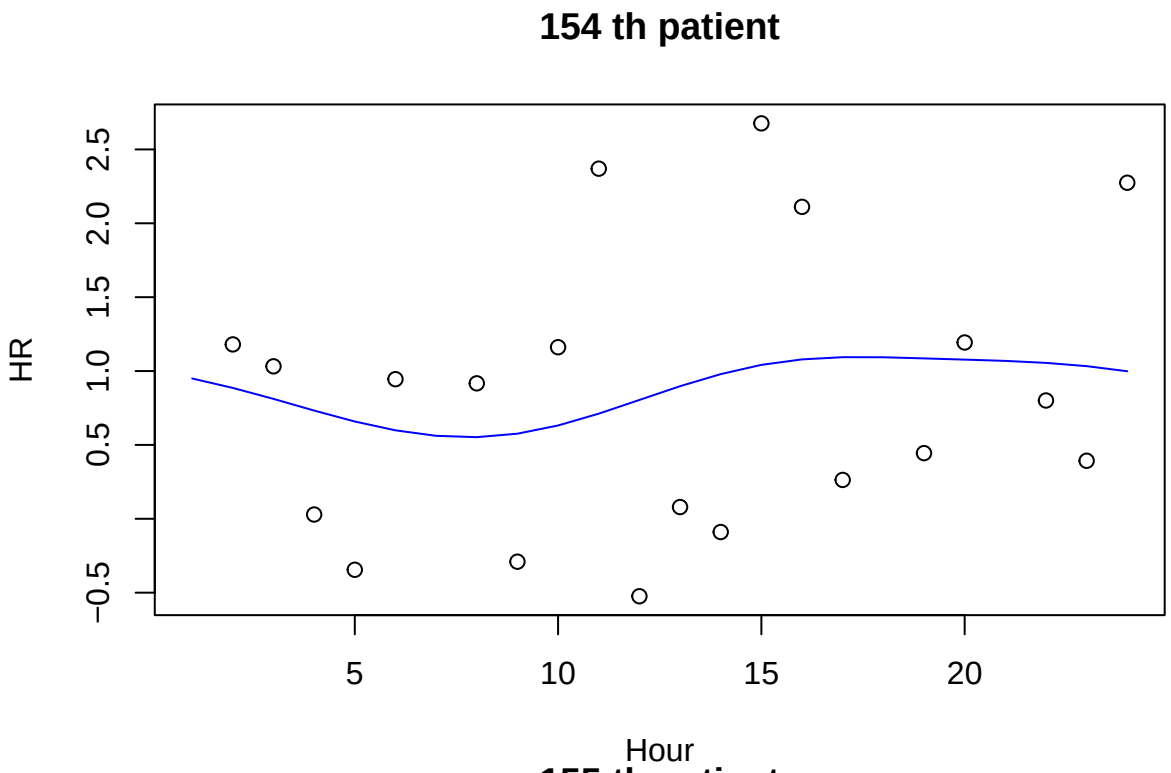
20
Hour


154 th patient
HR
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1.5
2.0
2.5
5
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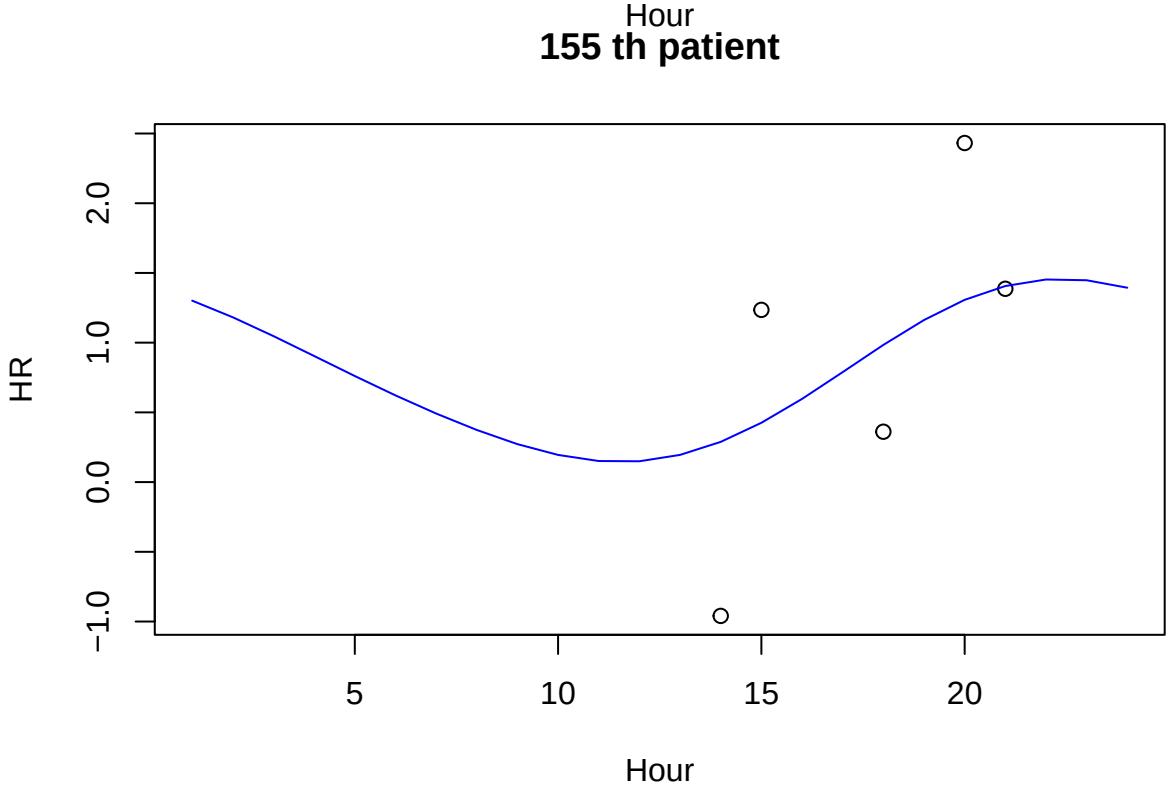
15
20
Hour


155 th patient
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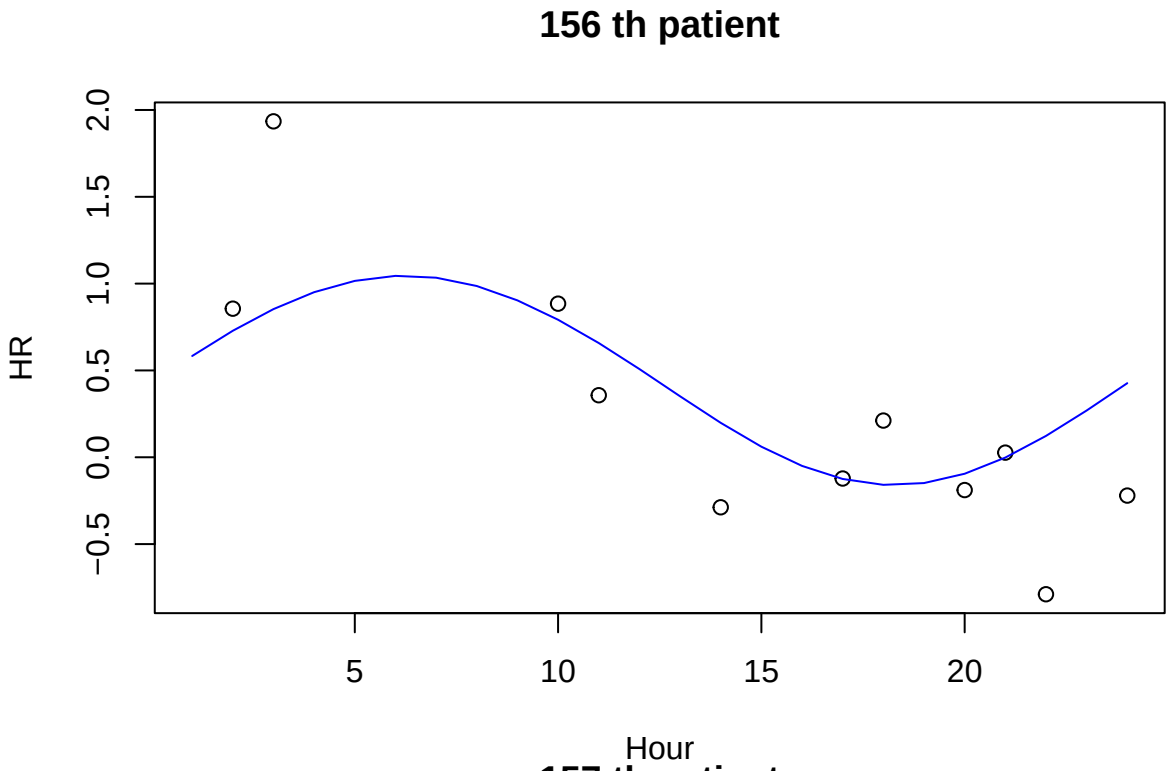
Hour


156 th patient
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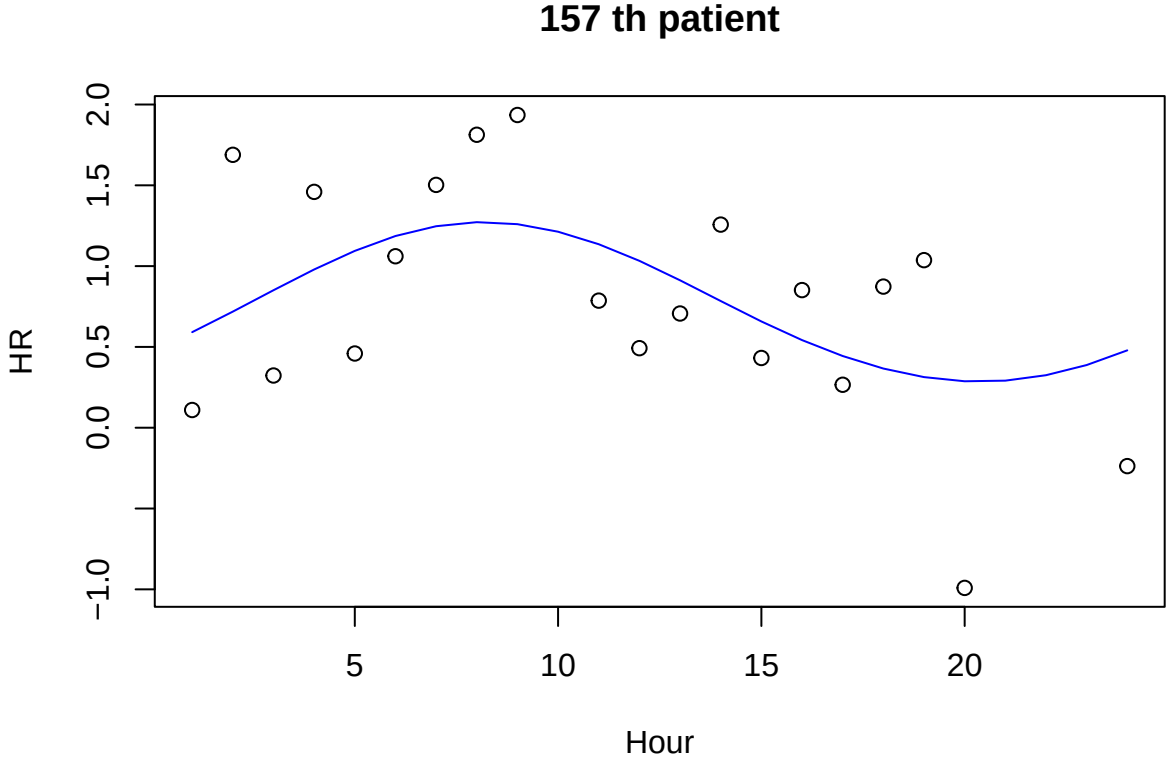
Hour


157 th patient
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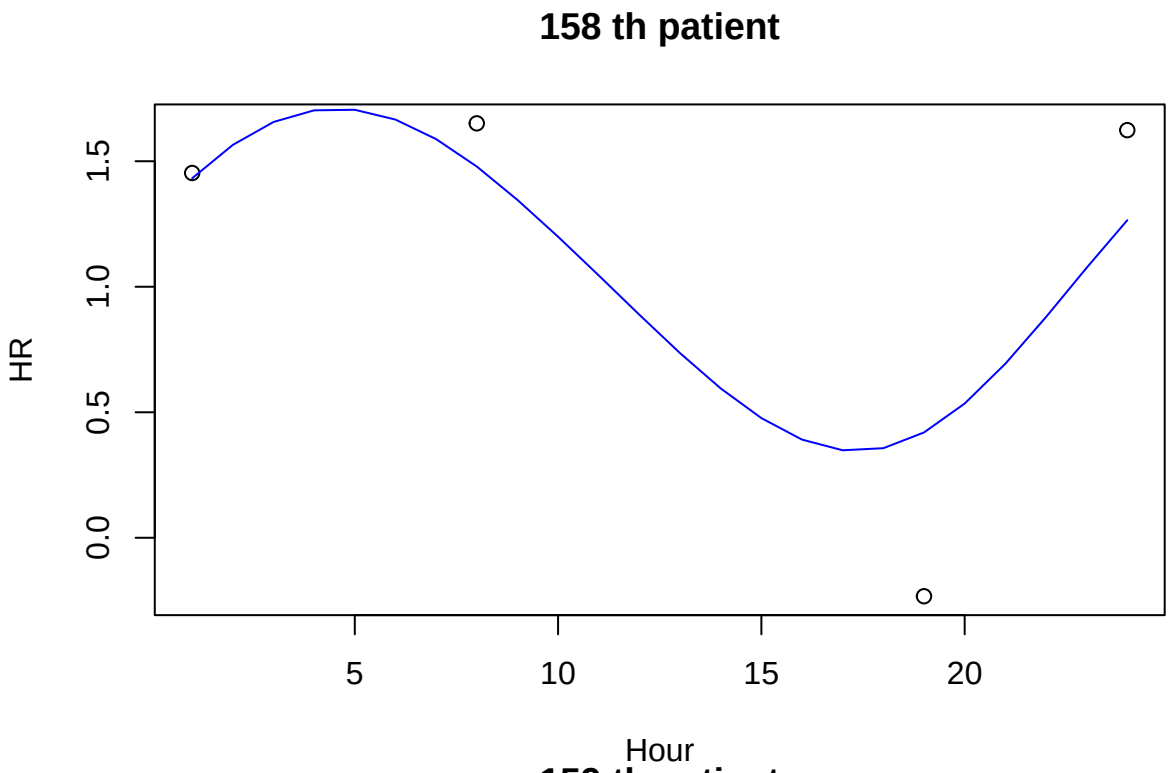
Hour


158 th patient
HR
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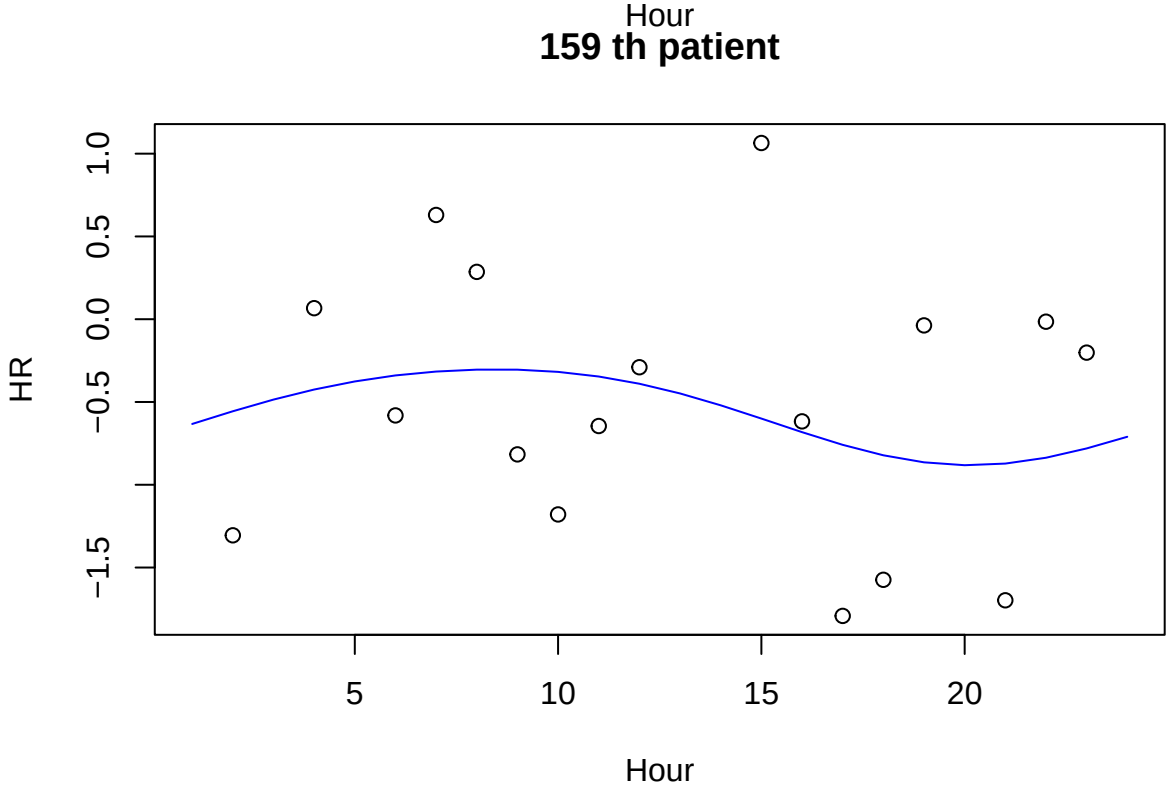
Hour


159 th patient
HR
−1.5
−0.5
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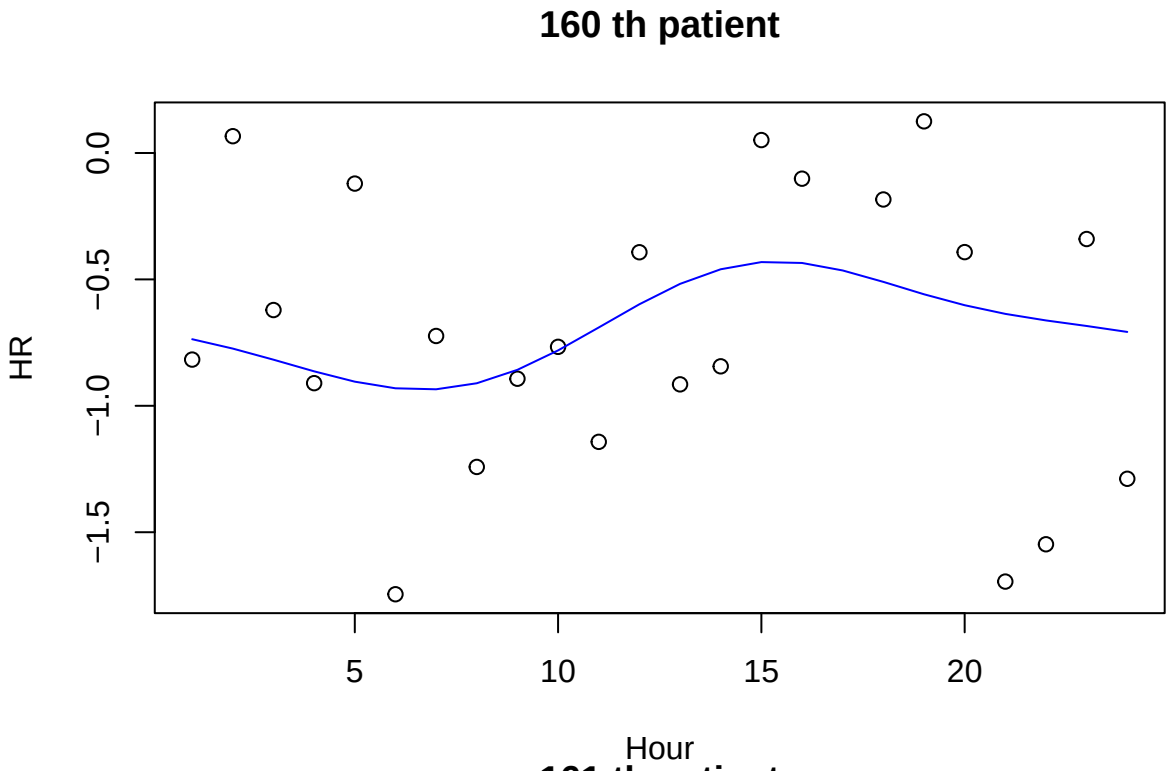
Hour


160 th patient
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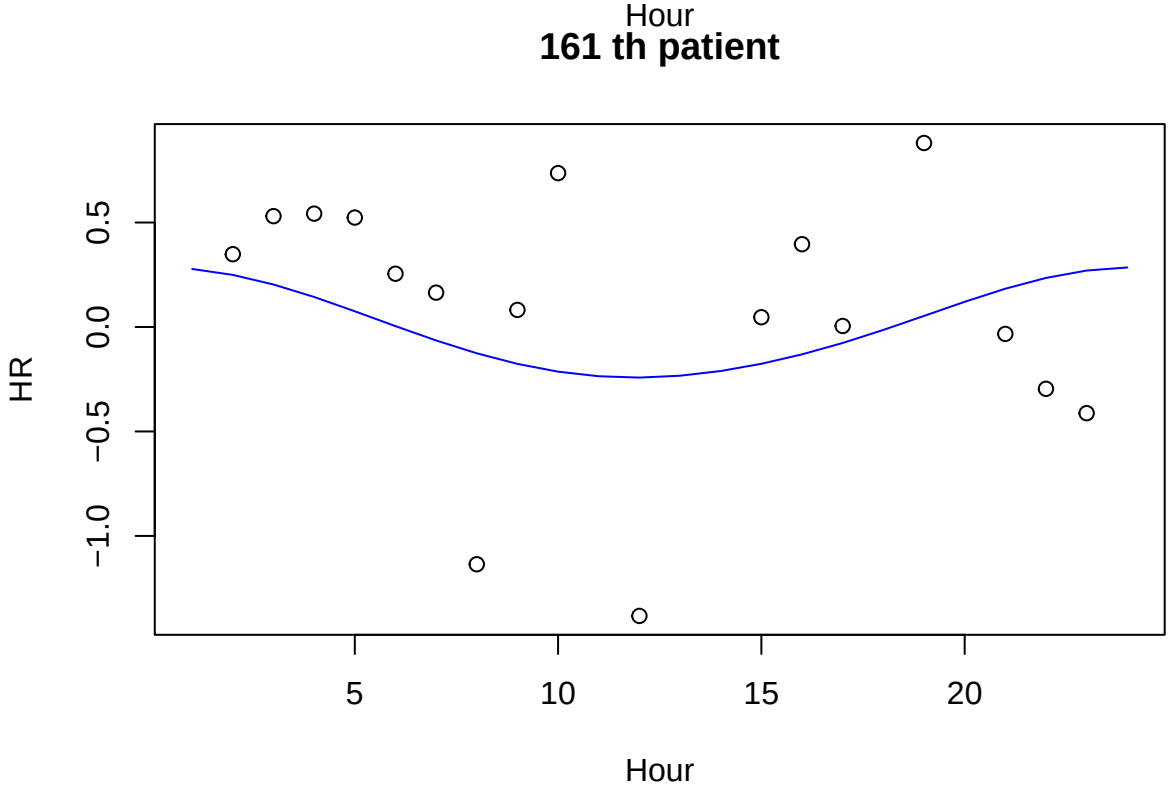
Hour


161 th patient
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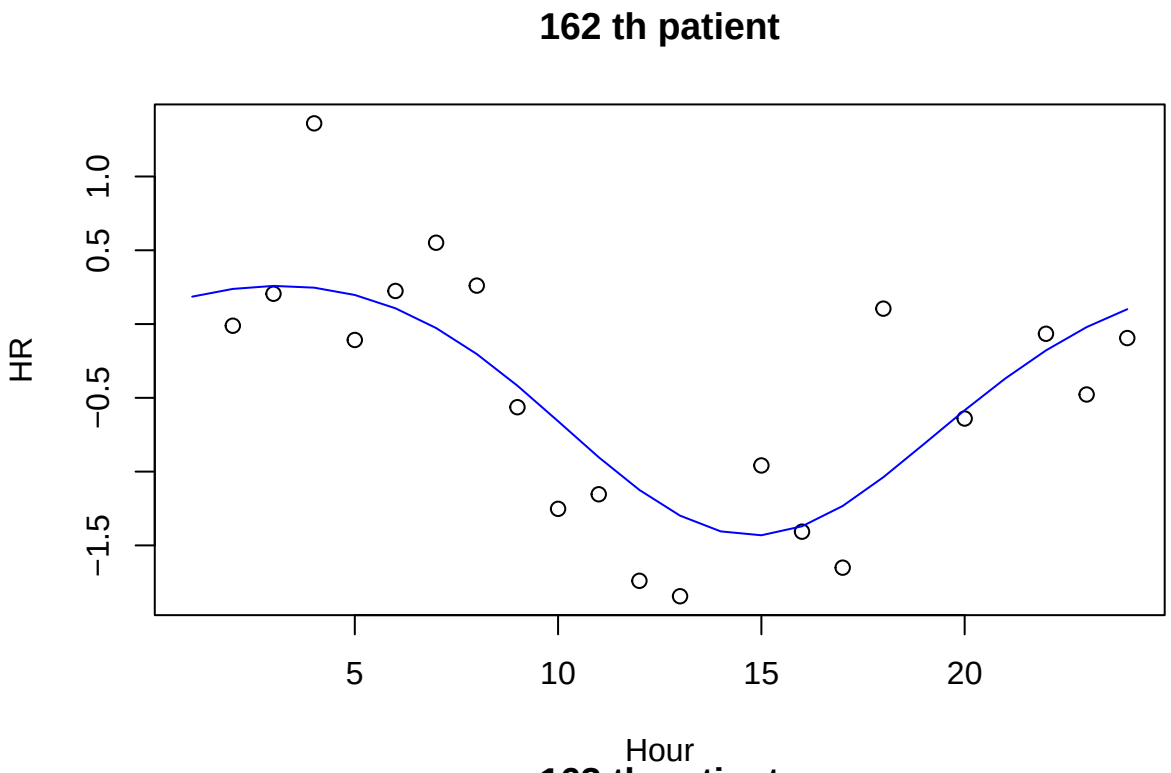
Hour


162 th patient
HR
1.0
0.5
−0.5
−1.5
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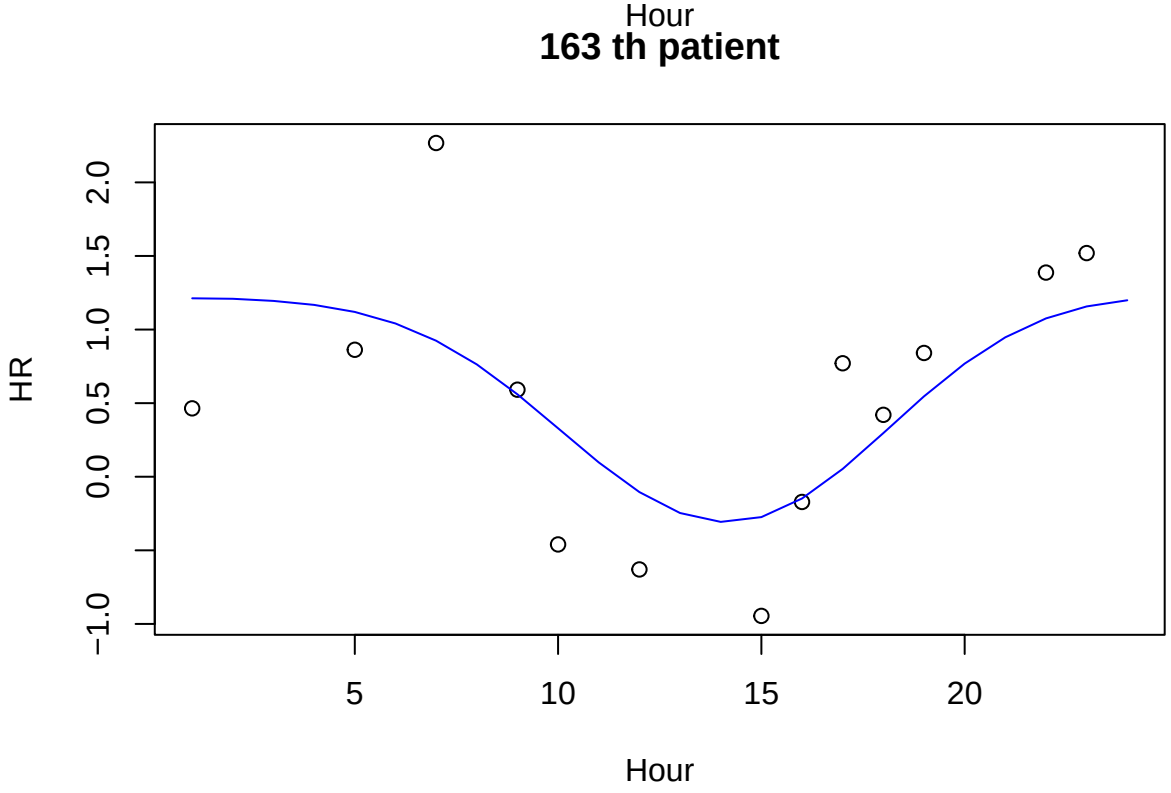
Hour


163 th patient
HR
2.0
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1.0
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−1.0
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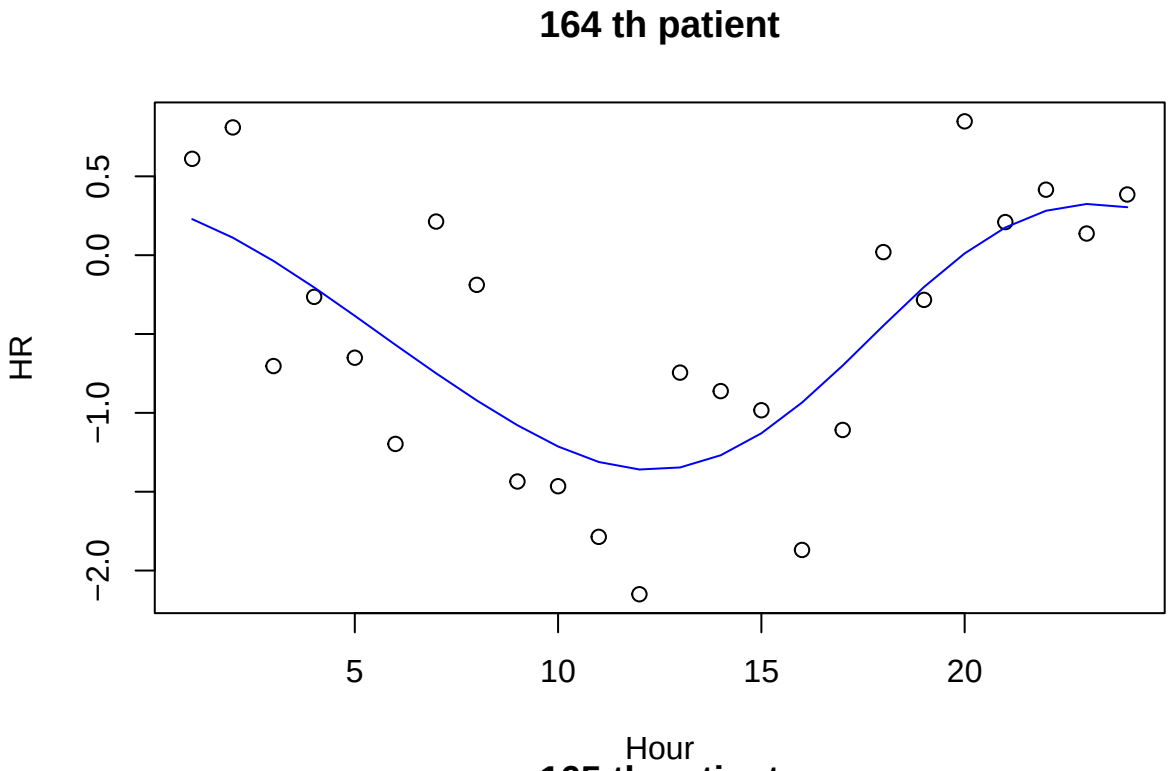
Hour


164 th patient
HR
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−2.0
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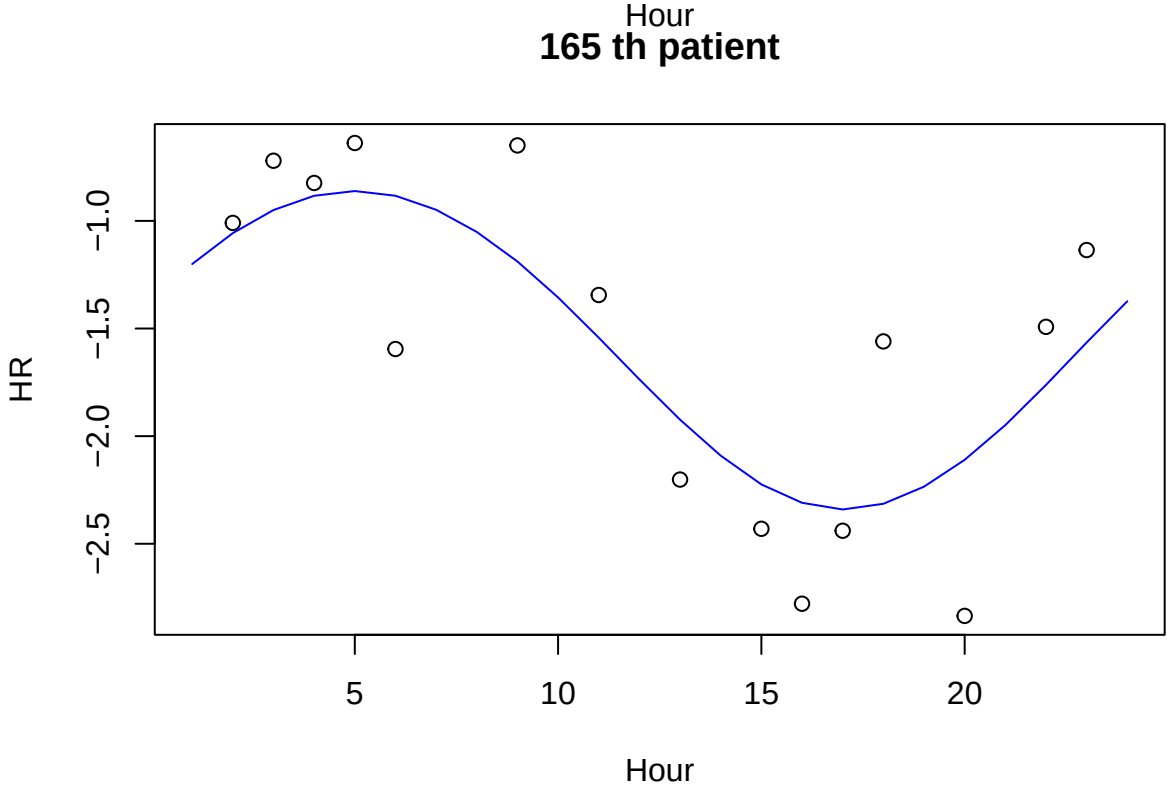
Hour


165 th patient
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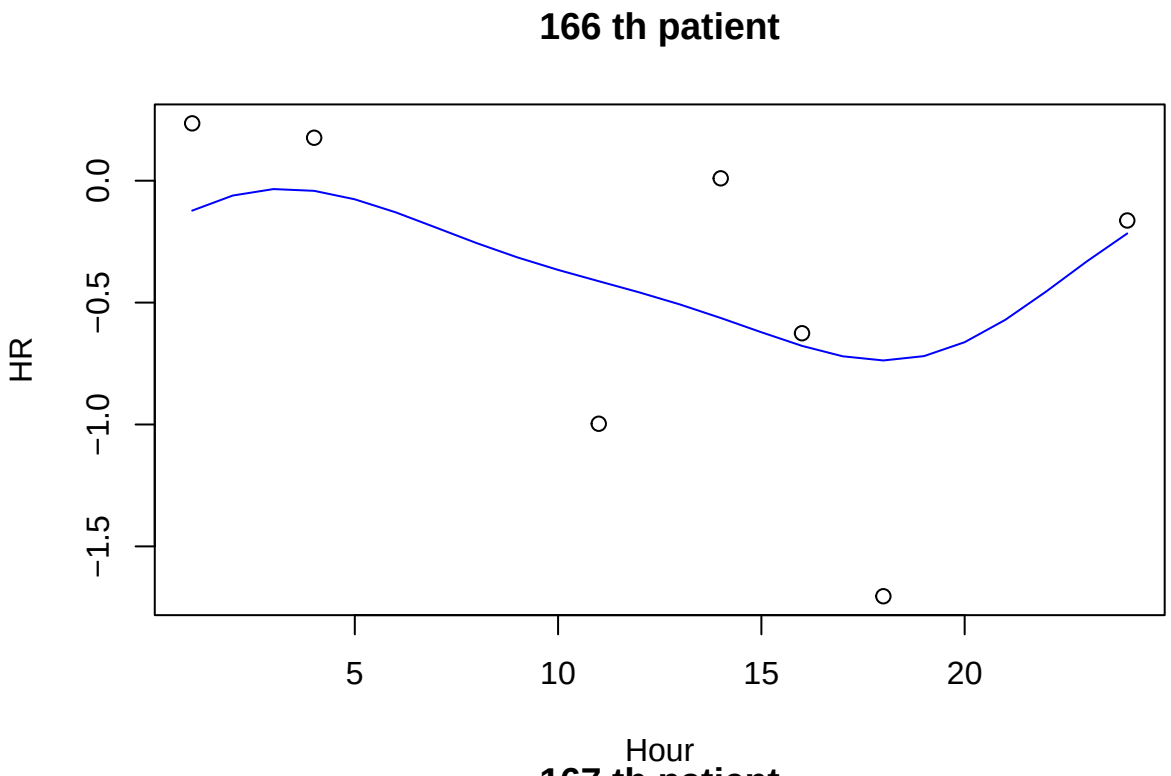
Hour


166 th patient
HR
0.0
−0.5
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−1.5
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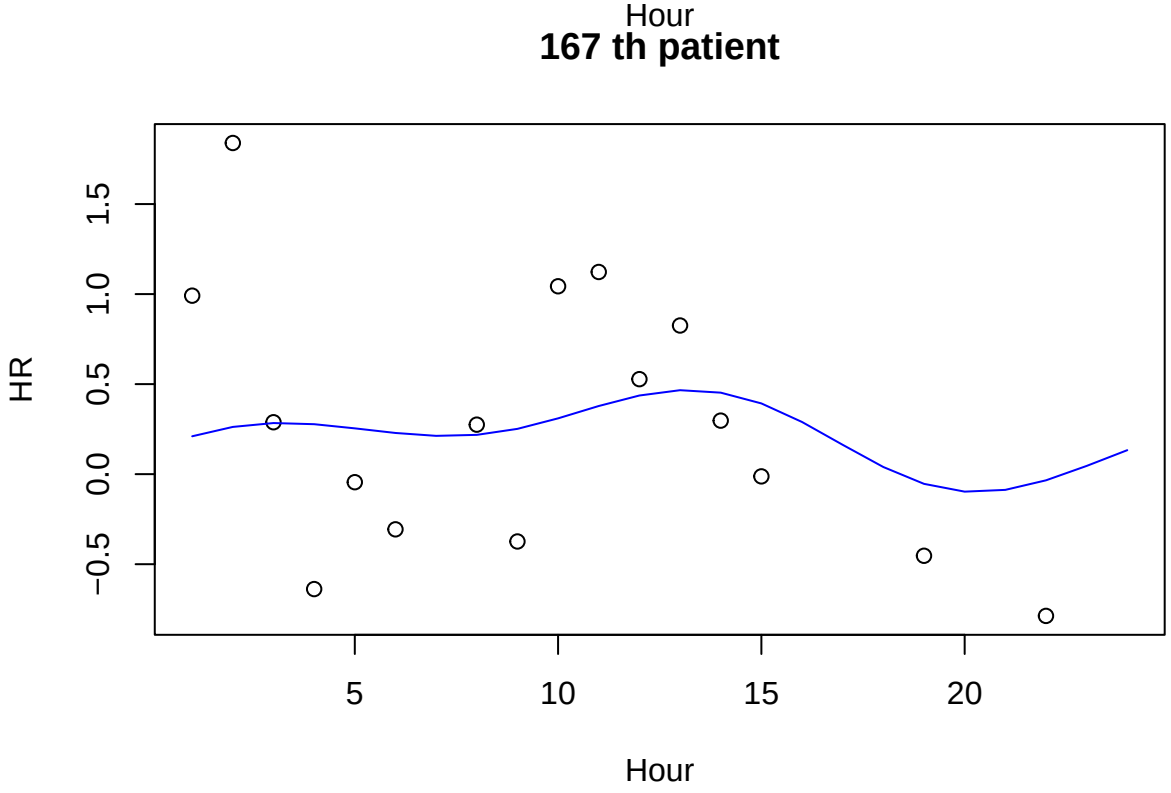
Hour


167 th patient
HR
1.5
1.0
0.5
0.0
−0.5
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15
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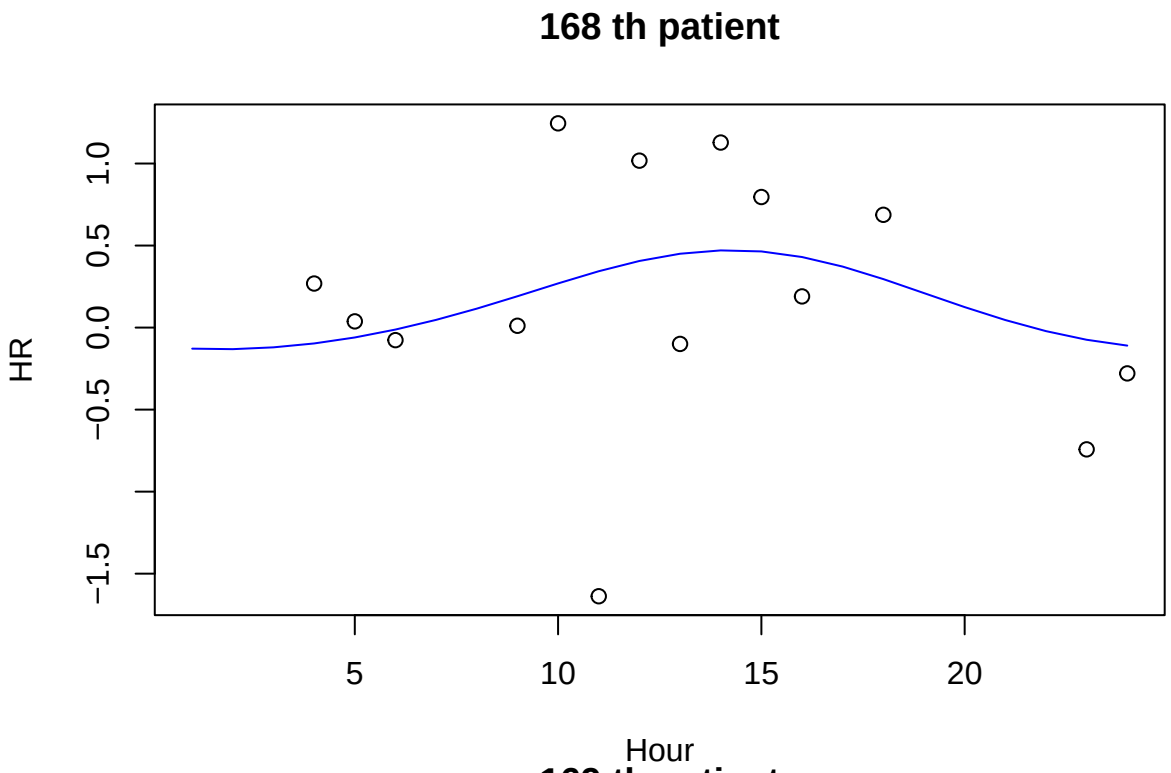
Hour


168 th patient
HR
1.0
0.5
0.0
−0.5
−1.5
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15
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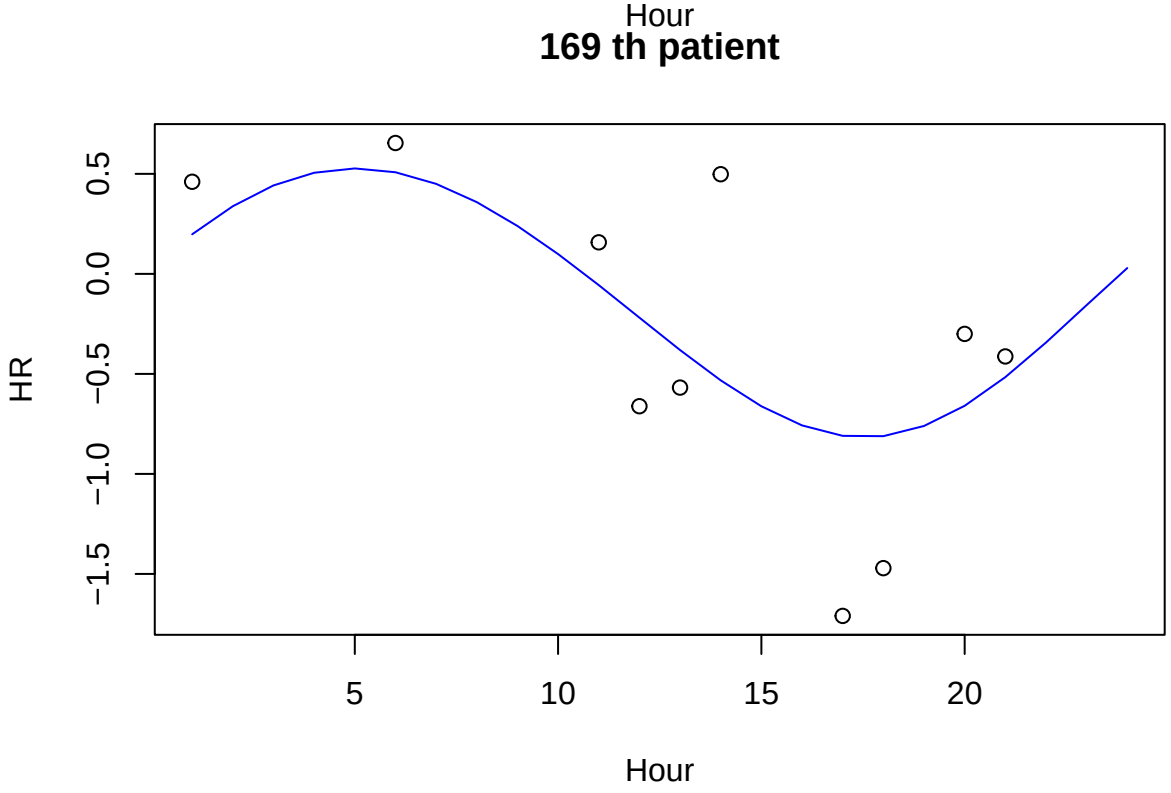
Hour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HR
0.5
0.0
−0.5
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−1.5
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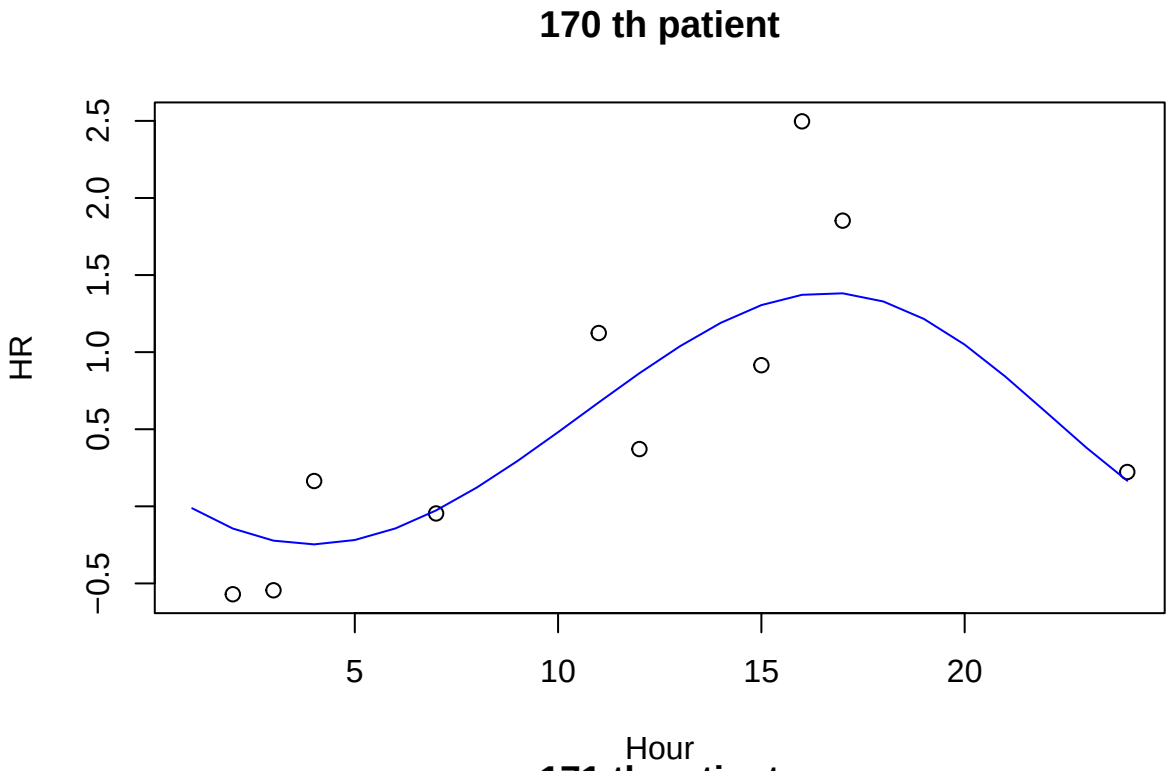
Hour


170 th patient
HR
2.5
2.0
1.5
1.0
0.5
−0.5
5
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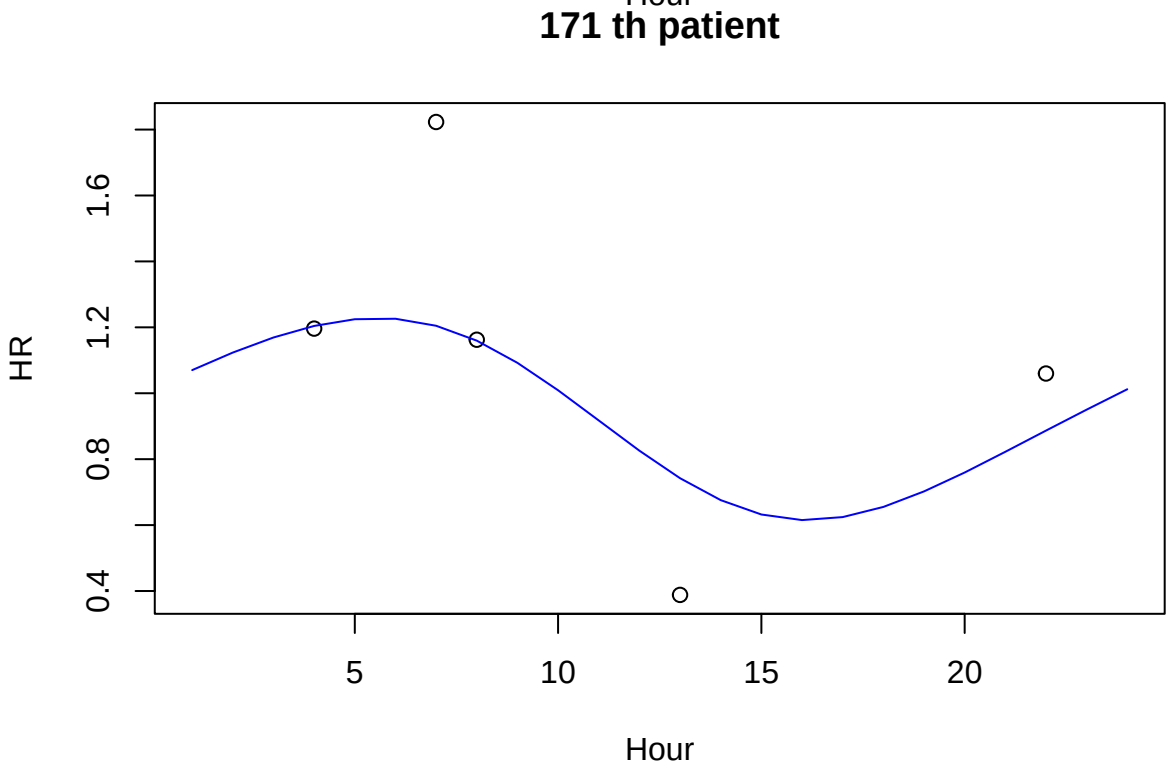
15
20
Hour


171 th patient
HR
1.6
1.2
0.8
0.4
5
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15
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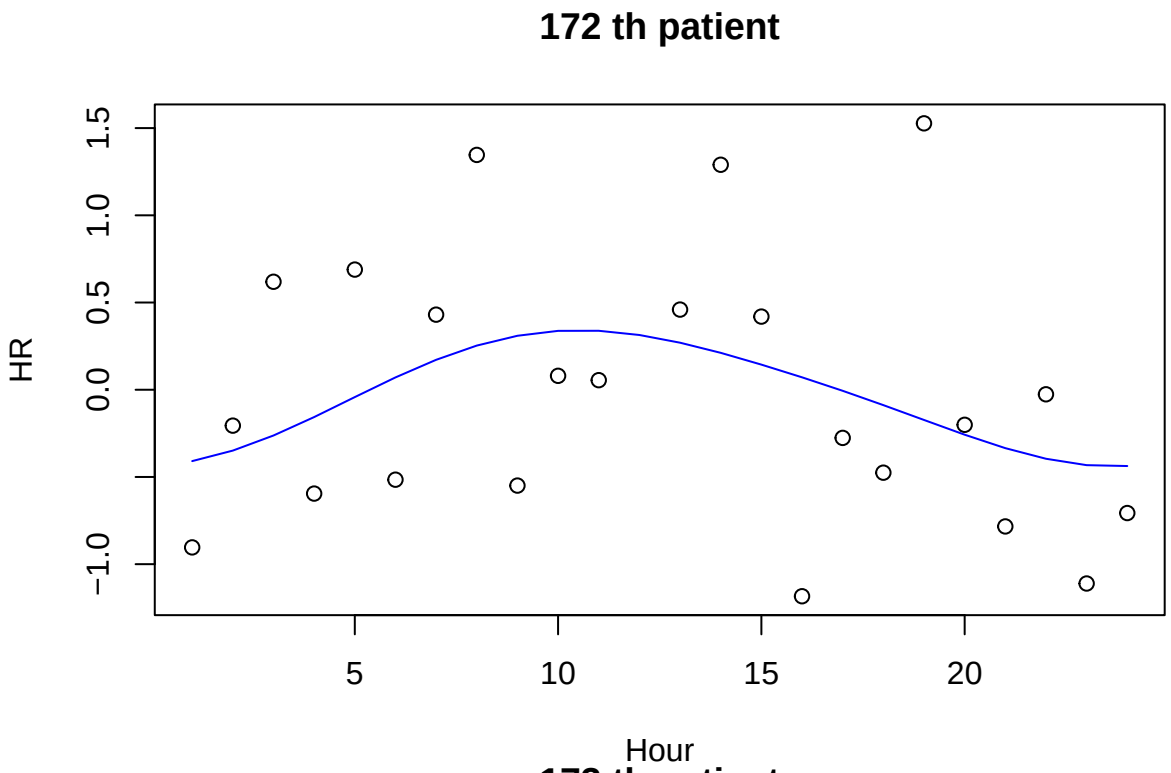
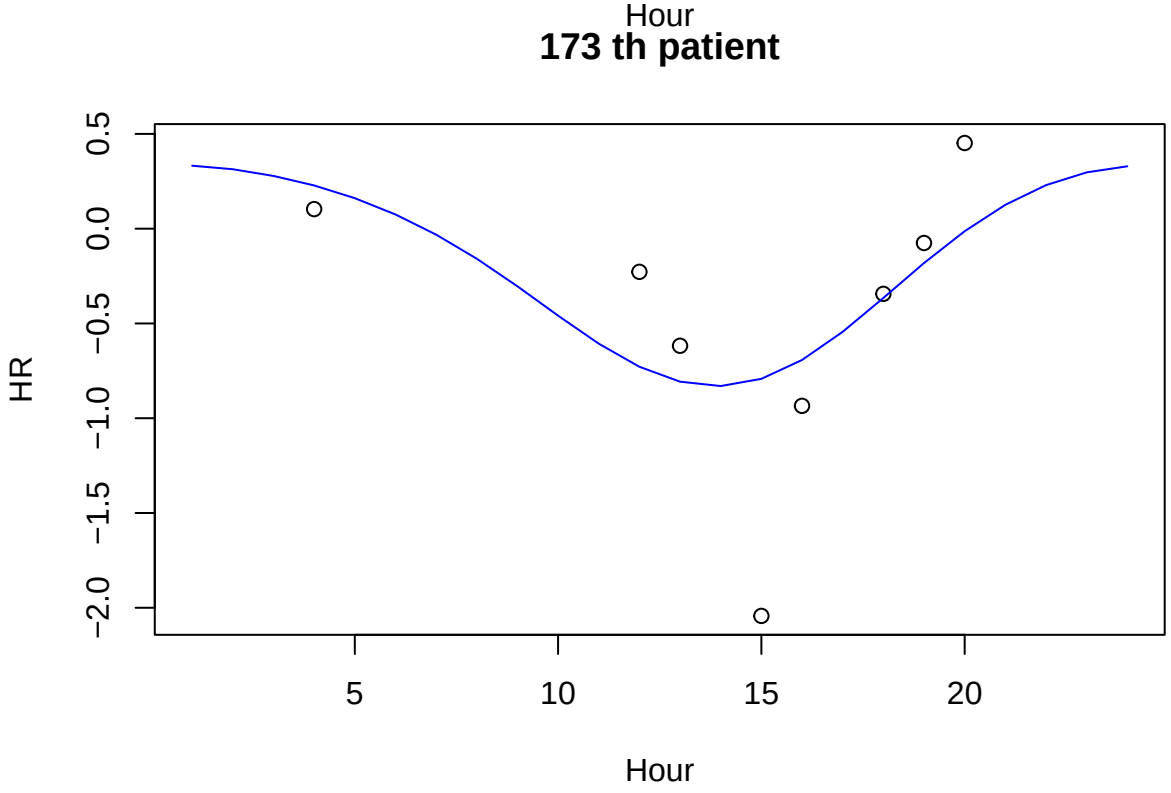
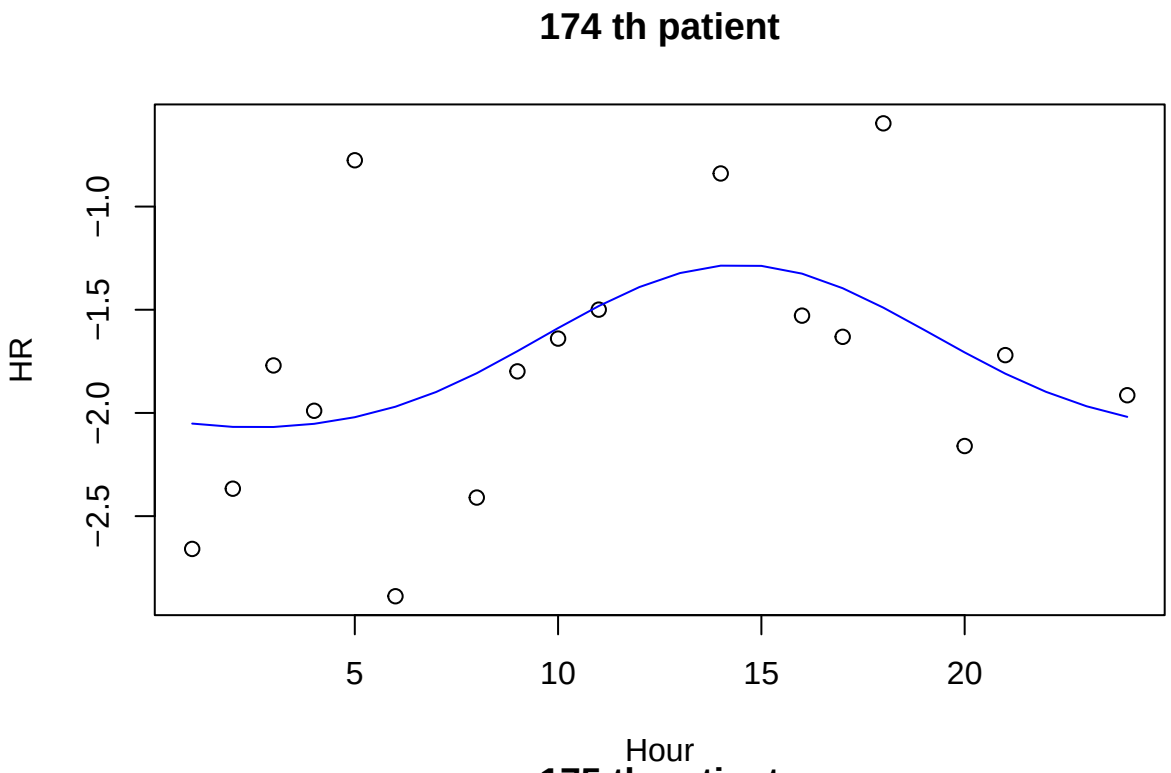
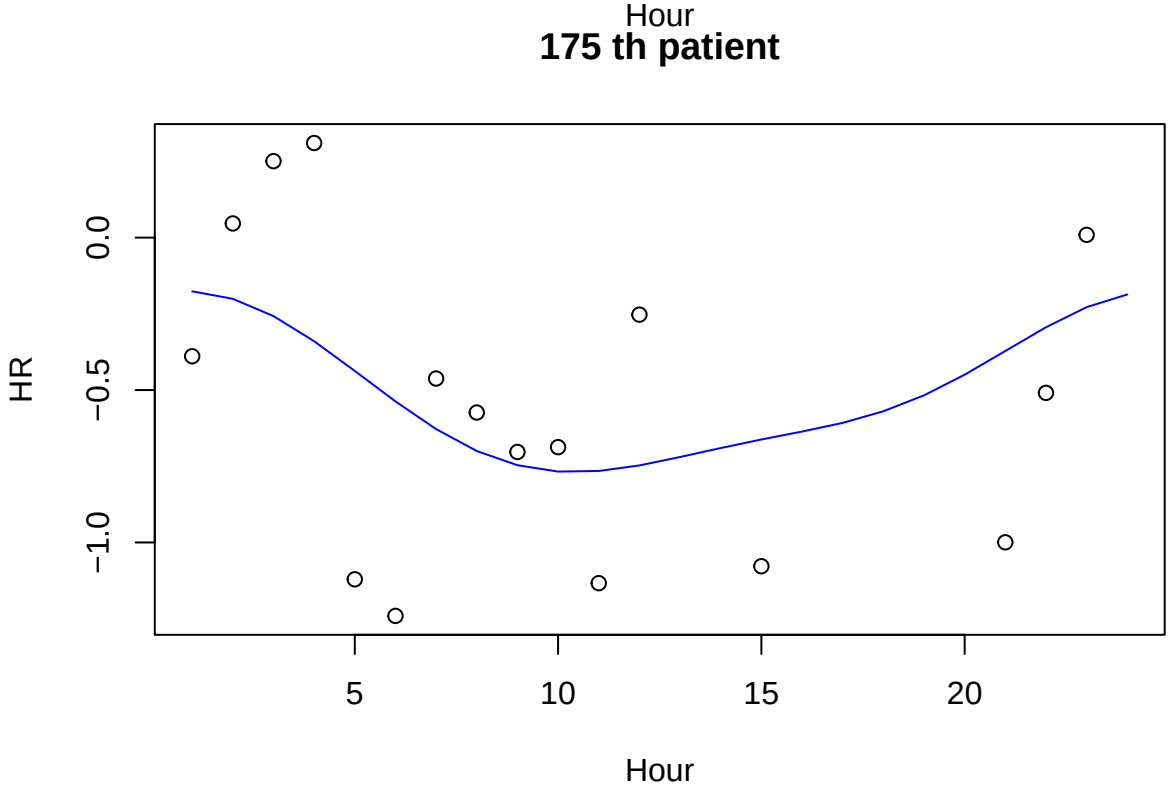
Hour


172 th patient
HR
1.5
1.0
0.5
0.0
−1.0
5
10
15
20
Hour


173 th patient
HR
0.5
0.0
−0.5
−1.0
−1.5
−2.0
5
10
15
20
Hour

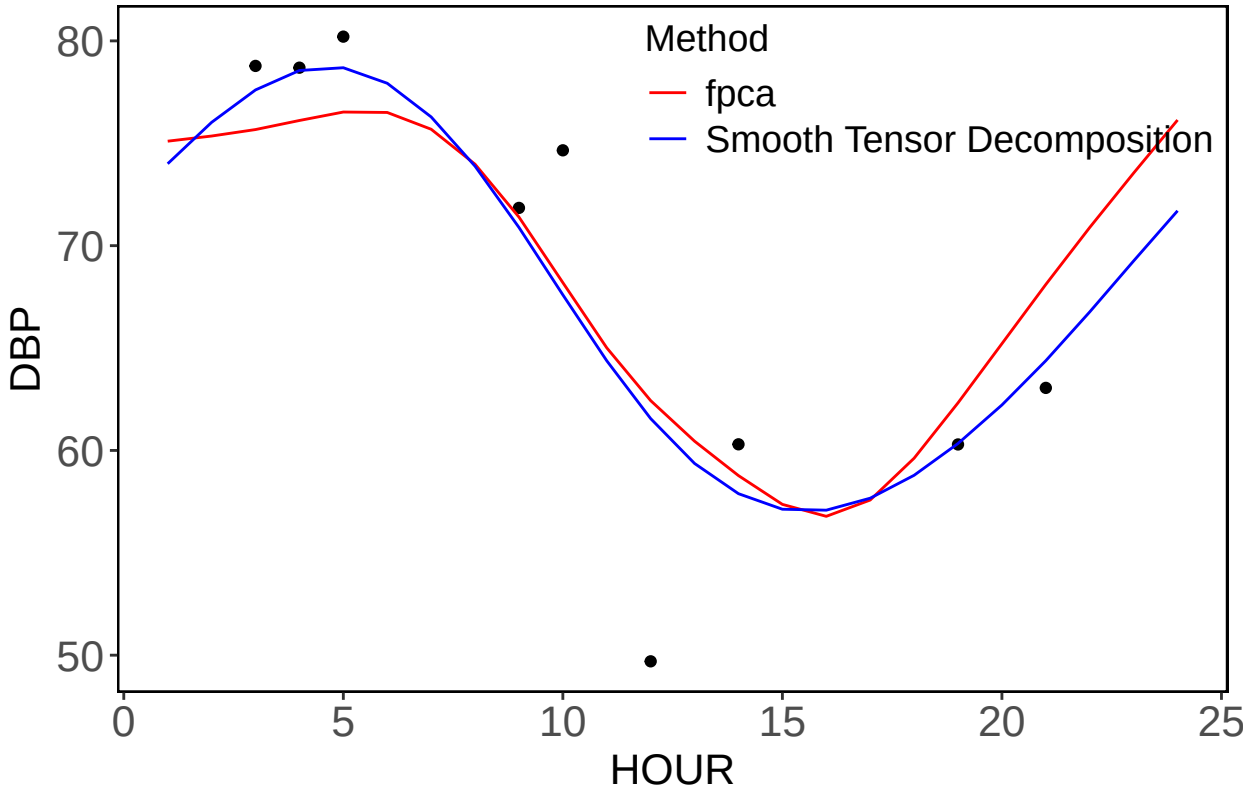




Comparison with FPCA (Example)

```
library(refund)
h1 <- rTensor::unfold(synthetic_dat[,1,], row_idx = 2, col_idx = 1)@data
```

```r
outfpca1 <- refund::fpca.sc(Y = as.matrix(h1), npc = 3, center=FALSE)

res <-  mglram(tnsr = synthetic_dat@data, ranks = c(6, 3), init=0, D = D2,
                 lambda = 12, max_iter = 500, tol = 1e-5, L0 = NULL)

for (i in c(111)){
df <- data.frame(cbind(c(1:24), (res$est[,1,i])*12+70, (outfpca1$Yhat[i,])*12+70))
colnames(df) <- c("hour", "my", "fpca")
original <- (synthetic_dat@data[ , 1, i])*12+70
org_df <- data.frame(cbind(c(1:24), original))
colnames(org_df) <- c("hour", "original")

df_long <- pivot_longer(df, cols=c("my", "fpca"), names_to = "method")

custom_colors <- c("blue","red")
names(custom_colors) <- c("my", "fpca")

p <- ggplot() +
  geom_point(data = org_df, aes(x = hour, y = original), color = "black") +  # Original data
  geom_line(data = df_long, aes(x = hour, y =value, color = method)) +
  labs(title = "",
       x = "HOUR", y = "DBP") +
  scale_color_manual(values = custom_colors,
                     labels = c("my" = "Smooth Tensor Decomposition", "fPCA" = "Functional Principal Co
                    name =  "Method") +
  theme(legend.position = c(1, 1),
    legend.justification = c(1, 1),
    panel.grid = element_blank(),
    panel.background = element_blank(),
    plot.background = element_blank(),
    panel.border = element_rect(color = "black", fill = NA, linewidth = 0.8),  # add border rectangle
    axis.line = element_blank(),
    legend.background = element_blank(),  # removes the outer background & border
    legend.key = element_blank(),
    axis.text = element_text(size = 16),
    axis.title = element_text(size = 16),
    legend.text = element_text(size = 14,hjust=0),
    legend.title = element_text(size = 14)
    )
print(p)
}
```


Method
fpca
Smooth Tensor Decomposition
DBP
HOUR
80
70
60
50
0
5
10
15
20
25