

# **Non-invasive assessment of intracranial pressure - a plugin function of ICM+ system**

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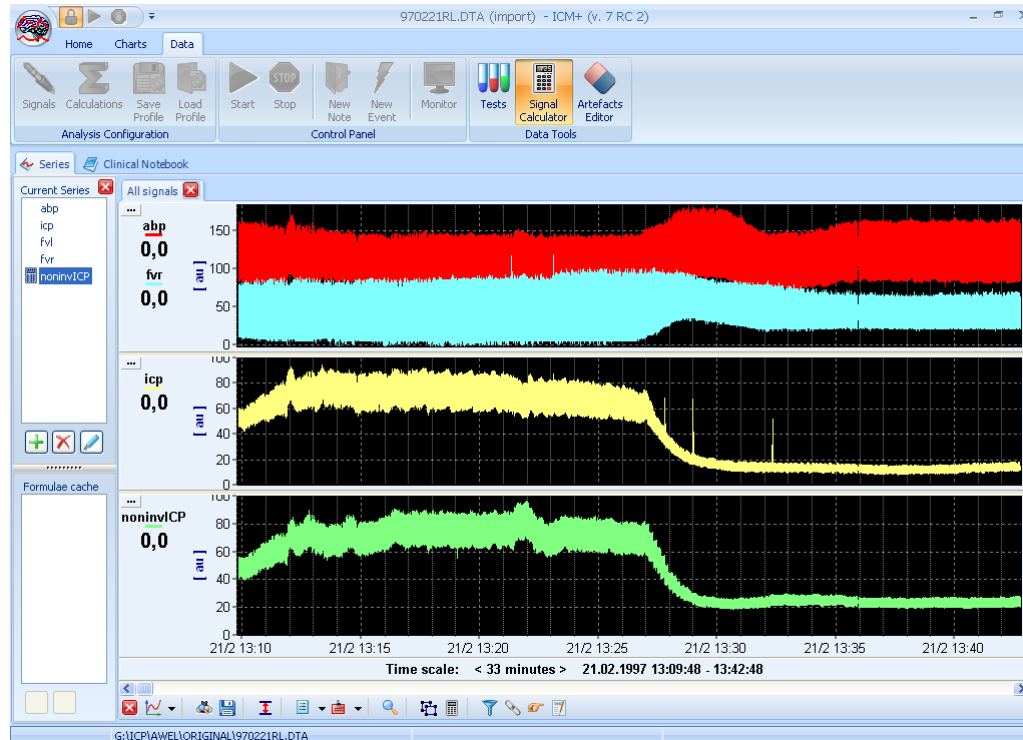
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# Non-invasive ICP assessment procedure

- The procedure calculates Intracranial Pressure from Arterial Blood Pressure and Transcranial Doppler Blood Flow Velocity of Middle Cerebral Artery
- Patented: by Patent Nr. DE 196 00 983
- Distributed by the authors as a Plugin of ICM+ Monitoring Software / University Cambridge, UK  
- for scientific use only -

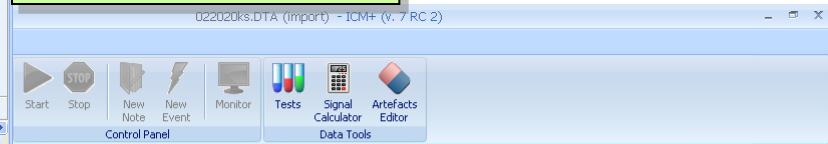
The list of functions in ICM+ can be extended by **plugins**.

One such plugin already available for ICM+ enables non-invasive calculation of ICP from TCD FV and ABP signals in real time.



ICP

Non-invasive ICP



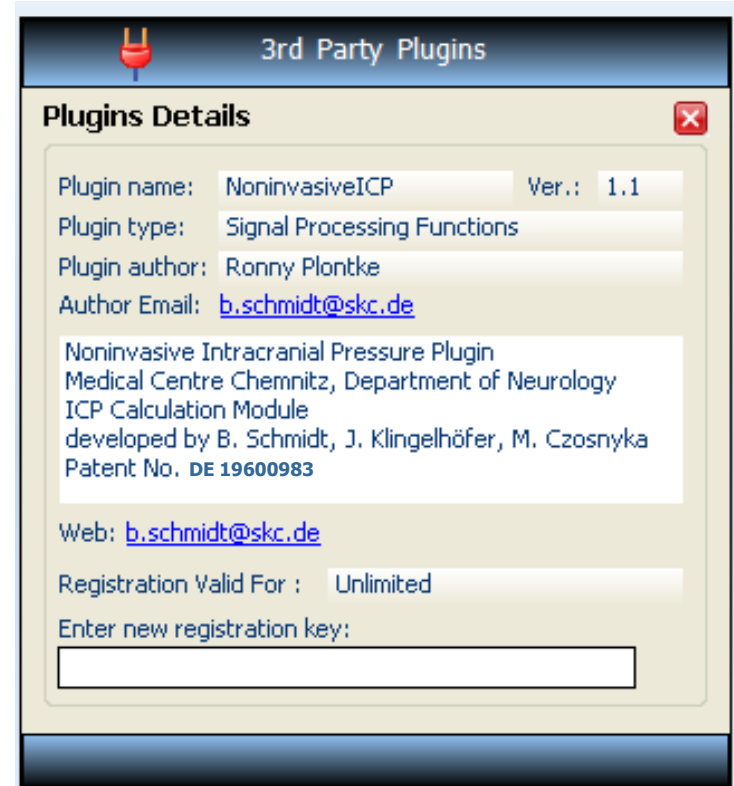
ICP

Non-invasive ICP



## How to insert nICP plugin into ICM+:

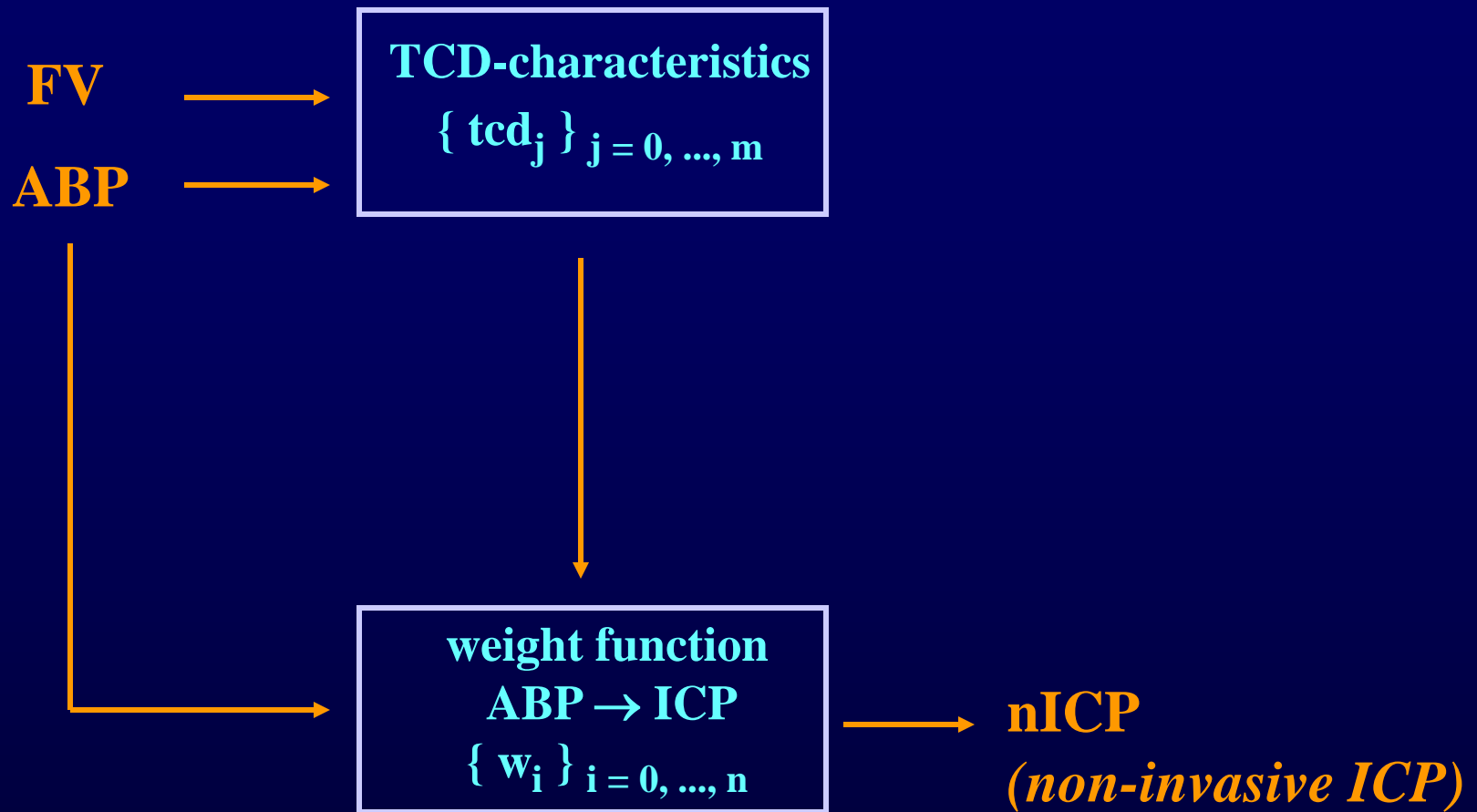
- The non-invasive ICP plugin is a DLL file, developed in a C++ Borland environment.
- Copy the plugin into the ICM+ plugin folder,  
e.g. pathname is "C:\Documents and Settings\All Users\Documents\ICM+\Plugins\"
- Now start ICM+. The plugin should be shown registration dialogue under "3rd Party Plugins.  
You send us the registration data of your ICM+ license, which contains name, company and ICM+ install code.  
The data should be exactly the same as it is in the ICM+ registration form.
- Using this data we calculate your registration key for the nICP plugin and send it back to you by email.
- You enter the registration key of this plugin in the ICM+ dialogue. This activates the nICP plugin, unlimited in time.



# Basic principle of the procedure

Calculate the signal of intracranial pressure (**ICP**) from signals of arterial blood pressure (**ABP**) and blood flow velocity (**FV**) of the middle cerebral artery (**MCA**)

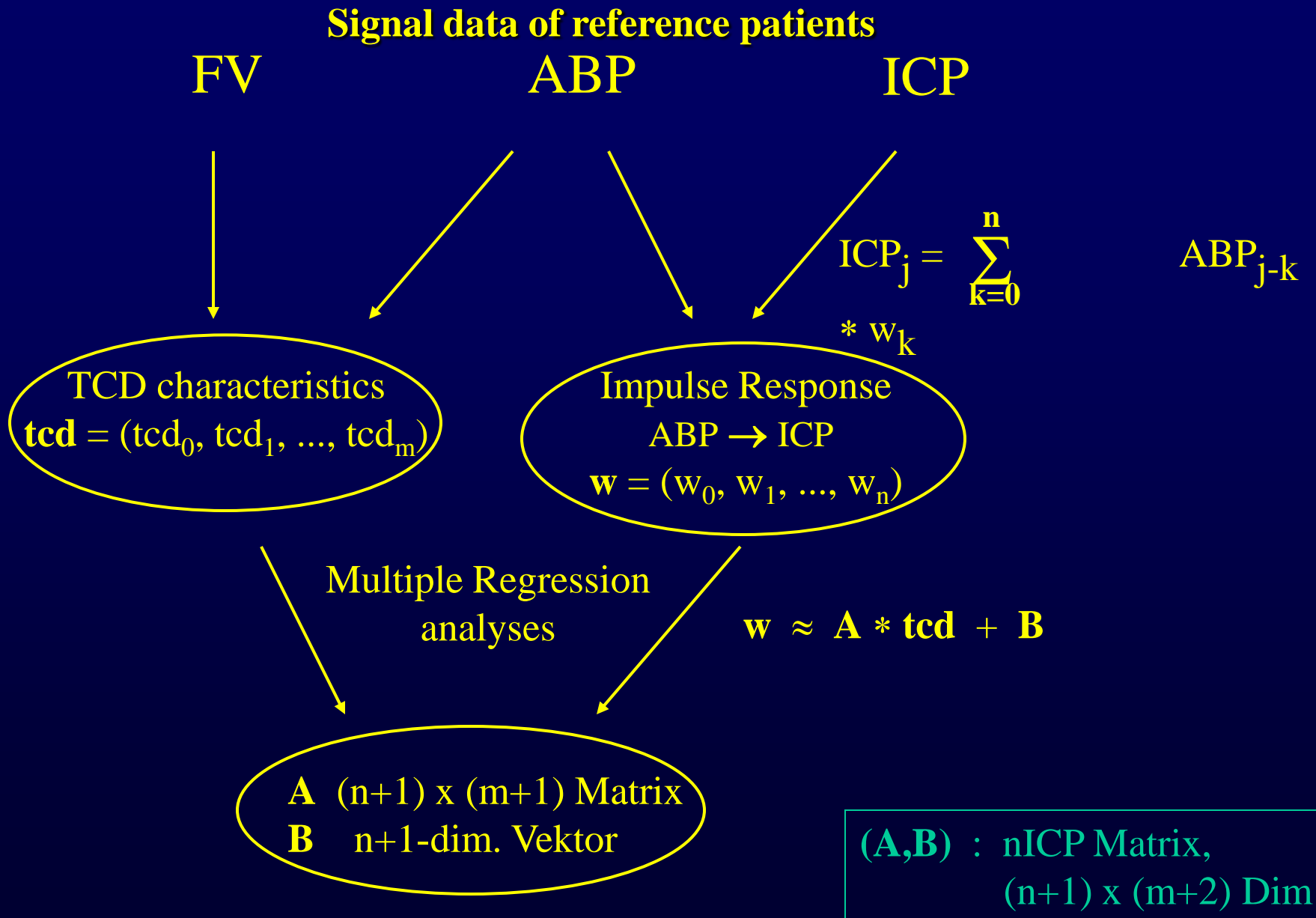
# Non-invasive ICP assessment – basic method



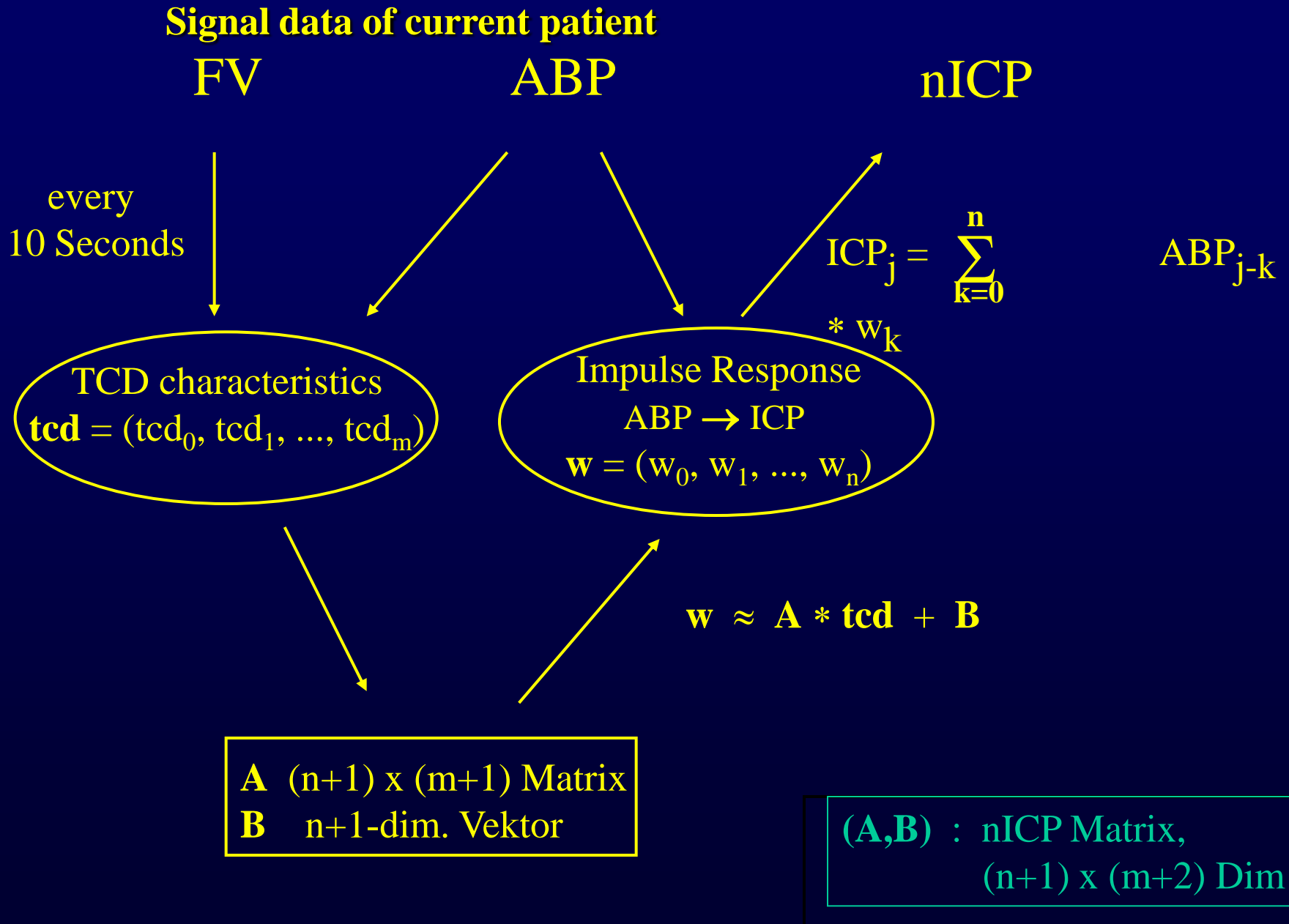
**FV :** blood flow velocity in middle cerebral artery  
**ABP:** arterial blood pressure  
**ICP:** intracranial pressure  
**TCD:** transcranial Doppler ultrasound

**weight function = impulse response:**  
signal transformation,  
time domain equivalent of **transfer function**

# Generation of the nICP Procedure

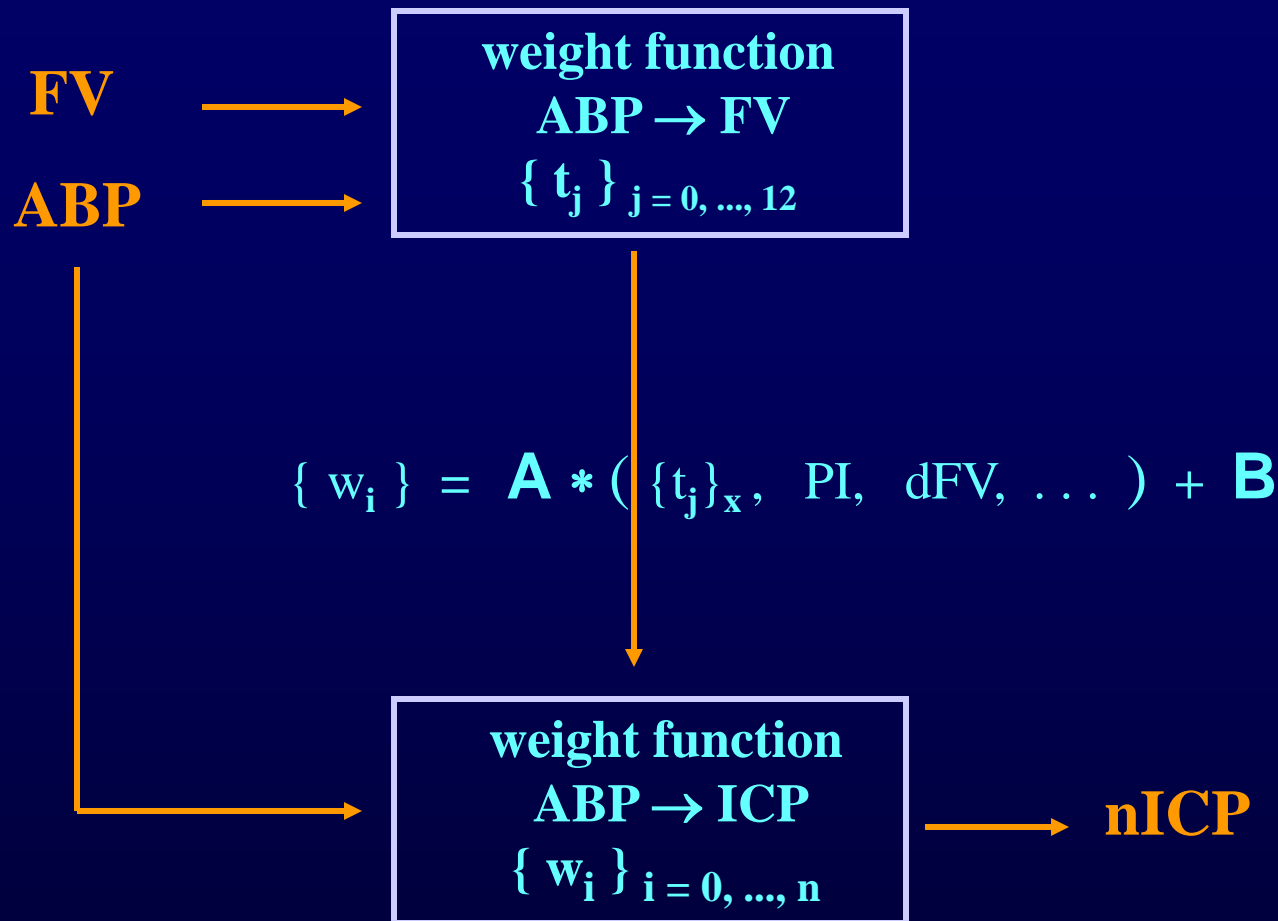


# Flow diagram of the nICP procedure





# non-invasive ICP assessment – basic method



Matrix **A**, Vector **B** generated by multiple regression analyses of reference data  
TCD-characteristics → weight function  $ABP \rightarrow ICP$

**PI:** Pulsatility index  
**dFV:** diastolic FV

# Results 1 - non-invasive ICP assessment

on average of

- **367 patient-day recordings:**      mean  $\Delta$ ICP =  $6.0 \pm 5.5$  mm Hg  
95% CI = 16.4 mm Hg  
median  $\Delta$ ICP = 4.8 mm Hg
- **199 patient recordings:**      mean  $\Delta$ ICP =  $5.5 \pm 5.3$  mm Hg  
95% CI = 15.2 mm Hg  
median  $\Delta$ ICP = 3.9 mm Hg

$\Delta$ ICP = mean abs (ICP-nICP)

## Results 2 - non-invasive ICP assessment

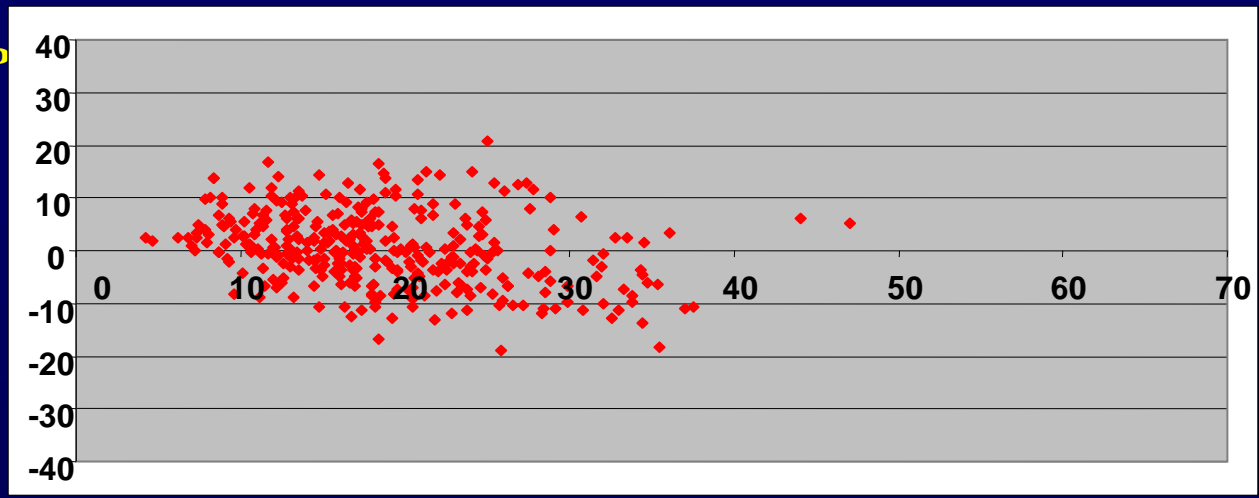
Restricted to Patients with ICP < 45 mm Hg

on average of

- **352 patient-day recordings:**      mean  $\Delta$ ICP =  $5.4 \pm 4.2$  mm Hg  
95% CI = 13.7 mm Hg  
median  $\Delta$ ICP = 4.6 mm Hg
- **193 patient recordings:**      mean  $\Delta$ ICP =  $5.0 \pm 4.0$  mm Hg  
95% CI = 12.7 mm Hg  
median  $\Delta$ ICP = 3.7 mm Hg

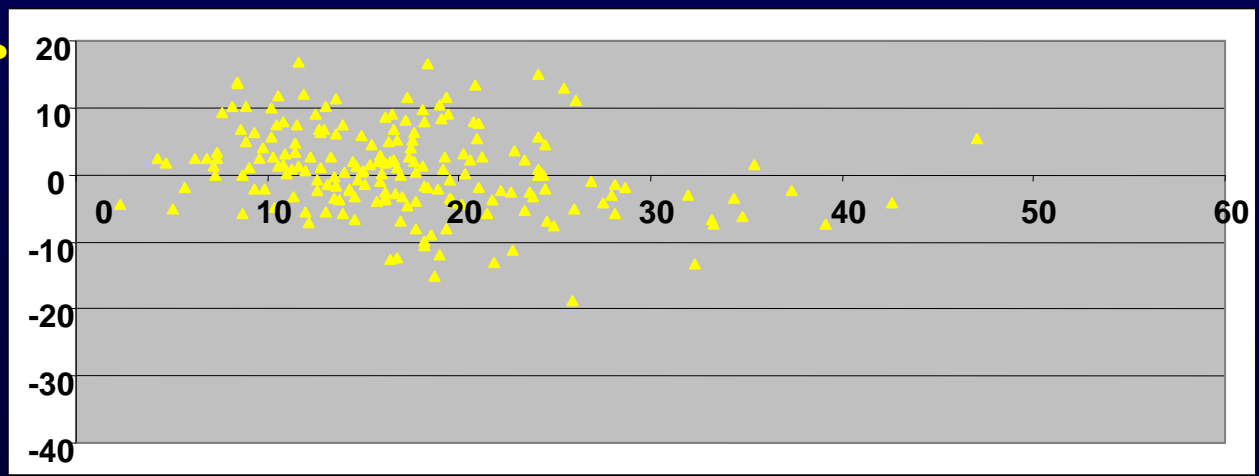
$\Delta$ ICP = mean abs (ICP-nICP)

**nICP-ICP  
[mm Hg]**



**Bland-Altman Plot  
of nICP - ICP  
comparison,  
ICP < 45 mm Hg  
on average of  
Daily Recordings:  
N = 352**

**nICP-ICP  
[mm Hg]**



**Bland-Altman Plot  
of nICP - ICP  
comparison,  
ICP < 45 mm Hg  
on average of  
Patient Recordings:  
N = 193**

**(nICP+ICP)/2 [mm Hg]**

## Results 3 - non-invasive ICP assessment

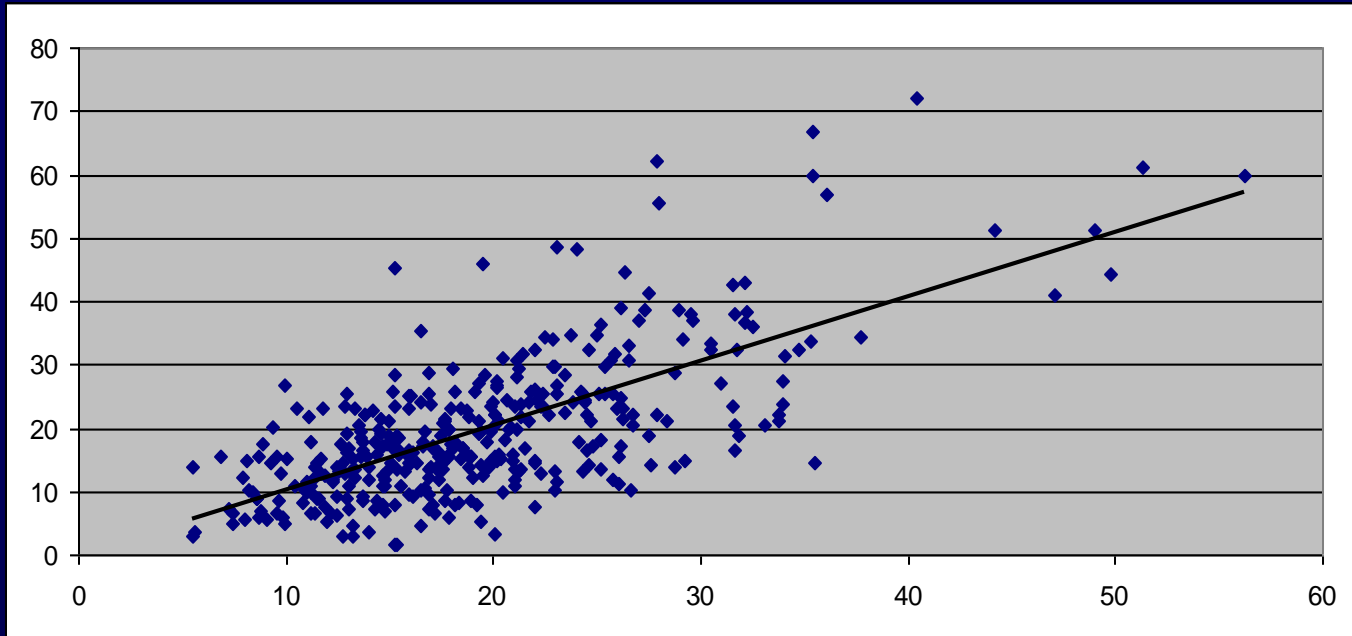
nICP assessment replicates ICP trends

in recordings with high ICP dynamic:

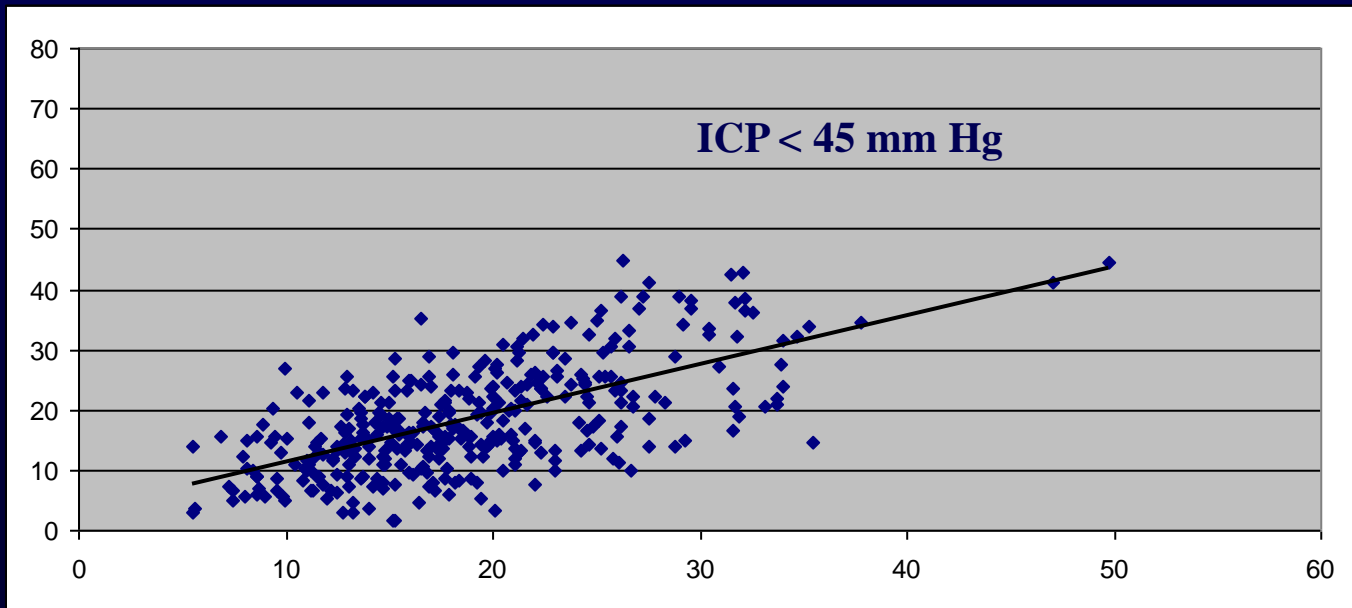
- ICP max > ICP min + 10 mm Hg , 68 recordings,  
mean nICP - ICP correlation  $R = 0.67 \pm 0.40$
- ICP max > ICP min + 15 mm Hg , 30 recordings,  
mean nICP - ICP correlation  $R = 0.82 \pm 0.26$

# nICP - ICP comparison in daily recordings

ICP  
[mm Hg]



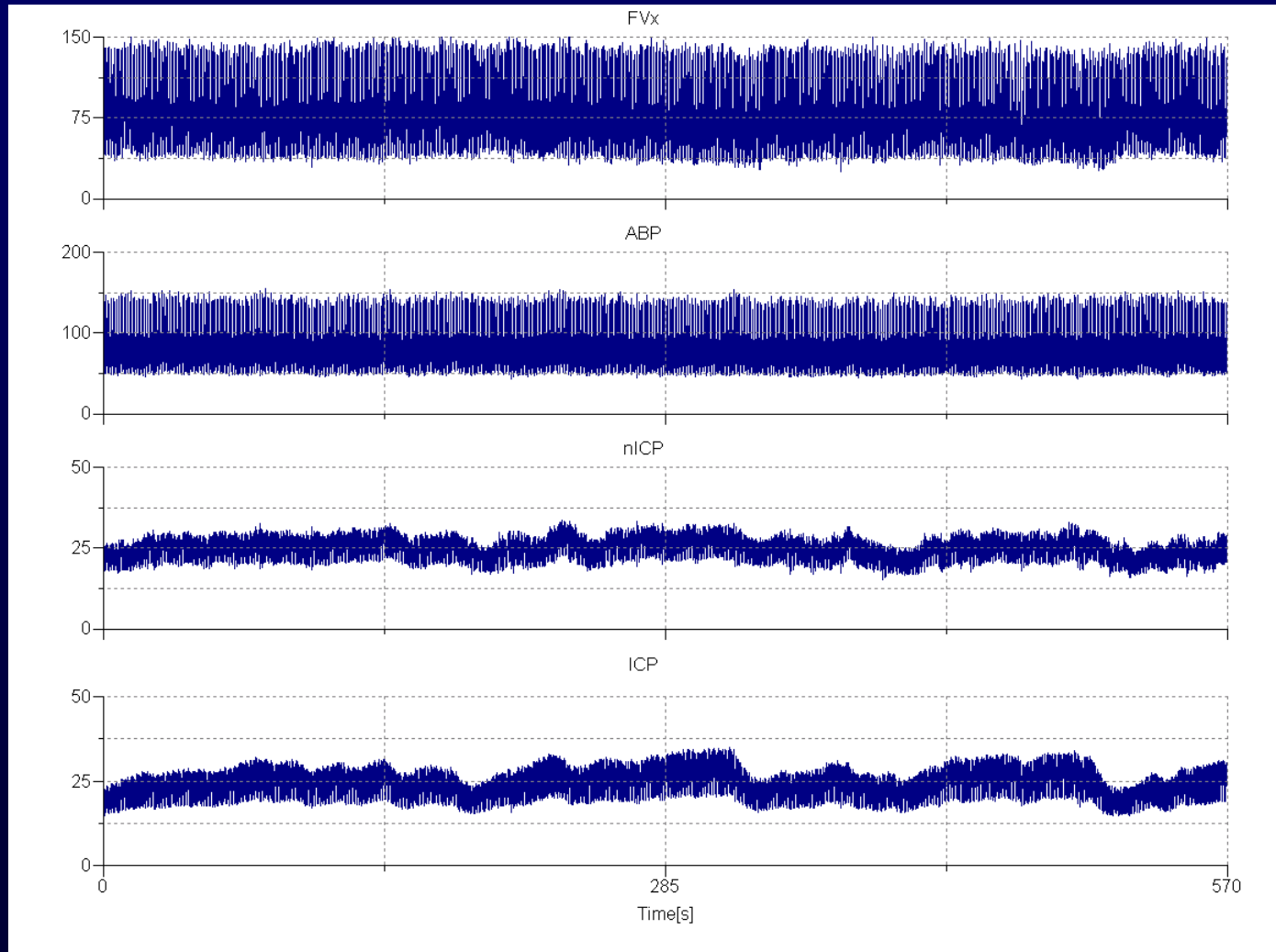
ICP  
[mm Hg]



nICP [mm Hg]

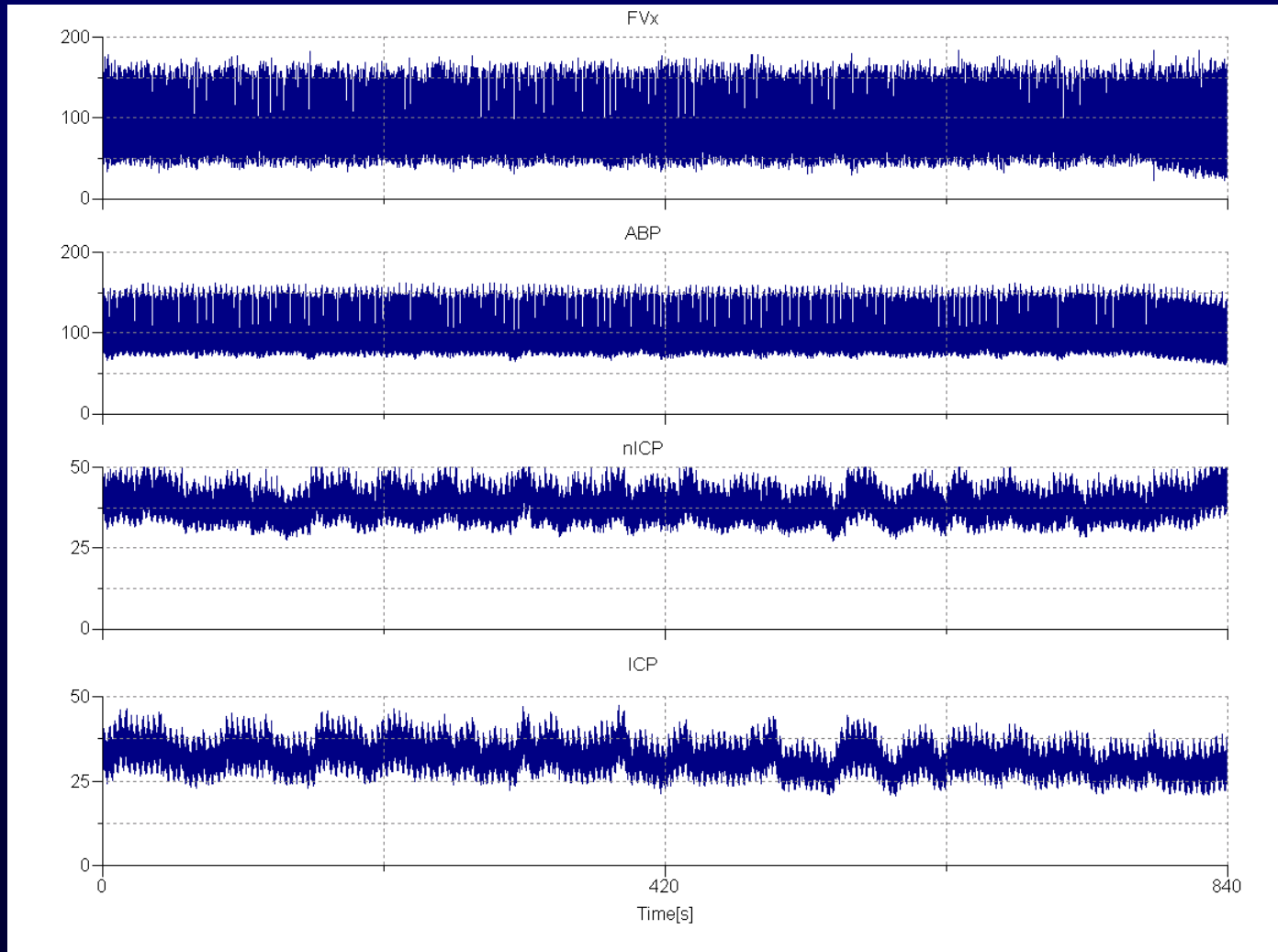
# Example 1

033040AL.IL5



# Example 2

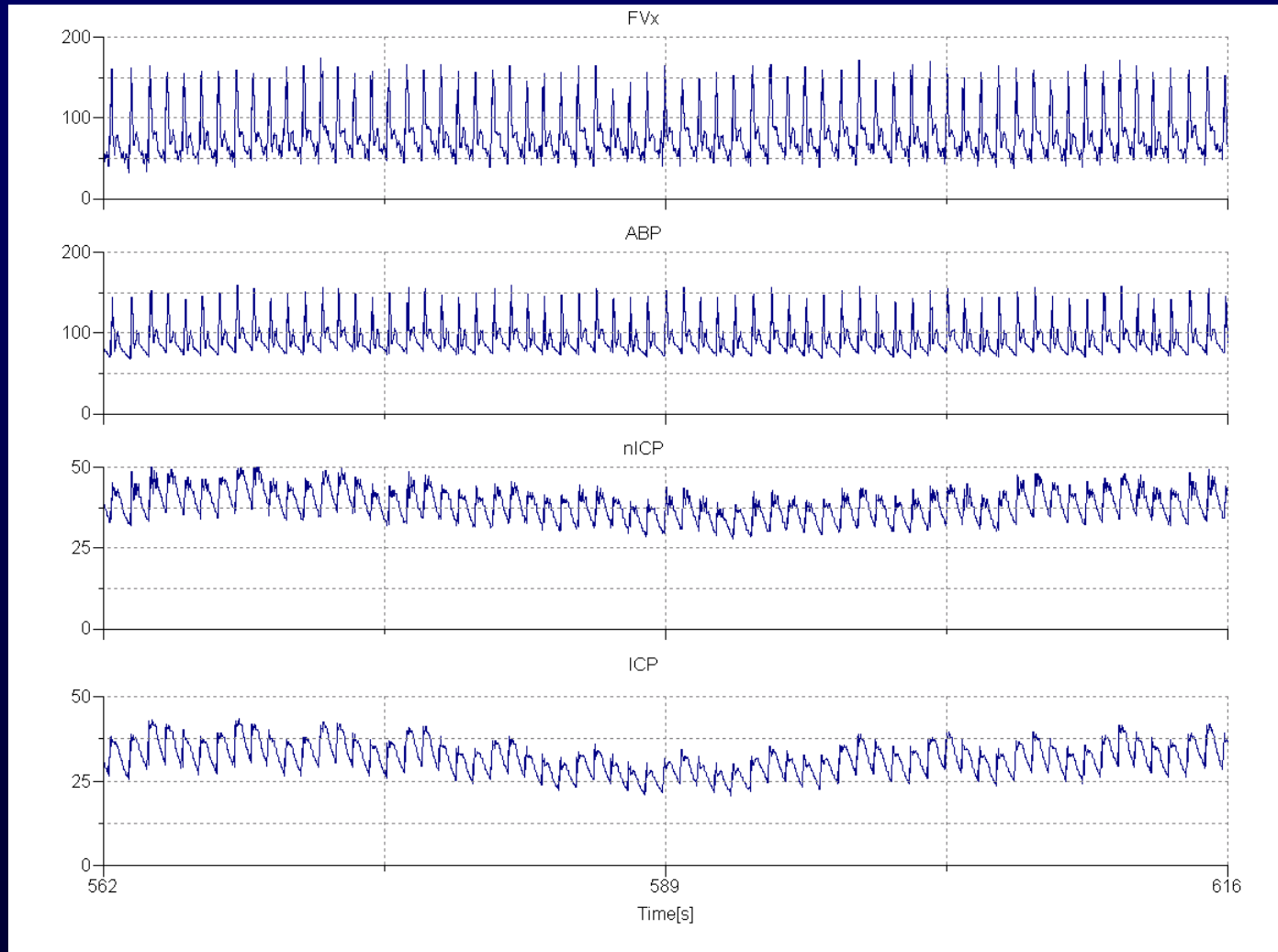
038080JM.0L5





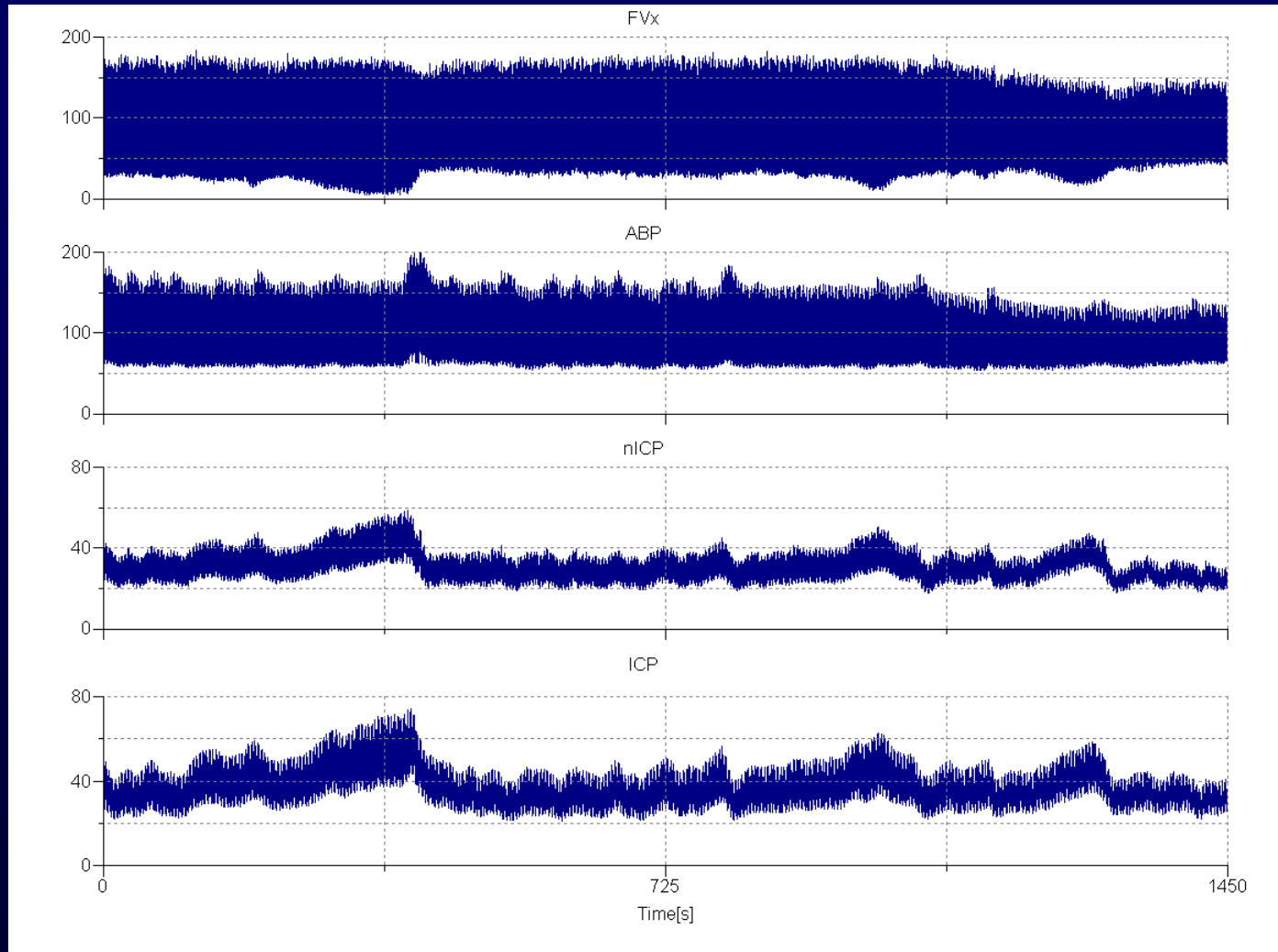
# Example 2

038080JM.0L5



# Example 4

053022AW.0L5



# Conclusions

- **in the clinically relevant range of ICP the nICP assessment showed a reasonable accuracy**
- **nICP assessment replicates ICP changes and trends**
- **nICP plugin of ICM+ may be used for clinical studies in patients without implanted ICP probes**