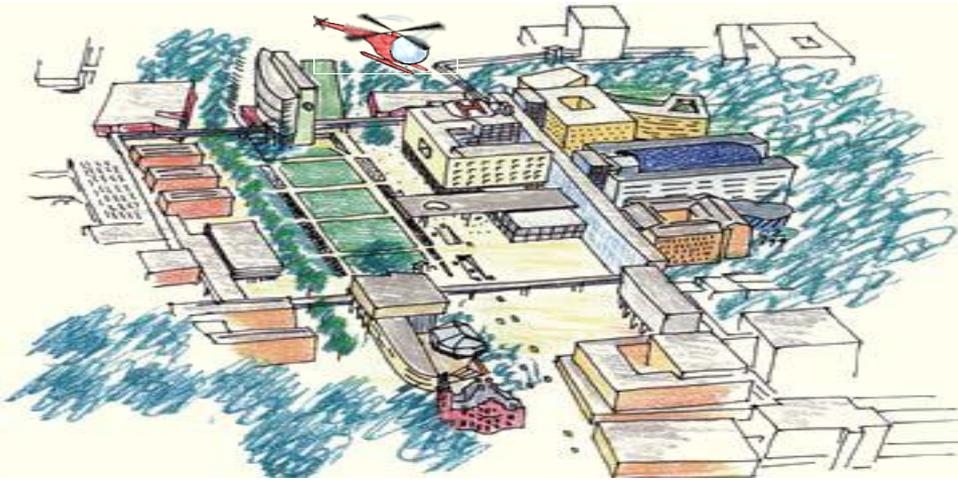


# Neuromonitoring op de IC



Astrid Hoedemaekers  
Internist-intensivist

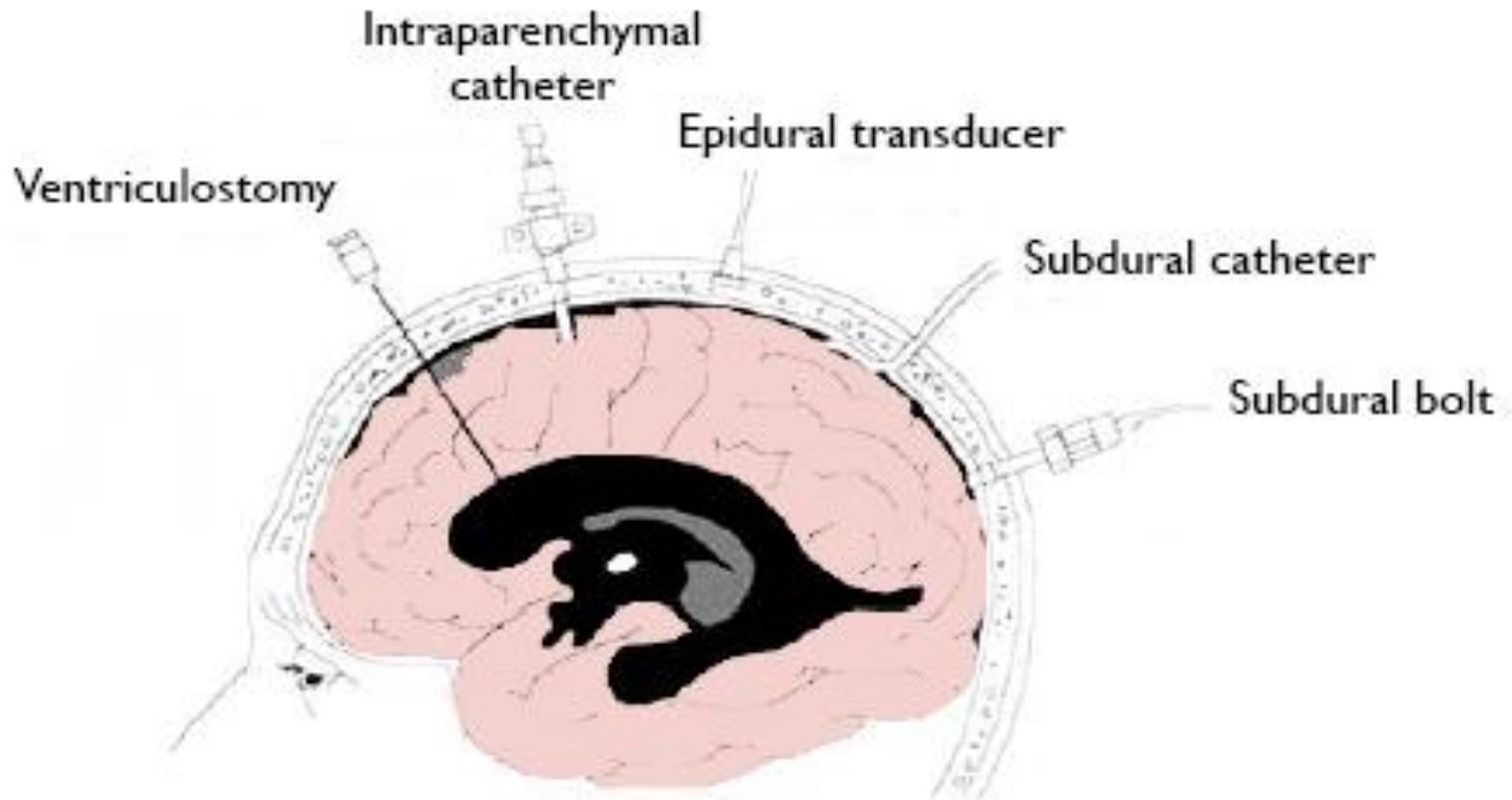
## Doel

- Minimaliseren van secundaire hersenschade door
  - Detectie van secundaire letsels in reversibele fase
  - Monitoring/sturing van therapie
- Focaal vs globaal

# Monitoring

- ICP en CPP
- Bulbus jugularis oxymetrie
- Transcraniële doppler
- Cerebrale PO<sub>2</sub> meting
- Cerebrale microdialyse
- EEG
- Beeldvorming

# ICP

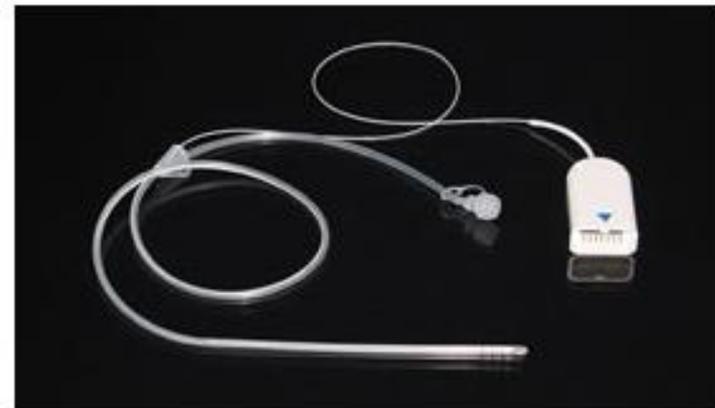


# ICP meting

- Parenchymateus
  - Betrouwbaar
  - Minder infectie
  - Minder bloeding
  - Inbrengen gemakkelijk
  - Geen therapie mogelijk
- Intraventriculair
  - Betrouwbaar
  - Meer infectie
  - Meer bloeding
  - Soms inbrengen moeilijk
  - Drainage mogelijk

# Sophysa pressio proefplaatsing

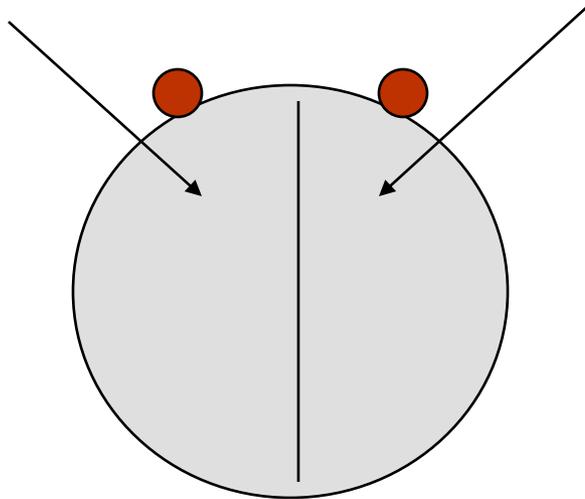
## Ventricular Tunneling ICP Monitoring Pressio Kit



des:

- Transducer tipped 9.0 Fr silicone catheter preloaded with an introducing stylet and with a dedicated lumen for CSF drainage. Depth markings

## Is de ICP in het hoofd overal gelijk?

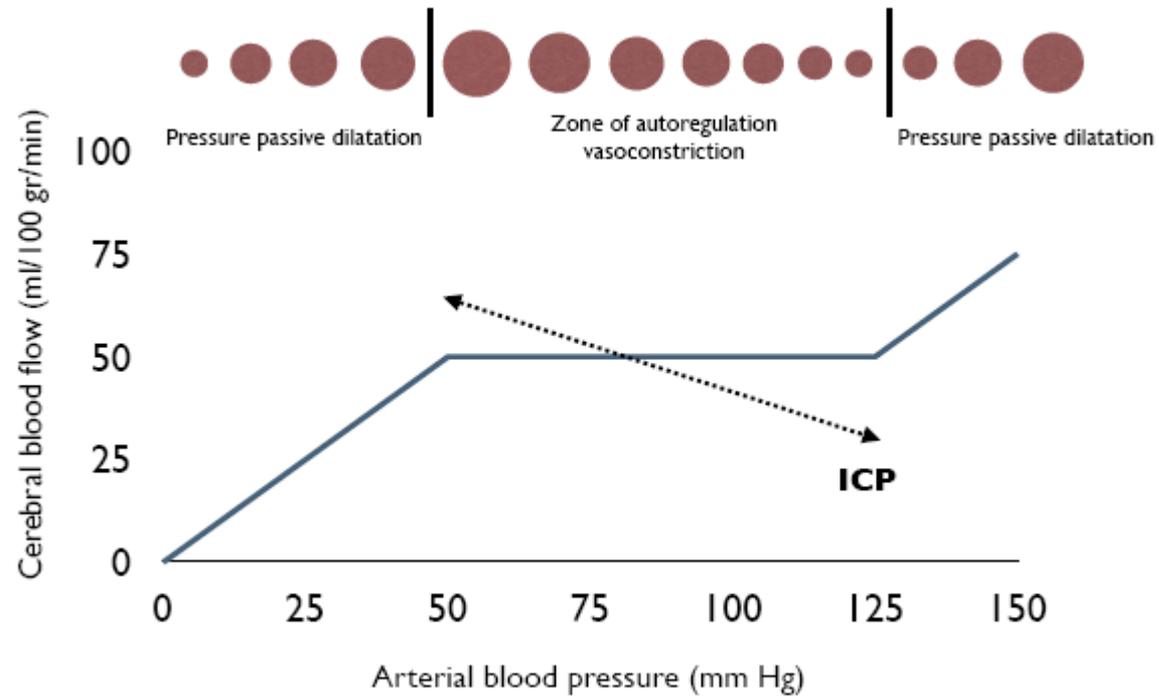


- Diffuus letsel: ICP li = re
- Focaal (25 ml) zonder shift: ICP ongelijk, wel congruent
- Focaal met shift (> 3 mm): ICP ongelijk en dyscongruent
- Oorzaak: verschil in compliantie weefsel
- Advies: ICP meter aan aangedane zijde

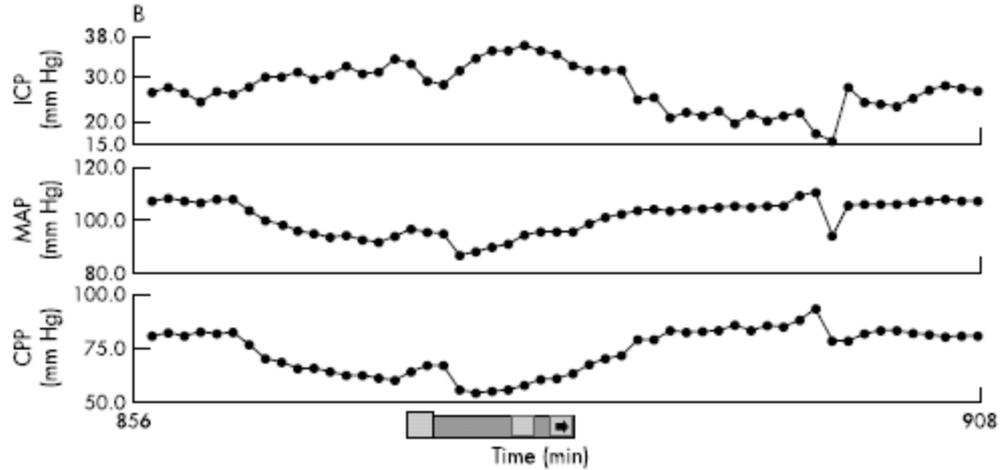
## Welke streefwaardes??

- CPP > 60 mmHg
  - Lager risico op ARDS
  - Lager risico op refractaire hoge ICPs
  - Plateau voor PbrO<sub>2</sub>
- Individualiseren obv autoregulatie (Lund vs rest vd wereld)

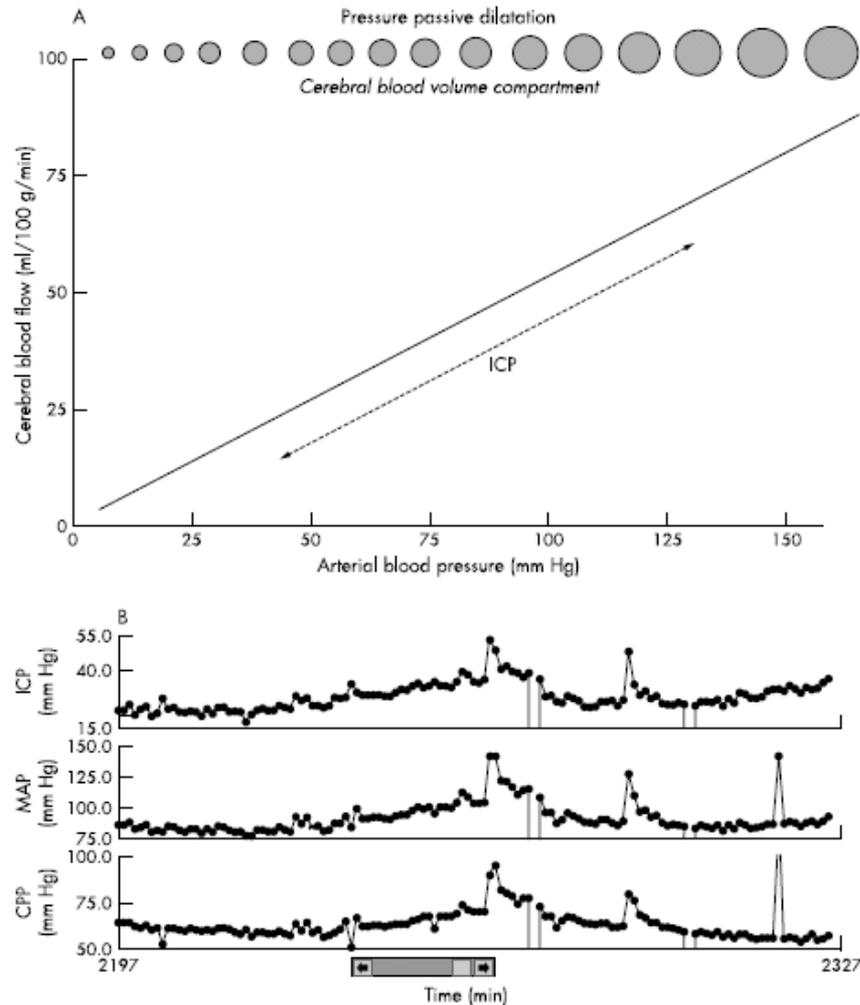
# Normale autoregulatie



# Autoregulatie en ICP



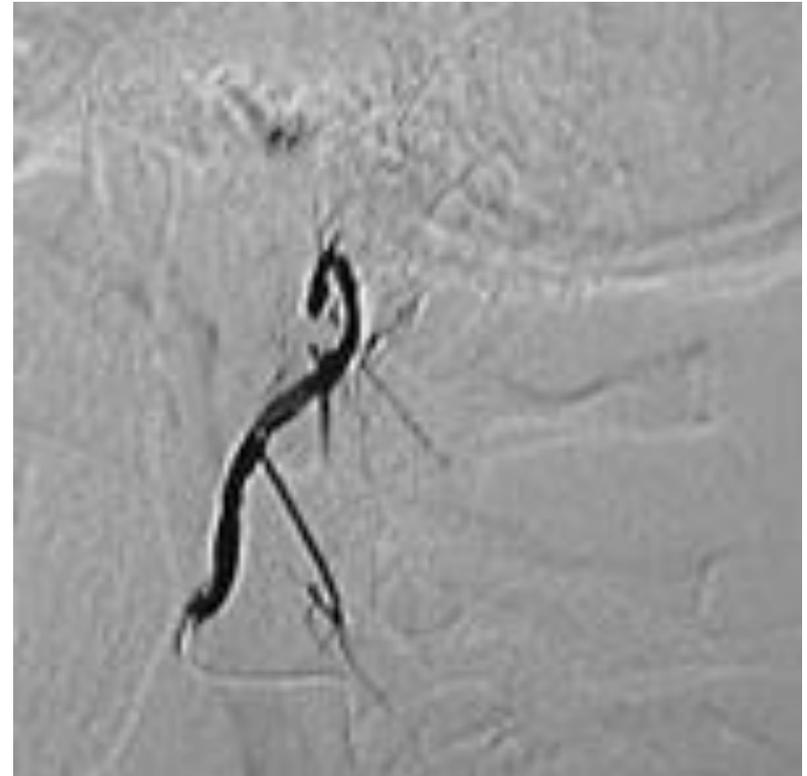
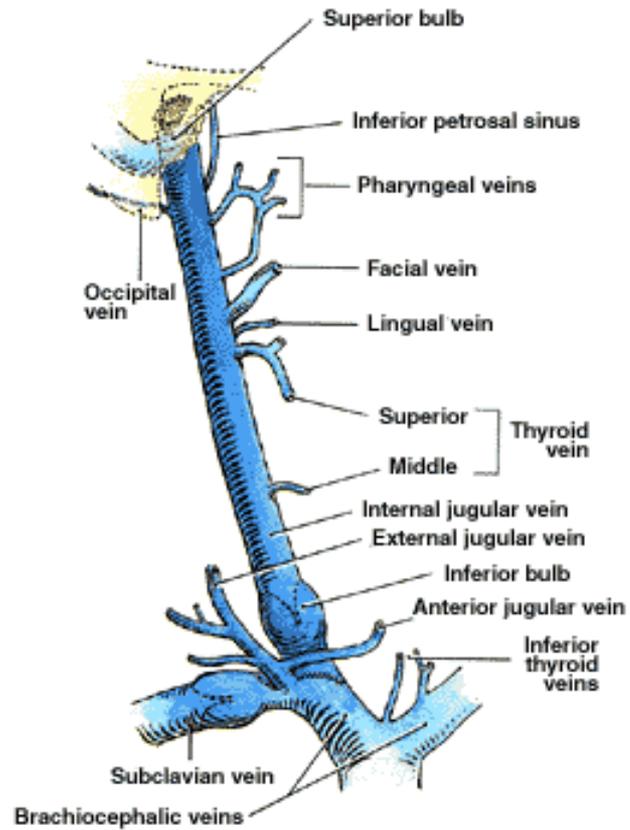
# Gestoorde autoregulatie en ICP



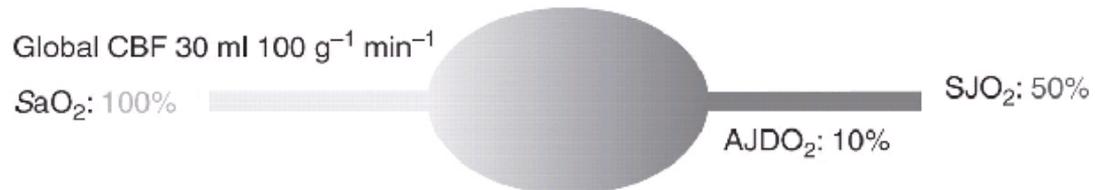
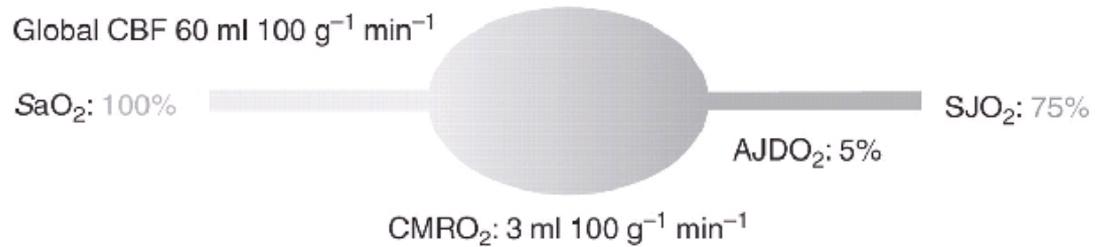
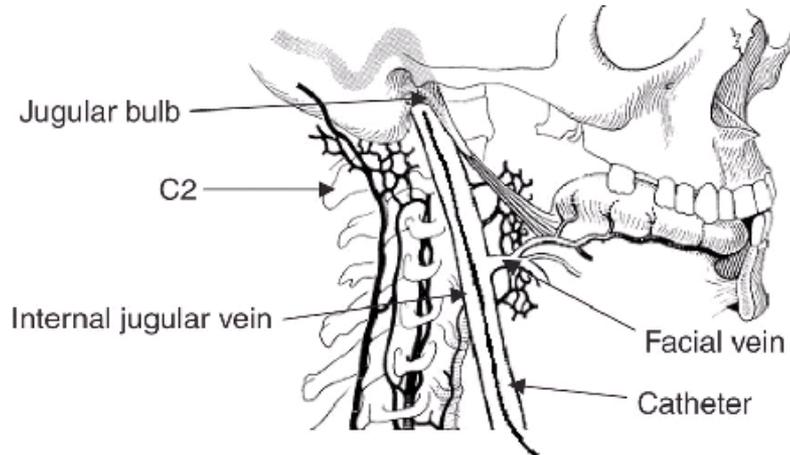
# Autoregulatie bij hoge ICP

- Autoregulatie intact: CPP geleide behandeling
- Autoregulatie gestoord: ICP geleide behandeling

# Bulbus jugularis oxymetrie (Sj<sub>b</sub>O<sub>2</sub>)



# Pathofysiologie SjO<sub>2</sub>



# SjbO<sub>2</sub>

## Laag

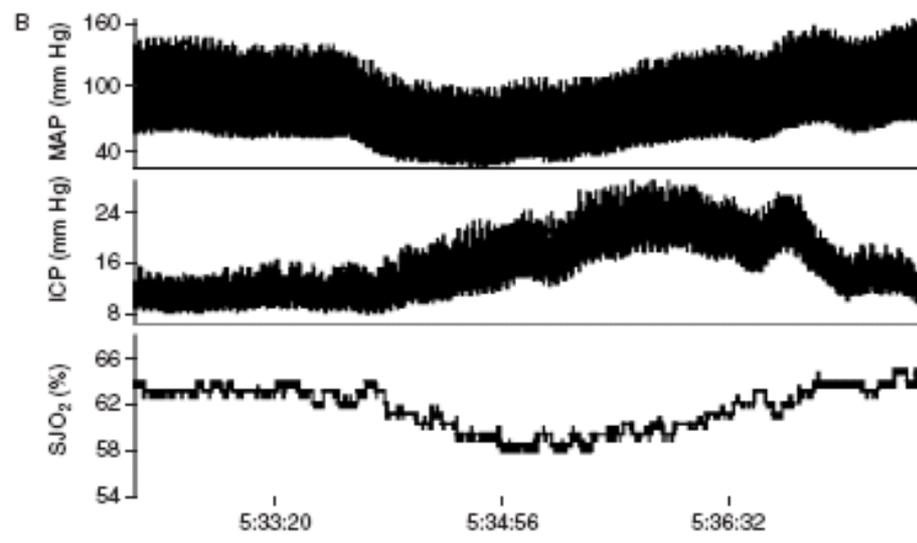
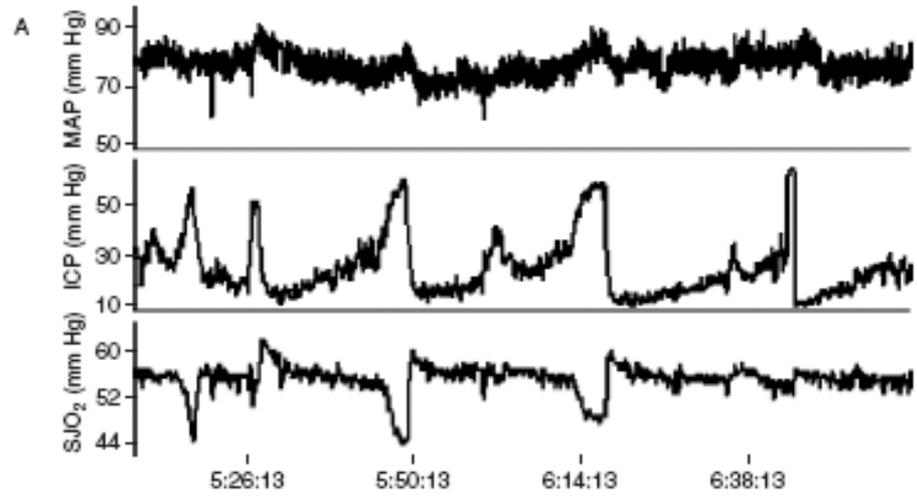
- Afname O<sub>2</sub> aanbod
  - Hoge ICP, lage CPP
  - Hypocapnie
  - Vaatspasmen
  - Hypoxie
  - Hypotensie
  - Anemie

## Hoog

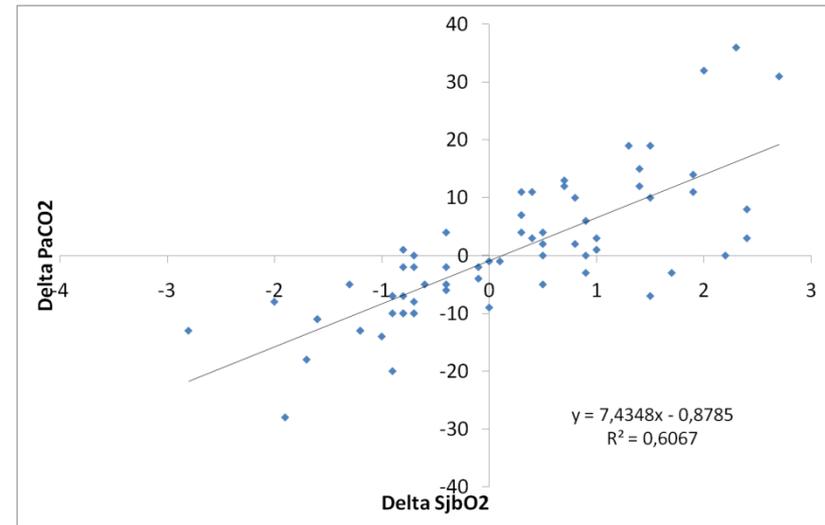
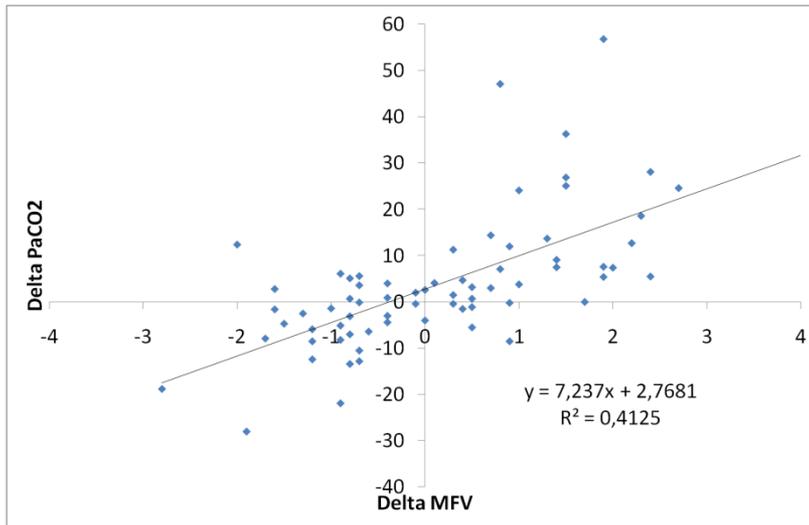
- Toename O<sub>2</sub> aanbod
  - Afname ICP, Stijgen CPP
  - Hypercapnie
  - Medicatie (vasodilatatie)
  - Hypertensie
  - A-V malformatie
  - Hoge Pa)2

- Toename O<sub>2</sub> verbruik
  - Toename metabolisme
  - Hyperthermie
  - Pijn
  - Rillen
  - Insulten

- Afname O<sub>2</sub> verbruik
  - Coma
  - Hypothermie
  - Sedativa
  - Infarct/hersendood



# Effect van hyperventilatie op CBF



# Beperkingen

- Globale cerebrale perfusie
- Foutieve positie
- Te snelle aspiratie bloed

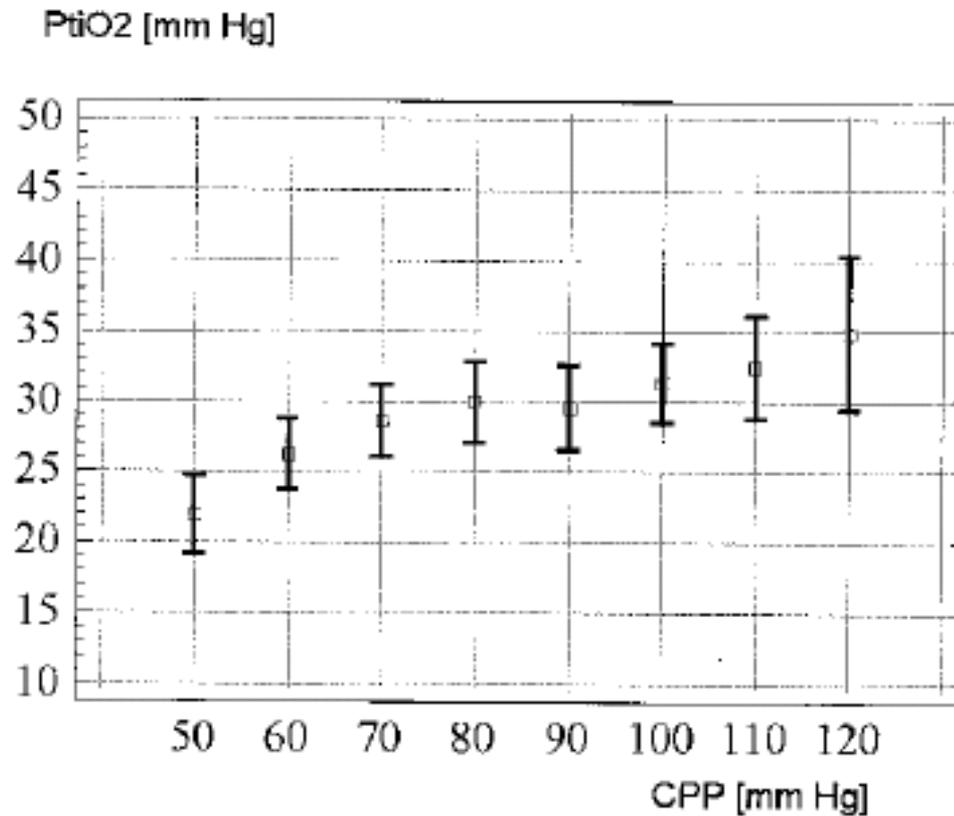
## Hersenweefsel PbrO<sub>2</sub>

- Directe meting via probe in parenchym (circa 15 mm rondom probe)
- Meting 2-3 cm onder dura
- PbrO<sub>2</sub> mn afhankelijk van flow, saturatie en Hb
- Waar te plaatsen?

# Relatie PbrO<sub>2</sub> en andere fysiologische parameters

Author (year)	F <sub>i</sub> O <sub>2</sub>	P <sub>a</sub> O <sub>2</sub>	Hgb	MAP or CPP	CBF
Jaeger (2005) [21**]					+
Johnston (2005) [11**]	+			+	no
Hemphill (2005) [3*]	+			+	no
Smith (2005) [18**]			+		
Stocchetti (2005) [10*]					
Johnston (2004) [12**]				+	
Lang (2003) [13]				+ <sup>a</sup>	
McLeod (2003) [16]	+				
Menzel (2003) [14]				+	
Reinert (2003) [15]	+			+	
Reinprecht (2003) [17]		+			
Zhi (2003) [9]					

# PbrO<sub>2</sub> en TBI



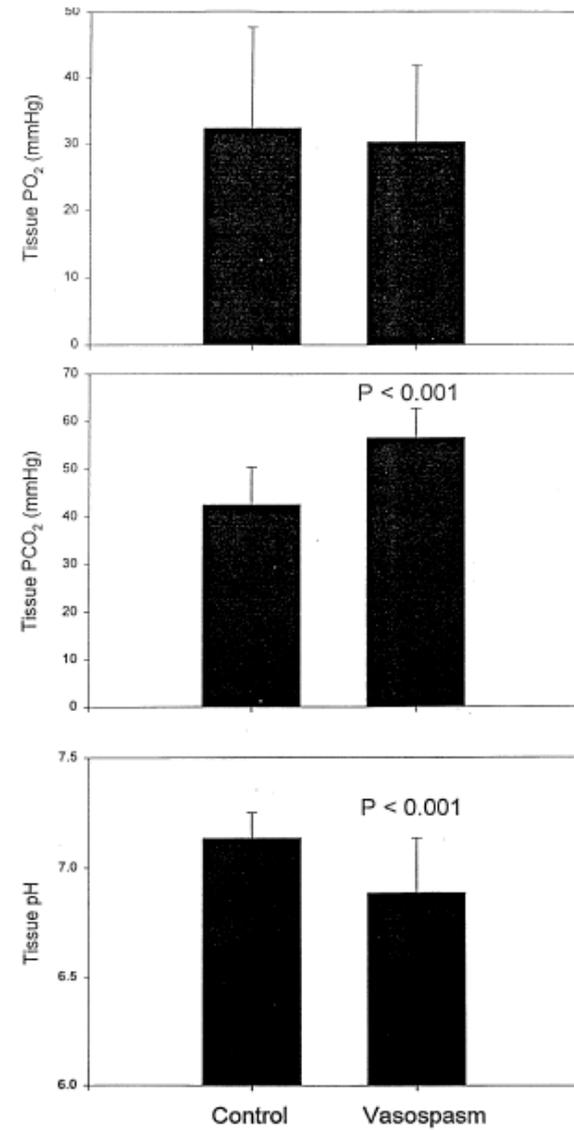
Lang et al, CCM 2003

# PO<sub>2</sub>, PCO<sub>2</sub> en pH bij vaatspasmen

Oxygenatie

Metabolisme

Mitochondriële dysfunctie



**3** Average PO<sub>2</sub>, PCO<sub>2</sub>, and pH over 2 days (eight 6-hr measurements) after vasospasm in three patients compared to a similar time period in control patients. Data are reported as mean ± SD. P value indicates difference compared to control.

# Oxygen directed therapy

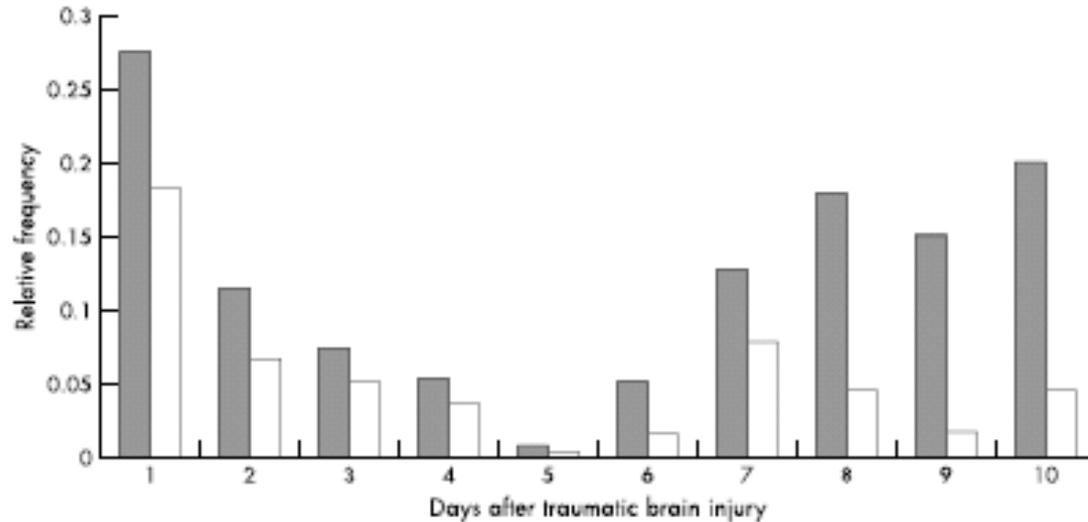


Figure 2 Relative frequency of hypoxic events (P<sub>t</sub>O<sub>2</sub> < 1.33 kPa (10 mm Hg)) lasting ≥ 30 minutes for the ICP/CPP guided group (grey columns) and the P<sub>t</sub>O<sub>2</sub> guided group (white columns) on each post-trauma day. CPP, cerebral perfusion pressure; ICP, intracranial pressure.

Table 4 Outcome after six months for the two treatment groups

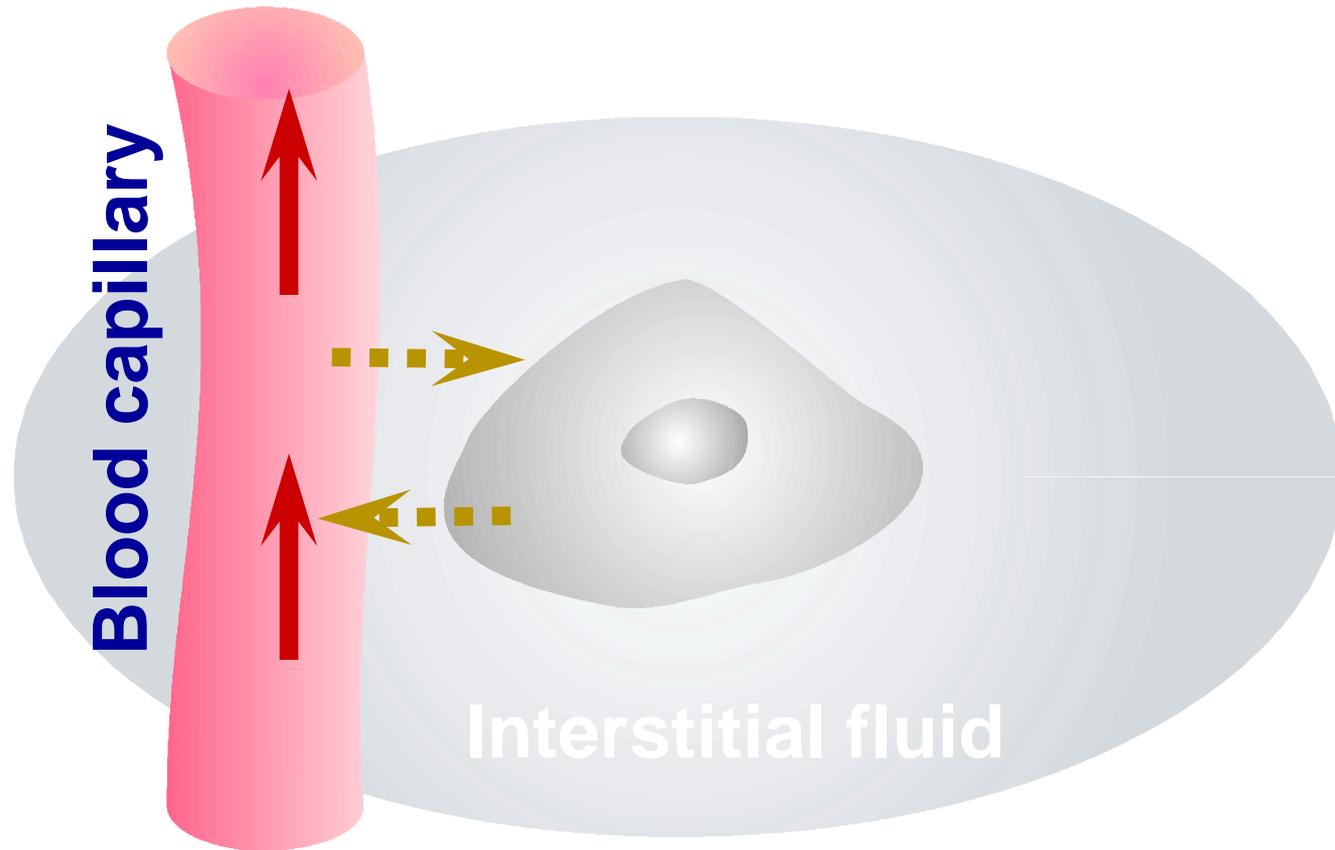
Variable	Group 1: ICP/CPP guided (n=39)	Group 2: P <sub>t</sub> O <sub>2</sub> guided (n=52)	p Value <sup>a</sup>
Poor outcome (GOS=1-3)	18 (46%)	18 (35%)	0.27
Good outcome (GOS=4-5)	21 (54%)	34 (65%)	

<sup>a</sup>2 × 2 table  $\chi^2$  test.

ICP, intracranial pressure; CPP, cerebral perfusion pressure; GOS, Glasgow outcome scale; P<sub>t</sub>O<sub>2</sub>, partial pressure of brain tissue oxygen.

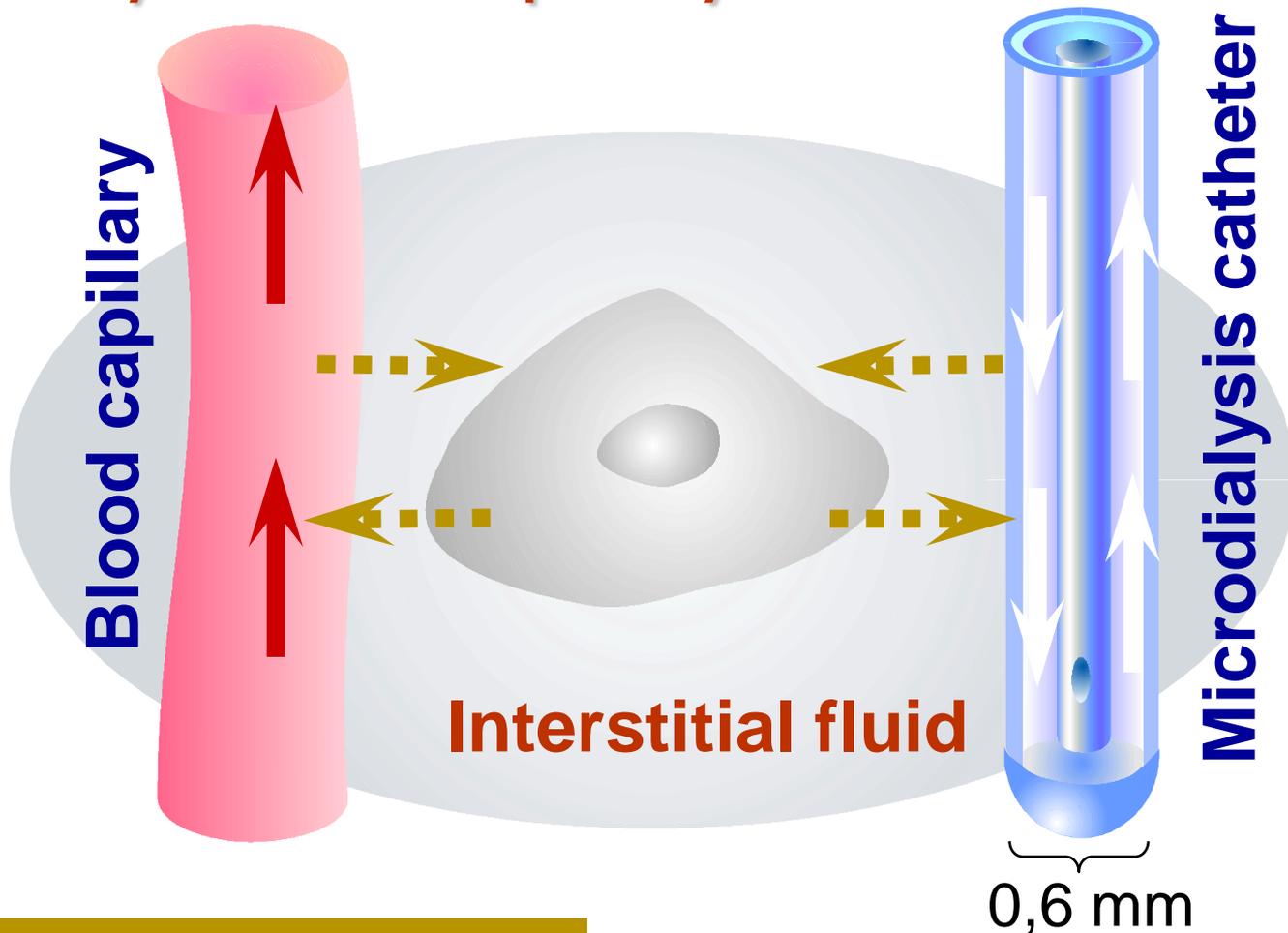
# Microdialyse

Blood capillaries delivers and receives substances from the interstitial fluid...

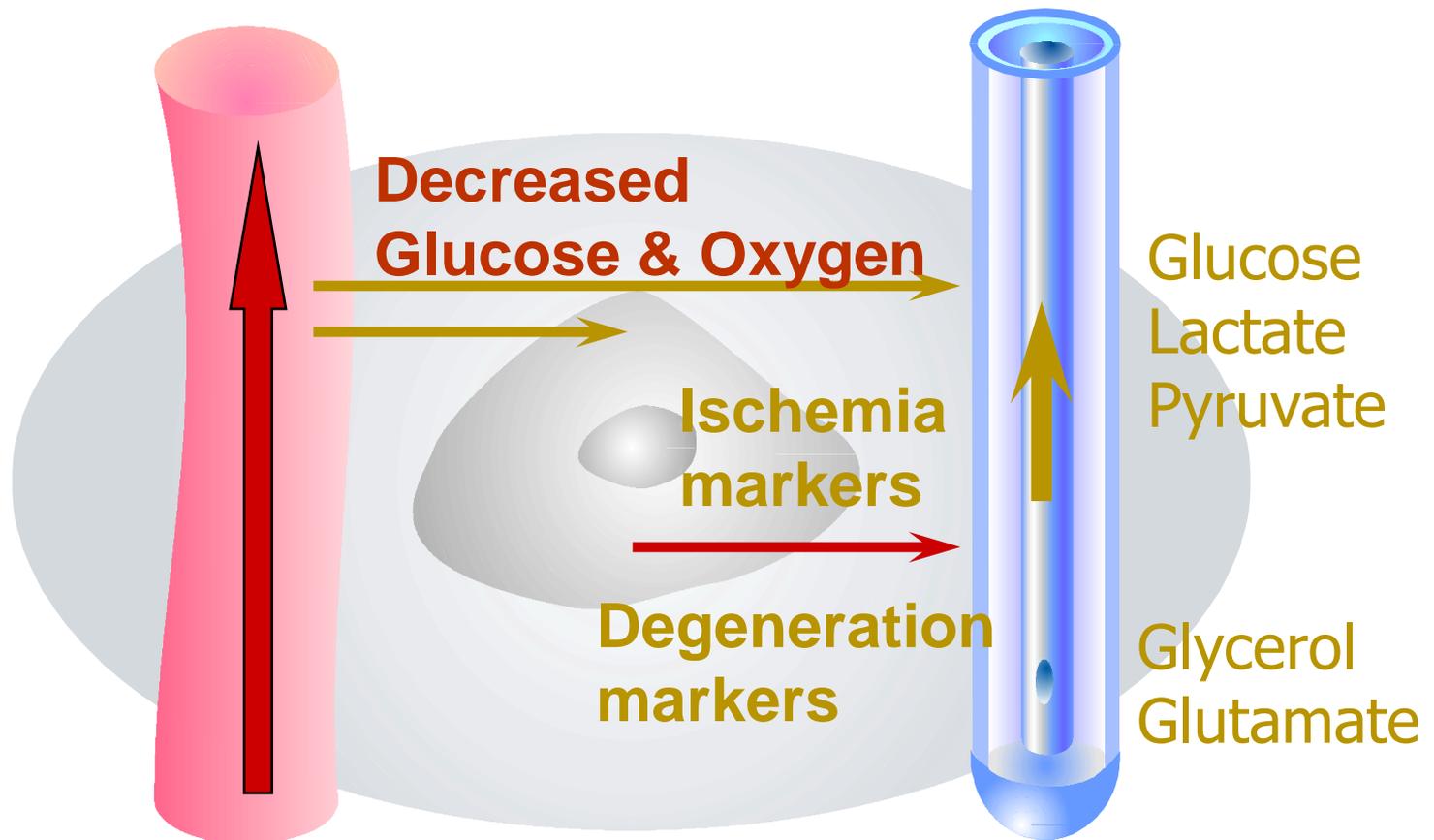


# Principles of microdialysis

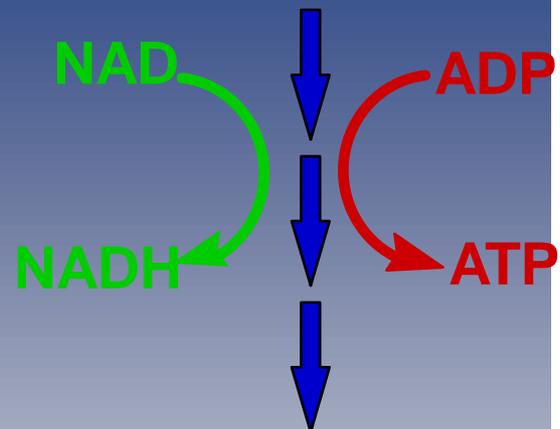
...a microdialysis catheter functions the same way as the capillary



# Microdialysis detects ischemia and cell damage....



**Glucose**



**Pyruvate**

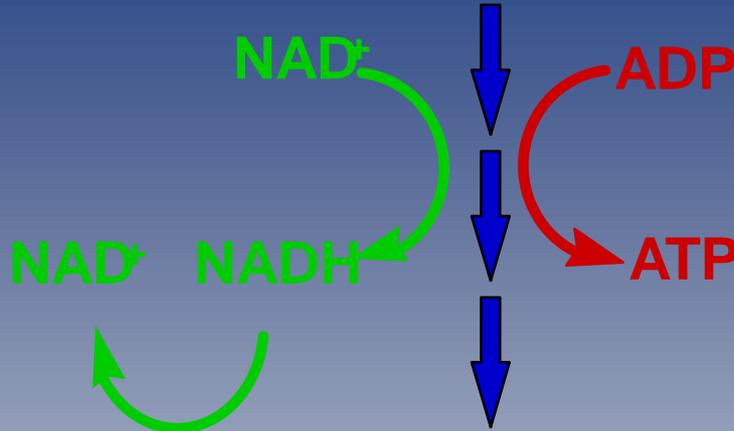
Oxygen



Normal glucolysis in the presence of oxygen

**ATP**

**Glucose**



**Lactate** ← **Pyruvate**

**Ischemia**



**ATP**  
**ATP**  
**ATP**

During ischemia the amount of Lactate synthesized from Pyruvate increases

Glucose ↓

Lactate/Pyruvate ↑

## If ischemia is severe...

- the cell membrane begins to decompose...
- and glycerol is released into the interstitial fluid as a sign of cell damage...

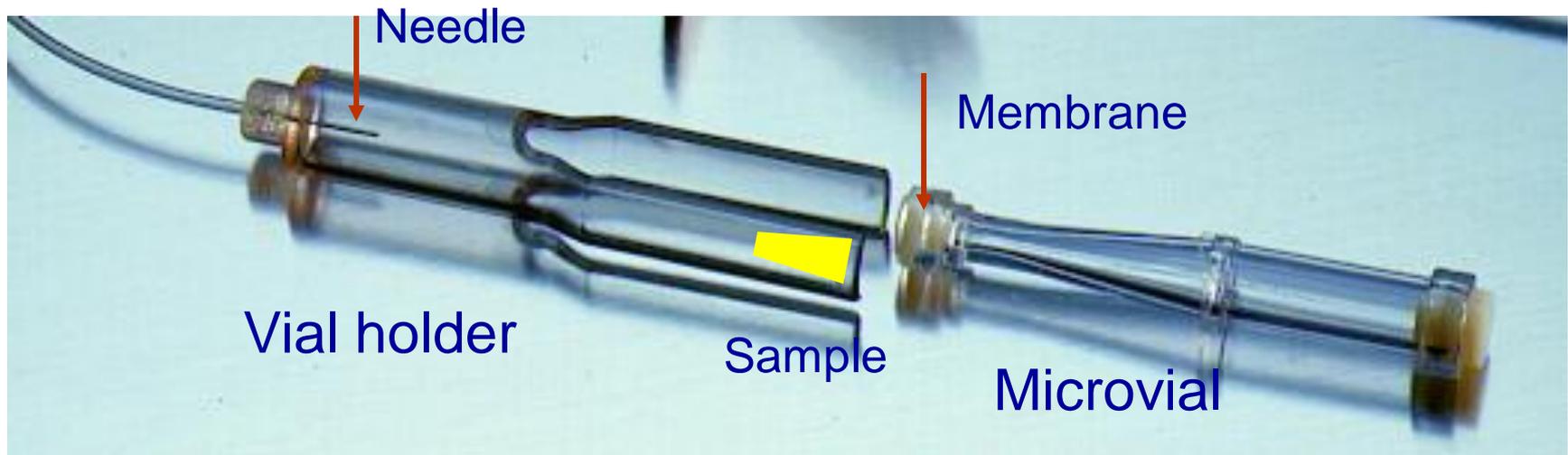
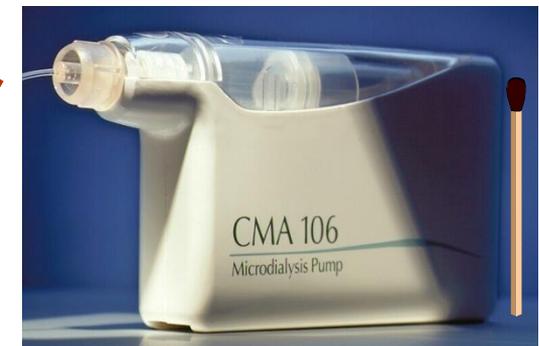
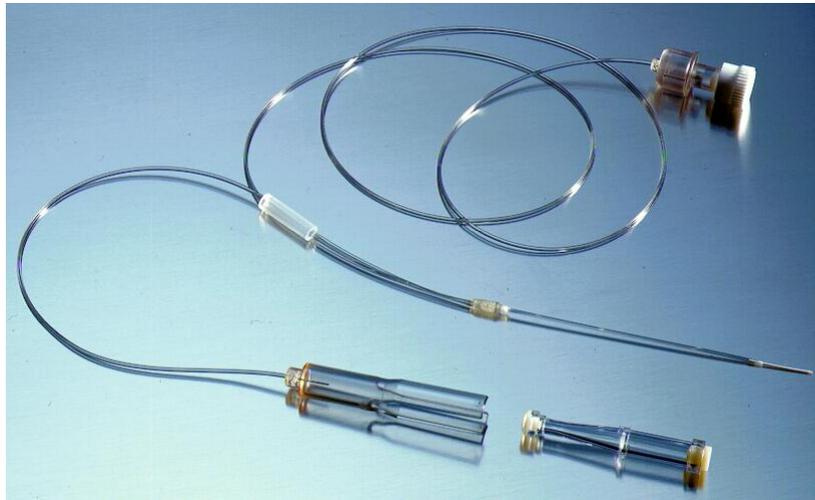
## Ischemia is characterized by...

- Glucose down
- Lactate/Pyruvate up
- Glycerol up

# The microdialysis instrumentation consists of

- Pumps
- Catheters
- Microvials
- Bedside analyzer
- Analysis software (ICUpilot)

The microdialysis pump perfuses the catheter and the sample is collected in microvials....



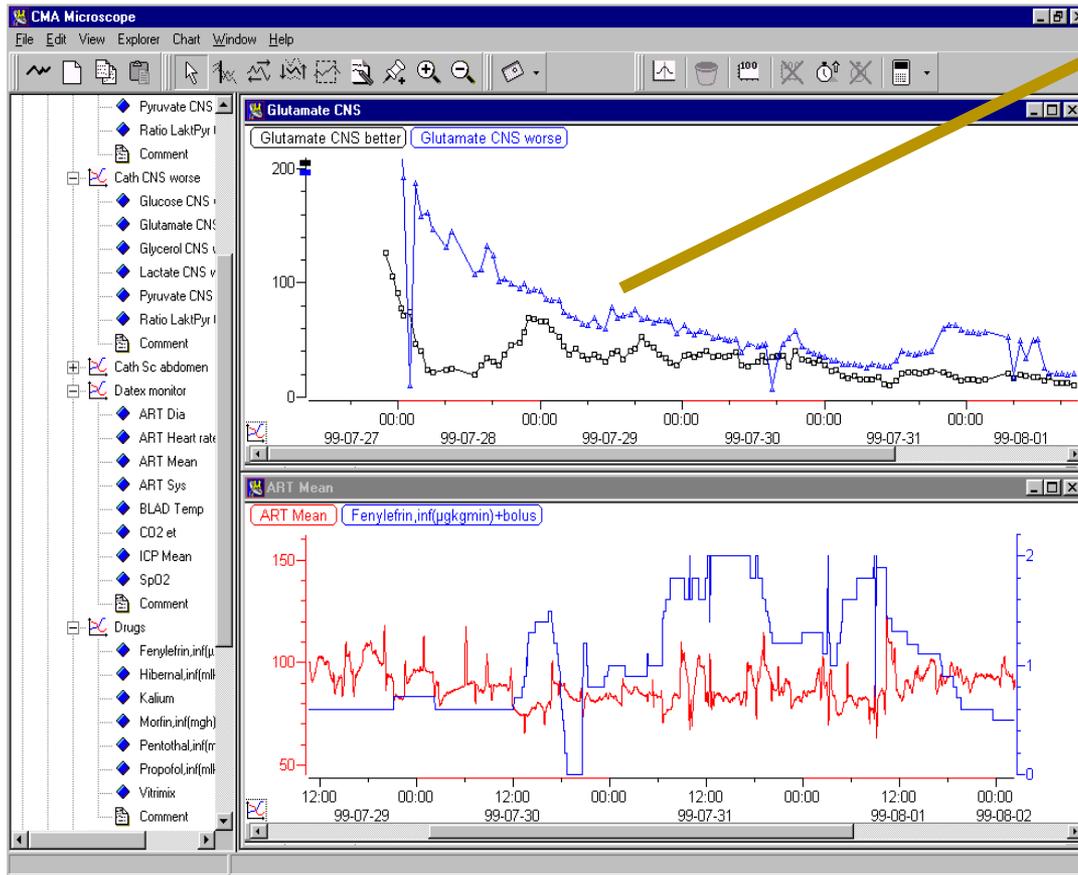
# The bedside analyzer integrates chemistry and physiology

- Tissue chemistry
- Physiology (ICP, CPP, MAP etc)
- Tissue oxygen
- Ventilation
- Drug infusions

Network



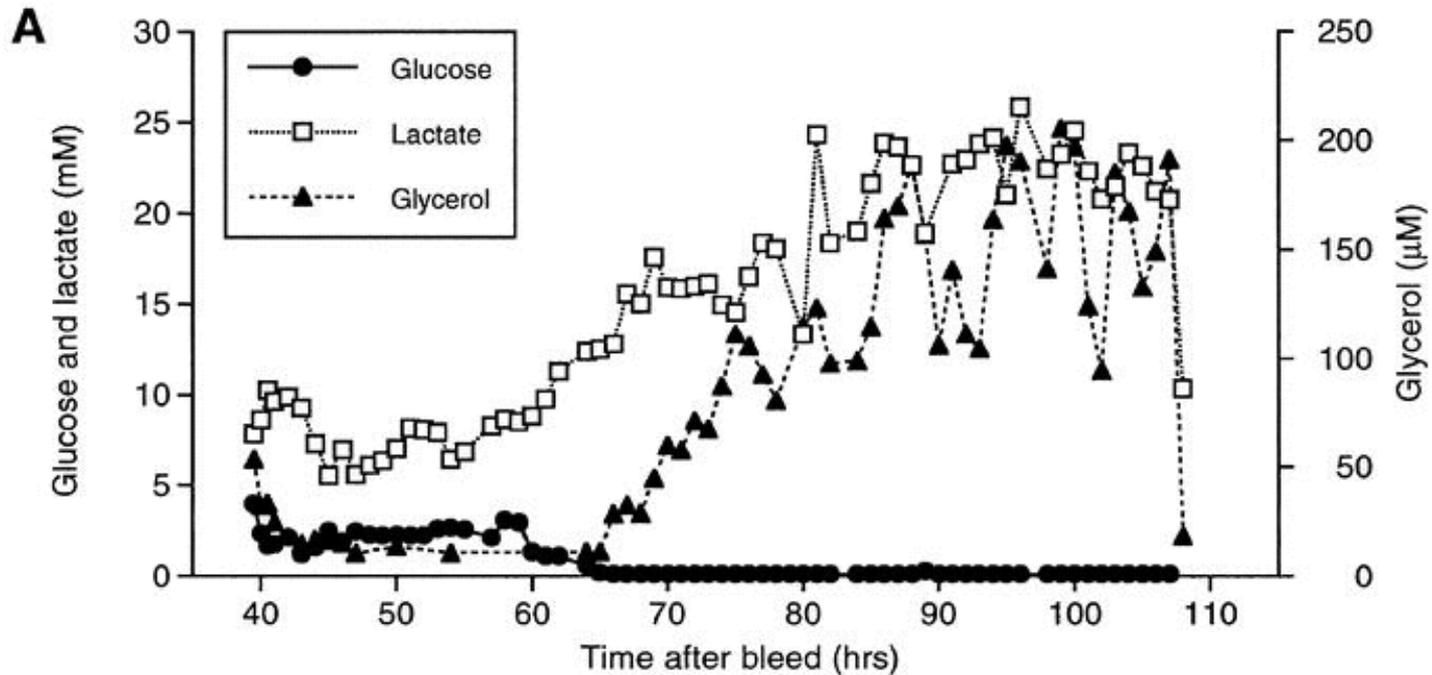
# The bedside analyzer integrates chemistry and physiology



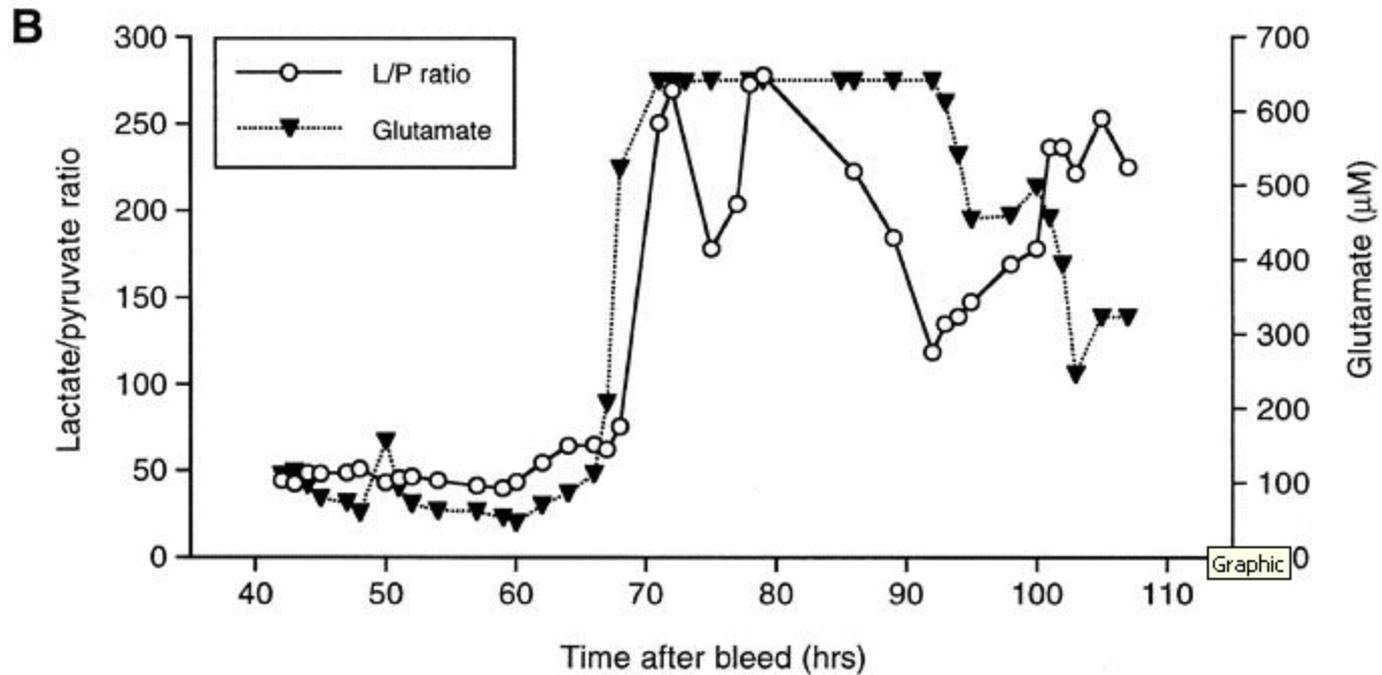
# Rol van microdialyse op de neuroIC

- Consensus bijeenkomst
- Voorkeursplaats
  - re frontaal bij diffuse schade
  - penumbra bij focaal letsel
- Alleen in kader van onderzoek

# Vaatspasmen bij SAB

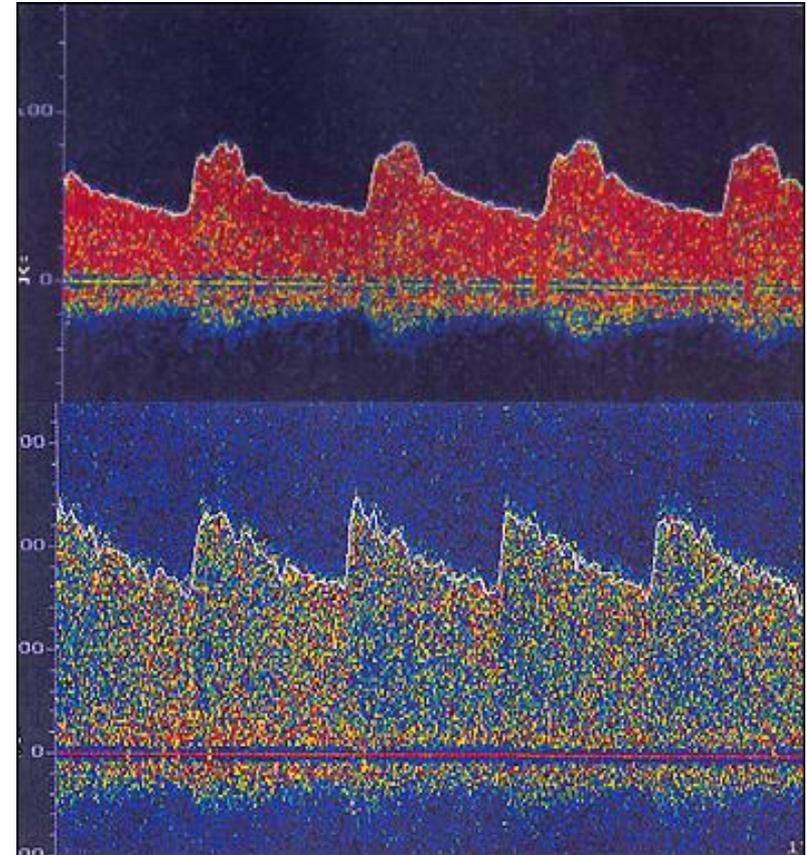
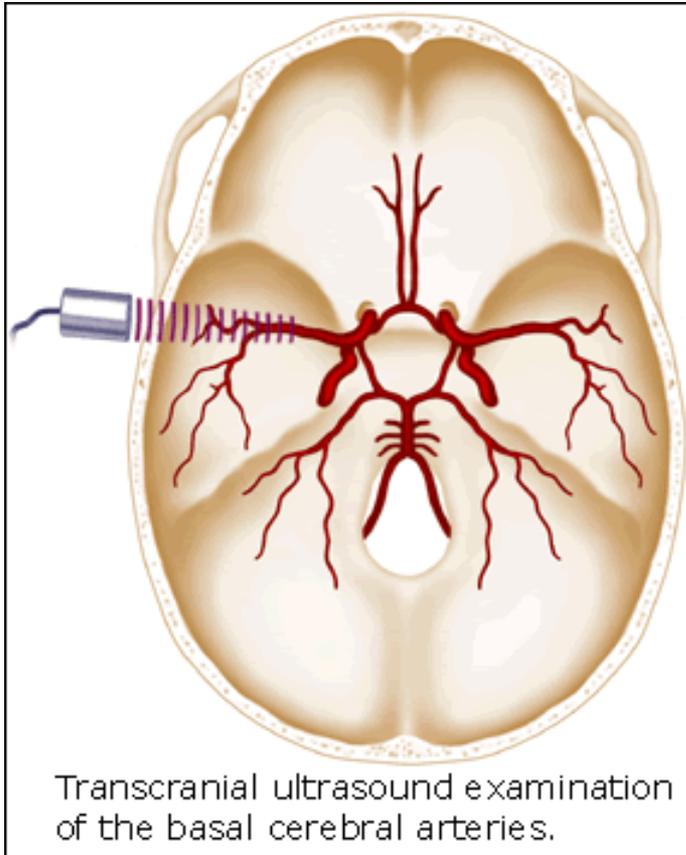


# Vaatspasmen bij SAB



Nilsson et al, Neurosurgery 1999

# Transcraniële doppler



# TCD

- Systolische, diastolische en mean FV
- Anterior, Media, Posterior
- Vorm van de curve: pulsatiliteit
- Pulsatility index:  $FV (sys-dias) / FV \text{ mean}$  (0.6-1.1)
- Lindegaard ratio: ratio flow MCA / A. car. int

# Normaal waardes

Artery	Window	Depth (mm)	Transducer orientation	Flow direction	Velocity (cm/s)
OA	Orbital	40–50	Slightly medial	Toward	16–26
MCA	Temporal	35–60	En face	Toward	46–86
ACA	Temporal	60–75	Anteriorly	Away	41–76
PCA	Temporal	60–75	Posteriorly	Toward	33–64
VA	Foraminal	45–75	Superiorly and obliquely	Away	27–55
BA	Foraminal	70–120	Superiorly	Away	30–57

# TCD

## Toename MFV

- Vaatspasmen
- Hyperemie
- Verlies van autoregulatie
- Hypercapnie
- Intracraniele art stenose
- Hyperdynamische circulatie
- AV malformatie
- Bacteriele meningitis
- Pre-eclampsie
- Damp vormige anaesthetica

## Afname MFV

- Hypotensie
- Daling CBF
- Hersendood
- Toename ICP
- Hypocapnie
- Zwangerschap
- Hypothermie
- Leverfalen

## PI

- Toename:
  - Hoge ICP
  - Hydrocephalus
  - Neurotrauma
  - Intracerebrale bloeding
  - Leverfalen
  - CVA
  - Hersendood
  - Intracraniele art. occlusie
  - Bacteriele meningitis
- Afname
  - Vaatspasmen
  - AV malformatie
  - Opwarmen na hypothermie
  - Hyperemie

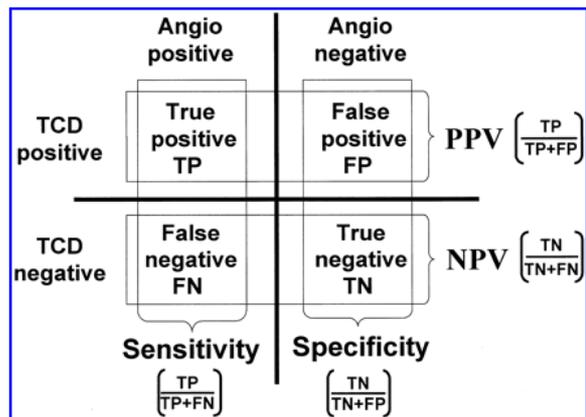
## Lindegaard ratio

- Toename
  - Vaatspasmen
- Afname
  - Hyperemie

White et al, ICM, 2006

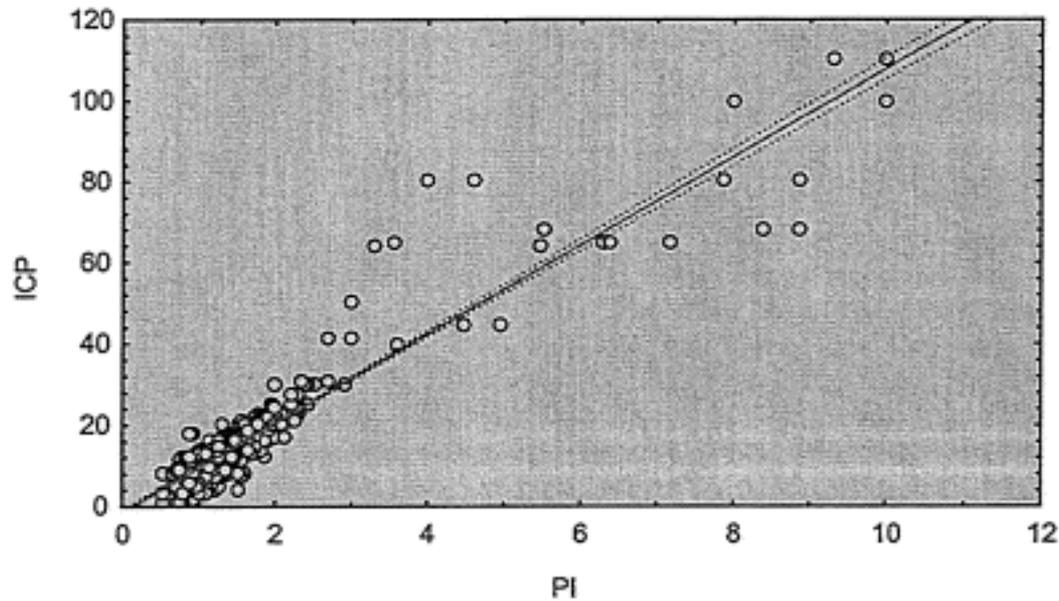
# Meta analyse angiografie vs TCD vaatspasmen

	Sens	Spec	PPV	NPV
ACM	67(48-87)	99 (99-100)	97 (95-98)	78 (65-91)
ACA	42 (11-72)	76 (53-100)	56 (27-84)	69 (43-95)



Lysakowski et al, Stroke, 2001

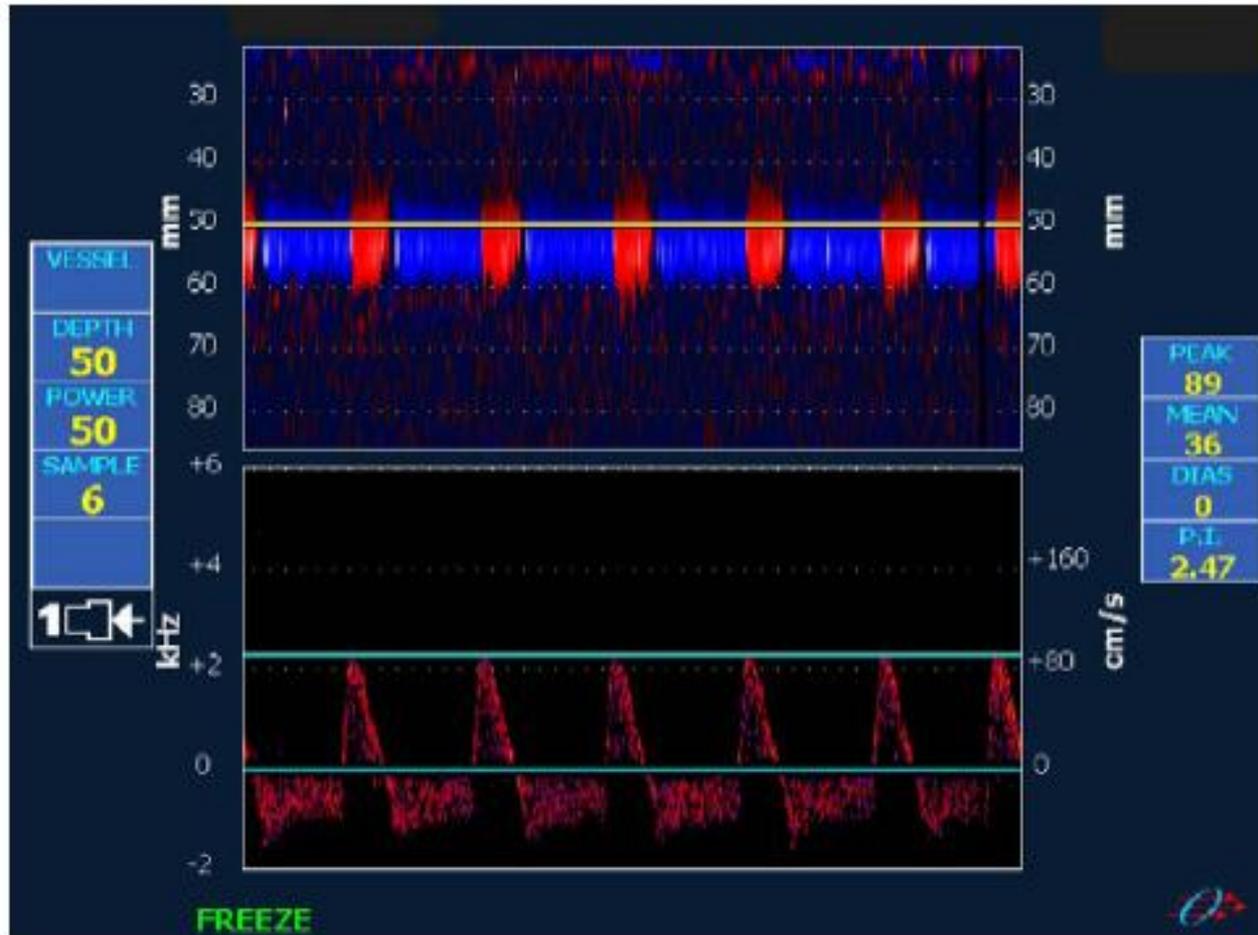
## Voorspellen van ICP (tot ICP 40)



$$R = 0.938, P < 0.001$$
$$ICP = 10.927 \times PI$$

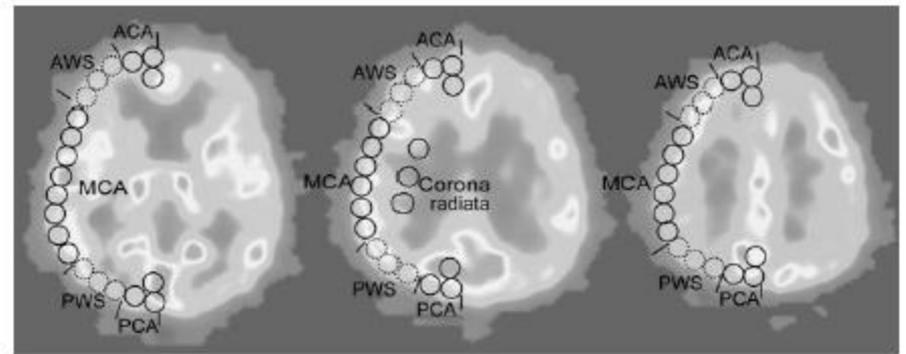
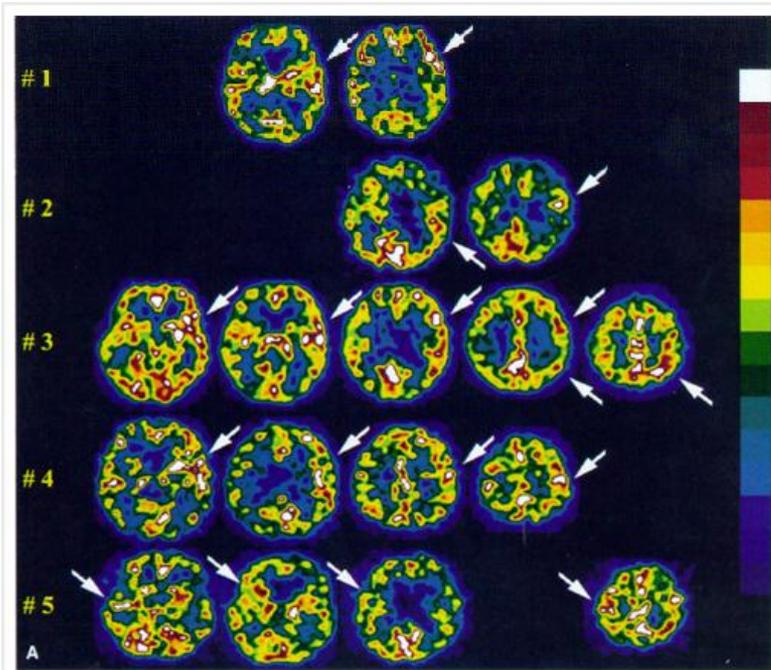
Bellner et al, Surg Neurol, 2004

# Hersendood: omkeer van diastolische flow



White et al, ICM, 2006

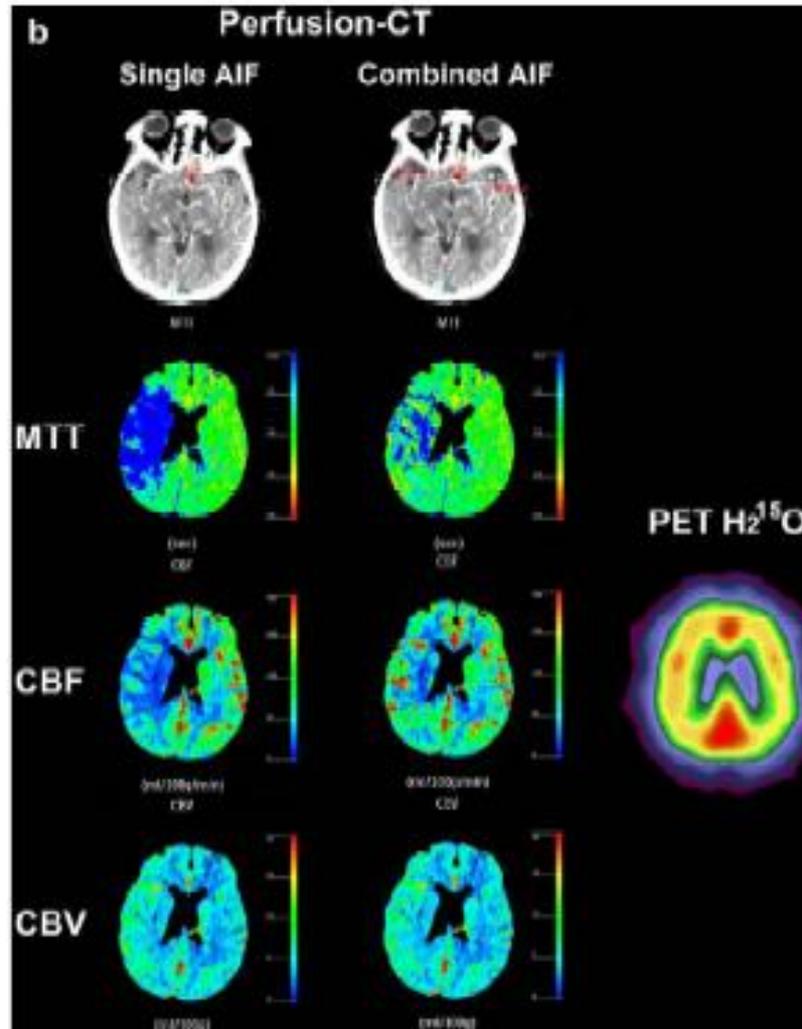
# PET



## PET scan: nadelen

- Toedienen van radioactieve stoffen
- Buiten IC (niet bedside)
- Relatief lage resolutie
- Geen herkenbare structuren
- Alleen herkenbaar als ischemie (niet mitochondriële dysfunctie)

# Perfusie CT vs PET



	n	Acute stroke		Acute ischaemic stroke	
		CT	MRI	CT	MRI
<b>Sensitivity</b>					
All	356	26% (20-32)	83% (78-88)	16% (12-23)	83% (77-88)
>12 h	135	22% (14-33)	91% (82-96)	16% (9-27)	92% (83-97)
3-12 h	131	29% (19-41)	81% (70-89)	20% (12-33)	81% (69-90)
<3 h	90	27% (17-40)	76% (64-86)	12% (5-24)	73% (59-84)
<b>Specificity</b>					
All	356	98% (93-99)	97% (92-99)	98% (94-99)	96% (92-99)
>12 h	135	98% (89-100)	96% (86-99)	98% (90-100)	97% (88-99)
3-12 h	131	97% (87-99)	98% (90-100)	96% (87-99)	99% (91-100)
<3 h	90	100% (85-100)	96% (79-100)	100% (89-100)	92% (78-98)

Data in parentheses are 95% CI.

Bloedig CVA:

MRI: sens 81 (61-93), spec 100 (98-100)

CT: sens 89 (70-97), spec 100 (98-100)

Chalela et al, Lancet, 2007

## CT-perfusie

- Maakt onderscheid tussen irreversibele ischemie en reversibele penumbra
- Meet weefsel/capillaire bloedflow
  - CBF (flow vs tijd ml/100g brein/min)
  - CBV (volume bloed vs brein ml/100g brein)
  - MTT (sec)
- Core= volume lesie CBV
- Penumbra = volume lesie CBF
- Mismatch: verschil CBV-CBF

# CT-P

- Detectie van nog herstelbaar weefsel voor trombolyse (voorbij tijdwindow)
- Vroege detectie ischemie na hartchirurgie
- Detectie van klinisch relevante vaatspasmen (beter tov angio/TCD)

# CVAi

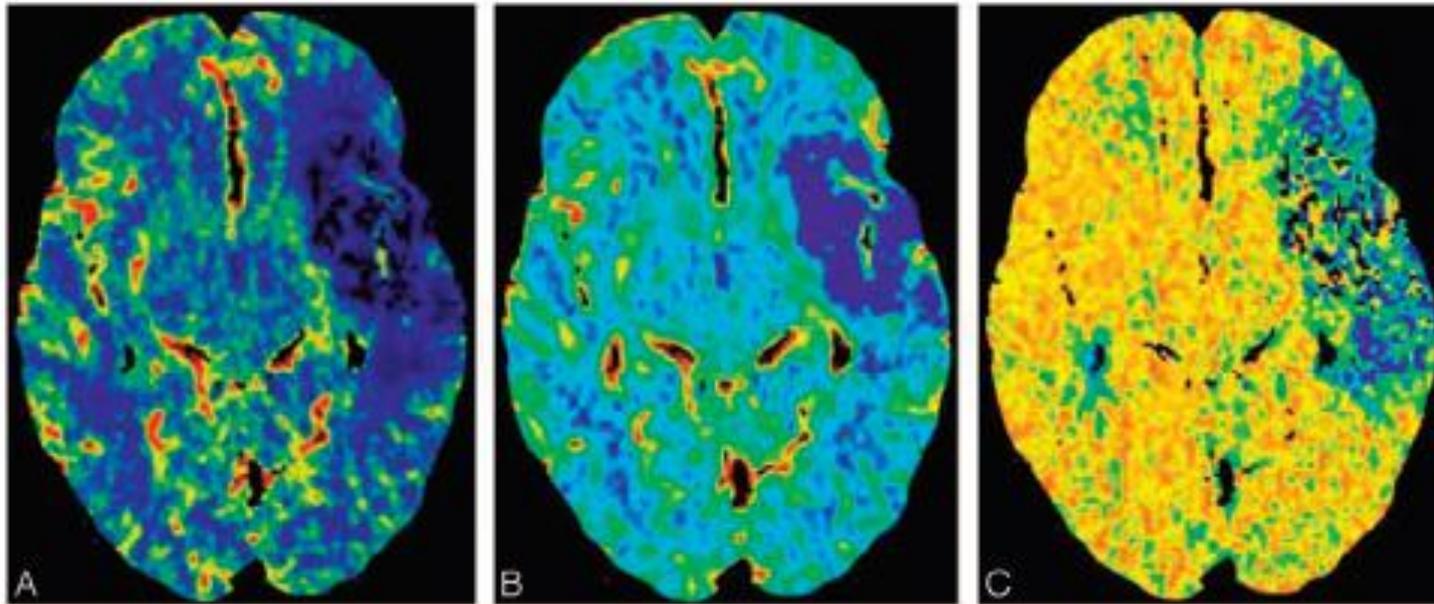
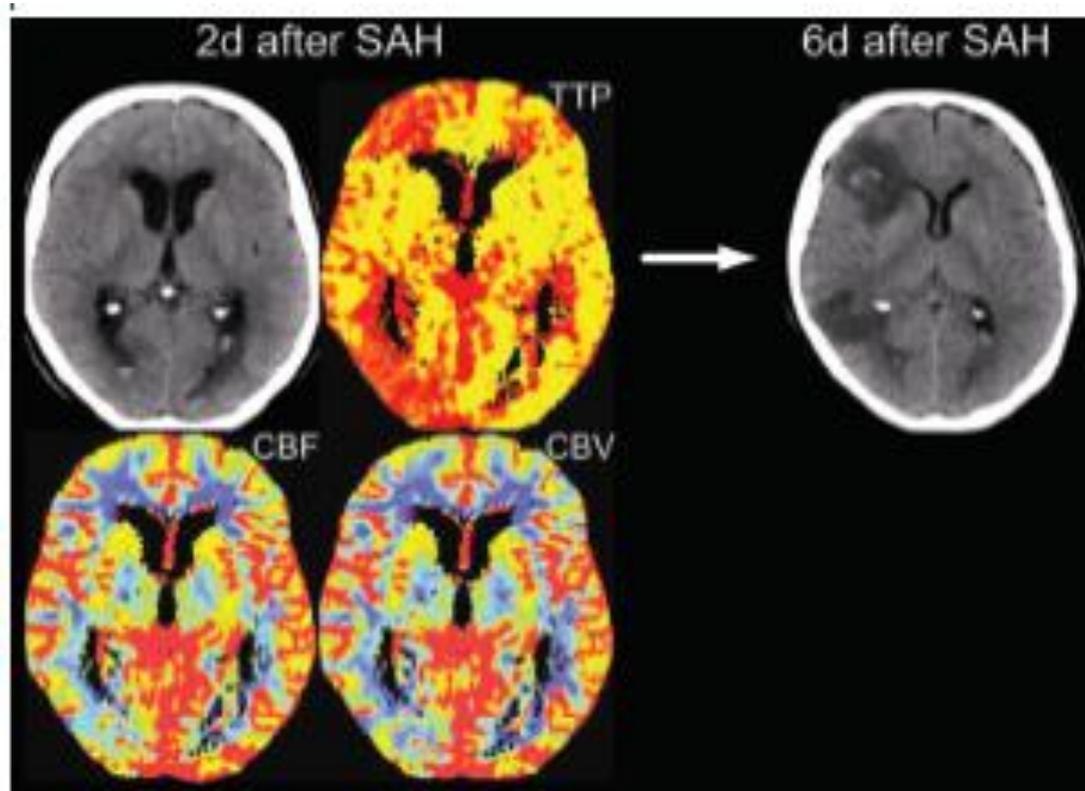


Fig 1. CT perfusion images obtained in a patient with acute ischemic stroke demonstrate a large perfusion defect in the left MCA distribution, with minimal CBN/MTT or CBF mismatch.  
 A, CBF. B, CBV. C, MTT.

# SAB met vaatspasmen



Pham et al, Neurology, 2007

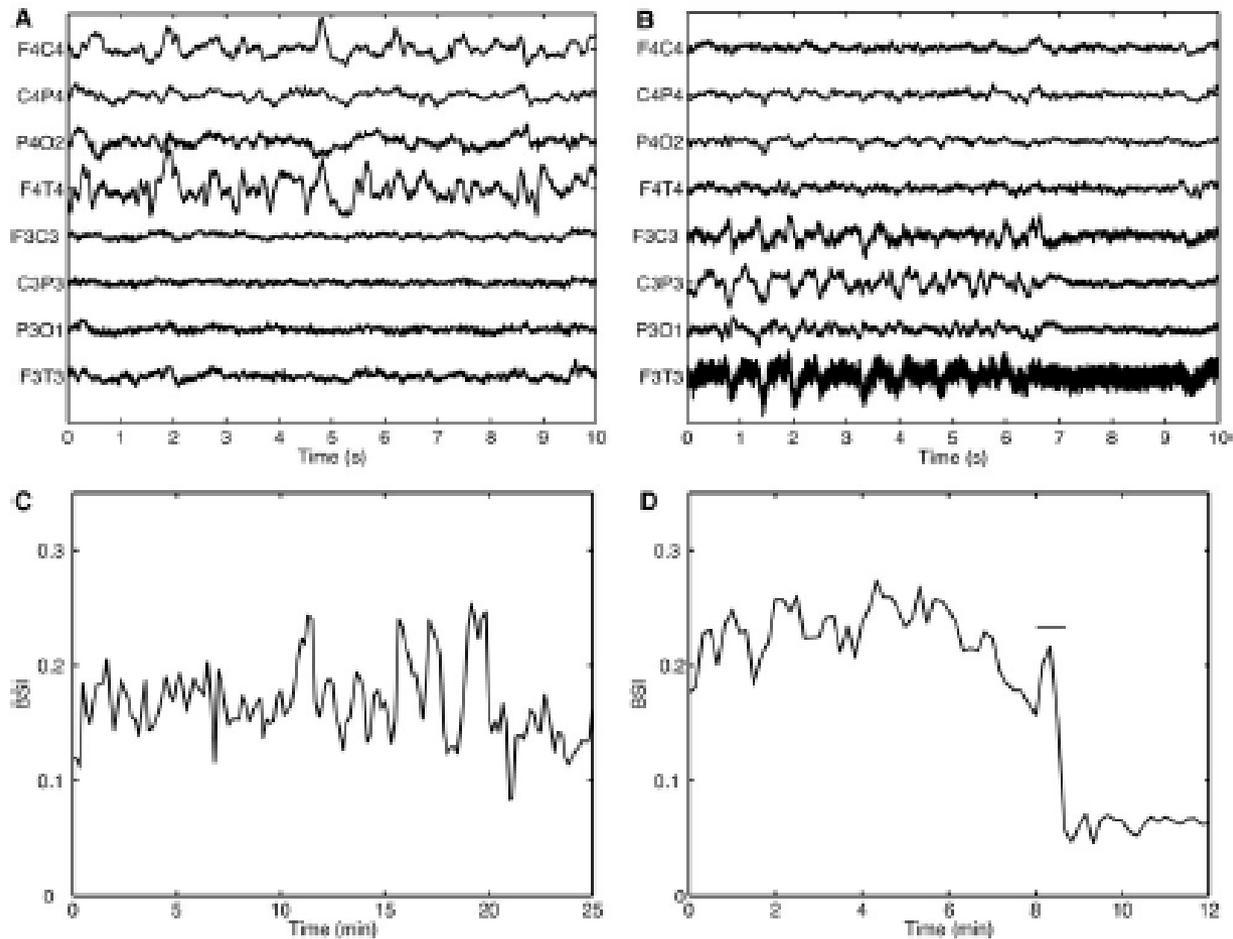
# Kwantitatief EEG

- EEG is functionele monitoring
- Sterk afhankelijk van metabolisme
- Gevoelig voor ischemie en hypoxie
- Alle gebieden van de hersenen
- Niet invasief
- Bij vaatspasmen en SAB:
  - 100% sensitief voor vaststellen vaatspasmen (angio)
  - Gem 2.9 dagen eerder dan met TCD of angio
  - In dat stadium nog reversibele schade

## Revised brain symmetry index

- Symmetrie links-rechts
- Symmetrie in tijd
- Spectraal analyse

# Revised brain symmetry index



V Putten et al, Stroke 2004

# Prevalentie insulden op neuroIC

**TABLE 1.** Rate of Seizures in Nontraumatic and Traumatic Intracerebral Hemorrhage

	N (with hemorrhage)	Percentage with Seizure
<b>Non-EEG Studies</b>		
Berger et al., 1988	112	17
Temkin et al., 1990	208	3.6
Lee et al., 1995	2,574	4.1
Burn et al., 1997	99	13
Arboix et al., 1997	208	4.3
Bladin et al., 2000	265	10.6
Labovitz et al., 2001	200	7.5
<b>ICU cEEG studies</b>		
Jordan et al., 1995	124	35
Vespa et al., 1999a	91	22
Vespa et al., 1999b	300	21
Vespa et al., 2003b	65	28
Claassen et al., 2004	204	17

**TABLE 2.** Physiologic Impact of Seizures After Cerebral Injury

Study	Effect
Vespa et al., 1998	Increase in glutamate
Vespa et al., 1999a	Increase in mortality with status epilepticus
Vespa et al., 2002	Increase in lipid membrane breakdown
Vespa et al., 2003b	Increase in midline shift and mortality

# Detectie van insulsten

