Place du monitorage non-invasif du CO_2 en VNI

Actualités en Ventilation 2008

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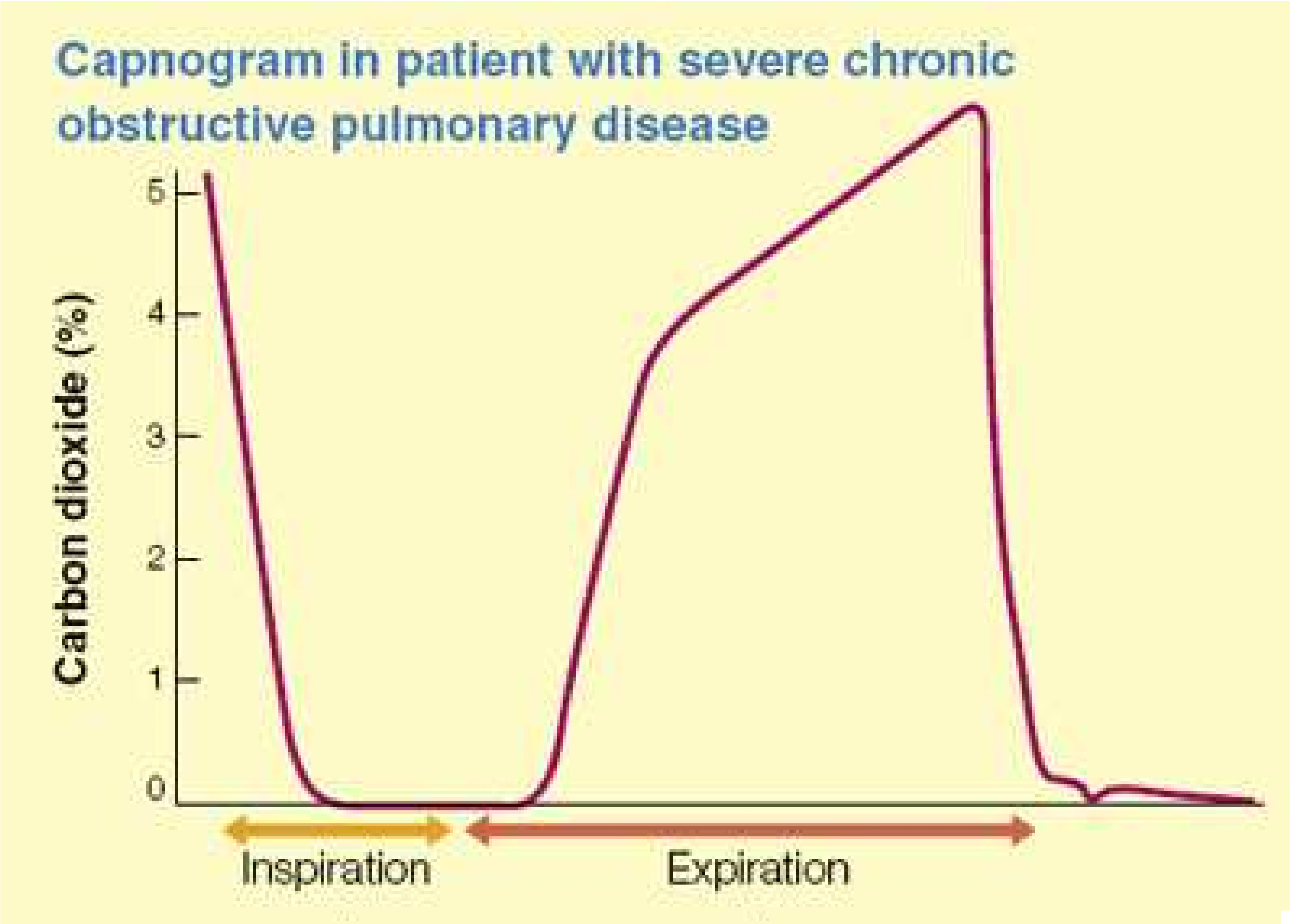
Points abordés

- 1: Place du End-tidal CO_2
- 2: Mesure trans-cutanée du CO_2:
  - Principe
  - Temps de réaction (lag time)
  - Concordance avec mesures artérielles
    - En réanimation
    - Lors de VNI au long cours
  - Dérive (Drift)
  - Caveats
- Conclusions

1.$ETCO_2$


Capnogram in patient with severe chronic obstructive pulmonary disease
Carbon dioxide (%)
5
4
3
2
1
0
Inspiration
Expiration

$ETCO_2$

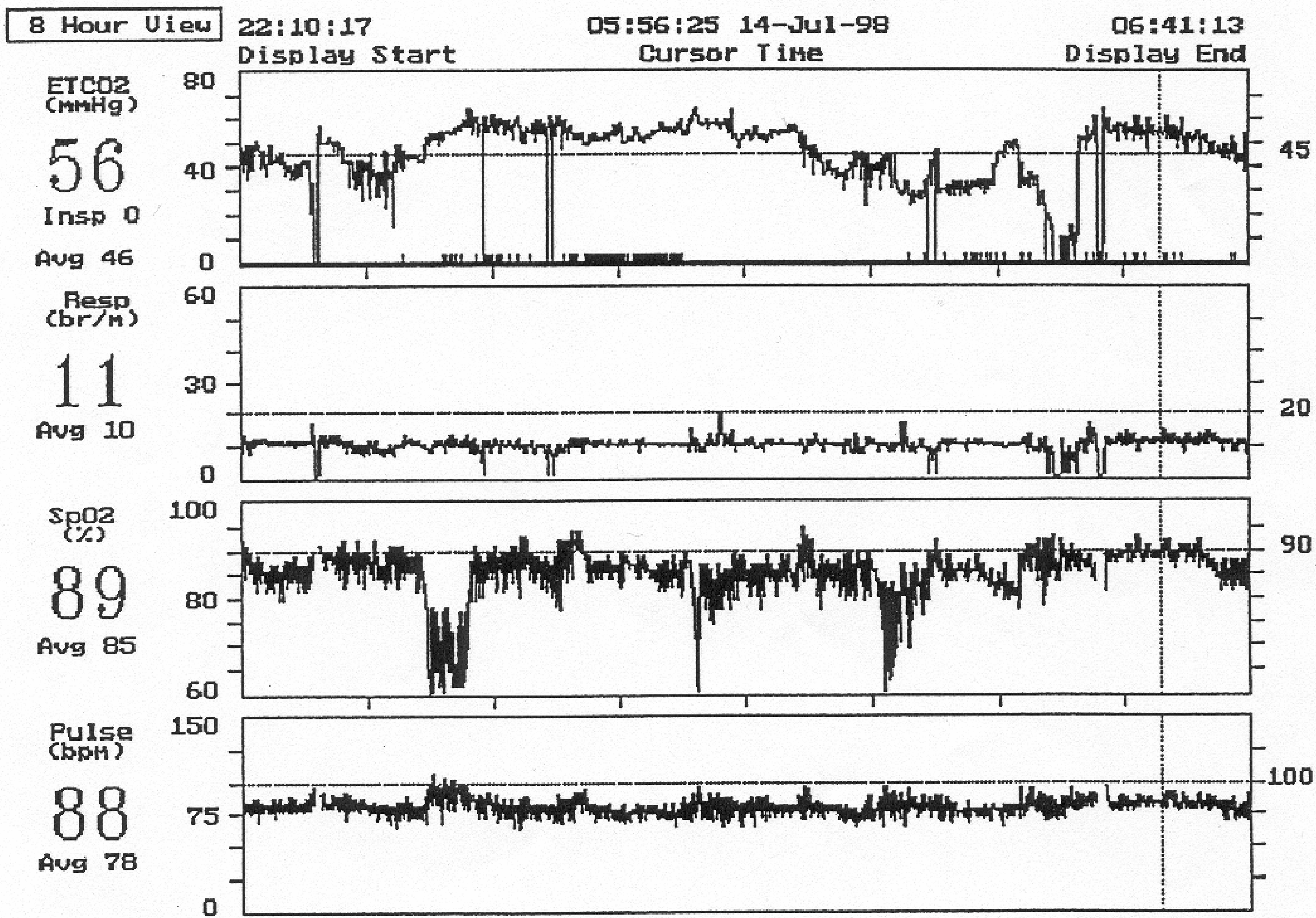
- Largement utilisé par les anesthésistes et réanimateurs

Mais:

- Mauvais reflet de la $PaCO_2$
- Δ ($PETCO_2$ - $PaCO_2$) $\Uparrow$ lors d'atteintes parenchymateuses (BPCO, pneumopathies interstitielles, maladies vasculaires pulmonaires..)

$$\boxed{PETCO_2 = PaCO_2\ (1-V_D/V_T)}$$

V_D = : Espace mort physiologique; V_T = Volume courant



8 Hour View
22:10:17
Display Start
05:56:25 14-Jul-98
Cursor Time
06:41:13
Display End
ETCO2 (mmHg)
56
Insp 0
Avg 46
80
40
0
45
Resp (br/m)
11
Avg 10
60
30
0
20
SpO2 (%)
89
Avg 85
100
80
60
90
Pulse (bpm)
88
Avg 78
150
75
0
100

$ETCO_2$

- N=100 patients ; prise en charge extra-hospitalière en urgence; comparaison $ETCO_2$ vs. $PaCO_2$ à T0 et fin de la prise en charge extra-hospitalière.

Correlation of arterial P_{CO_2} and P_{ETCO_2} in prehospital controlled ventilation 855

Table 3 Arterial blood gases results and $PaCO_2 - PETCO_2$ gradient (mm Hg)

Variables	T_0	T_{end}	P
$PaCO_2$ (mm Hg)	48.4 ± 17.7 (21-130)	44.1 ± 14.6 (23.2-122)	.0001
$ETCO_2$ (mm Hg)	40 ± 13.3 (17-80)	36.4 ± 8.9 (23-71)	.0002
$PaCO_2 - PETCO_2$ gradient (mm Hg) calculated values	9.0 ± 13.6 (−19.7 to 75)	7.3 ± 12.9 (−11.8 to 98)	NS

Values are presented as mean ± SD (range).

V Belpomme et al; Am J Emerg Med 2005; 23: 852

V Belpomme et al;
Am J Emerg Med 2005; 23: 852

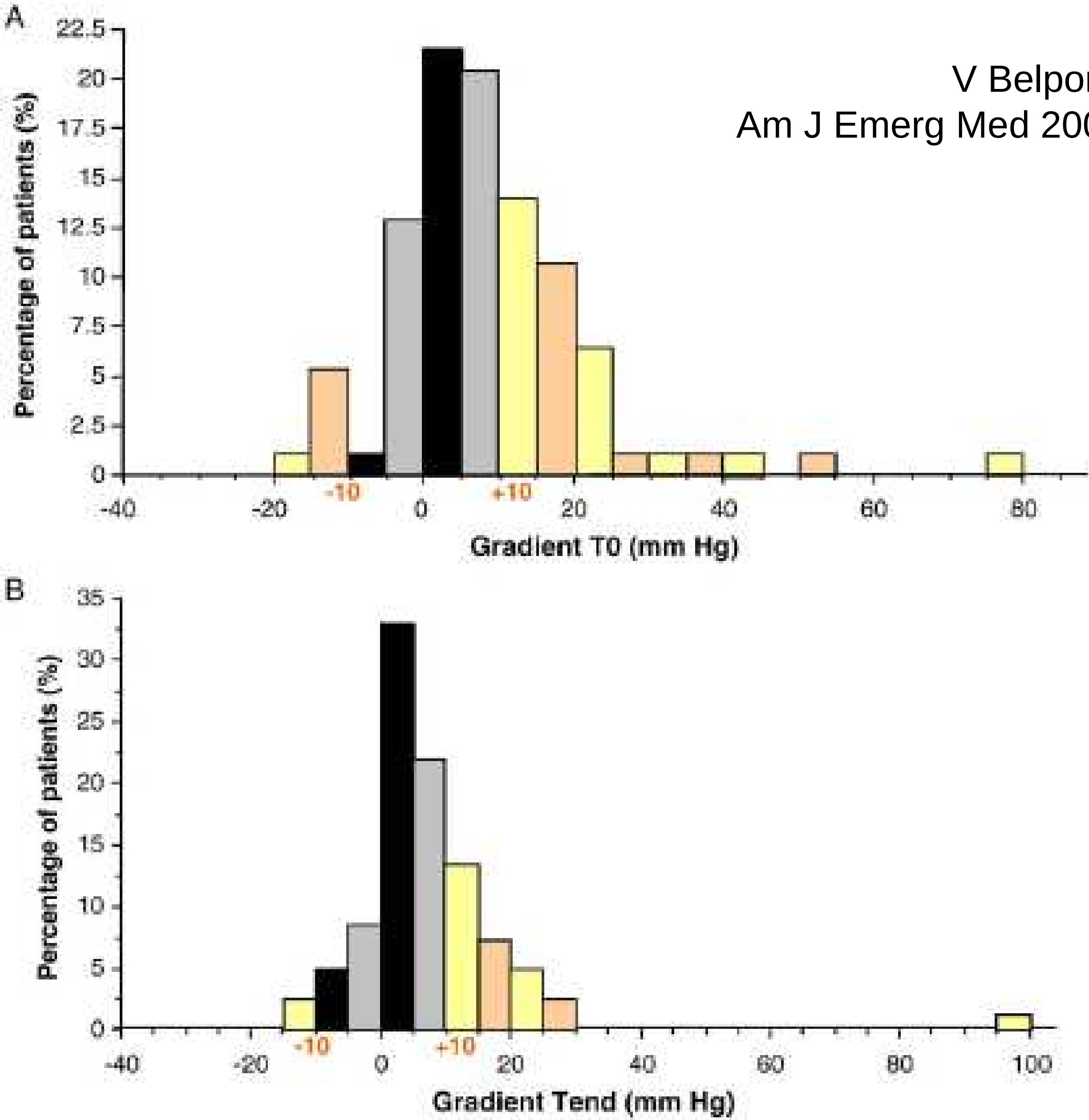


Fig. 1 A, $PaCO_2 - PETCO_2$ gradient (mm Hg) at the beginning of prehospital management (T_0). B, $PaCO_2 - PETCO_2$ gradient (mm Hg) at the end of prehospital management (T_{end}).

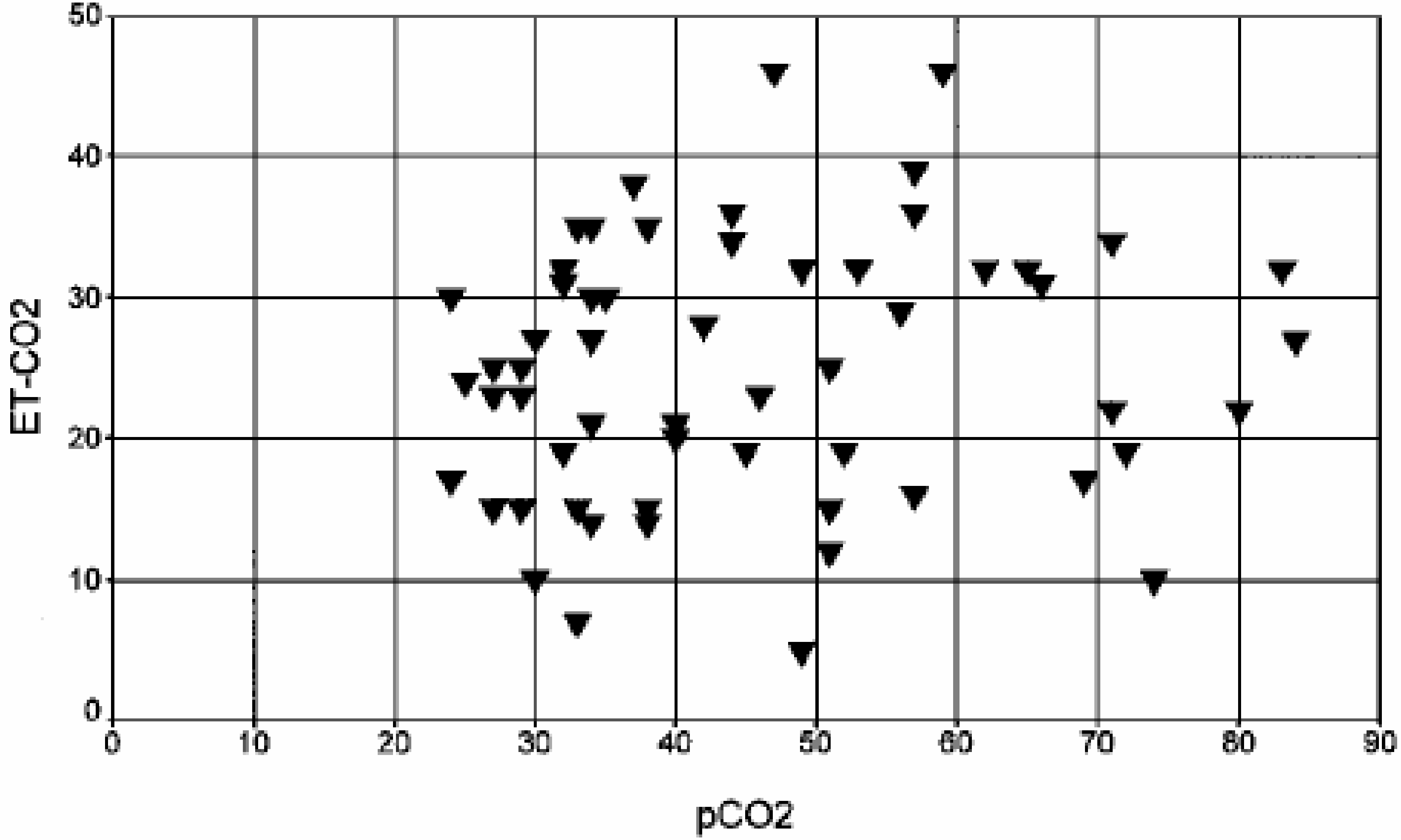


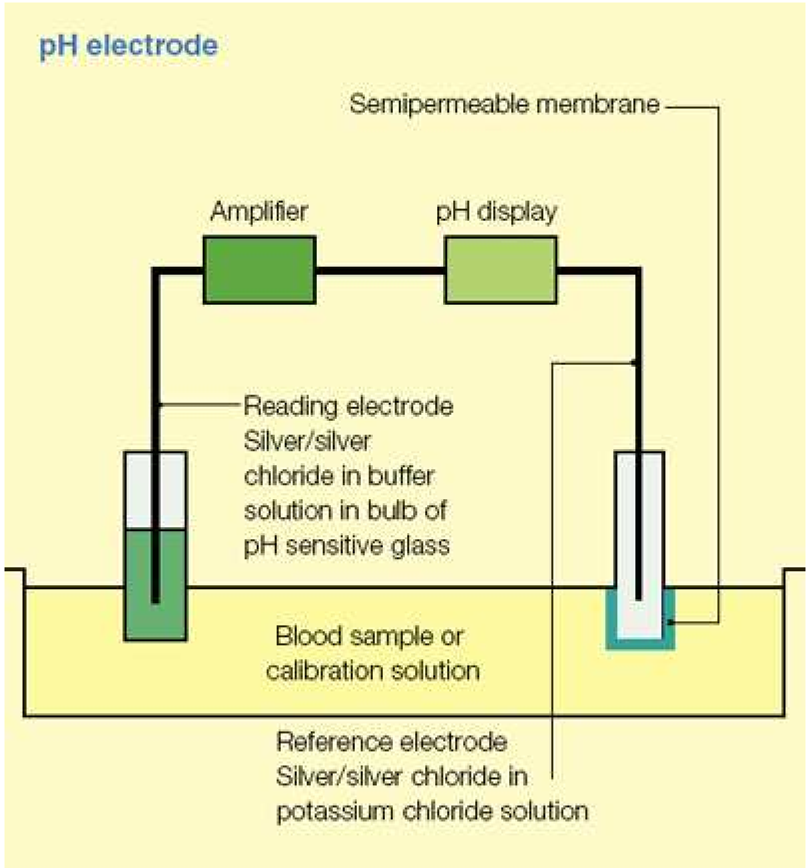
Fig. 1. Scatter plot of the $ETCO_2$ and pCO_2 values in the whole group of patients.

G Prause et al; Resuscitation 1997; 35: 145

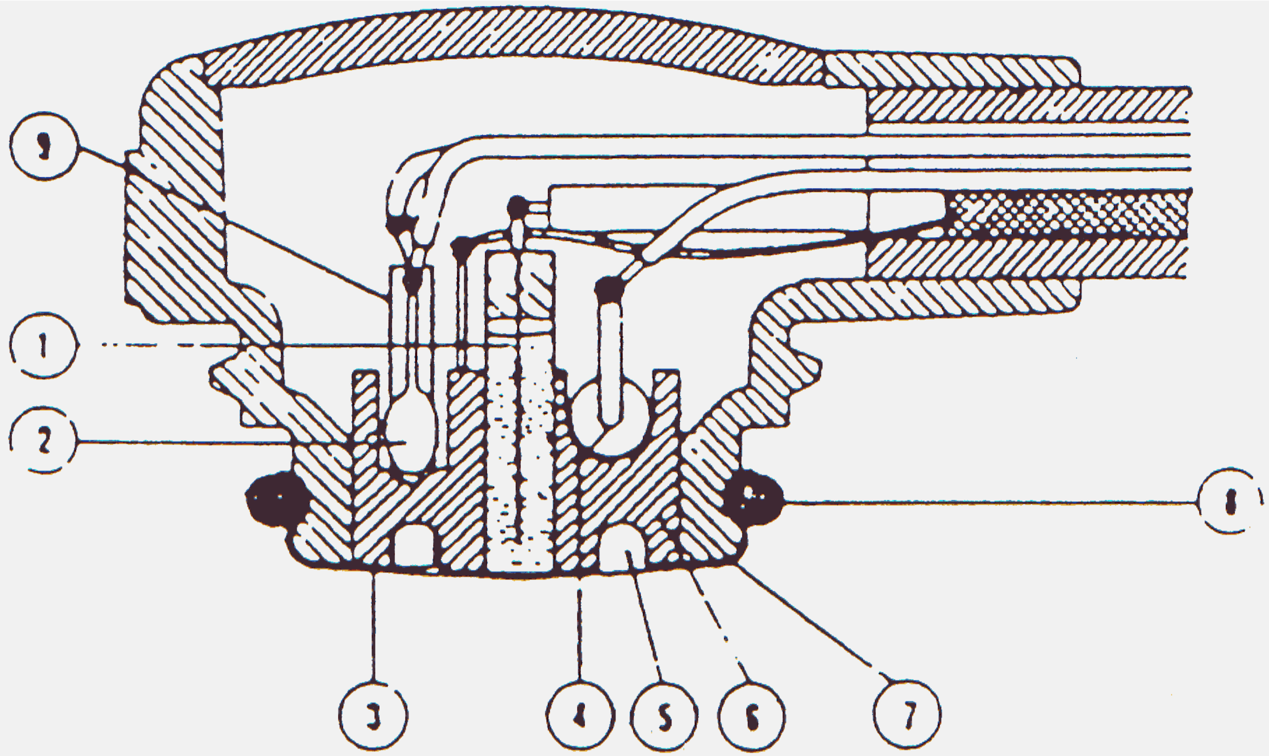
$ETCO_2$ lors de VNI

- Simple, d’emploi aisé, mais
- Sous-estime la $PaCO_2$
- Non fiable lors d’atteinte parenchymateuse pulmonaire
- Peut, en l’absence d’atteinte parenchymateuse pulmonaire, montrer des trends de manière fiable
- Utilisé par certains centres pour le monitoring de patients neuro-musculaires
- Option pratique pour les visites à domicile

$PtcCO_2$: Mesure transcutanée du CO_2



Severinghaus JW. Electrodes for blood PO_2 and PCO_2 determination. *J Appl Physiol* 13: 515—520, 1958



(1) Glass electrode with a buffer solution (the inner liquid) and a pH sensitive membrane.
(2) Temperature sensors.
(3) Electrolyte.
(4) Heating element.
(5) Electrolyte reservoir.
(6) Ag/AgCl reference electrode.
(7) O_2/CO_2 permeable membranes.
(8) 0-ring to secure the membranes.
(9) Platinum cathode.

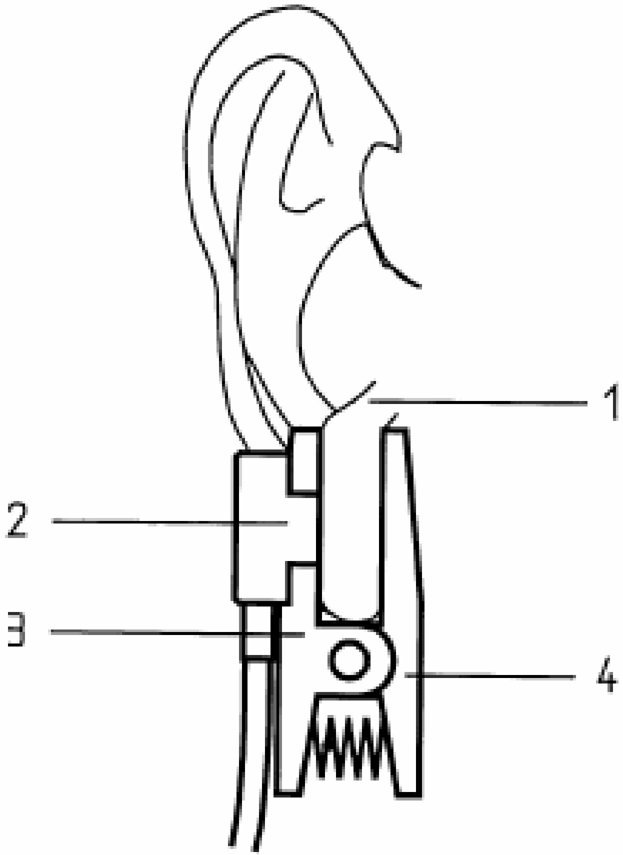


Fig. 1. Schematic drawing of the SpO_2–PCO_2 sensor with clip, placed at the ear lobe. (1) = earlobe, (2) = SpO_2–PCO_2 sensor, (3) = side of clip which fits the probe, (4) side of the clip with reflecting surface.

Rohling R, Biro P. Clinical investigation of a new combined pulse oximetry and carbon dioxide tension sensor in adult anaesthesia.

J Clin Monit 1999; 15: 23–27

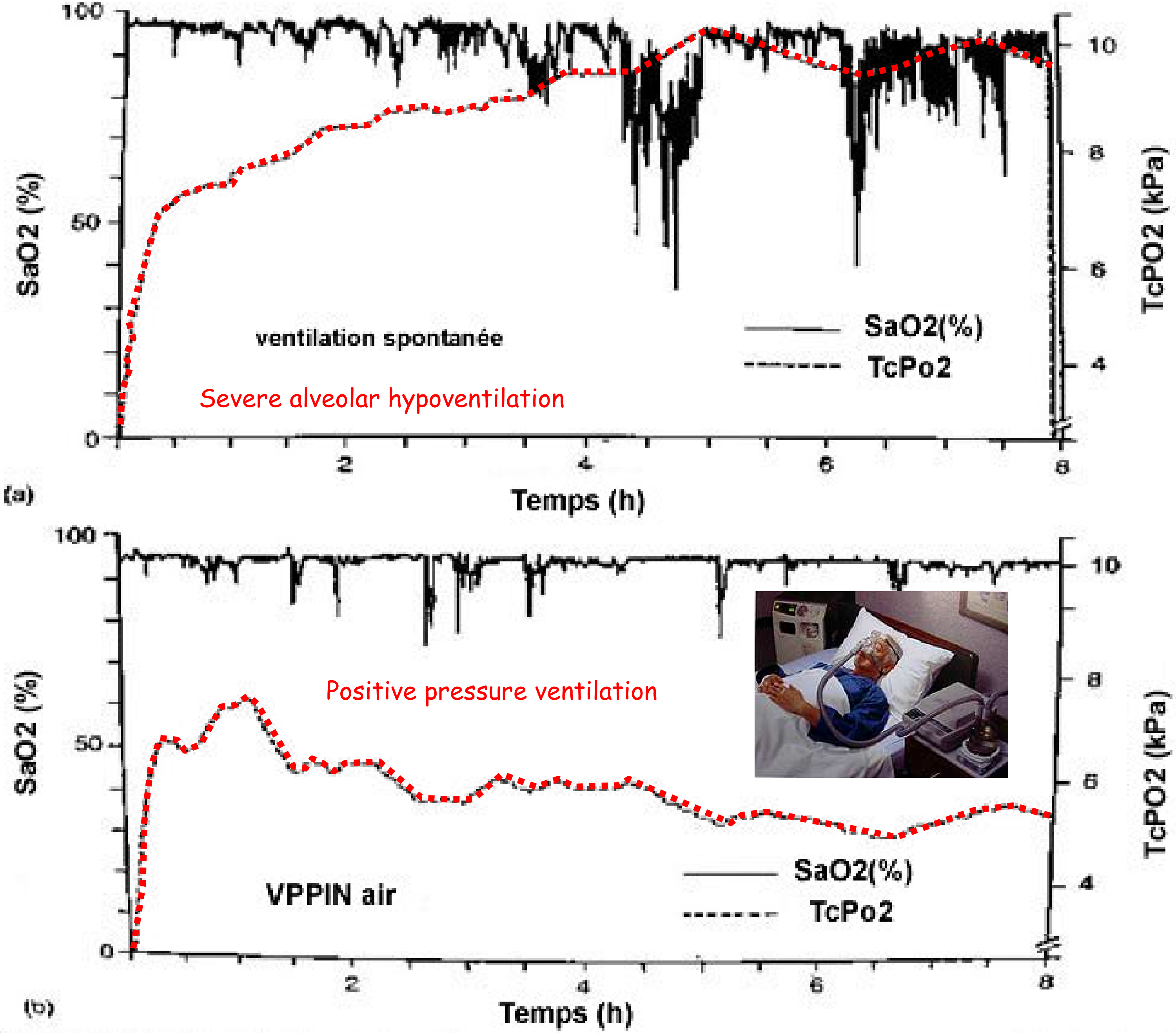
Cutaneous carbon dioxide monitoring in adults

Prashant N. Chhajed[a,c], Ludwig T. Heuss[b] and Michael Tamm[a,c]

Table 1. Clinical applications of $PcCO_2$ monitoring

Operating room – patient monitoring during and after anaesthesia
Intensive care unit
Monitoring patients receiving noninvasive ventilation
Guiding mechanical ventilation
Monitoring of patients after extubation
Endoscopy under conscious sedation
Bronchoscopy
Thoracoscopy
Gastroscopy/colonoscopy
Sleep laboratory
Assessment of alveolar hypoventilation
Titration of noninvasive ventilation
Lung function laboratory
Oxygen titration in patients with severe chronic obstructive pulmonary disease
Diagnosis of hyperventilation
Assessment of hyperventilation response in patients with hypercapnia

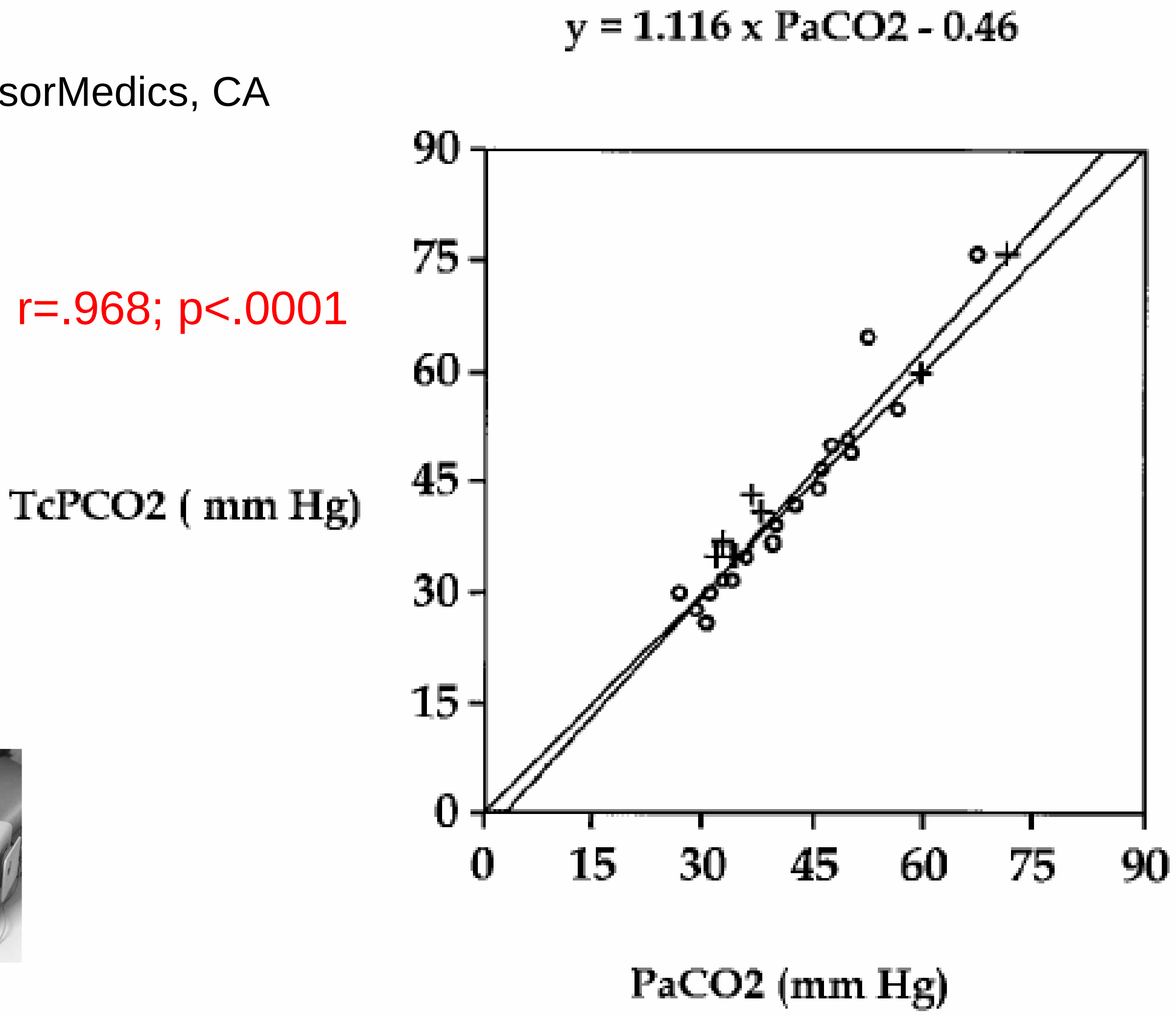
Current Opinion in Anaesthesiology 2004, 17:521–525


100
50
0
SaO2 (%)
10
8
6
4
TcPO2 (kPa)
2
4
6
8
Temps (h)
(a)
ventilation spontanée
Severe alveolar hypoventilation
SaO2(%)
TcPo2
100
50
0
SaO2 (%)
10
8
6
4
TcPO2 (kPa)
2
4
6
8
Temps (h)
(b)
Positive pressure ventilation
VPPIN air
SaO2(%)
TcPo2

Concordance avec valeurs artérielles

Fastrac, SensorMedics, CA

r=.968; p<.0001



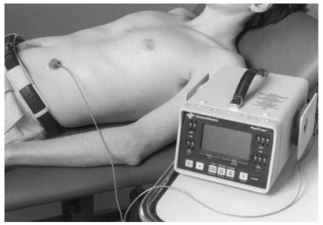
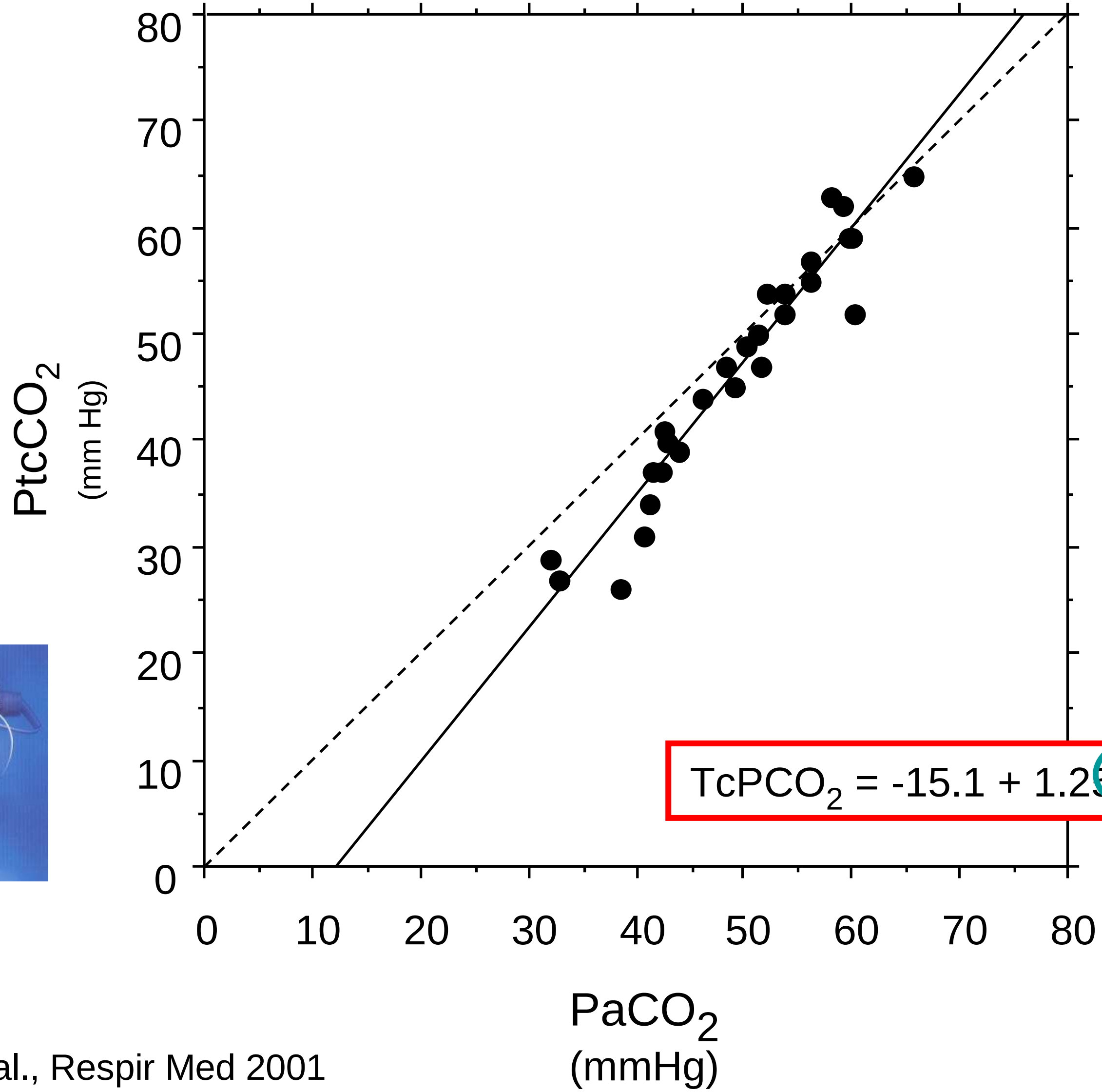


FIGURE 2. Regression line for $TcPco_2$ on $PaCO_2$, and identity line; values are in mm Hg. Data shown are those of 26 patients without dopamine (open circles) or with low-dose dopamine (crosses).

Janssens JP et al., Chest 1998; 1113: 768

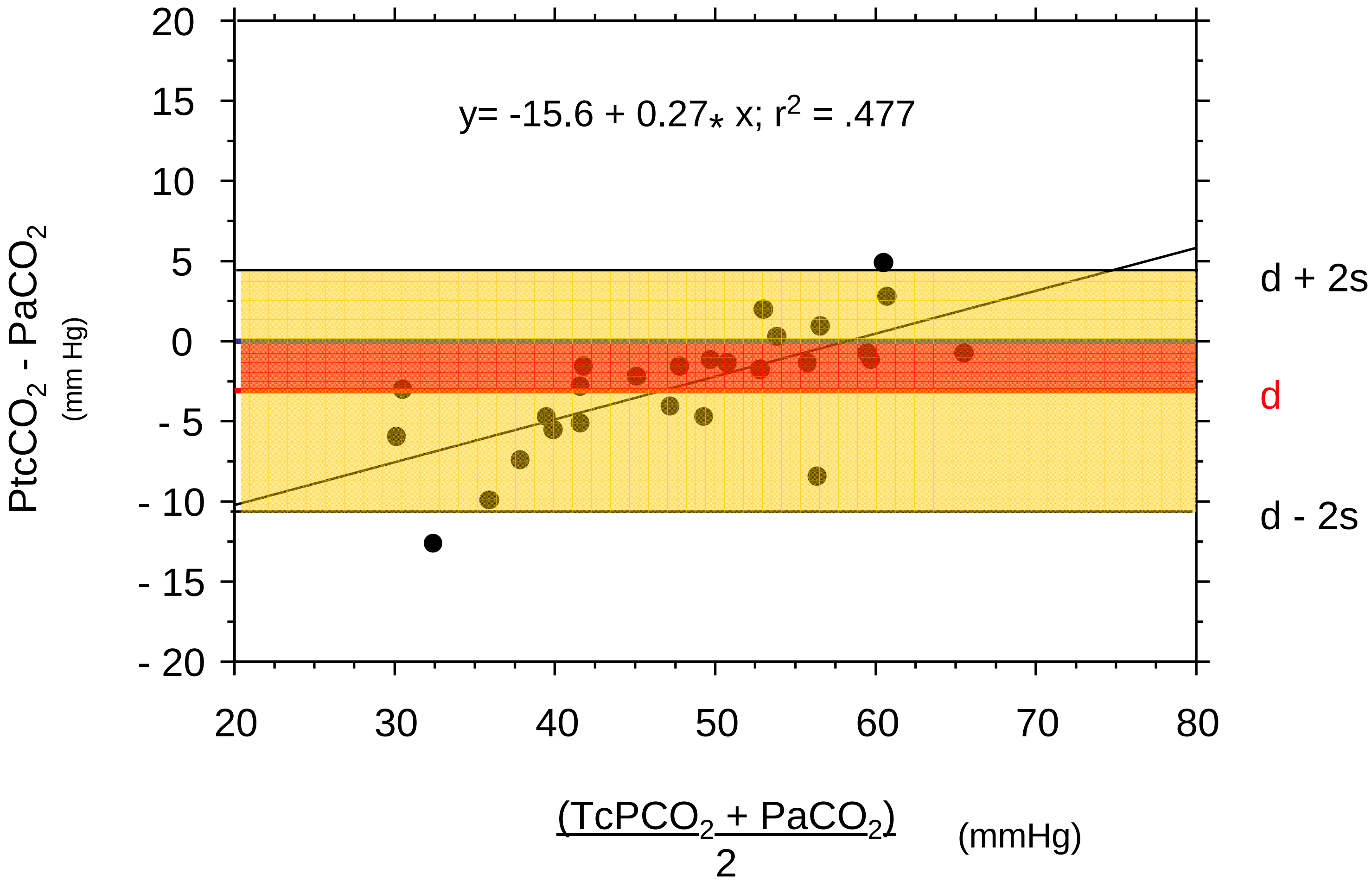
$PtcCO_2$ vs. $PaCO_2$: Radiometer® TINA TCM3



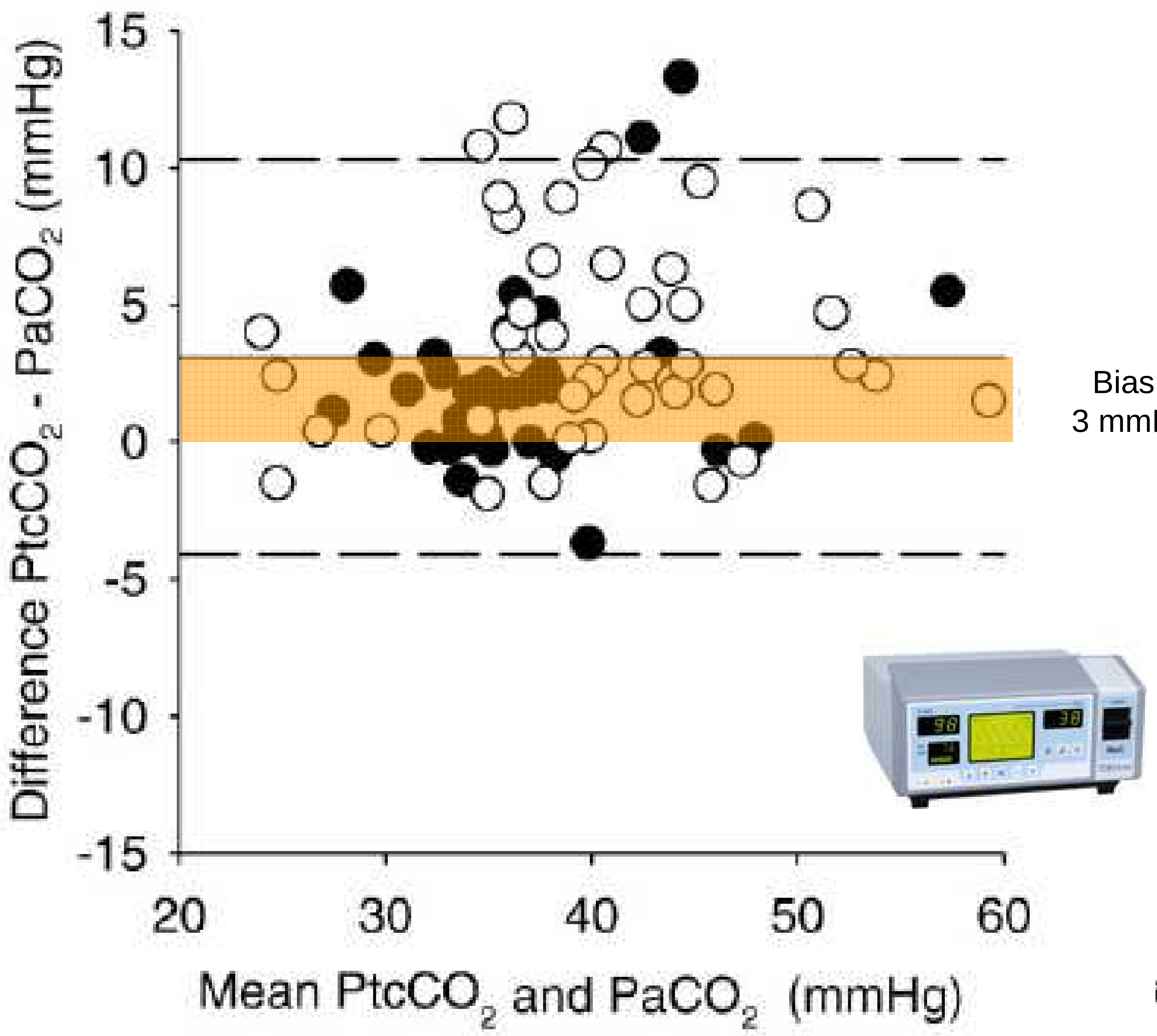
$TcPCO_2 = -15.1 + 1.25 \times PaCO_2$; $r^2 = .922$

Janssens JP et al., Respir Med 2001

$PtcCO_2$ vs. $PaCO_2$: Radiometer® TINA TCM3
Bias and limits of agreement according to Bland & Altman



Janssens JP et al., Respir Med 2001


Difference PtcO2 - PaCO2 (mmHg)
15
10
5
0
-5
-10
-15
20
30
40
50
60
Mean PtcCO2 and PaCO2 (mmHg)

Bias:
3 mmHg

Moins bonne concordance au dessus de 55 mmHg?

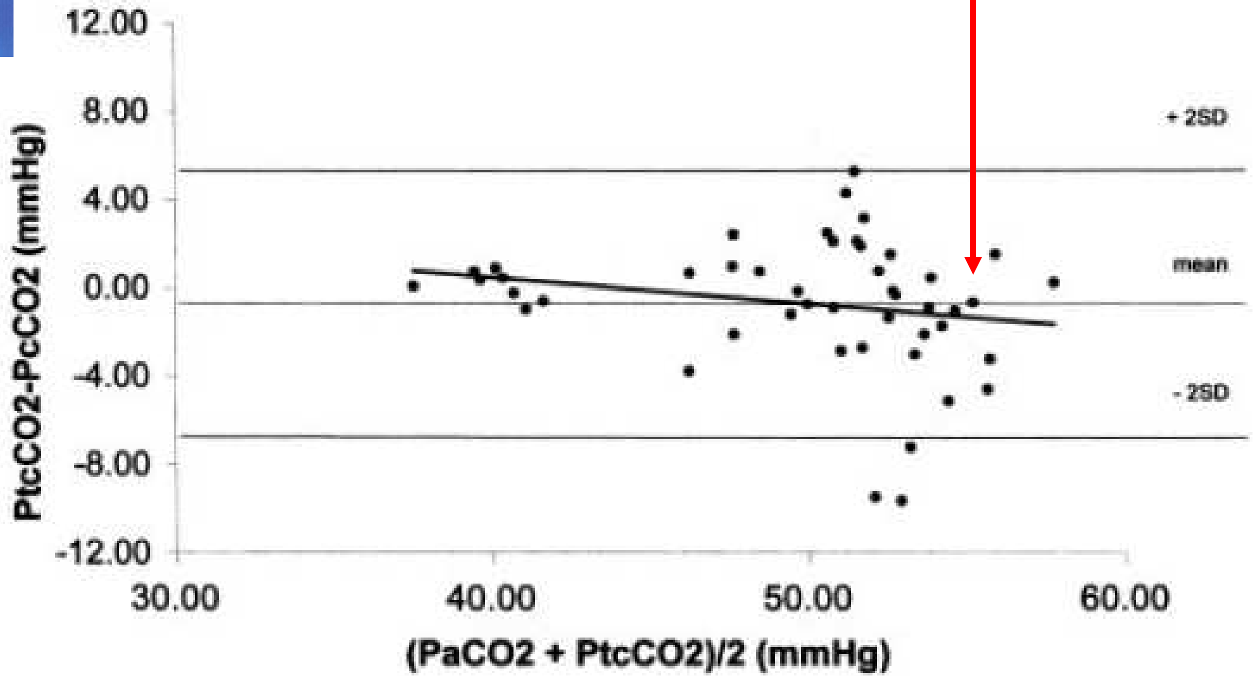
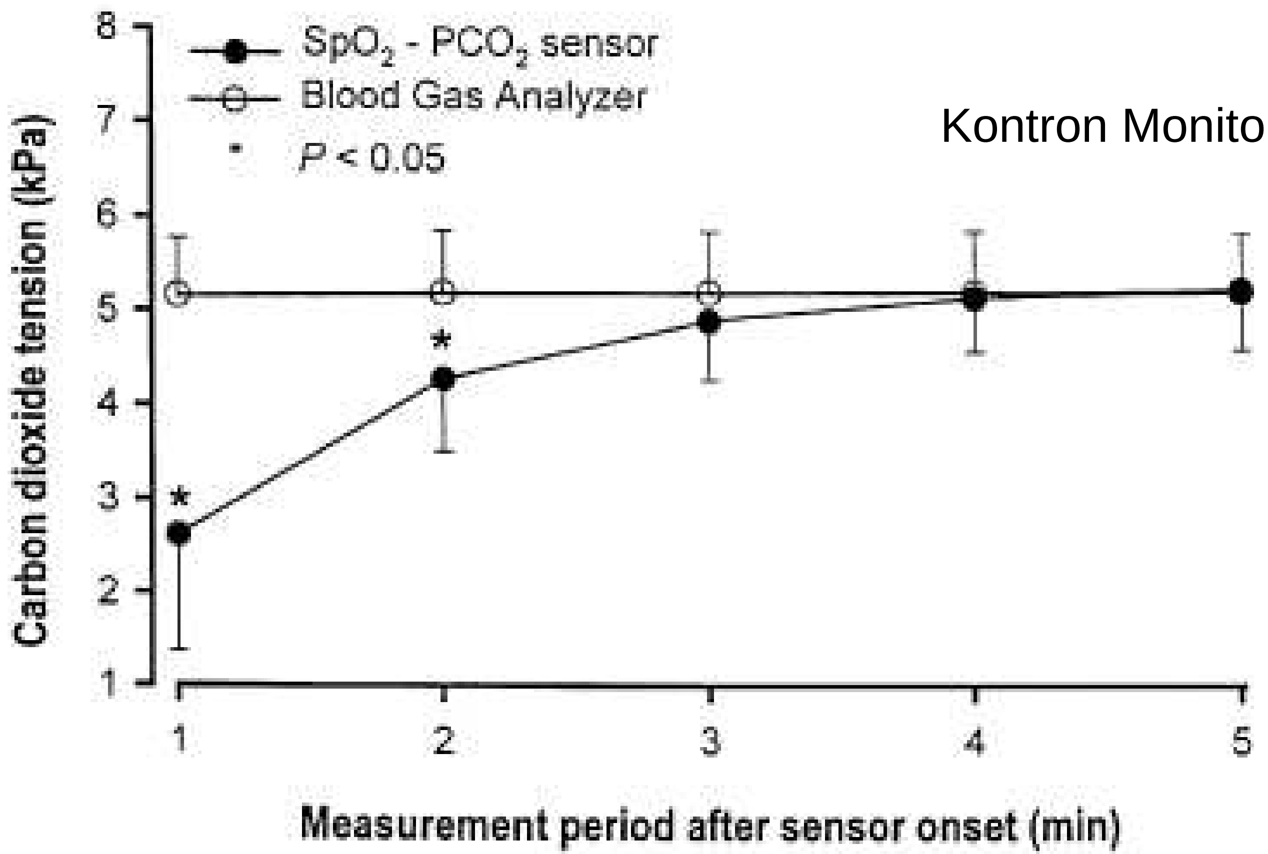


FIGURE 2. Differences against mean for P_{CO_2} data according to Bland and Altman (n = 48).[7] Arterial and transcutaneous values were assessed every 10 min during 40 min of spontaneous breathing in the stable state and with room air, except for three patients who did not tolerate room air and were receiving low-flow oxygen.

A Cuvelier et al; Chest 2005; 127: 1744

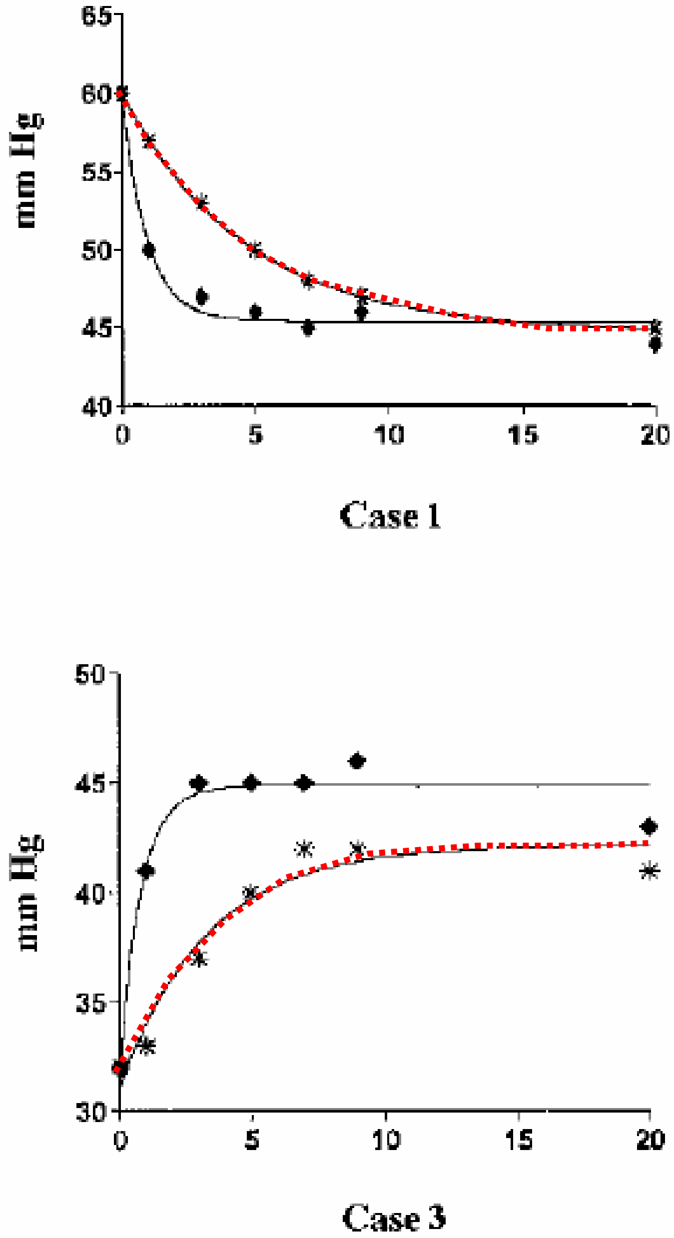
Temps de reaction (Lagtime)

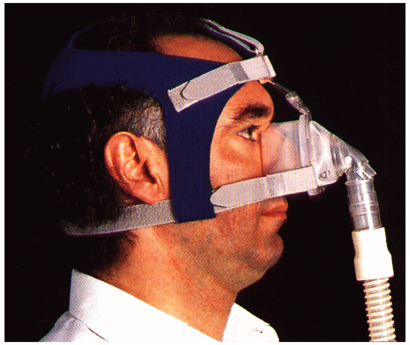


Kontron Monitor 7650

Fig. 2. SpO_2–PCO_2 sensor and arterial carbon dioxide tension courses during the first 5 min. Each point represents the mean ± standard deviation value of 10 measurements from 10 patients. Three min after electrode placement, no significant difference ($p = 0.037$) was obtained between SpO_2–PCO_2 sensor and arterial carbon dioxide tension.

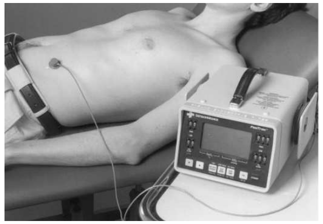
R Rohling et al; J Clin Monitor Comput 1999; 15: 23



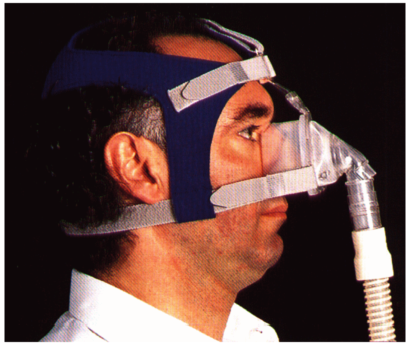


TcPCO$_2$ values

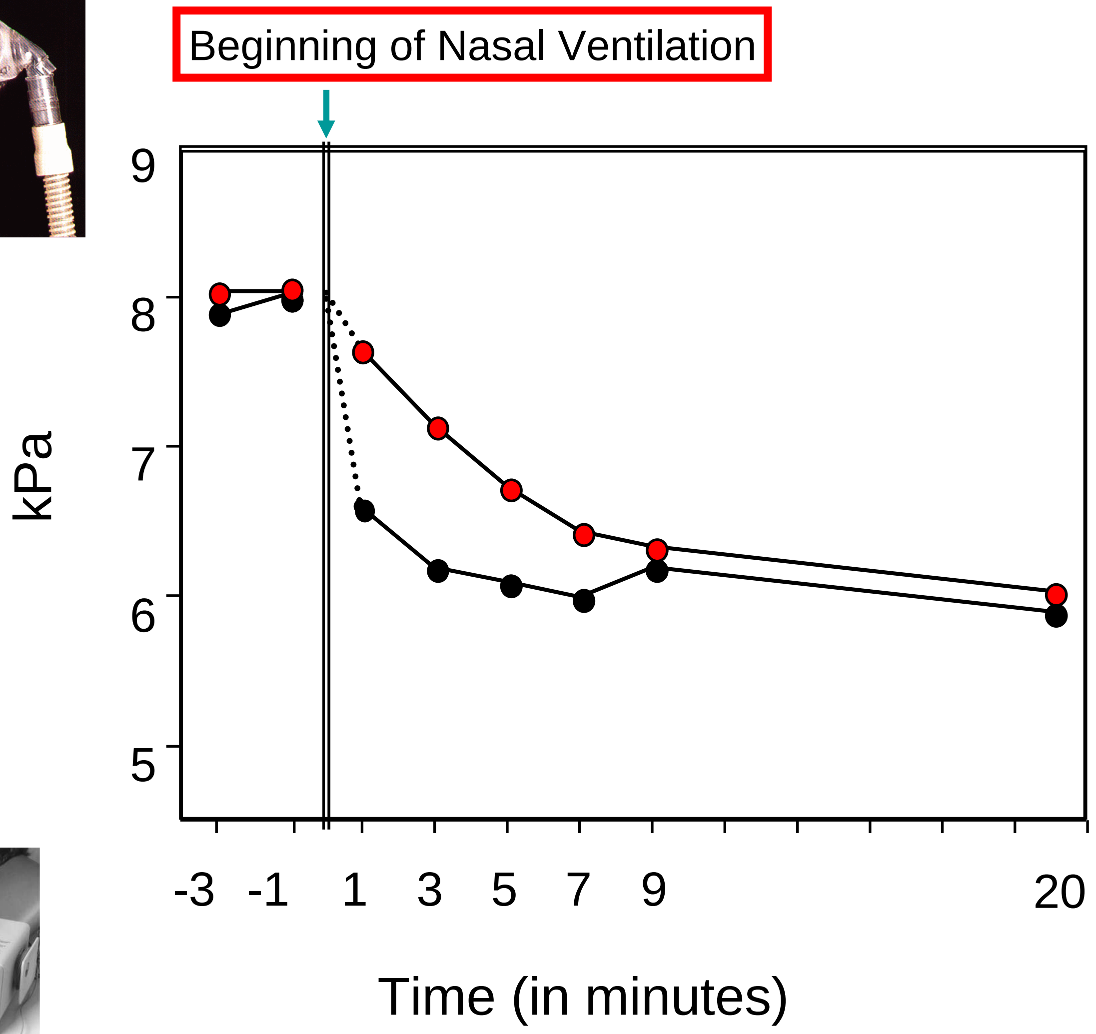
PaCO$_2$ values (arterial samples)

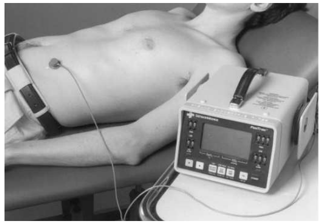


Janssens JP et al;
Chest 1998; 113: 768

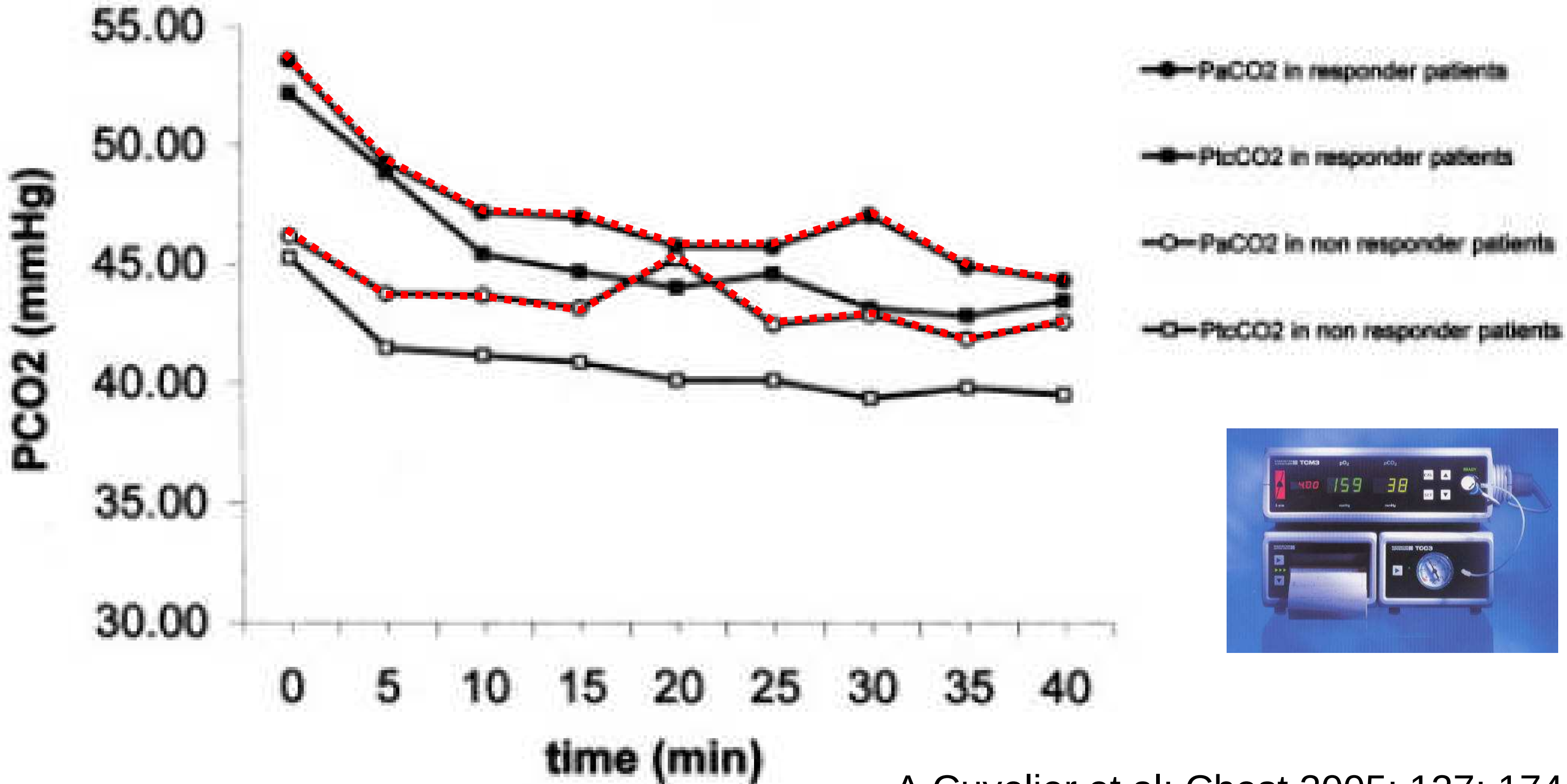


Lagtime of $PtcCO_2$ vs. $PaCO_2$





Janssens JP et al; Chest 1998; 113: 768



A Cuvelier et al; Chest 2005; 127: 1744

FIGURE 3. Parallel evolution of Pa_{CO_2} and Ptc_{CO_2} among responders (n = 7) and nonresponders (n = 5) to mechanical ventilation. Responder patients were defined as patients whose Pa_{CO_2} decreased by ≥ 4 mm Hg between T0 and T35, and also between T0 and T40 during mechanical ventilation (n = 7).

Dérive (Drift)

SenTec capnograph, Therwil, CH

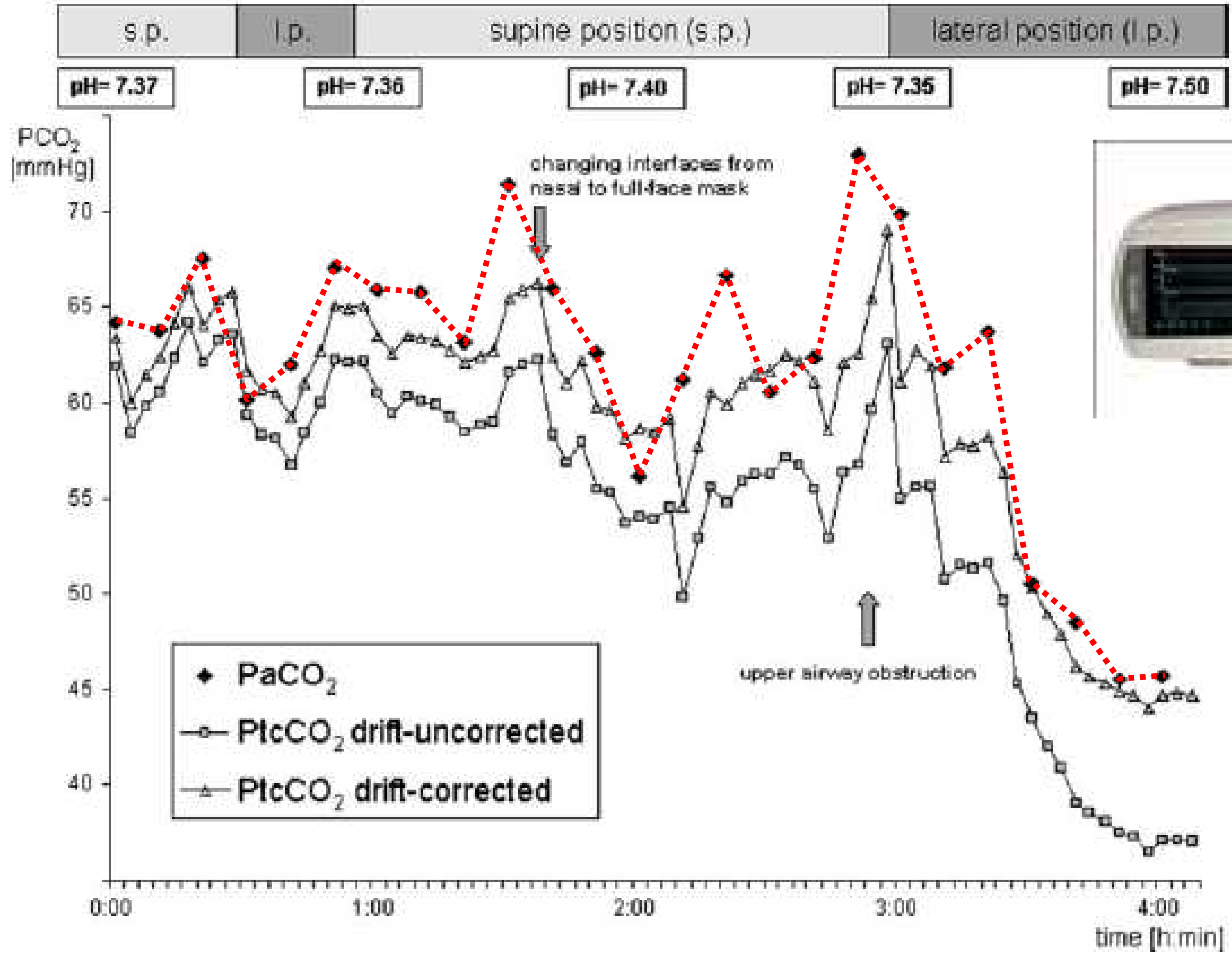
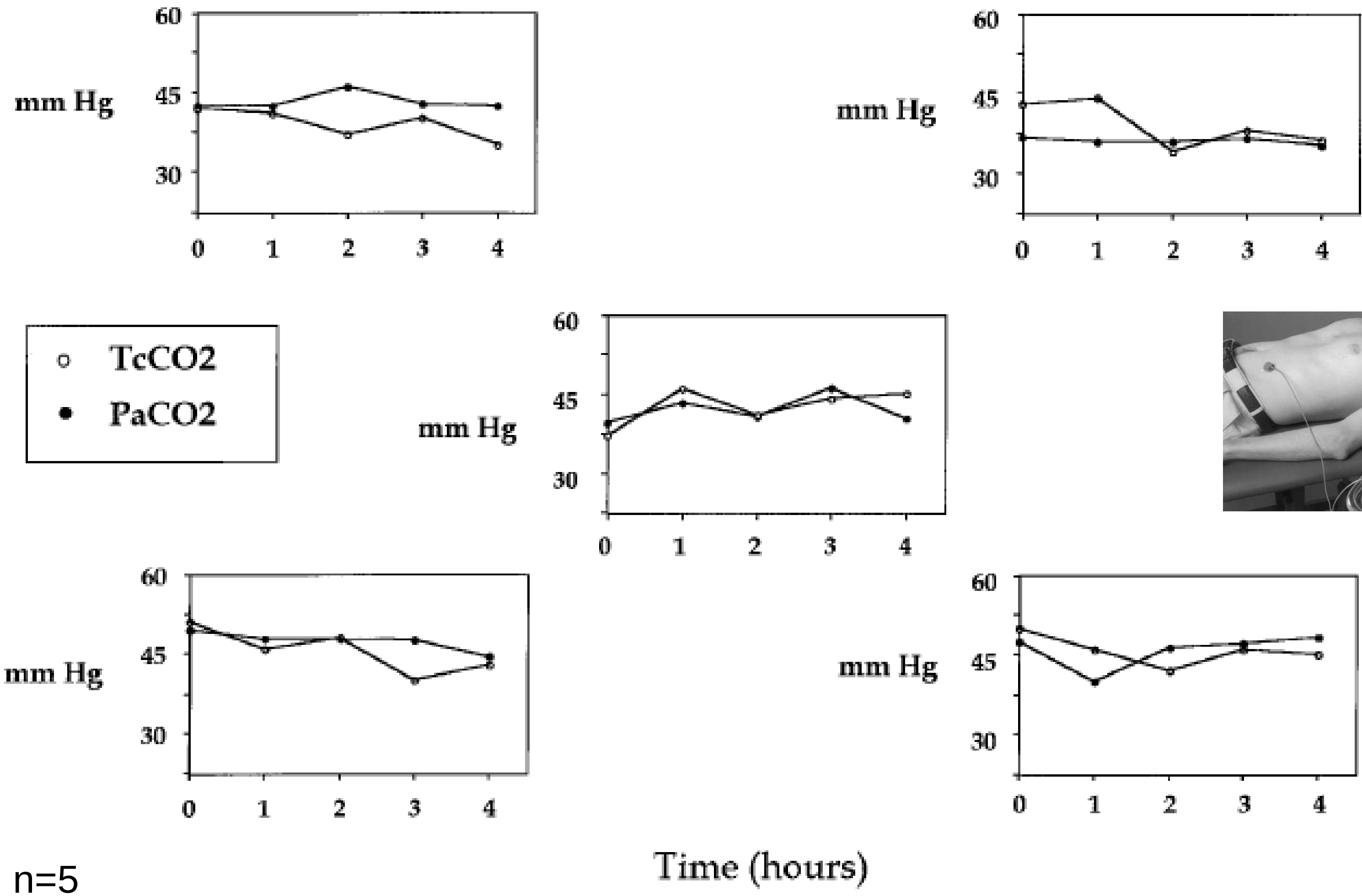


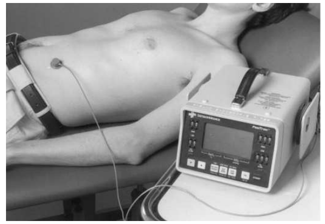
FIGURE 1. Trends of Pa_{CO_2} and Ptc_{CO_2} at T0 during 4 h of NPPV in a COPD patient (60 years of age; body mass index, 35.4 kg/m²).

≈1 kPa

n=10

JH Storre et al; Chest 2007; 132: 1810



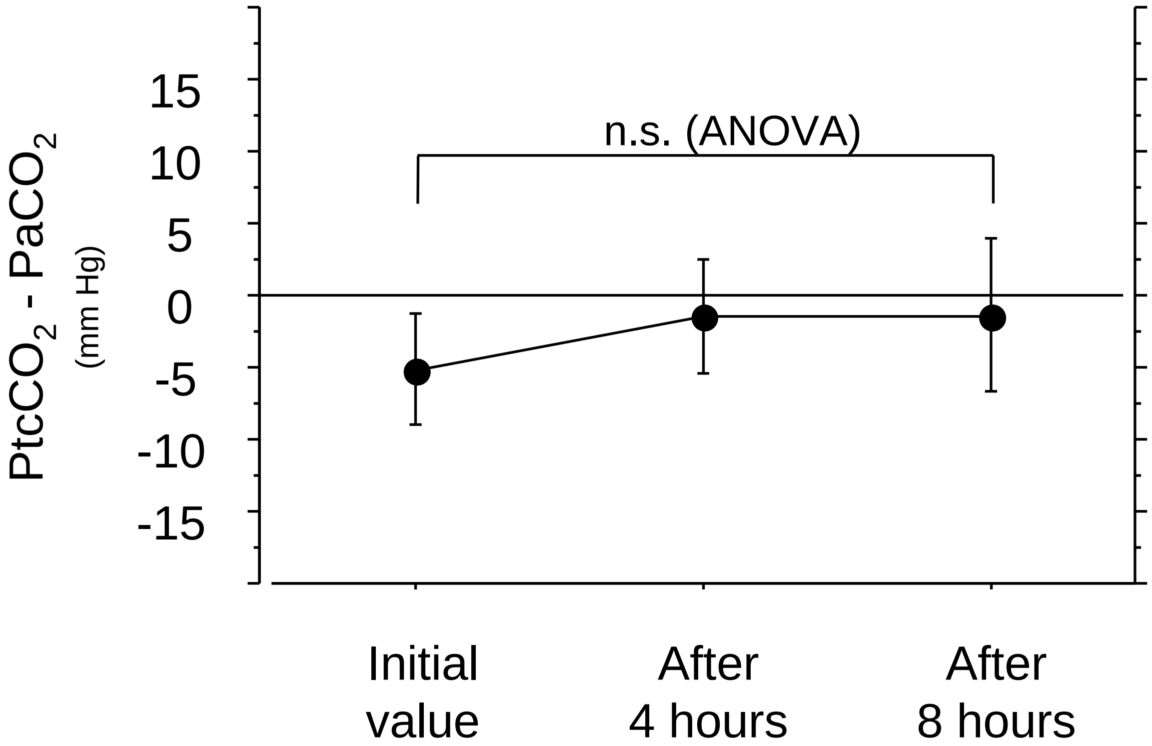


n=5

FIGURE 4. TcP_{CO_2} and $PaCO_2$ values for five patients over a 4-h period.

Janssens JP et al; Chest 1998; 113: 768

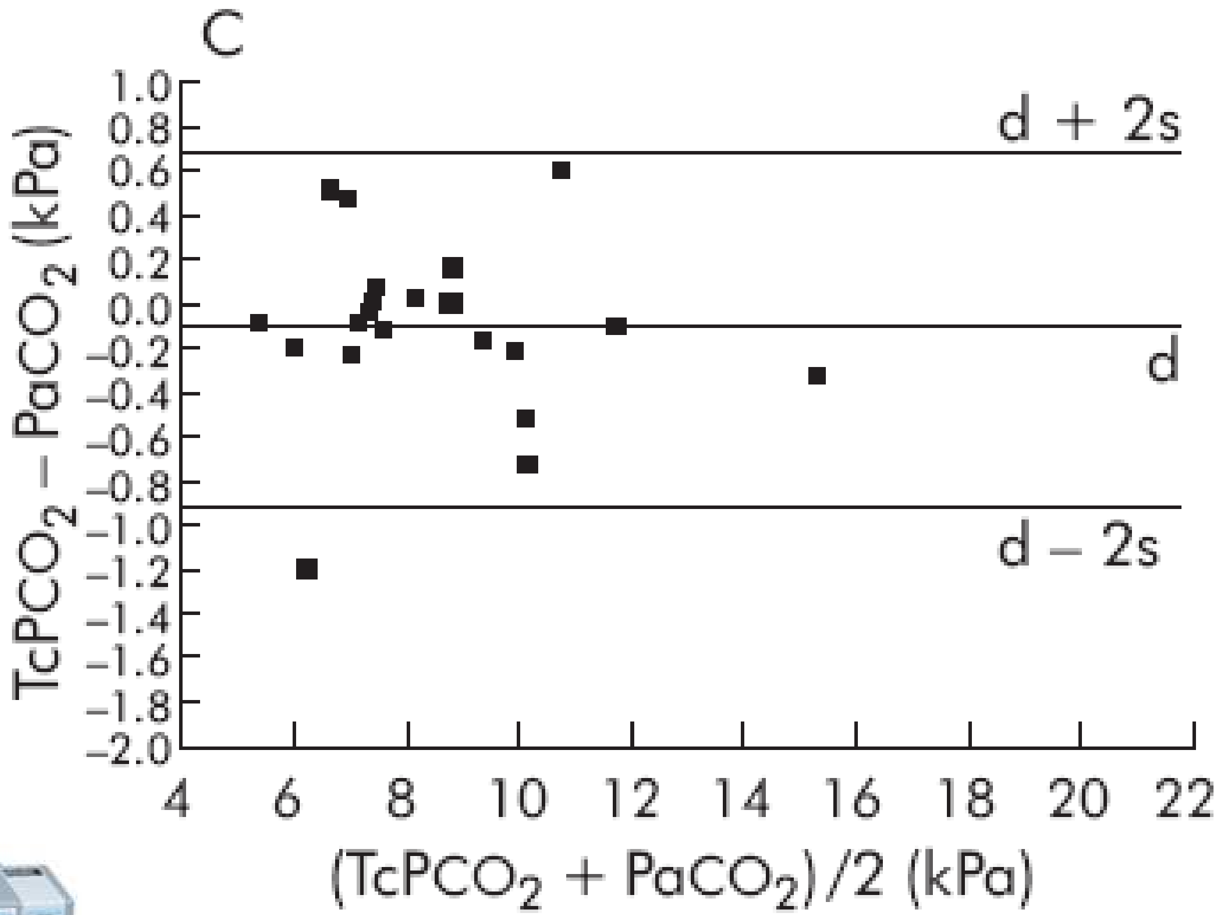
$PtcCO_2$ vs. $PaCO_2$: trend over an 8 hour period



n=10

Janssens JP et al., Respir Med 2001

PtcCO$_2$ vs. PaCO$_2$: Tosca 500: AECOPD and NIV; T0, & after 1hr, and 4 hours



n=21

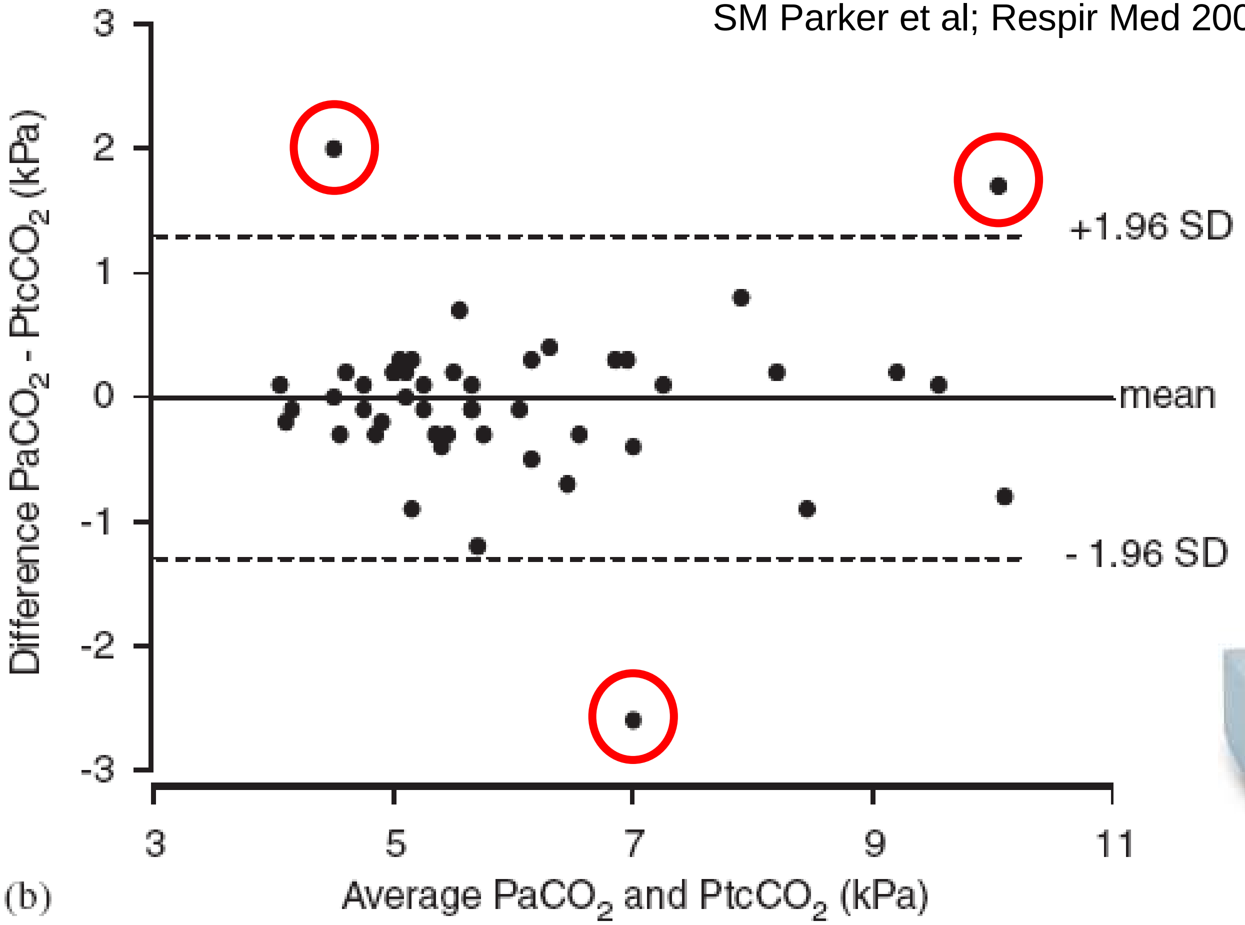
M Cox et al; Thorax 2006

Errand values (valeurs absurdes)

Evaluation of a transcutaneous carbon dioxide monitor ("TOSCA") in adult patients in routine respiratory practice

S.M. Parker, G.J. Gibson*

SM Parker et al; Respir Med 2007; 101: 261

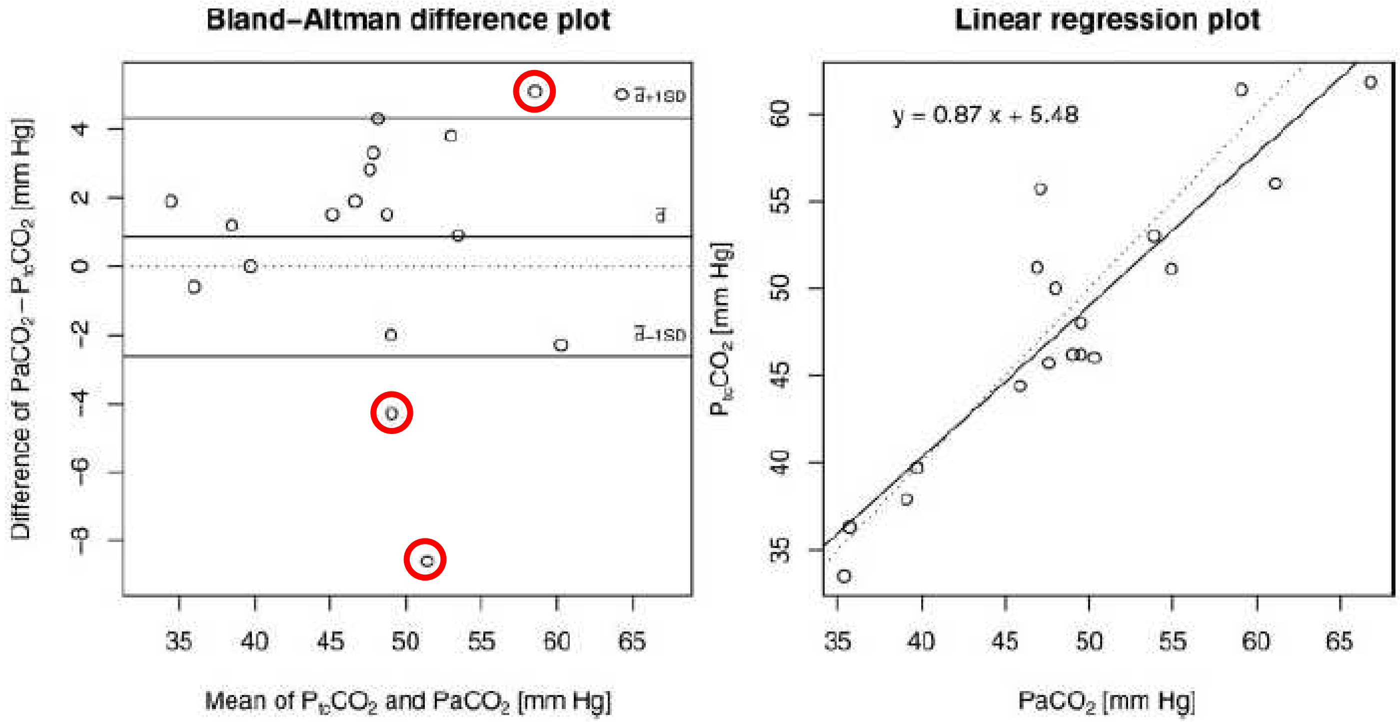


(b)

n=48

Combined Oximetry-Cutaneous Capnography in Patients Assessed for Long-term Oxygen Therapy*

Salome Schafroth Török, MD; Jörg D. Leuppi, MD; Florent Baty, PhD; Michael Tamm, MD, FCCP; and Prashant N. Chhajed, MD



n=20

FIGURE 1. Comparison of $Ptc\text{co}_2$ and $Pa\text{co}_2$. $Ptc\text{co}_2$ is compared with $Pa\text{co}_2$ (Copenhagen ABL 725; Radiometer) at the end of titration. Measurements were compared using both a Bland-Altman plot (*left*) and a linear regression plot (*right*). The Bland-Altman plot displays the mean bias and limits of agreement (solid lines). The linear regression plot displays the line of best fit (solid line) and the identity line (dashed line).

(CHEST 2008; 133:1421–1425)

Causes possibles d'erreur et de dysfonctionnement lors de mesure de la $PtcCO_2$

Facteurs techniques

- Mauvaise mise en place de la membrane
- Bulles d'air sous la membrane
- Membrane défectueuse ou changée trop tard
- Fuite du gaz de calibration

Facteurs liés au patient

- Hypoperfusion; baisse du débit cardiaque
- Anatomie et épaisseur du lobe de l'oreille
- Médicaments vaso-constricteurs

Valeurs absurdes occasionnelles inexpliquées…

Current Opinion in Anaesthesiology 2004, 17:521–525

Auteur	Capnograph	Biais (mmHg)	Precision	Limits of agreement
JD Tobias	Radiometer TCM3	2.3	± 1.4	0.9; 3.7
M Oshibuchi	Radiometer TCM3	-0.4	± 4.3	-9: + 8.2
O Senn	Tosca 500	3	± 7	-4; +11
A Cuvelier	Radiometer TCM3	-0.7	± 3	-6.7; 5.2
JH Storre	SenTec	4.6	± 4.3	-3.9; + 13.2
M Cox	Tosca 500	-1.1	± 1.7	- 6.7; + 4.5
K Benjelid	Tosca 500	1.2	± 6	
JP Janssens	Radiometer TCM3	-2.8	± 3.8	-10.4; +4.8
R Rohling	Kontron	-0.6	± 1.1	-2.8; +1.6
P Rodriguez	SenTec	0	± 4.5	-9; + 9
Range		[-2.8]- [+ 4.6]	± [1.1 - 7]	

Les pros et contras des mesures de $PtcCO_2$

Contras:

- Valeurs absurdes occasionnelles, imprévisibles
- Cher; fragile, de manipulation délicate
- Pour le TCMIII, membranes doivent être changées plus souvent que recommandé
- Lag-time
- Software et connexion avec systèmes de PG et PSG à améliorer

Conclusions

$ETCO_2$:

- peu fiable, mais d'utilisation très facile
- Utilisation comme screening lors de MNM sous VNI au long cours?

$PtcCO_2$:

- Performances variables d'un appareil à l'autre
- A présent largement utilisé et reconnu comme faisant part du monitoring standard de la VNI au long cours
- Fragile, à manier avec précaution
- Valeurs absurdes occasionnelles imprévisibles

Monitoring of efficacy of NIV:
Reference value: Median nocturnal $PtcCO_2$ > or < 45 mmHg

	Sensitivity	Specificity	PPV	NPV
Daytime $PaCO_2$ w/o ventilator > 45 mmHg	64%	81%	75%	72%
Daytime $PaCO_2$ with ventilator > 45 mmHg	59%	92%	86%	73%
Mean nocturnal SaO_2 < 90%	32%	87%	70%	58%
Nocturnal SaO_2 < 90% for > 20% of total recording time	56%	73%	66%	64%

N=107 recordings, CARAD data

Janssens JP et al.;
Eur Respir J, 2002; 20; Suppl 38; 155 S

Table 1—*Correlation Between TcPCO$_2$ and PaCO$_2$, Bias, and Limits of Agreement for Different Capnographs According to Available Published Data**

First Author	No. of Patients	r	d, mm Hg	s, mm Hg	Limits of Agreement d−2 s	Limits of Agreement d+2 s	Capnograph†
Sanders[3]	17	0.45	10.5	15.1	−19.7	40.7	Sensormedics
Lanigan[8]	12	0.52	0.0	7.9	−15.7	15.7	Novametrix 850 Commonsensor
Sanders[3]	15	0.67	6.8	11.5	−16.2	29.8	Novametrix
Sanders[3]	17	0.80	0.2	10.9	−21.7	22.0	Radiometer
Hoffmann[13]	9	0.84	NA	NA	NA	NA	Radiometer TINA TCM-3
Lanigan[8]	12	0.85	−6.6	3.4	−13.4	0.2	Radiometer E5270
Healey[12]	20	0.87	7.5	5.6	−3.8	18.7	Radiometer TCM-20
Kesten[14]	20	0.90	NA	NA	NA	NA	Radiometer TINA TCM-3
Lanigan[8]	12	0.91	−0.5	2.8	−6.2	5.2	Kontron, Microgas Combisensor
Reid[15]	22	0.92	NA	NA	NA	NA	Sensormedics TM TcCO$_2$ monitor
Palmisano[16]	251	0.93	1.3	3.9	−6.5	9.1	Radiometer TINA TCM-3
Mahutte[9]	47	0.93	NA	NA	NA	NA	Sensormedics, Transcutaneous Gas System
Pilsbury[7]	28	0.97	NA	NA	NA	NA	Kontron Sensor 51
Hanly[11]	5	0.97	NA	NA	NA	NA	Kontron 7640
Sridhar[17]	24	NA	0.2	1.0	−1.7	2.2	Radiometer TINA TCM-3
Blanchette[10]	30	NA	−0.5	5.2	−11.0	9.9	Sensormedics Transcend Po$_2$−Pco$_2$ monitor

*Limits of agreement: d−2 s; d+2 s (expressed as described by Bland and Altman.[22]

NA=not available from original publication.

†Sensormedics, Yorba Linda, Calif; Novametrix, Wallingford, Conn; Radiometer, Copenhagen; Kontron, St. Quentin En Yvelines, France.

Janssens JP et al;
Chest 1998; 113: 768

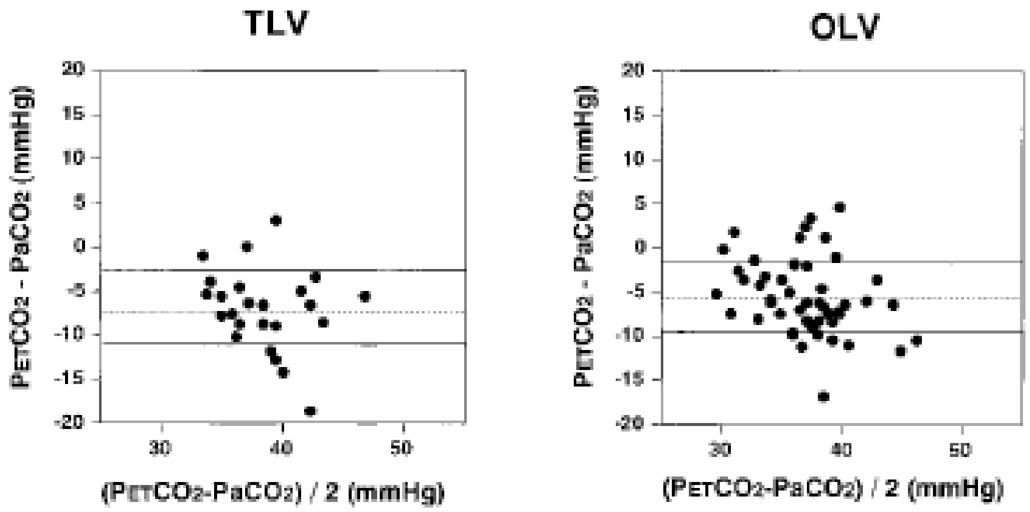


Figure 1. Bland-Altman analysis of end-tidal CO_2 ($P_{ET}co_2$) versus arterial CO_2 ($Paco_2$) during two-lung ventilation (TLV) and one-lung ventilation (OLV). Bias and precision are labeled.

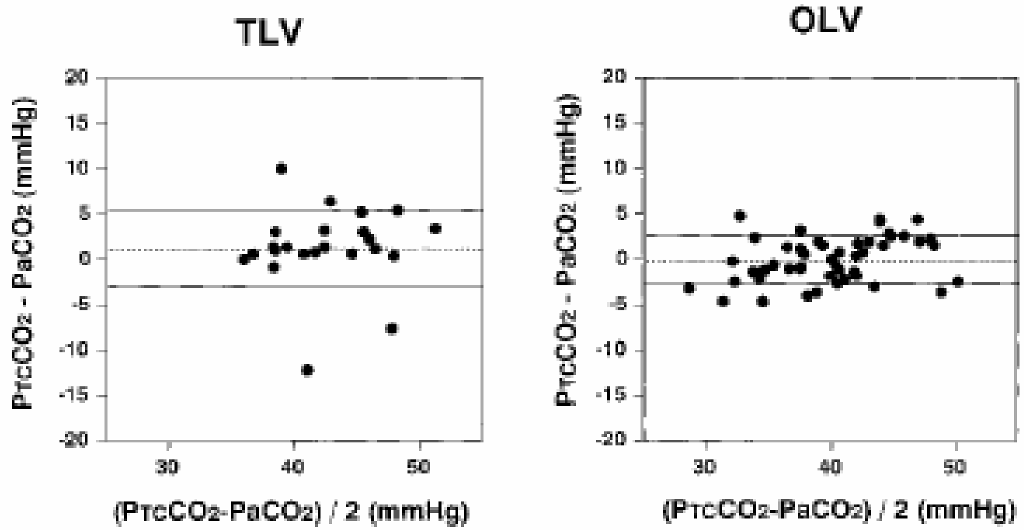


Figure 2. Bland-Altman analysis of transcutaneous CO_2 ($PTCco_2$) versus arterial CO_2 ($Paco_2$) during two-lung ventilation (TLV) and one-lung ventilation (OLV). Bias and precision are labeled.