

# Data analysis with ICM+

Peter Smielewski, PhD Division of Neurosurgery, Department of Clinical Neursciences



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DISCLOSURE



### **Data examples**

📕   🕑 📕 🔻   Patient_0						- 0 X
File Home Share View						~ 6
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Cipbdard Or	ganise		New	Open	Select	220
← → ✓ ↑ A > This PC > Documents > ICM+	> Data >	> Day 1 > P	atient_0	~ 0	Search Patie	ent_0 P
Configs	^	Name	<u>.</u>	Date	modified	Туре
Data		confi	as	21/10	)/2017 08:52	File folder
CPPopt meeting		work	folder	21/10	)/2017 08:52	File folder
📕 Day 1		🔽 🔙 patie	ntl	11/10	0/2017 07:32	ICM+ data file
Patient_0		🗋 patie	nt1_r01.artf	17/05	9/2017 21:31	ARTE File
configs	1.0	📳 patie	nt1_r01	08/05	9/2009-00:05	ICM+ raw data file
work folder		🗋 patie	nt1_r02.artf	17/05	9/2017 21:32	ARTF File
Patient1 JD		📓 patie	nt1_r02	08/09	9/2009 07:22	ICM+ raw data file
Patient2 ID		🖳 patie	nt1_r03	08/05	3/2009 14:39	ICM+ raw data file
Deficient2.1D		関 patie	nt1_r04	08/05	9/2009 21:55	ICM+ raw data file
Patients_JD		📓 patie	nt1_r05	09/09	9/2009-05:13	ICM+ raw data file
Patient4_JD		🗋 patie	nt1_r06.artf	17/09	2/2017 21:34	ARTE File
Patient5_Refractory Hypertension		D patie	nt1_r06	09/09	3/2009 12:30	ICM+ raw data file
Day 2		Patie	nt1_r07	09/05	/2009 19:46	ICM+ raw data file
Patient_CrCP	~ «	-	1.055	- 1 (2)		
23 items 1 item selected 536 KB						





### **Open the data file**







### The main (summaries) file







### **Close the file**







### **Open the raw data file**





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### **Raw data loading period selection**



Estimate of memory needed to load

![](_page_7_Picture_3.jpeg)

![](_page_7_Picture_4.jpeg)

### Viewing the data

![](_page_8_Figure_1.jpeg)

![](_page_8_Picture_2.jpeg)

![](_page_8_Picture_4.jpeg)

### Viewing the data

![](_page_9_Figure_1.jpeg)

![](_page_9_Picture_2.jpeg)

![](_page_9_Picture_4.jpeg)

### Viewing the data

![](_page_10_Figure_1.jpeg)

![](_page_10_Picture_2.jpeg)

![](_page_10_Picture_4.jpeg)

### Open the file in 're-analysis' mode

![](_page_11_Picture_1.jpeg)

![](_page_11_Picture_2.jpeg)

![](_page_11_Picture_3.jpeg)

### **Do NOT** load any configuration yet

![](_page_12_Picture_1.jpeg)

### **Analysis configuration editor**

![](_page_13_Picture_1.jpeg)

### Add signals to be analysed

🌺 On Line Analy	sis Configuration Dia	ialog	
Virtual Signals P	rimary Analysis Final	I Apahreis	
		Virtual Signal Definition Editor	
Name	Formula	Name : Valid range for values	d
icp	icp	ABP Min Value : 0 ABP Enabled	
abp	abp	Formula:	
pto2	pto2	abp	
ecg	ecg	Clear Constants Operators	
		Variables: Functions Extended Functions	
		abp 7 8 9 + DelayFilter(,)	
		icp 4 5 6 - Differentiate() Filter(.)	
		pto2 1 2 3 * FIRFilter(,) fixAngle()	
		1 0 . / ifPresent(,,)	
		() ) IIRFitter(,,)	
		Integrate() MedianFilter()	
		Sampling frequency conversion MovingAvgFilter(,)	
		Sampling Frq [Hz]: 200.0 SampleIdx()	
		Use Decimating Filter SamplingFrq()	
<b>NO</b> 11			
Modify	+ <u>A</u> dd	Cancel & Keyboard	
✓ OK	X Cancel	Save Load Advanced Sp Keyboard	

![](_page_14_Picture_2.jpeg)

![](_page_14_Picture_4.jpeg)

### **Add basic summaries**

![](_page_15_Picture_1.jpeg)

![](_page_15_Picture_2.jpeg)

![](_page_15_Picture_4.jpeg)

# Adding more formulae

Virtual Signals Prin	nary Analysis Final Analysis				
Name	Formula	Calc. Window	Updated [s]	Min Ma	ax E
icp	Mean(icp)	10	10	0 0	Y
abp pto2	oose the calculation window siz	е	10	<u> </u>	× .
ecg	Name : Calculation Window Specification		Valid values range		
	CPP Calculation Period : 10	s	Max Value: 0		
	Enabled Vpdate Period : 10	s	Min Value : 0		
	K	Choose	the calcula	ation rate	
	Formula:				Function
	abs	A Inser	rt Function	Ser	Arguments ies 1 : icp
Modify	Tops     Function:     Option       7     8     9     +       HRVstats     Index     Index       Intercept     IsNANFree	s:			abp icp pto2
ose Mean fur	Ction 3 * Kurtosis Length Max	Dou	uble click to	o choose	the variab
	Delete () MeanFW *				
	Function description:	uffer			

### **Adding PRx calculation**

Calculatio	on window Final Analysis Configur	v size 5 min
Data Acquis	Name : PRx Units :	Calculation Window Specification Calculation Period: 300 s Max Value: 0 Update Period: 60 Calculation rate - every 1 minute
Name	Enabled 🔽	Brief description of the parameter
ICP pto2	Formula: Correl( abp,icp ) abs	Double click 'abp' and then 'icp' Function Arguments: Series 1: abp Series 2: icp
Choose Correl function	Dn 7 8 9 + 4 5 6 - 1 2 3 * 0 . / Delete () Function descripti Function calculates F	AUC BaroIndex BaroIndexEx BaroSpidxEx Coherence Correl Correl ConseCorrel Consecorrel C

![](_page_17_Picture_2.jpeg)

![](_page_17_Picture_4.jpeg)

### **Final parameters**

irtual Signals	Primary Analysis Fi	nal Analysis							
Data Acqu	isition Period [s] :	60.0		Adjust Calc. Period					
Name	Formula			Units	Calc. Windo	Updated [s]	Min	Max	En.
icp	Mean(icp)			1.1112	60	60	0	0	Y
abp	Mean(abp)				60	60	0	0	Y
pto2	Mean(pto2)				60	60	0	0	Y
CPP	Mean(CPP)				60	60	0	0	Y
PRx	Correl( abp.icp )				300	60	0	0	Y
Moo	lify + Add	<u> </u>	ete	Ciear Au	to <u>F</u> ill De	fault Period [s]:	60.0		

![](_page_18_Picture_2.jpeg)

![](_page_18_Picture_4.jpeg)

### **Start analysis**

![](_page_19_Figure_1.jpeg)

![](_page_19_Picture_2.jpeg)

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### **Running the calculation**

![](_page_20_Figure_1.jpeg)

![](_page_20_Picture_2.jpeg)

### **Resulting trends**

![](_page_21_Figure_1.jpeg)

Build the desired visualisation by adding more charts

![](_page_21_Picture_3.jpeg)

![](_page_21_Picture_4.jpeg)

### Load preconfigured charts layout

![](_page_22_Figure_1.jpeg)

![](_page_22_Picture_2.jpeg)

![](_page_22_Picture_3.jpeg)

### Multipage view of the data

![](_page_23_Figure_1.jpeg)

![](_page_23_Picture_2.jpeg)

![](_page_23_Picture_4.jpeg)

### **Histograms**

![](_page_24_Figure_1.jpeg)

![](_page_24_Picture_2.jpeg)

![](_page_24_Picture_4.jpeg)

### Histograms

![](_page_25_Figure_1.jpeg)

![](_page_25_Picture_2.jpeg)

![](_page_25_Picture_3.jpeg)

![](_page_25_Picture_4.jpeg)

# Visualising PRx against CPP

![](_page_26_Figure_1.jpeg)

![](_page_26_Picture_2.jpeg)

![](_page_26_Picture_3.jpeg)

### 'Optimal CPP' curve

![](_page_27_Figure_1.jpeg)

![](_page_27_Picture_2.jpeg)

![](_page_27_Picture_4.jpeg)

### 'Optimal CPP' curve

![](_page_28_Figure_1.jpeg)

![](_page_28_Picture_2.jpeg)

![](_page_28_Picture_4.jpeg)

# Limits of autoregulation

![](_page_29_Figure_1.jpeg)

![](_page_29_Picture_2.jpeg)

![](_page_29_Picture_4.jpeg)

### 'LOW RES summaries 10s.dta' data file

To speed up further analysis we'll use pre-processed data source file (for the purpose of this workshop)

![](_page_30_Picture_2.jpeg)

![](_page_30_Picture_3.jpeg)

### 10s downsampled data file

![](_page_31_Figure_1.jpeg)

![](_page_31_Picture_2.jpeg)

![](_page_31_Picture_4.jpeg)

### Select the LOW RES data file for analysis

![](_page_32_Picture_1.jpeg)

![](_page_32_Picture_2.jpeg)

![](_page_32_Picture_4.jpeg)

### **Configuring real time CPPopt calculation**

### Right click on the 'Final Analysis'

🌺 On Line An	alysis Configuration E	)ialog	tab	_	_	_			<b>_ D X</b>
Virtual Signals Data Acqui	Primary Analysis Fin	al Analysis 60.0	Inser Add	t Extra Analysis Extra Analysis P	Page				
			Delet	e Current Analy	rsis Page				
Name	Formula	-		Units	Calc. Wind	lo Updated [s]	Min	Max	En.
іср	Mean(icp)				60	60	0	0	Y
abp	Mean(abp)				60	60	0	0	Y
pto2	Mean(pto2)				60	60	0	0	Y
CPP	Mean(CPP)				60	60	0	0	Y
PRx	Correl( abp,icp )				300	60	0	0	Y
Mod	lify <u>+ A</u> dd	<u>– D</u> e	lete	Clear	Auto <u>F</u> ill	Default Period [s]:	60.0 (	4	
🗸 ок	X Cancel	P	ave 📔	j Load	Advanced	🛞 Кеу	board		

![](_page_33_Picture_3.jpeg)

### **Configuring real time CPPopt calculation**

0 🤃	n Line Ana	alysis Configuration	Dialog							x
Virtu	al Signals	Primary Analysis S	econdary Analysis 1	Final Analysis						
D	ata Acqui	sition Period [s] :	60.0	Adjust Cal	c. Period	]				
	Name	Formula		Unit	s	Calc. Wind	Updated [s]	Min	Max	E
	СР	Mean(ICP)				60	60	0	0	Y
	ABP	Mean(ABP)				60	60	0	0	Y
F	PtO2	Mean(PtO2)				60	60	0	0	Y
F	PRx	Mean(PRx)				60	60	0	0	Y
	CPP	Mean(CPP)				60	60	0	0	Y
						Popu	ate the	e me	an va	lues
						first				
(	🖹 Modi	ify <u>A</u> dd	<u> </u>	🙀 Clea <u>r</u>	Aut	o <u>F</u> ill	Default Period	[s]: 60.0		
	🖊 ок	X Cancel	😫 Save	\rm Load		Advanced		Keyboard		

![](_page_34_Picture_2.jpeg)

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### **Configuring real time CPPopt calculation**

	Final Analysis Configuration Editor	Function options	×	
	Name : Calculation Window Specificatio	Function: OptimalValue		
Vitu	Calculation Period : 1440	Missing Data Limit [%]	100.00	
D	Update Period : 60	Number of bins	16	
	Enabled V Optimal Cerebral Perfusion	Minimum bin value	40	the input variables
		Maximum bin value	120	
	OptimalValue( CPP,PRx,'BINS=16&MINVAL=40&MAXV	Minimum bin data count [%]	1.00	Function Y Arguments :
Choose Ontima	Value function	Minimum included data [%]	50.00	: СРР
Choose Optima		Minimum Y span	0.00	PRx Y
	9 + Min Moment	Concave		abp CPP
	4 5 MSEntropy OptimalValue	Need not include 'best'		icp PRx
	1 2 3 * OptimalValueFlex Percentile	Use error weighting		pto2
	0 . / PhaseShift Power	Enforce Y range		
	Delete () DuiseState	Enforce Y region - Min	0.00	
	Function description:	Enforce Y region - Max	0.00	
	fit a parabolic function to the resulting XY plot. Point of the	Optimal range threshold	NAN	alue.
	The function can also return:	Min value of lower breakpoint	0.00	
	- relative size of data included in the curve - span of the fitted curve, and	Max value of upper breakpoint	0.00	
	- the fit type: 0 - no fit possible,	Output value type	Optimal X 🔹	
		VOK X Cancel		
	OK X Cancel X Keyboard			

![](_page_35_Picture_2.jpeg)

![](_page_35_Picture_3.jpeg)

![](_page_35_Picture_4.jpeg)

### **Calculating lower limit of AR**

ame :	Calculation Window Spec	ification			Valid va	Function options	-	2		
LA	Calculation Period :	14400		s	Max Va					
nits :	Update Period :	60		s	Min Val	Function: OptimalValue				
	Priof description of the	paramet	ar			Missing Data Limit [%]	100.00			
Enabled 🔽	Lower limit of autorem	ulation	er			Number of bins	16			
	20mol minicol datologi	ancaron				Minimum bin value	40			
ormula:						Maximum bin value	120			
OptimalValue( CI	PP,PRx,'BINS=16&MINVAL=40&	MAXVAL=	=120&TH	RSHLD=0.2&OUT	=LL')	Minimum bin data count [%]	1.00			
						Minimum included data [9/]	50.00			
abs 🔻 📋	Function :	Ор	otions:		Insert Fun	Minimum included data [%]	50.00			
7 8 9 4	OptimalValue	A MC	DLIM	Missing Data Li	mit [%] (0 - 1	Minimum Y span	0.00	6		
4 5 6 .	Percentile	BI	INS (AL	Number of bins	(1 - 1000)	Concave				
	PhaseShift	M	INVAL AXVAL	Maximum bin va Maximum bin va	alue	Need not include 'best'				
	PulseStats	M	INBIN	Minimum bin da	ta count [%]	Use error weighting				
	Range	- MI	INDATA INVSP	Minimum includ Minimum V sna	ed data [%] ( n	Enforce Y range				
Delete (	RankCorrel		ONCAVE	Concave (Y/N)		Enforce Y region - Min	0.00			
Function descrip	tion: h. can be used to track 'Optimal C	DD' divide	ae V variat	lee valuee into hi	and calou	Enforce Y region - Max	0.00	8		
fit a parabolic funct	ion to the resulting XY plot. Point	of the min	nimum/max	imum of the funct	ion is returne	Optimal range threshold	0.2			
The function can a	et the function can return the lov so return:	ver and up	pper limit o	r the optimal range	ə.	Min value of lower breakpoint	0.00			
<ul> <li>relative size of da span of the fitted</li> </ul>	ta included in the curve fit, curve, and					Max value of upper breakpoint	0.00			
the fit type:	,					Output value or upper or eatpoint	Louis Ontlint	<u>ک</u>		
J - no fit possible,						Output value type	Lower Opt Limit	•		

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![](_page_36_Picture_2.jpeg)

### Analysis with CPPopt added

4	👷 On Line Ana	alysis Configuratio	on Dialog							_ 0	x
	Virtual Signals	Primary Analysis	Secondary Analysis 1	Final Analysis							
	Data Acqui	sition Period [s]	60.0	Adjust Calc. I	Period						
	Name	Formula		Units	C	alc. Windo	Updated [s]	Min	Max	En.	
	icp	Mean(icp)			6	0	60	0	0	Y	
	abp	Mean(abp)			6	0	60	0	0	Y	
	pto2	Mean(pto2)			6	0	60	0	0	Y	
L	CPP	Mean(CPP)			6	0	60	0	0	Y	
L	PRx	Mean(PRx)			6	0	60	0	0	Y	
	CPPopt	OptimalValue(	CPP, PRx, 'BINS=16&MIN	/AL=40&MA	1	440	60	0	0	Y	
	Mod	ify <u>+ A</u> dd	<u> <u>D</u>elete</u>	Clear	Auto <u>F</u> il	I Def	fault Period [s]:	60.0			
	🗸 ок	X Cancel	Save	🖺 Load	Ad 🔊	vanced	🛞 Key	board			

![](_page_37_Picture_2.jpeg)

![](_page_37_Picture_4.jpeg)

### Load the complete analysis configuration profile

![](_page_38_Picture_1.jpeg)

![](_page_38_Picture_2.jpeg)

![](_page_38_Picture_3.jpeg)

### Do not start analysis yet Lets examine the configuration first

![](_page_39_Figure_1.jpeg)

![](_page_39_Picture_2.jpeg)

![](_page_39_Picture_4.jpeg)

### View the analysis configuration

![](_page_40_Figure_1.jpeg)

![](_page_40_Picture_2.jpeg)

### View the analysis config

![](_page_41_Figure_1.jpeg)

![](_page_41_Picture_2.jpeg)

![](_page_41_Picture_4.jpeg)

### **Start the analysis**

![](_page_42_Figure_1.jpeg)

![](_page_42_Picture_2.jpeg)

![](_page_42_Picture_4.jpeg)

### **Running the calculation**

![](_page_43_Figure_1.jpeg)

![](_page_43_Picture_2.jpeg)

![](_page_43_Picture_4.jpeg)

### **Results - CPPopt trend page**

![](_page_44_Figure_1.jpeg)

![](_page_44_Picture_2.jpeg)

![](_page_44_Picture_4.jpeg)

### Adding variables to the chart

![](_page_45_Figure_1.jpeg)

![](_page_45_Picture_2.jpeg)

![](_page_45_Picture_3.jpeg)

### Adding ULA and LLA to the chart

![](_page_46_Figure_1.jpeg)

![](_page_46_Picture_2.jpeg)

![](_page_46_Picture_3.jpeg)

# Modify the plot type to 'Area'

![](_page_47_Figure_1.jpeg)

![](_page_47_Picture_2.jpeg)

![](_page_47_Picture_3.jpeg)

### **Modify the colours**

![](_page_48_Figure_1.jpeg)

![](_page_48_Picture_2.jpeg)

![](_page_48_Picture_4.jpeg)

# Final presentation of the limits of autoregulation trend (the green band)

![](_page_49_Figure_1.jpeg)

![](_page_49_Picture_2.jpeg)

![](_page_49_Picture_3.jpeg)

### Time to explore other examples

### Patient 1

### Patient 2

Presentation: <u>19 year old</u> male GCS 7 diffuse axonal injury or Presentation: 20 yr male, Motor cyclist hit by a car. GC5 9, initial CT with left frontal contusions op CT shown).

### Patient 3

Presentation <u>18 year-old</u> female RTA GCS 6, pupils reactive

On CT contusions with oe Decompression after 4 da

![](_page_50_Picture_8.jpeg)

![](_page_50_Picture_9.jpeg)

Monitoring shows goo

Good recovery at 6 m

Monitoring features – Disturbed PRx,

Patient died.

# C. E

Before

Severe disability at 6 mor

### Patient 4

Presentation

25 year-old male RTA (paedestrian hit by lorry). Both pupils reactive and GCS 3.

Initial CT: Left subdural, frontal contusions, skull fracture.

![](_page_50_Picture_21.jpeg)

Monitoring features- 'solid red line' PRx, and high PbTO2 and then refractory high ICP.

Patient died.

![](_page_50_Picture_24.jpeg)

![](_page_50_Picture_26.jpeg)