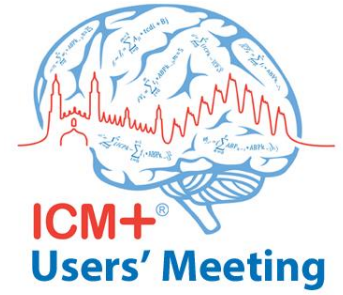




UNIVERSITY OF
CAMBRIDGE



Processing large volumes of data with ICM+ CENTER-TBI case study

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Brain Physics Lab



Research question

1) What is the Dose of ICP>22 behaviour in TBI patients in CENTER-TBI HR cohort in the first 3 days from the date of injury ?

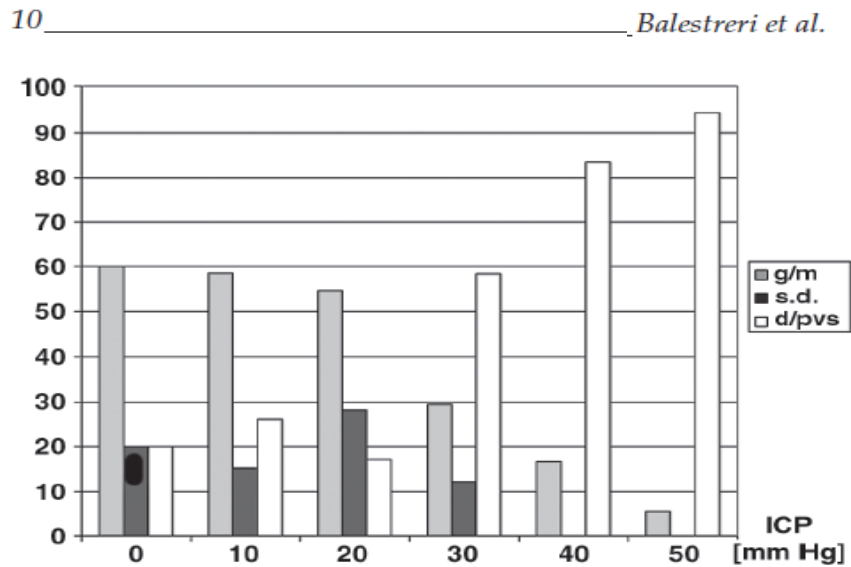
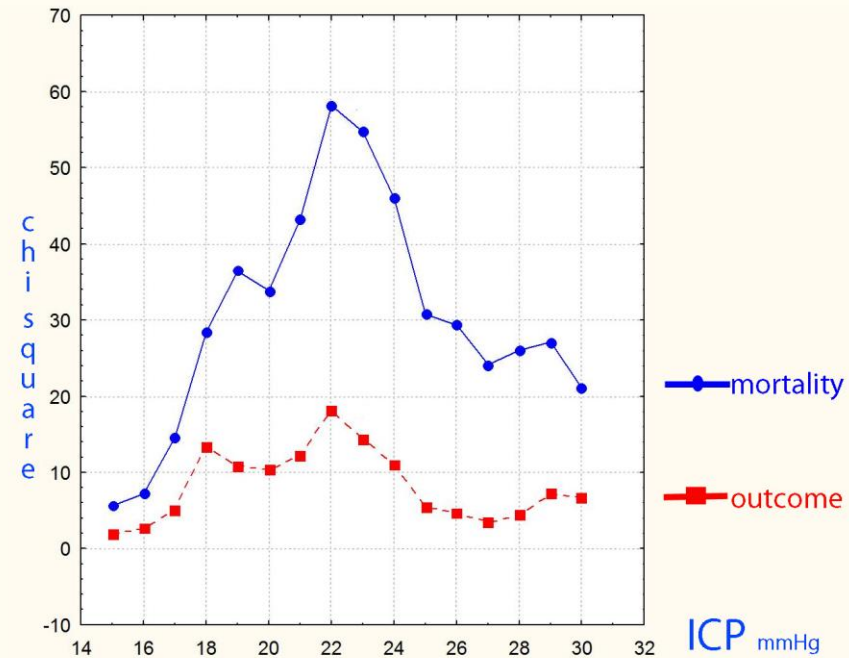


Fig. 1. Mortality and persistent vegetative state (d/pvs) rate, rate of favorable outcome (g/m), and rate of severe disability (s.d.) expressed as a function of ICP.

Critical Thresholds for Cerebrovascular Reactivity After Traumatic Brain Injury

E. Sorrentino · J. Diedler · M. Kasprowicz · K. P. Budohoski · C. Haubrich · P. Smielewski · J. G. Outtrim · A. Manktelow · P. J. Hutchinson · J. D. Pickard · D. K. Menon · M. Czosnyka

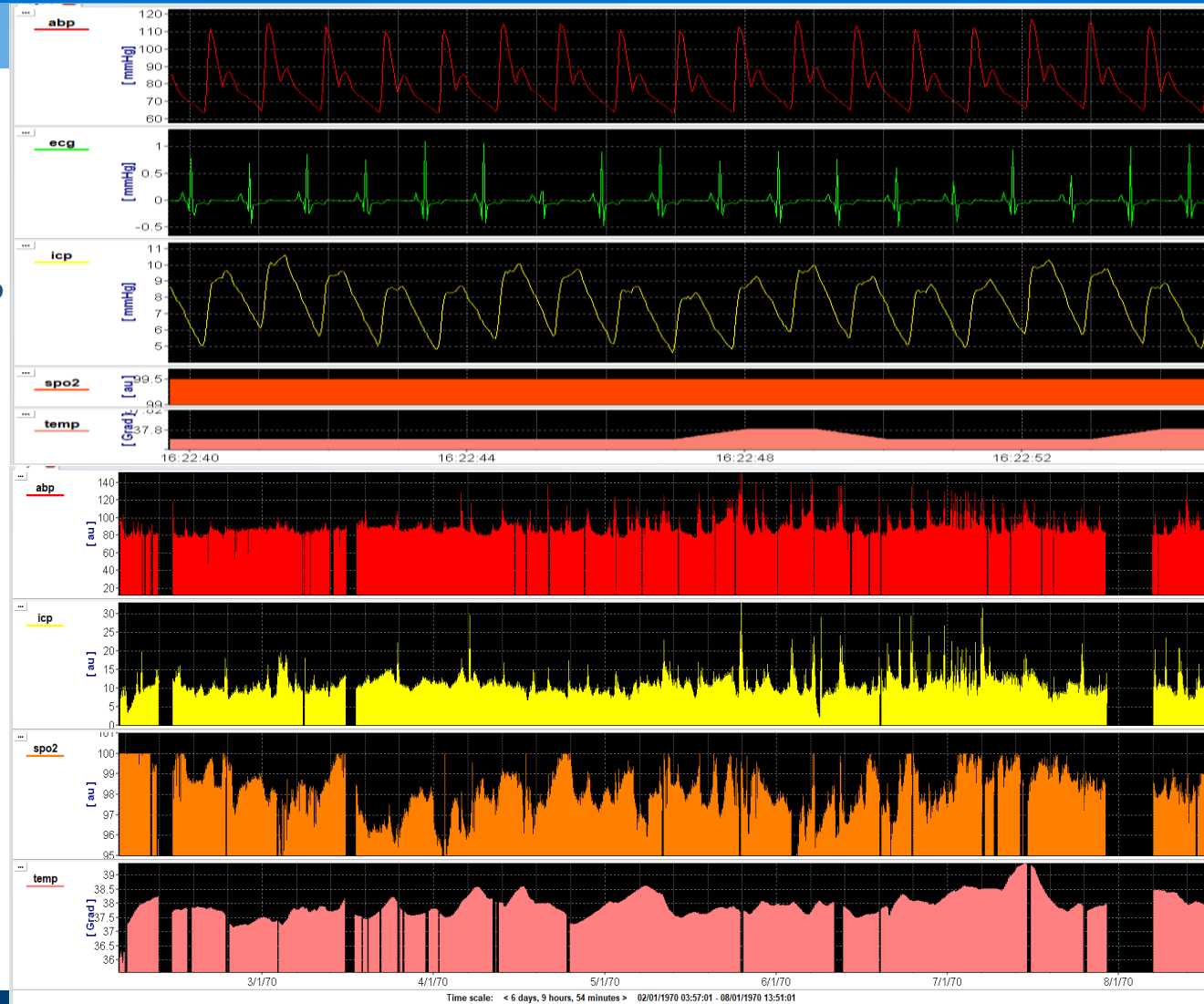


Data browsing

The data used for this demonstration is from the CENTER-TBI HR-ICU:

- Data from 21 centres
- 230 Recordings with parenchymal ICP
- Data recorded at multiple sampling frequencies
- Saved in HDF5 files
- More than 1600 days of recording
- Data is somewhat clean but with some outstanding artefacts

Answering this question will require the use of ICM+ advanced tools!



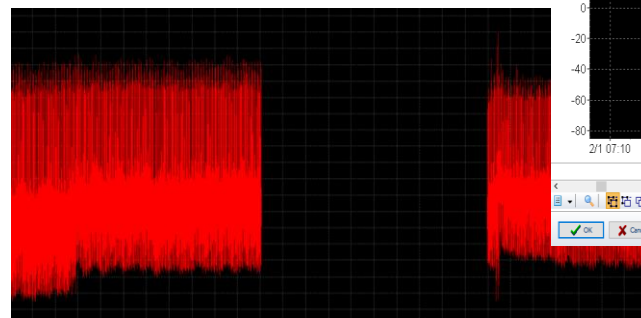
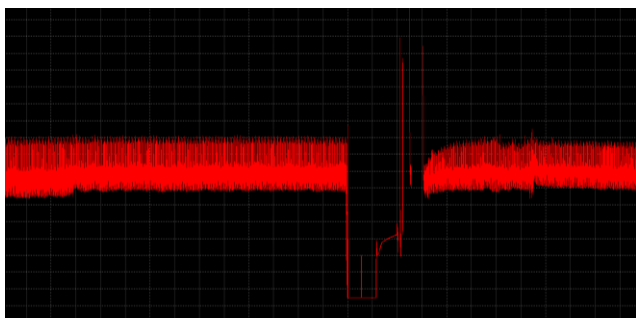
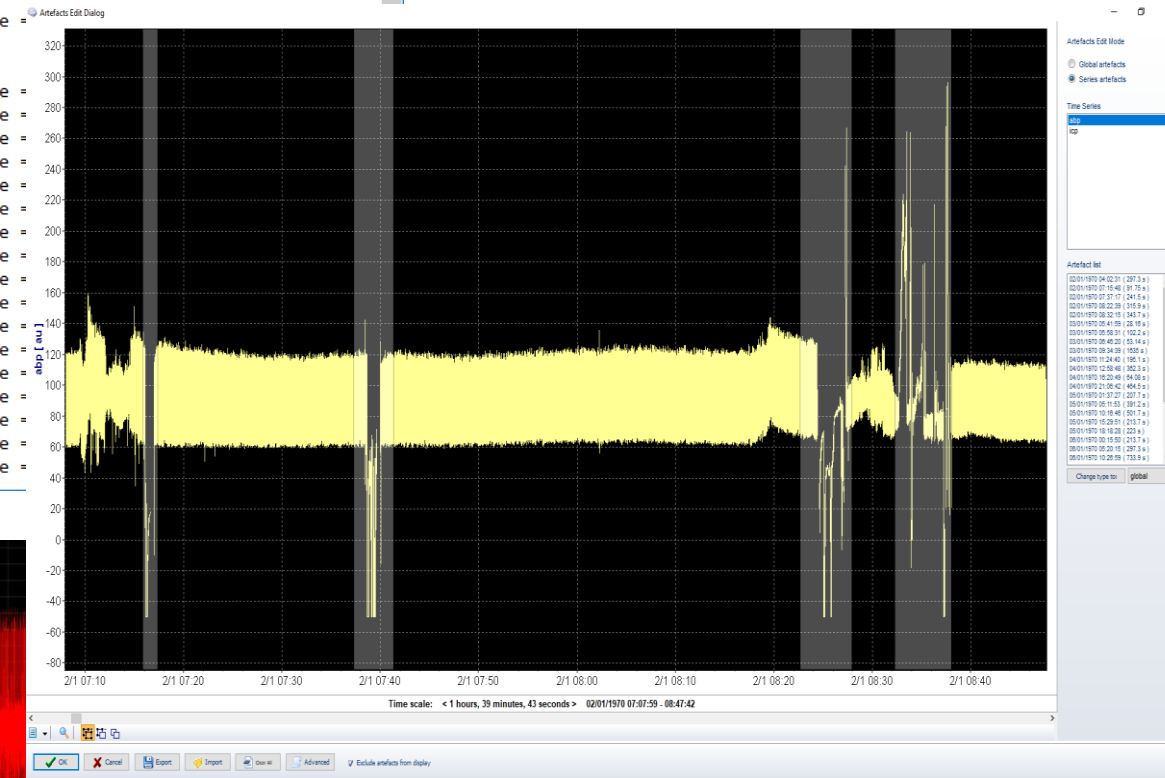
- 4EMh985.hdf5
 - annotations
 - events
 - definitions
 - dataTypes
 - eventTypes
 - indexStruct
 - qualityRef
 - qualityStruct
 - numerics
 - etco2
 - etco2.index
 - etco2.quality
 - spo2
 - spo2.index
 - spo2.quality
 - temp
 - temp.index
 - temp.quality
 - summaries
 - TenSec
 - TenSec.index
 - hour
 - hour.index
 - minute
 - minute.index
 - waves
 - abp
 - abp.index
 - abp.quality
 - ecg
 - ecg.index
 - ecg.quality
 - icp
 - icp.index
 - icp.quality

Summary of the steps of data analysis

1. Pre-processing - Manual Data Cleaning
2. Pre-processing - Automatic data cleaning + Downsampling
3. Pre-processing - re-slicing with time relative to the date of injury
4. Analysis – Create an analysis profile and apply it to your dataset
5. Analysis – Calculate one value of dose of ICP per patient
6. Analysis – Post-ICM+ statistical analysis

Step 1: Pre-processing - Manual Data Cleaning

```
4EMh985 - Notepad
File Edit Format View Help
<ICMArtefacts>
<Global>
  <Artefact ModifiedBy = "Administrator" ModifiedDate = "20/02/2019 20:58:05" StartTime = "08/01/1970 12:54:57.675" EndTime = "08/01/1970 12:54:57.675" >
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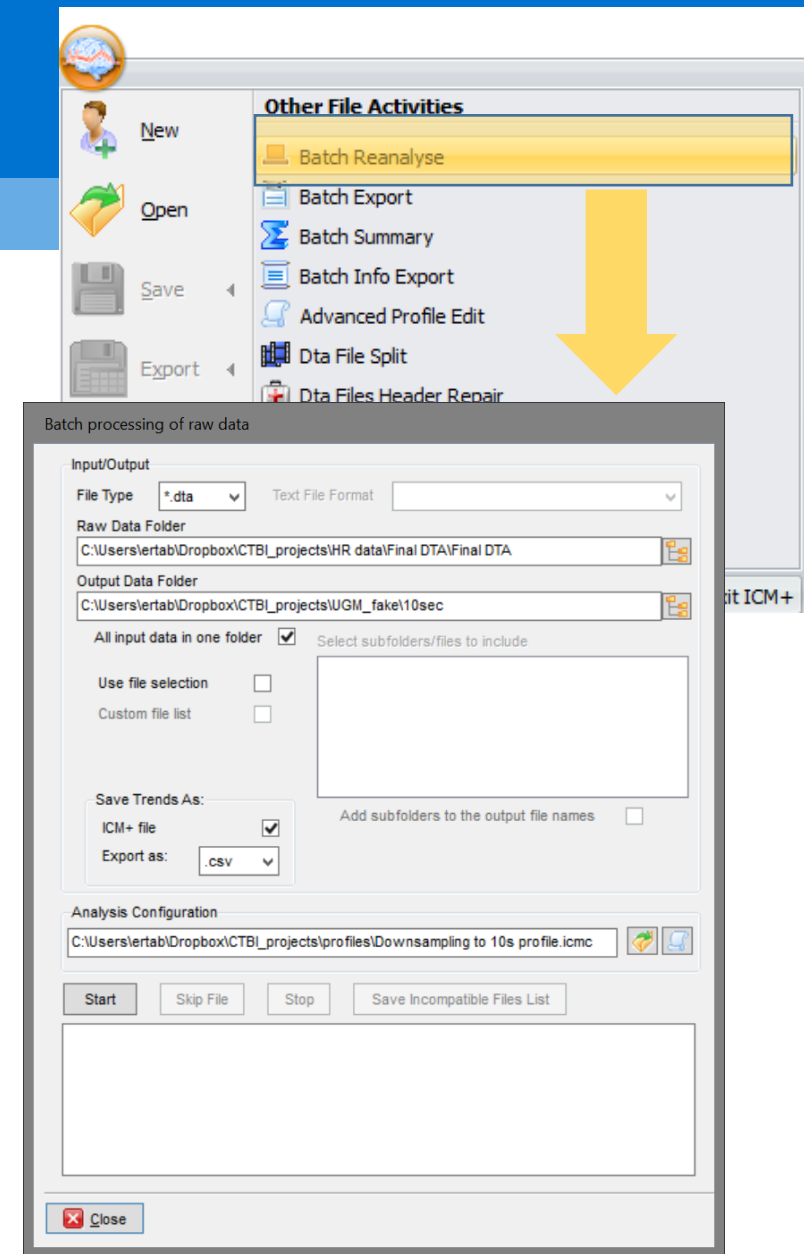
Step 2: Pre-processing - Automatic data cleaning + Downsampling

- To clean the data further we can apply some automatic artefact detection algorithms
- In order to make the data more 'workable' we need to downsample
 - As most of the calculations we usually do are based on 10 second averages of data, this is a good downsample target

If we use the [Batch reanalysis tool](#) we can then apply the profile to all the dataset in one run!!

To apply these transformations to the data systematically we will have to build an ICM+ profile.

The Original dataset of 127GB of data is transformed, in this way, in a much more manageable ~1Gb CSV data



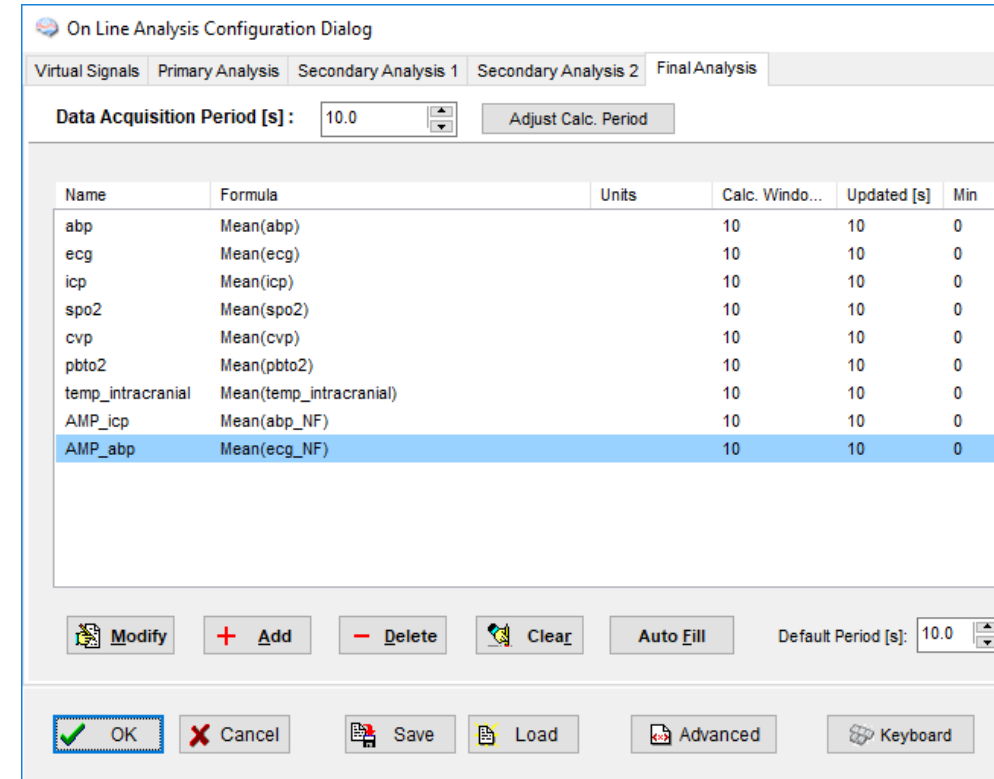
Step 2: Pre-processing - Automatic data cleaning + Downsampling

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On Line Analysis Configuration Dialog

Virtual Signals Primary Analysis Secondary Analysis 1 Secondary Analysis 2 Final Analysis

Data Acquisition Period [s]: 10.0 Adjust Calc. Period

Name	Formula	Units	Calc. Windo...	Updated [s]	Min
abp	Mean(abp)		10	10	0
ecg	Mean(ecg)		10	10	0
icp	Mean(icp)		10	10	0
spo2	Mean(spo2)		10	10	0
cvp	Mean(cvp)		10	10	0
pbto2	Mean(pbto2)		10	10	0
temp_intracranial	Mean(temp_intracranial)		10	10	0
AMP_icp	Mean(abp_NF)		10	10	0
AMP_abp	Mean(ecg_NF)		10	10	0

Modify Add Delete Clear Auto Fill Default Period [s]: 10.0

OK Cancel Save Load Advanced Keyboard

Step 3: Pre-processing - re-slicing with time relative to the date of injury

- In here we will use the batch export to convert time axis of the data to number of days post injury using the 'Make time relative' box
- We will also Re-slice the data time points evenly in order to make the times compatible
- In this dataset moment of injury = 01/01/1970 00:00, so we just need to subtract this date to the absolute time and we have the # of days post injury
- Clicking start will generate new CSVs with the new time scale and a dataset ready to be used in any further analysis

Batch export of ICM+ data

Input/Output

File Type: Comma separated values file (*.csv) Output Type: .csv

Text File Format Definition csvformat_CENTER.xml

ICM+ files data folder C:\Users\Manuel Cabeleira\Desktop\10s csvs\ICPbot

Output data folder C:\Users\Manuel Cabeleira\Desktop\10s csvs\Step3 -

Change data granularity using the following summary function

Function Mean Period 10 seconds

Reslice the time scale evenly to the specified period

Make time relative to: Unix Zero Date (1/1/1970)

Patient Info file (generated by Batch Info Export)

Export this variables list only (comma separated)

Notes and events

Include Subfolders Incl. subfolders in output file names

Output in a single folder Join files from one folder

Join all files into one single file Insert DataSource column

Start Stop

Close

Other File Activities

- Batch Reanalyse
- Batch Export
- Batch Summary
- Batch Info Export
- Advanced Profile Edit
- Dta File Split
- Dta Files Header Repair
- Text File Split
- Open Software Config Folder
- Modify ICMP Variables Info

Unix Zero Date (1/1/1970)

Unix Zero Date (1/1/1970)

Windows Zero Date (31/12/1899)

Date of the data recording start

Date and Time of the data recording start

Date of Ictus

Date and Time of Ictus

Time of Admission

Date and Time of Admission

Function

None

Mean

High

Low

Median

Std Dev

MA Filter

Median Filter

10 Seconds

1 second

1 minute

1 hour

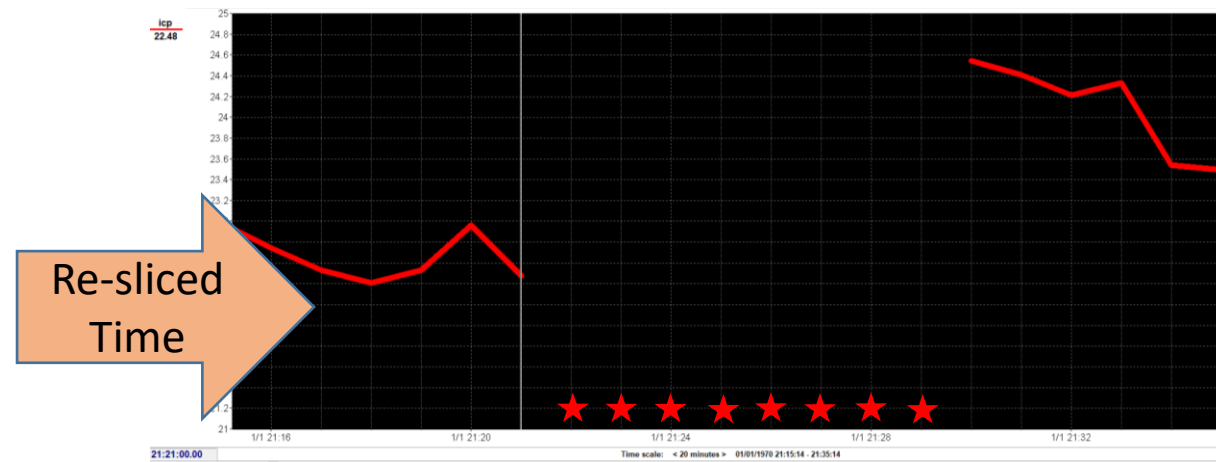
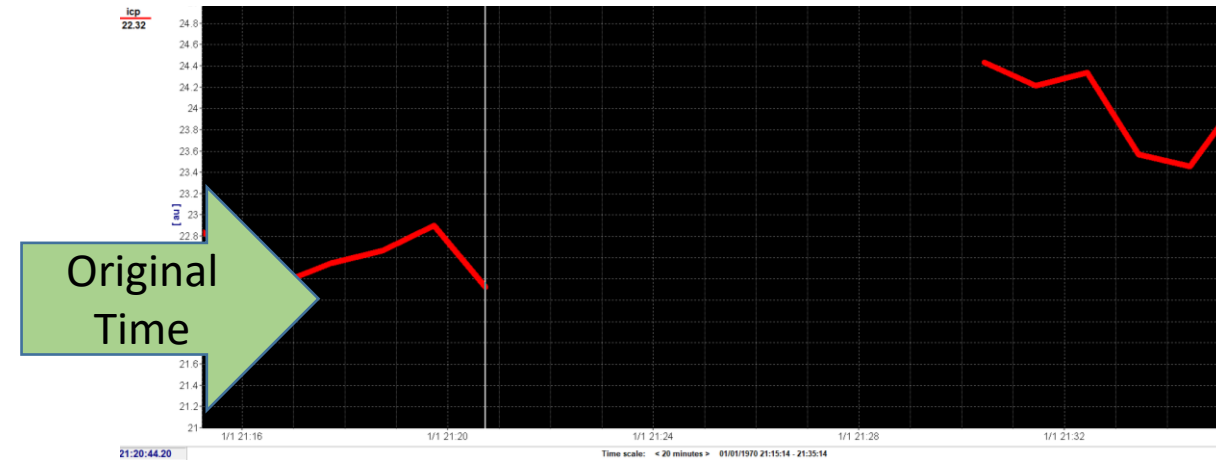
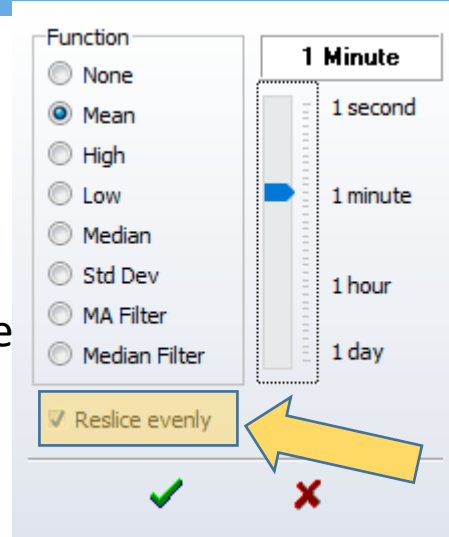
1 day

Reslice evenly

Time Re-slicing

Aligns the data in time

- Recalculates mean values according to fixed time anchors
- Makes time points compatible within the same file and in between files

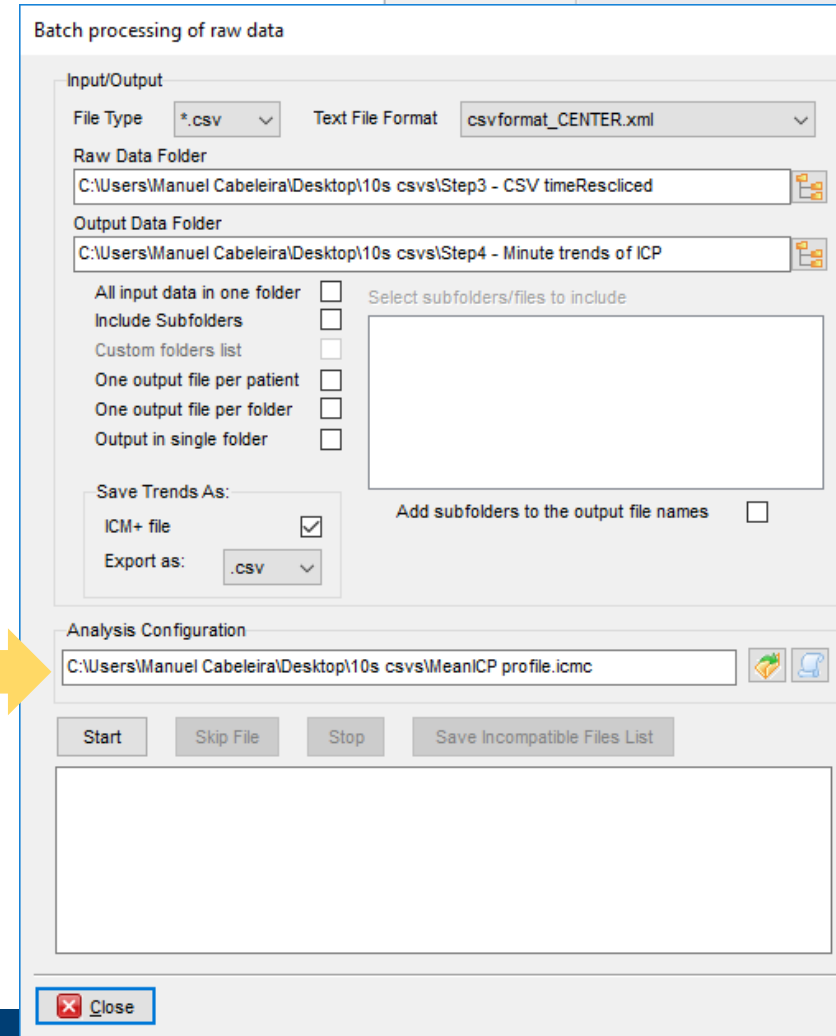
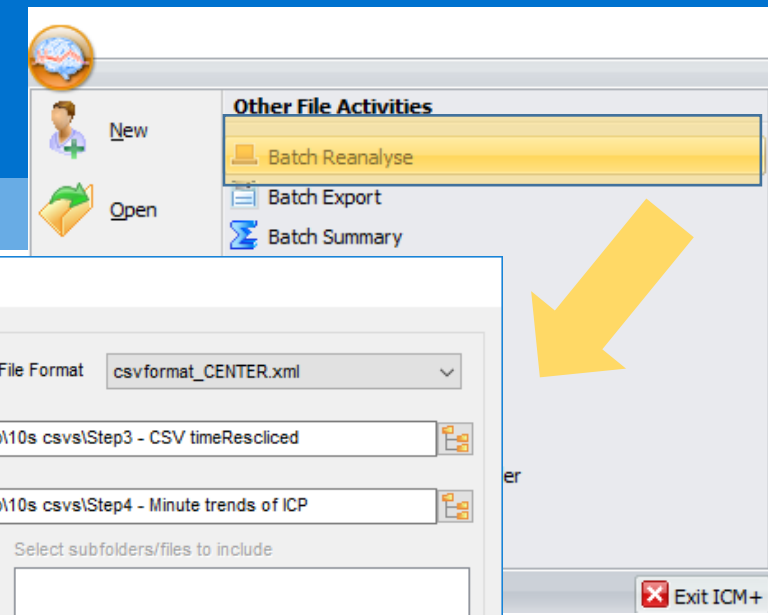


DateTime	icp
01/01/1970 21:18:44	22.67
01/01/1970 21:19:44	22.9
01/01/1970 21:20:44	22.32
01/01/1970 21:30:27	24.43
01/01/1970 21:31:27	24.22
01/01/1970 21:32:27	24.34

DateTime	icp
01/01/1970 21:19:00	22.53
01/01/1970 21:20:00	22.96
01/01/1970 21:21:00	22.48
01/01/1970 21:22:00	NAN
...	NAN
01/01/1970 21:29:00	NAN
01/01/1970 21:30:00	24.55
01/01/1970 21:31:00	24.41
01/01/1970 21:32:00	24.22

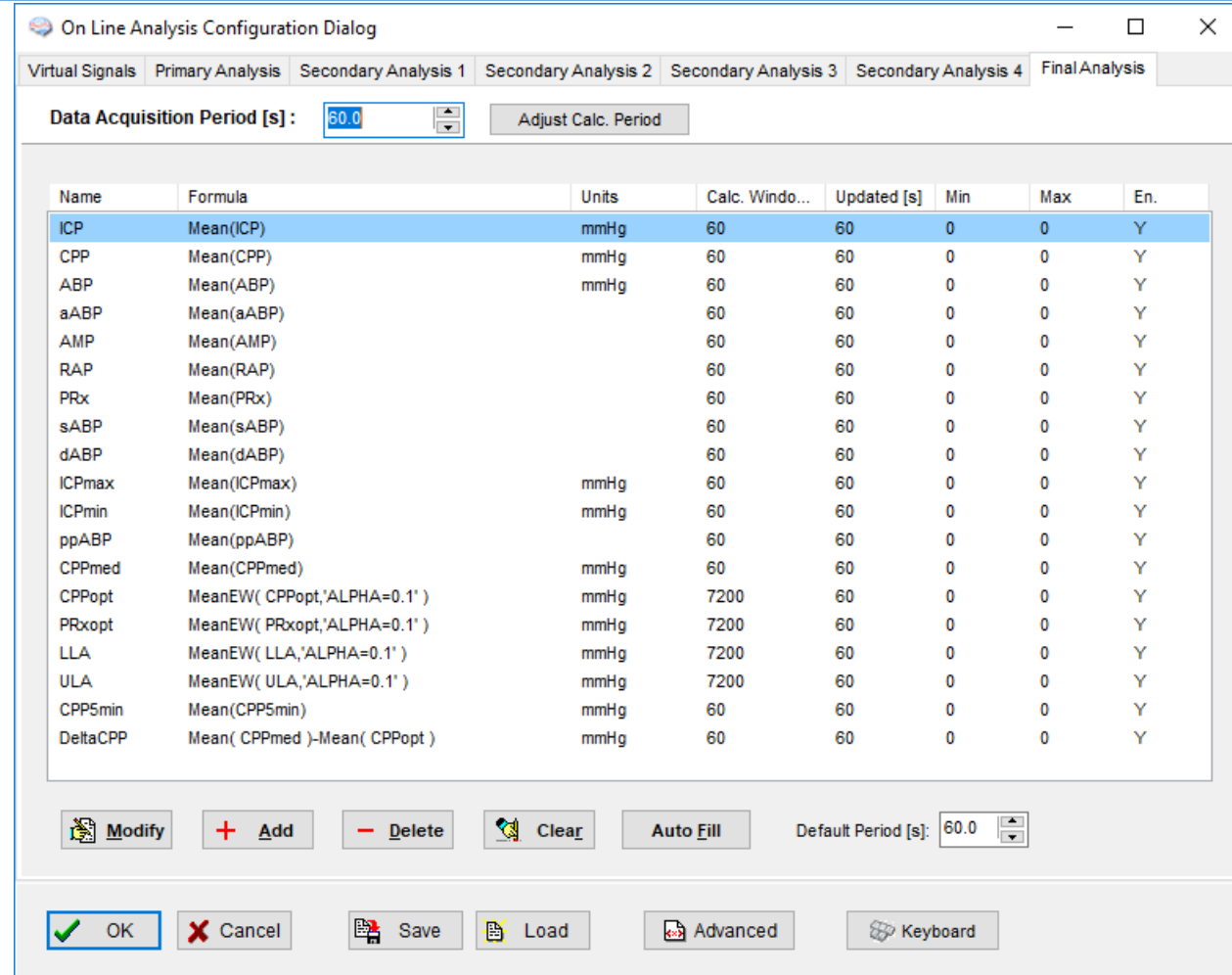
Step 4: Analysis – Create an analysis profile and apply it to your dataset

- Up to this moment all steps were fairly generic and are usually replicated in most types of analysis you will need (as long as these do not require higher frequency components, like pulse)
- From this moment on, the method of analysis will depend on your research question
- The usual SOP here is to:
 - Build a profile
 - Apply it to some of the data in a patient by patient basis
 - Readjust the profile as needed
 - Apply to all database with the batch analysis tool, once the profile is ready



Step 4: Analysis – Create an analysis profile and apply it to your dataset

- From this moment on, the method of analysis will depend on your research question
- The usual SOP here is to:
 - Build a profile
 - Apply it to some of the data in a patient by patient basis
 - Readjust the profile as needed
 - Apply to all database with the batch analysis tool, once the profile is ready
- For this demonstration the profile calculates 1 minute trends of ICP only



On Line Analysis Configuration Dialog

Virtual Signals Primary Analysis Secondary Analysis 1 Secondary Analysis 2 Secondary Analysis 3 Secondary Analysis 4 Final Analysis

Data Acquisition Period [s]: 60.0 Adjust Calc. Period

Name	Formula	Units	Calc. Windo...	Updated [s]	Min	Max	En.
ICP	Mean(ICP)	mmHg	60	60	0	0	Y
CPP	Mean(CPP)	mmHg	60	60	0	0	Y
ABP	Mean(ABP)	mmHg	60	60	0	0	Y
aABP	Mean(aABP)		60	60	0	0	Y
AMP	Mean(AMP)		60	60	0	0	Y
RAP	Mean(RAP)		60	60	0	0	Y
PRx	Mean(PRx)		60	60	0	0	Y
sABP	Mean(sABP)		60	60	0	0	Y
dABP	Mean(dABP)		60	60	0	0	Y
ICPmax	Mean(ICPmax)	mmHg	60	60	0	0	Y
ICPmin	Mean(ICPmin)	mmHg	60	60	0	0	Y
ppABP	Mean(ppABP)		60	60	0	0	Y
CPPmed	Mean(CPPmed)	mmHg	60	60	0	0	Y
CPPopt	MeanEW(CPPopt,'ALPHA=0.1')	mmHg	7200	60	0	0	Y
PRxopt	MeanEW(PRxopt,'ALPHA=0.1')	mmHg	7200	60	0	0	Y
LLA	MeanEW(LLA,'ALPHA=0.1')	mmHg	7200	60	0	0	Y
ULA	MeanEW(ULA,'ALPHA=0.1')	mmHg	7200	60	0	0	Y
CPPSmin	Mean(CPPSmin)	mmHg	60	60	0	0	Y
DeltaCPP	Mean(CPPmed)-Mean(CPPopt)	mmHg	60	60	0	0	Y

Modify Add Delete Clear Auto Fill Default Period [s]: 60.0

OK Cancel Save Load Advanced Keyboard

Create a Macro function using script lab tool

- To calculate the dose of ICP we will need to create a custom function and save it as a macro.
 - This is done in ScriptLab tool on ICM+

This function is :

$$Bool = \begin{cases} 0 & \text{if } ICP < \text{threshold} \\ 1 & \text{if } ICP > \text{threshold} \end{cases}$$

$$dose = \frac{\sum(ICP - \text{Threshold}) * Bool}{\text{SamplingFreq}(ICP) * 3600}$$

The screenshot shows the ICM+ software interface with a graph of ICP signals and the Script Lab tool. The graph displays a red signal over time, with a vertical blue line indicating a threshold. The Script Lab tool is open, showing workspace variables and a table of variables.

Name	Type	Value
icp	Vector	1x998
\$time	Vector	1x998

The Script Lab tool also shows a list of functions and operators, including a macro function named `Dose_Above_Thr(,)`.

Yellow arrows indicate the workflow: from the ICM+ interface to the Script Lab tool, and from the Script Lab tool to the macro function definition.

Create a Macro function using script lab tool

- To calculate the dose of ICP we will need to create a custom function and save it as a macro.
 - This is done in ScriptLab tool on ICM+

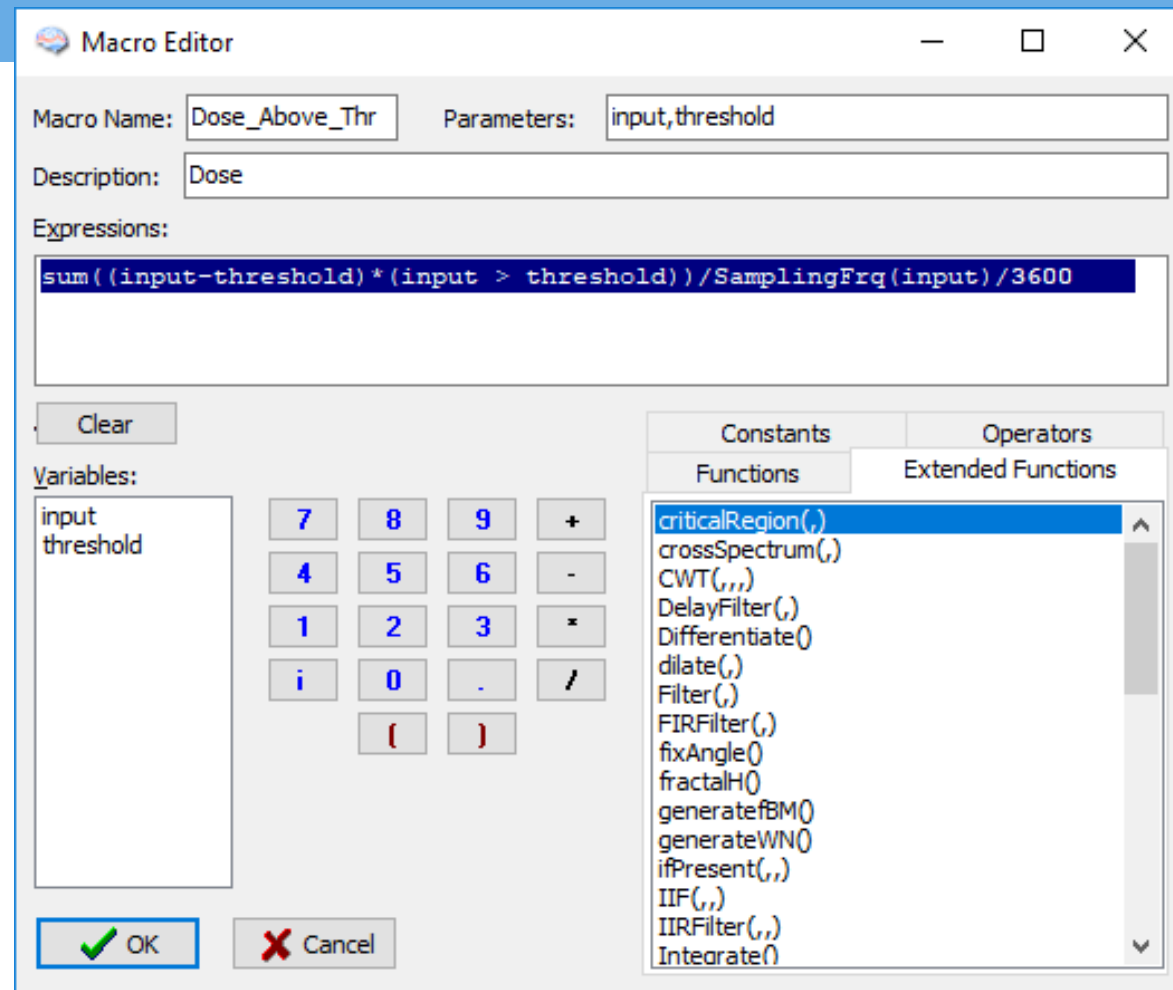
This function is :

$$Bool = \begin{cases} 0 & \text{if } ICP < threshold \\ 1 & \text{if } ICP > threshold \end{cases}$$

$$dose = \frac{\sum(ICP - Threshold) * Bool}{SamplingFreq(ICP) * 3600}$$

In ICM+ this would look as :

`sum((input-threshold)*(input > threshold))/SamplingFrq(input)/3600`



Step 5: Analysis – Calculate one value of dose of ICP per patient

Batch Summary tool allows the user to calculate one number/recording according to the required criteria.

In the case of our research question the criteria are:

- Time period = 3 days (72 hours)
- Calculate the dose of ICP as defined before

Clicking Start generates a file containing:

- Name of the recording
- Mean value
- Number of occurrences
- Dose of ICP

Batch summary calculation

Input/Output
File Type: Text File Format
Comma separated values file (*.csv) csvformat_CENTER.xml

Data files folder
C:\Users\Manuel Cabeira\Desktop\10s.csv\Step4 - Minute trends of ICP

Include Subfolders Variables suffix

Output file Extend the output file
C:\Users\Manuel Cabeira\Desktop\10s.csv\Step5 - Dose calculation\ICP_Dose.csv

Auxiliary lookup up data (matched by data filename)

Time Period
Full Period Period [h] 0.00 to 72.00
Relative to Windows Zero Date (31/12/1899)

Patient Info file (generated by Batch Info Export)

Formulae to apply to each variable (unless excluded by the filter)

Name	Function call	Filter
mean	mean(input)	
N	length(input)	
Dose_Above_Thr	Dose_Above_Thr(input,22)	

Start Stop

Advanced Stats Function Selection For...
Name: Dose_Above_Thr
Formula: Dose_Above_Thr(input,22)
Apply only to the these signals (comma separated, leave empty for all):
Constants Operators Functions Extended Functions Macros

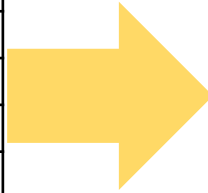
Step 5: Analysis – Calculate one value of dose of ICP per patient

Here you can also imbue the data with extra information by loading a comma separated text file

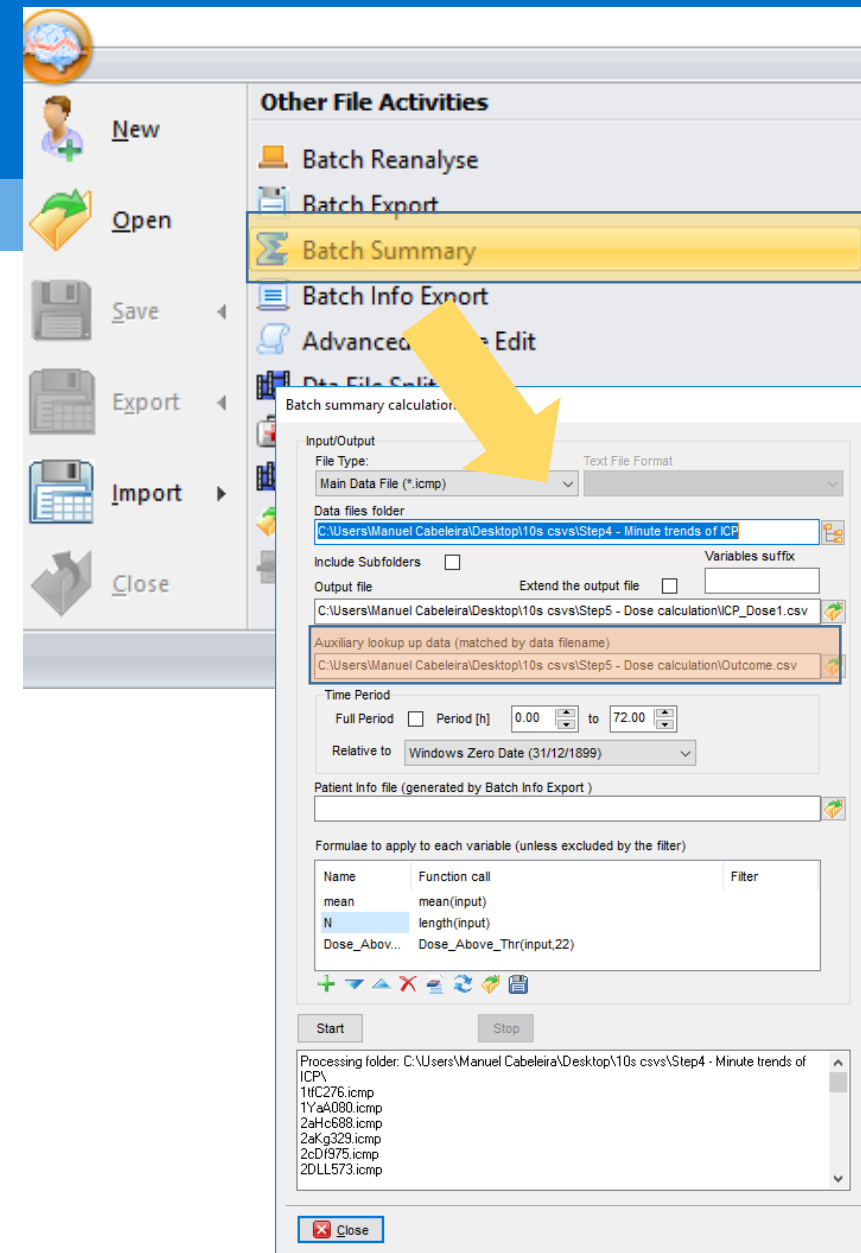
In this file, the patient identifiers need to be the same as in the dataset

For this demonstration we have added GOS information to the resulting file

DataSource	GOS
1tfC276	1
1YaA080	3
2aHc688	5
2aKg329	2
2cDf975	3
2DLL573	1
2eCT283	4
2EeT899	3
2GGu783	2
2KDX695	4
2LvU583	3



	A	B	C	D	E
1	DataSource	GOS	ICP_mean	ICP_N	ICP_Dose_Above_Thr
2	1tfC276	1	15.99	2375	0.0498
3	1YaA080	3	24.26	2279	160.5
4	2aHc688	5	12.01	3578	2.575
5	2aKg329	2	13.45	2040	0.1515
6	2cDf975	3	7.245	2228	0
7	2DLL573	1	16.23	3888	31.66
8	2eCT283	4	8.375	1955	1.128
9	2EeT899	3	55.9	3238	1748
10	2GGu783	2	8.372	3488	4.109
11	2KDX695	4	12.22	2185	0.5888
12	2LvU583	3	10.58	3408	0.0437



Another research question – ICP daily dose time profile

In here we proceed the same as we did for the previous case but here, we will have to run a Batch Summary for every day.

If you tick the ‘Extend the output file’ ICM+ will add every new run of the summary calculations to the same file

	DataSource	GOS	ICP_mean_Day1	ICP_N_Day1	ICP_Dose_Day1	ICP_mean_Day2	ICP_N_Day2	ICP_Dose_Day2	ICP_mean_Day3	ICP_N_Day3	ICP_Dose_Day3
1	1tfC276	1	0	0	0	16.72	935	0.0212	15.56	1440	0.0286
3	1YaA080	3	0	0	0	18.71	839	9.436	27.49	1440	151
4	2aHc688	5	12.8	698	1.481	10.49	1440	0.4148	13.11	1440	0.6797
5	2aKg329	2	0	0	0	13.58	600	0	13.39	1440	0.1515
6	2cDf975	3	0	0	0	8.372	788	0	6.628	1440	0
7	2DLL573	1	14.46	1008	0	18.99	1440	31.54	14.69	1440	0.1216
8	2eCT283	4	0	0	0	4.382	515	0	9.833	1440	1.128
9	2EeT899	3	36.58	358	54.47	55.62	1440	806.8	58.97	1440	887.2
10	2GGu783	2	8.54	690	0.8074	7.971	1440	2.2	8.92	1358	1.102
11	2KDX695	4	0	0	0	11.57	745	0.2692	12.57	1440	0.3196
12	2LvU583	3	12.27	528	0	9.575	1440	0	10.82	1440	0.0437

Thank you for listening!

Now you can concentrate mostly on having ideas and write papers as ICM+ will do the analysis for you =D

