R Packages for Noncompartmental Analysis

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Contents

Preface

In this book, we will cover R Packages for Noncompartmental Analysis.

Chapter 1

Introduction

There are growing number of open source noncompartmental analysis R packages and we will compare, review and discuss them.

Chapter 2

Comparison of Noncompartmental analysis software

We will perform NCA with a dataset `Theoph` and compare $\mathrm{C}_{\mathrm{max}}$ and $\mathrm{AUC}_{\mathrm{inf}}$ calculated by each software or package.

2.1 Certara Phoenix WinNonLin

https://www.certara.com/software/pkpd-modeling-and-simulation/phoenix-winnonlin/

2.1.0.1 Pros

- Validated for several years
- Industry standard
- Versatile unit setting
- Easy using by GUI
- Generating plots supported

2.1.0.2 Cons

- Expansive (~several thousand dollars)
- Not suitable for reproducible research
- CDISC SDTM not compatible (input and output)

2.2 R package: PKNCA

https://github.com/billdenney/pknca

2.2.0.1 Pros

- Open source and free of charge
- CDISC SDTM semi compatible (output)
- Calculate partial(interval) AUC with 'linear' or 'log' interpolation method but in a cumbersome way

2.2.0.2 Cons

- CDISC SDTM not compatible (input)
- More tests required
- Experience with R language required
- Generating plots not supported for now (To be supported soon)

2.3 R package: ncar

Extension of NonCompart for CDISC input

https://github.com/asancpt/ncar

2.3.0.1 Pros

- Open source and free of charge
- CDISC SDTM fully compatible (input - DM, EX, PC)
- Output of CDISC SDTM PP domain terms
- Calculate partial(interval) AUC with 'linear' or 'log' interpolation method

2.3.0.2 Cons

- More tests required
- Experience with R language required
- Generating plots not supported for now (To be supported soon)

2.4 R package: ncappc

NCA Calculation and Population PK Model Diagnosis

https://cran.r-project.org/web/packages/ncappc/index.html https://www.ncbi.nlm.nih.gov/pubmed/27000291

```
#install.packages("ncappc")
#library(ncappc) # Broken Link
```

2.5 R package: PK

Basic Non-Compartmental Pharmacokinetics

https://cran.r-project.org/web/packages/PK/index.html

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

```
##  **********   PK Version 1.3-3**********
```

```
## Type PKNews() to see new features/changes/bug fixes.
```

Chapter 3

Details

3.1 ncar

```r
library(ncar)

NCA(Theoph, "Subject", "Time", "conc", Dose=320)
```

```
##    Subject  CMAX      CMAXD TMAX TLAG CLST     CLSTP  TLST    LAMZHL
## 1        1 10.50 0.03281250 1.12    0 3.28 3.2801465 24.37 14.304378
## 2        2  8.33 0.02603125 1.92    0 0.90 0.8886398 24.30  6.659342
## 3        3  8.20 0.02562500 1.02    0 1.05 1.0550967 24.17  6.766087
## 4        4  8.60 0.02687500 1.07    0 1.15 1.1564216 24.65  6.981247
## 5        5 11.40 0.03562500 1.00    0 1.57 1.5556951 24.35  8.002264
## 6        6  6.44 0.02012500 1.15    0 0.92 0.9412712 23.85  7.894998
## 7        7  7.09 0.02215625 3.48    0 1.15 1.1607192 24.22  7.846668
## 8        8  7.56 0.02362500 2.02    0 1.25 1.2285268 24.12  8.510038
## 9        9  9.03 0.02821875 0.63    0 1.12 1.1164831 24.43  8.405999
## 10      10 10.21 0.03190625 3.55    0 2.42 2.4136923 23.70  9.246916
## 11      11  8.00 0.02500000 0.98    0 0.86 0.8598066 24.08  7.261237
## 12      12  9.75 0.03046875 3.52    0 1.17 1.1755390 24.15  6.286508
##          LAMZ LAMZLL LAMZUL LAMZNPT     CORRXY        R2     R2ADJ
## 1  0.04845700   9.05  24.37       3 -0.9999999 0.9999997 0.9999995
## 2  0.10408644   7.03  24.30       4 -0.9985967 0.9971954 0.9957931
## 3  0.10244431   9.00  24.17       3 -0.9996624 0.9993250 0.9986499
## 4  0.09928702   9.02  24.65       3 -0.9994619 0.9989241 0.9978483
## 5  0.08661888   7.02  24.35       4 -0.9993234 0.9986472 0.9979708
## 6  0.08779574   2.03  23.85       7 -0.9991203 0.9982413 0.9978896
## 7  0.08833650   6.98  24.22       4 -0.9993349 0.9986702 0.9980053
## 8  0.08145054   3.53  24.12       6 -0.9954961 0.9910124 0.9887655
## 9  0.08245863   8.80  24.43       3 -0.9997218 0.9994437 0.9988873
## 10 0.07495982   9.38  23.70       3 -0.9997543 0.9995087 0.9990174
## 11 0.09545856   9.03  24.08       3 -0.9999991 0.9999983 0.9999965
## 12 0.11025949   9.03  24.15       3 -0.9996984 0.9993968 0.9987936
##       AUCLST    AUCALL    AUCIFO   AUCIFOD    AUCPEO    AUCIFP   AUCIFPD
## 1  148.92305 148.92305 216.61193 0.6769123 31.248917 216.61496 0.6769217
## 2   91.52680  91.52680 100.17346 0.3130421  8.631687 100.06432 0.3127010
## 3   99.28650  99.28650 109.53597 0.3422999  9.357173 109.58572 0.3424554
## 4  106.79630 106.79630 118.37888 0.3699340  9.784331 118.44356 0.3701361
## 5  121.29440 121.29440 139.41978 0.4356868 13.000579 139.25463 0.4351707
## 6   73.77555  73.77555  84.25442 0.2632951 12.437174  84.49670 0.2640522
## 7   90.75340  90.75340 103.77180 0.3242869 12.545221 103.89315 0.3246661
## 8   88.55995  88.55995 103.90669 0.3247084 14.769730 103.64305 0.3238845
## 9   86.32615  86.32615  99.90872 0.3122147 13.594978  99.86607 0.3120815
## 10 138.36810 138.36810 170.65206 0.5332877 18.918002 170.56791 0.5330247
## 11  80.09360  80.09360  89.10274 0.2784461 10.110962  89.10072 0.2784397
## 12 119.97750 119.97750 130.58883 0.4080901  8.125757 130.63907 0.4082471
##       AUCPEP   AUMCLST   AUMCIFO  AUMCPEO   AUMCIFP  AUMCPEP MRTEVLST
## 1  31.249876 1459.0711 4505.5348 67.61603 4505.6709 67.61701 9.797483
## 2   8.532030  706.5866  999.7723 29.32525  996.0716 29.06267 7.719996
## 3   9.398325  803.1859 1150.9648 30.21629 1152.6529 30.31850 8.089578
## 4   9.833594  901.0842 1303.2524 30.85881 1305.4981 30.97775 8.437410
## 5  12.897403 1017.1143 1667.7216 39.01174 1661.7937 38.79419 8.385501
## 6  12.688246  609.1524  978.4285 37.74176  986.9665 38.28034 8.256833
## 7  12.647366  782.4199 1245.0984 37.16000 1249.4111 37.37691 8.621383
## 8  14.552931  739.5346 1298.1158 43.03015 1288.5201 42.60589 8.350666
## 9  13.558076  705.2296 1201.7715 41.31750 1200.2124 41.24126 8.169363
## 10 18.878001 1278.1800 2473.9934 48.33535 2470.8765 48.27018 9.237534
## 11 10.108918  617.2422  928.5600 33.52694  928.4900 33.52193 7.706511
## 12  8.161087  977.8807 1330.3840 26.49636 1332.0528 26.58844 8.150534
##     MRTEVIFO  MRTEVIFP     VZFO     VZFP     CLFO     CLFP
## 1  20.800031 20.800368 30.48675 30.48632 1.477296 1.477276
## 2   9.980411  9.954313 30.69044 30.72392 3.194459 3.197943
## 3  10.507642 10.518276 28.51710 28.50415 2.921415 2.920088
## 4  11.009163 11.022112 27.22596 27.21110 2.703185 2.701709
## 5  11.961873 11.933490 26.49799 26.52942 2.295227 2.297949
## 6  11.612785 11.680533 43.25973 43.13569 3.798020 3.787130
## 7  11.998427 12.025924 34.90844 34.86767 3.083689 3.080088
## 8  12.493092 12.432287 37.81051 37.90669 3.079686 3.087520
## 9  12.028695 12.018220 38.84279 38.85938 3.202924 3.204292
## 10 14.497296 14.486174 25.01554 25.02788 1.875160 1.876086
## 11 10.421227 10.420679 37.62219 37.62304 3.591360 3.591441
## 12 10.187579 10.196436 22.22429 22.21575 2.450439 2.449497
```

```
iAUC = data.frame(Name=c("AUC[0-12h]","AUC[0-24h]"), Start=c(0,0), End=c(12,24)) ; iAUC
```

```
##         Name Start End
## 1 AUC[0-12h]     0  12
## 2 AUC[0-24h]     0  24
```

```
NCA(Theoph, "Subject", "Time", "conc", Dose=320, iAUC=iAUC)
```

```
##    Subject  CMAX      CMAXD TMAX TLAG CLST     CLSTP  TLST    LAMZHL
## 1        1 10.50 0.03281250 1.12    0 3.28 3.2801465 24.37 14.304378
## 2        2  8.33 0.02603125 1.92    0 0.90 0.8886398 24.30  6.659342
## 3        3  8.20 0.02562500 1.02    0 1.05 1.0550967 24.17  6.766087
## 4        4  8.60 0.02687500 1.07    0 1.15 1.1564216 24.65  6.981247
## 5        5 11.40 0.03562500 1.00    0 1.57 1.5556951 24.35  8.002264
## 6        6  6.44 0.02012500 1.15    0 0.92 0.9412712 23.85  7.894998
## 7        7  7.09 0.02215625 3.48    0 1.15 1.1607192 24.22  7.846668
## 8        8  7.56 0.02362500 2.02    0 1.25 1.2285268 24.12  8.510038
## 9        9  9.03 0.02821875 0.63    0 1.12 1.1164831 24.43  8.405999
## 10      10 10.21 0.03190625 3.55    0 2.42 2.4136923 23.70  9.246916
## 11      11  8.00 0.02500000 0.98    0 0.86 0.8598066 24.08  7.261237
## 12      12  9.75 0.03046875 3.52    0 1.17 1.1755390 24.15  6.286508
##          LAMZ LAMZLL LAMZUL LAMZNPT     CORRXY        R2     R2ADJ
## 1  0.04845700   9.05  24.37       3 -0.9999999 0.9999997 0.9999995
## 2  0.10408644   7.03  24.30       4 -0.9985967 0.9971954 0.9957931
## 3  0.10244431   9.00  24.17       3 -0.9996624 0.9993250 0.9986499
## 4  0.09928702   9.02  24.65       3 -0.9994619 0.9989241 0.9978483
## 5  0.08661888   7.02  24.35       4 -0.9993234 0.9986472 0.9979708
## 6  0.08779574   2.03  23.85       7 -0.9991203 0.9982413 0.9978896
## 7  0.08833650   6.98  24.22       4 -0.9993349 0.9986702 0.9980053
## 8  0.08145054   3.53  24.12       6 -0.9954961 0.9910124 0.9887655
## 9  0.08245863   8.80  24.43       3 -0.9997218 0.9994437 0.9988873
## 10 0.07495982   9.38  23.70       3 -0.9997543 0.9995087 0.9990174
## 11 0.09545856   9.03  24.08       3 -0.9999991 0.9999983 0.9999965
## 12 0.11025949   9.03  24.15       3 -0.9996984 0.9993968 0.9987936
##       AUCLST    AUCALL    AUCIFO   AUCIFOD    AUCPEO    AUCIFP   AUCIFPD
## 1  148.92305 148.92305 216.61193 0.6769123 31.248917 216.61496 0.6769217
## 2   91.52680  91.52680 100.17346 0.3130421  8.631687 100.06432 0.3127010
## 3   99.28650  99.28650 109.53597 0.3422999  9.357173 109.58572 0.3424554
## 4  106.79630 106.79630 118.37888 0.3699340  9.784331 118.44356 0.3701361
## 5  121.29440 121.29440 139.41978 0.4356868 13.000579 139.25463 0.4351707
## 6   73.77555  73.77555  84.25442 0.2632951 12.437174  84.49670 0.2640522
## 7   90.75340  90.75340 103.77180 0.3242869 12.545221 103.89315 0.3246661
## 8   88.55995  88.55995 103.90669 0.3247084 14.769730 103.64305 0.3238845
## 9   86.32615  86.32615  99.90872 0.3122147 13.594978  99.86607 0.3120815
## 10 138.36810 138.36810 170.65206 0.5332877 18.918002 170.56791 0.5330247
## 11  80.09360  80.09360  89.10274 0.2784461 10.110962  89.10072 0.2784397
## 12 119.97750 119.97750 130.58883 0.4080901  8.125757 130.63907 0.4082471
##       AUCPEP   AUMCLST   AUMCIFO   AUMCPEO   AUMCIFP   AUMCPEP MRTEVLST
## 1  31.249876 1459.0711 4505.5348 67.61603 4505.6709 67.61701 9.797483
## 2   8.532030  706.5866  999.7723 29.32525  996.0716 29.06267 7.719996
## 3   9.398325  803.1859 1150.9648 30.21629 1152.6529 30.31850 8.089578
## 4   9.833594  901.0842 1303.2524 30.85881 1305.4981 30.97775 8.437410
## 5  12.897403 1017.1143 1667.7216 39.01174 1661.7937 38.79419 8.385501
## 6  12.688246  609.1524  978.4285 37.74176  986.9665 38.28034 8.256833
## 7  12.647366  782.4199 1245.0984 37.16000 1249.4111 37.37691 8.621383
## 8  14.552931  739.5346 1298.1158 43.03015 1288.5201 42.60589 8.350666
## 9  13.558076  705.2296 1201.7715 41.31750 1200.2124 41.24126 8.169363
## 10 18.878001 1278.1800 2473.9934 48.33535 2470.8765 48.27018 9.237534
## 11 10.108918  617.2422  928.5600 33.52694  928.4900 33.52193 7.706511
## 12  8.161087  977.8807 1330.3840 26.49636 1332.0528 26.58844 8.150534
##     MRTEVIFO  MRTEVIFP     VZFO     VZFP     CLFO     CLFP AUC[0-12h]
## 1  20.800031 20.800368 30.48675 30.48632 1.477296 1.477276   91.73552
## 2   9.980411  9.954313 30.69044 30.72392 3.194459 3.197943   67.48030
## 3  10.507642 10.518276 28.51710 28.50415 2.921415 2.920088   70.17971
## 4  11.009163 11.022112 27.22596 27.21110 2.703185 2.701709   73.05115
## 5  11.961873 11.933490 26.49799 26.52942 2.295227 2.297949   84.61490
## 6  11.612785 11.680533 43.25973 43.13569 3.798020 3.787130   51.75887
## 7  11.998427 12.025924 34.90844 34.86767 3.083689 3.080088   62.09875
## 8  12.493092 12.432287 37.81051 37.90669 3.079686 3.087520   62.71486
## 9  12.028695 12.018220 38.84279 38.85938 3.202924 3.204292   60.12123
## 10 14.497296 14.486174 25.01554 25.02788 1.875160 1.876086   90.81742
## 11 10.421227 10.420679 37.62219 37.62304 3.591360 3.591441   58.53963
## 12 10.187579 10.196436 22.22429 22.21575 2.450439 2.449497   85.02136
##   AUC[0-24h]
## 1   147.69459
## 2    91.24908
## 3    99.10481
## 4   105.99811
## 5   120.73101
## 6    73.91422
## 7    90.49567
## 8    88.40890
## 9    85.82985
## 10  139.08507
## 11   80.02431
## 12  119.79884
```

3.2 PKNCA: Automation of Noncompartmental Analysis in R

3.2.1 ISoP Pharmacometrics Study Group Presentation

- 강의 동영상 https://www.youtube.com/watch?v=WCmFrheYtcc
- 프로젝트 https://github.com/billdenney/pknca
- Package https://cran.r-project.org/web/packages/PKNCA/
  - 예제 R Markdown 파일 : https://github.com/billdenney/pknca/tree/master/vignettes
- PPT 파일
- PKNCA 패키지란 무엇인가? * Pharmacokinetic(PK) data를 위한 모든 noncompartmental analysis (NCA) 계산이 가능한 R용 패키지

```
library(devtools)
install_github("billdenney/pknca")
```

3.2.2 오픈소스 NCA - 지금이 적기이다.

- Data standards 가 점점 많아짐
- CDISC/SDTM가 FDA requirement
- CDISC ADaM working group is standardizing NCA data set (ADNCA) |
  - CDISC SDTM pharmacokinetic concentration (PC) and pharmacokinetic parameter (PP) domains have been standardized
- 우리도 R로 NCA?

3.2.3 할수 있는 것

- Organizes concentration/time and dose/time data
- Predicts what you most likely need from NCA parameters from the concentration and dosing data.
- Allows user control of all NCA parameter and summary calculations
- Calculates all (standard) NCA parameters (Targeting the SDTM PK 파라메터)
- Summarizes the parameters

3.2.4 한계

- 그래픽 못그림
- 파라메터의 statistics 못구함 (곧 기능 추가할듯)

3.2.5 PKNCA 현재는 0.7

- NCA 파라메터 계산가능 (Cmax, Tmax, AUClast, AUCinf, AUMC, half-life, ⋯)
- NCA-related calculations (Superposition, Concentration interpolation/extrapolation (with AUC methods), Time to steady-state)
- SDTM PP-READY OUTPUT 가능
- 인풋에서 아웃풋까지 TRACK가능하다.
- 800개 넘는 테스트 케이스가 있음.

3.2.6 PKNCA 곧 1.0이 나올것이다.

- Improved prediction of desired parameters (정확도 accuracy, number 등)

3.2.7 참고사항

- Github에서 모두 다운로드 가능
- CRAN에 package올라왔다. (0.7) https://cran.r-project.org/web/packages/PKNCA/
  - wdenney@humanpredictions.com 으로 메일 보내라
- 모든게 오픈이기 때문에 Github에서 기여 환영

3.2.8 RStudio를 사용한 Hands-on 실습

3.2.8.1 Example-theophylline.Rmd

- Theophylline 농도를 가지고 PK Parameter 구하는 법
- https://raw.githubusercontent.com/billdenney/pknca/master/vignettes/Example-theophylline.Rmd
- 이 파일을 RStudio에서 실행해본다.
- 이후 article에서 분석할 것입니다.

3.2.8.2 Superposition.Rmd

- https://raw.githubusercontent.com/billdenney/pknca/master/vignettes/Superposition.Rmd
- 이 파일을 RStudio에서 실행해본다.

3.2.9 Closing

- PKNCA.options() 모든 옵션을 볼 수 있다.

3.2.10 결론

- 써보고 feedback주고 contribute해라.

```
## It is always a good idea to look at the data
knitr::kable(head(datasets::Theoph))
```

Table 3.1: Example dosing data extracted from theophylline data set

	Dose	Time	Subject
1	4.02	0	1
12	4.40	0	2
23	4.53	0	3
34	4.40	0	4
45	5.86	0	5
56	4.00	0	6
67	4.95	0	7
78	4.53	0	8
89	3.10	0	9
100	5.50	0	10
111	4.92	0	11
122	5.30	0	12

Subject	Wt	Dose	Time	conc
1	79.6	4.02	0.00	0.74
1	79.6	4.02	0.25	2.84
1	79.6	4.02	0.57	6.57
1	79.6	4.02	1.12	10.50
1	79.6	4.02	2.02	9.66
1	79.6	4.02	3.82	8.58

```r
## By default it is groupedData; convert it to a data frame for use
my.conc <- PKNCAconc(as.data.frame(datasets::Theoph), conc~Time|Subject)

## Dosing data needs to only have one row per dose, so subset for
## that first.
d.dose <- unique(datasets::Theoph[datasets::Theoph$Time == 0,
                                  c("Dose", "Time", "Subject")])
knitr::kable(d.dose,
             caption="Example dosing data extracted from theophylline data set")
```

```r
my.dose <- PKNCAdose(d.dose, Dose~Time|Subject)
```

```r
my.data.automatic <- PKNCAdata(my.conc, my.dose)
knitr::kable(PKNCA.options("single.dose.aucs"))
```

start	end	auclast	aucall	aumclast	aumcall	cmax	cmin	tmax	tlast	tfirst	clast.obs	f
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS

```r
knitr::kable(my.data.automatic$intervals)
```

start	end	auclast	aucall	aumclast	aumcall	cmax	cmin	tmax	tlast	tfirst	clast.obs	f
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS
0	24	TRUE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	FALS
0	Inf	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALS

```r
my.intervals <- data.frame(start=0,
                           end=Inf,
                           cmax=TRUE,
                           tmax=TRUE,
                           aucinf.obs=TRUE,
                           auclast=TRUE)
my.data.manual <- PKNCAdata(my.conc, my.dose,
                            intervals=my.intervals)
knitr::kable(my.data.manual$intervals)
```

start	end	auclast	aucall	aumclast	aumcall	cmax	cmin	tmax	tlast	tfirst	clast.obs	f
0	Inf	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE

```r
my.results.automatic <- pk.nca(my.data.automatic)
knitr::kable(head(my.results.automatic$result))
```

start	end	Subject	PPTESTCD	PPORRES
0	24	1	auclast	92.3654416
0	Inf	1	cmax	10.5000000
0	Inf	1	tmax	1.1200000
0	Inf	1	tlast	24.3700000
0	Inf	1	lambda.z	0.0484570
0	Inf	1	r.squared	0.9999997

```r
summary(my.results.automatic)
```

start	end	auclast	cmax	tmax	half.life	aucinf
0	24	74.6 [24.3]	.	.	.	.
0	Inf	.	8.65 [17.0]	1.14 [0.630, 3.55]	8.18 [2.12]	115 [28.4]

```
my.results.manual <- pk.nca(my.data.manual)
knitr::kable(head(my.results.manual$result))
```

start	end	Subject	PPTESTCD	PPORRES
0	Inf	1	auclast	147.23475
0	Inf	1	cmax	10.50000
0	Inf	1	tmax	1.12000
0	Inf	2	auclast	88.73128
0	Inf	2	cmax	8.33000
0	Inf	2	tmax	1.92000

```
summary(my.results.manual)
```

```
## Warning in summary.PKNCAresults(my.results.manual): No results to summarize
## for aucinf.obs in result row 1
```

start	end	auclast	cmax	tmax	aucinf.obs
0	Inf	98.7 [22.5]	8.65 [17.0]	1.14 [0.630, 3.55]	.