SERVIZIO SANITARIO REGIONALE
EMILIA-ROMAGNA
Azienda Ospedaliero-Universitaria Bologna

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

NIV for Acute Respiratory Failure: are sophisticated ventilators really needed ?

Amsterdam September 2011

Stefano NAVA
Terapia Intensiva Respiratoria e Pneumologia
AO Sant'Orsola Malpighi, Bologna

Choosing the Ventilator

- **Ventilator characteristics**
  - gas source
  - performance
  - circuit
  - monitoring
  - ease of use

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Choosing the ventilator: gas source

- **HIGH PRESSURE (4 atm.) GAS SOURCE (O_2 + AIR)**
  Stable FiO_2 guaranteed ("blender") (ICU)
- **TURBINE OR PISTON DRIVEN VENTILATORS WITH LOW PRESSURE O_2 PROVIDED AT LOW PRESSURE**
  Stable FiO_2 not guaranteed ("no blender") (Home)
- **TURBINE OR PISTON DRIVEN VENTILATORS WITH HIGH PRESSURE O_2 INLET**
  Stable FiO_2 guaranteed ("blender") (Hospital)

Choosing the ventilator: gas source

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- **TURBINE OR PISTON DRIVEN VENTILATORS WITH HIGH PRESSURE O_2 INLET**
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Severely hypoxemic patients need ventilators with high pressure O_2 inlet because:

- **stable FiO_2 provided**
- **possibility to assess PaO_2/FiO_2 ratio**

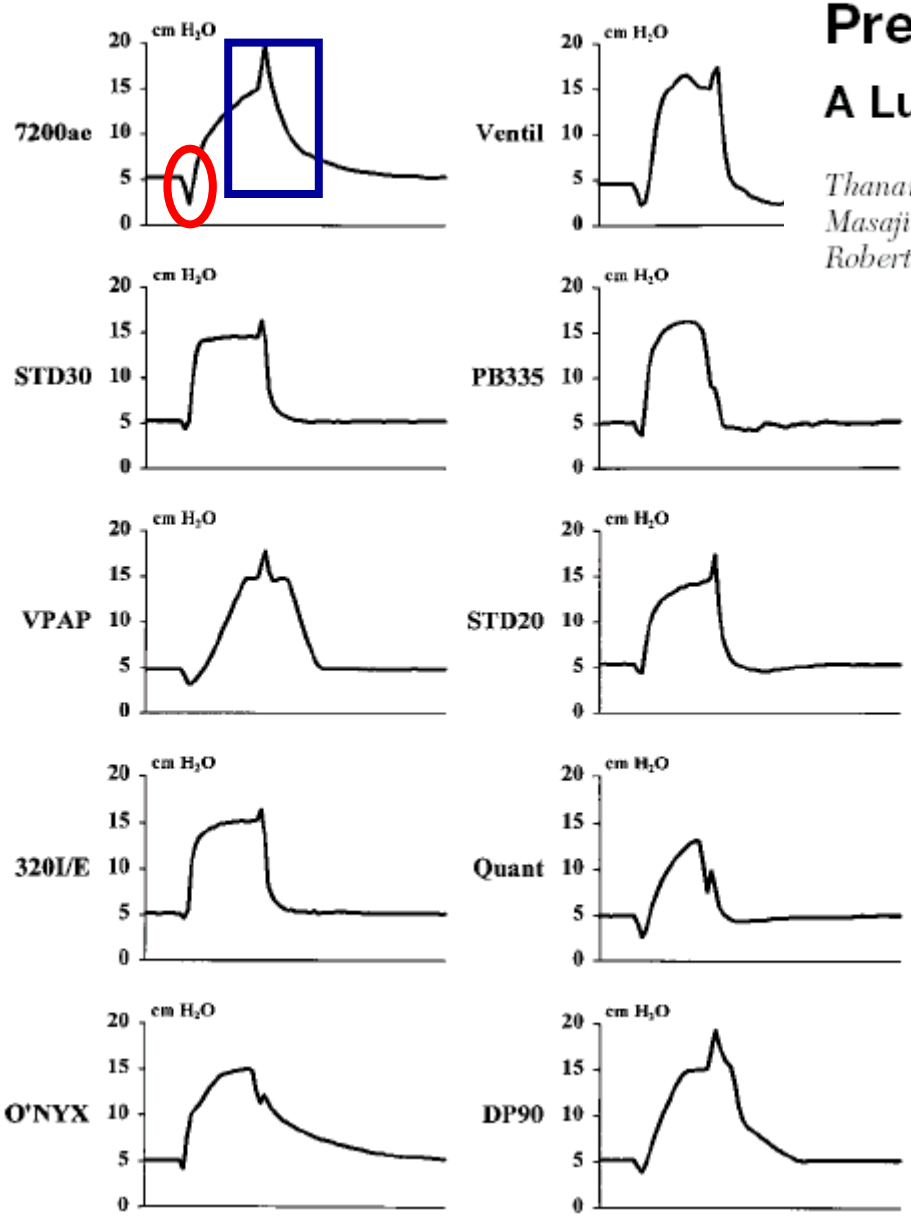
Choosing the Ventilator

- **Ventilator characteristics**
  - gas source
  - **performance**
  - circuit
  - leaks compensation algorithms
  - monitoring
  - ease of use

Performance Characteristics of Bilevel Pressure Ventilators*

A Lung Model Study

Thananchai Bunburaphong, MD; Hideaki Imanaka, MD; Masaji Nishimura, MD;† Dean Hess, PhD, RRT; and Robert M. Kacmarek, PhD, RRT



Inspiratory System of Synchronization

Detects the patient's inspiratory effort and thereafter triggers the mechanical breath.

Intensive Care Med (2008) 34:1669–1675
DOI 10.1007/s00134-008-1125-5

ORIGINAL

Juliana C. Ferreira
Daniel W. Chipman
Robert M. Kacmarek

Trigger performance of mid-level ICU mechanical ventilators during assisted ventilation: a bench study

Table 3 Overall performance of the ventilators

	Ttrig (ms)	Tdelay (ms)	Ptrig (cm H_2O)	TEsett (ms)
PB840	80 ± 9	96 ± 14	−1.7 ± 0.8	785 ± 182
Vela	79 ± 17	101 ± 21	−1.4 ± 0.7	1,103 ± 90[a]
PB760	90 ± 17[a]	118 ± 18[a]	−2.1 ± 1.0	754 ± 193
Servo S	90 ± 17[a]	122 ± 60	−2.3 ± 0.9[a]	677 ± 209
Esprit	94 ± 26[a]	122 ± 34[a]	−2.5 ± 1.4[a]	1,056 ± 163[a]
LTV1000	99 ± 14[a]	124 ± 20[a]	−2.6 ± 1.3[a]	987 ± 193[a]
eVent	119 ± 28[a]	164 ± 50[a]	−3.3 ± 1.4[a]	788 ± 175
Savina	129 ± 17[a]	258 ± 70[a]	−2.3 ± 1.0[a]	473 ± 157[b]
Raphael	142 ± 54[a]	215 ± 81[a]	−4.3 ± 1.3[a]	702 ± 140
Ivent	171 ± 61[a]	251 ± 79[a]	−4.0 ± 1.3[a]	643 ± 189[b]
HT50	197 ± 82[a]	318 ± 126[a]	−5.1 ± 1.4[a]	974 ± 112[a]

Inspiratory trigger time evaluates the ability of the ventilator to sense inspiratory effort and open the inspiratory flow valve. Ttrig was less than 100 ms.

Inspiratory Delay Time reflects the ventilator's ability to pressurize the system above baseline and reflects

Inspiratory Trigger pressure determines the pressure change required to activate gas delivery, and it is related

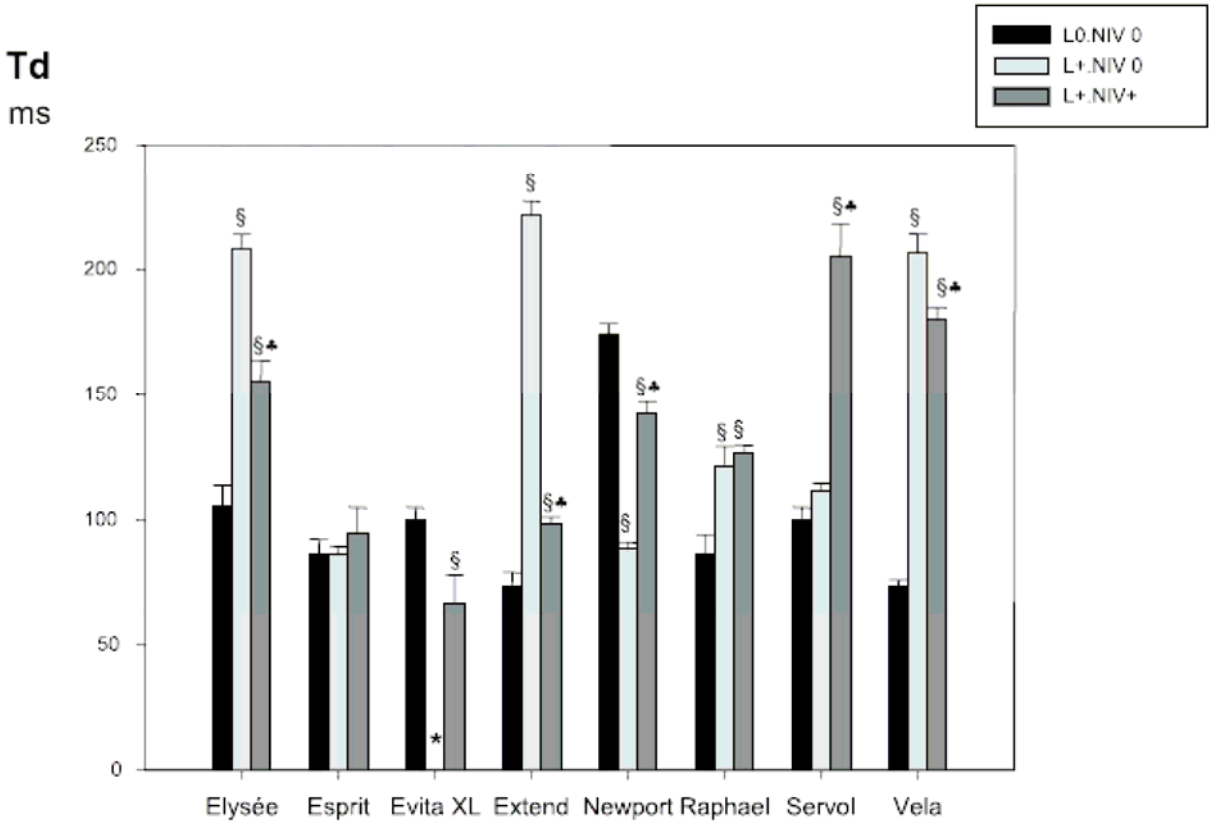
Expiratory Settling Time reflects the ventilator's ability to decompress the circuit during exhalation while maintaining PEEP and essentially evaluates the function of the expiratory valve. However, it is also influenced by

Intensive Care Med (2007) 33:1444–1451
DOI 10.1007/s00134-007-0713-0

EXPERIMENTAL

Laurence Vignaux
Didier Tassaux
Philippe Jolliet

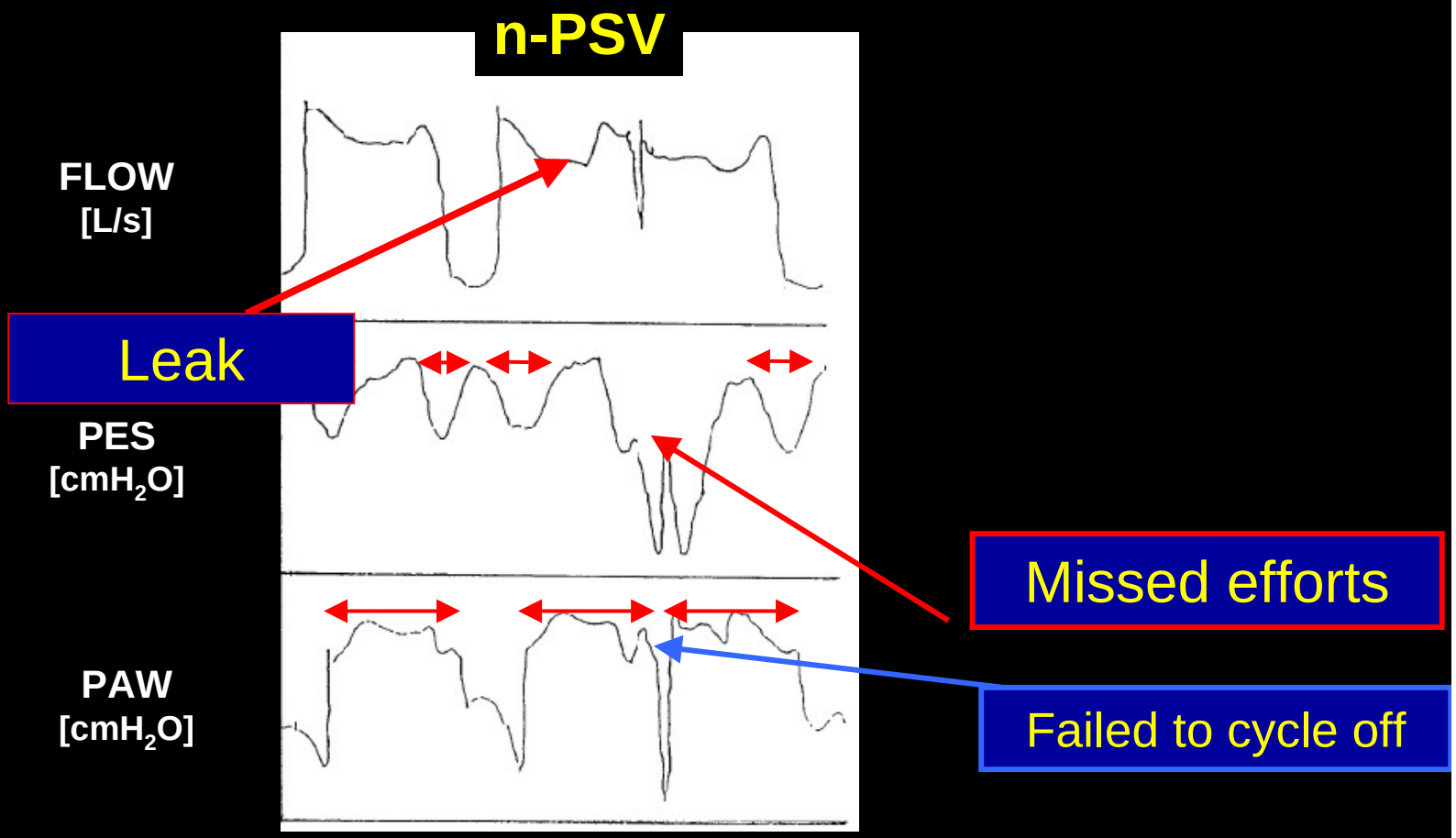
Performance of noninvasive ventilation modes on ICU ventilators during pressure support: a bench model study



tion. *Conclusions:* The results of this bench-model NIV study confirm that leaks interfere with several key functions of ICU ventilators. Overall, NIV modes can correct part or all of this interference, but with wide variations between machines in terms of efficiency. Clinicians should be aware of these differences when applying NIV with an ICU ventilator.

Switching inspiration to expiration

Flow cycling OFF with leaks



Calderini et al. Intensive Care Med 1999; 25:662-667

CHEST

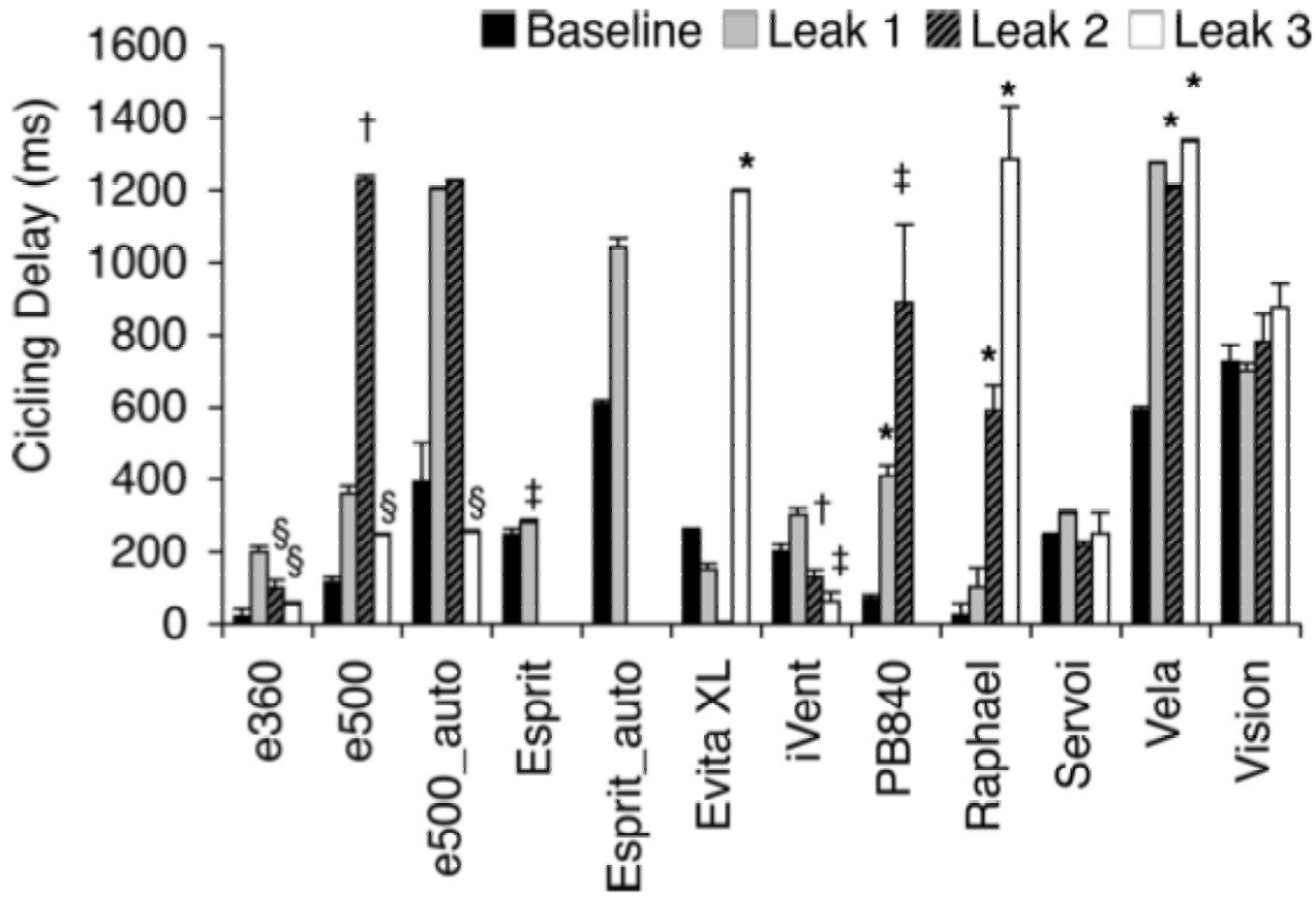
Original Research

CRITICAL CARE MEDICINE

Bilevel vs ICU Ventilators Providing Noninvasive Ventilation: Effect of System Leaks

A COPD Lung Model Comparison

Juliana C. Ferreira, MD; Daniel W. Chipman, RRT; Nicholas S. Hill, MD, FCCP; and Robert M. Kacmarek, PhD, RRT



Intensive Care Med (2010) 36:2053–2059
DOI 10.1007/s00134-010-1994-2

ORIGINAL

Laurence Vignaux
Didier Tassaux
Guillaume Carteaux
Jean Roeseler
Lise Piquilloud
Laurent Brochard
Philippe Jolliet

Performance of noninvasive ventilation algorithms on ICU ventilators during pressure support: a clinical study

Conclusion: In acute respiratory failure, NIV algorithms provided by ICU ventilators can reduce the incidence of asynchronies because of leaks, thus confirming bench test results, but some of these algorithms can generate premature cycling.

Choosing the Ventilator

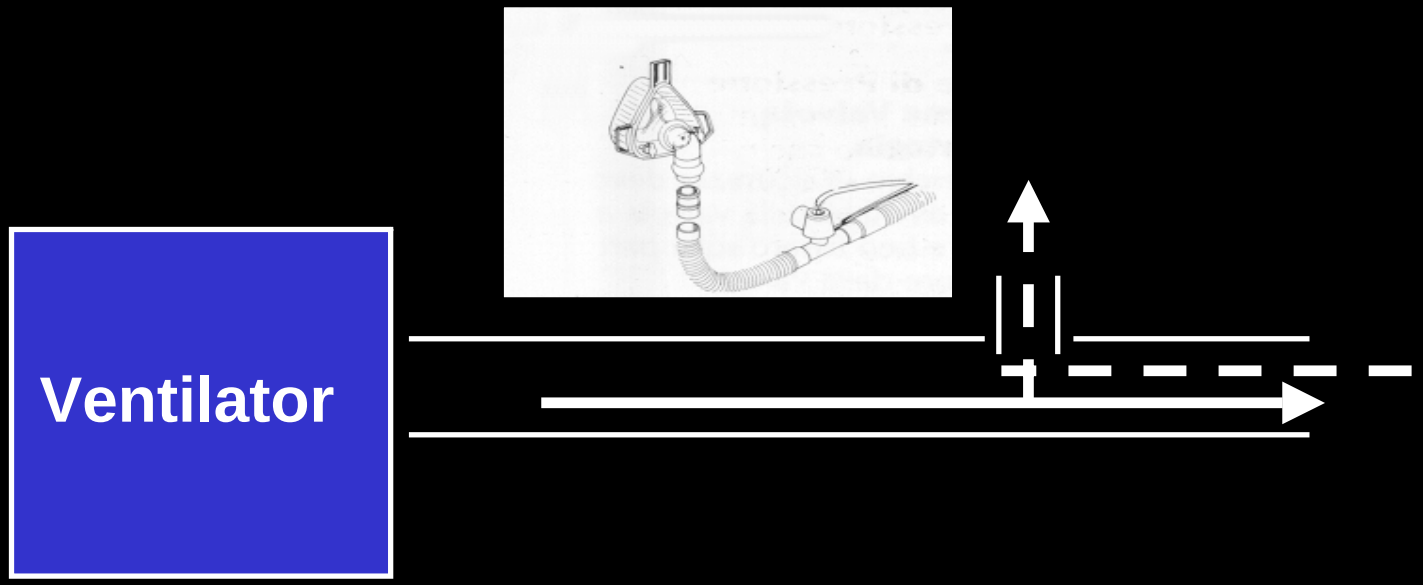
- **Ventilator characteristics**
  - gas source
  - performance
  - **circuit**
  - monitoring
  - ease of use

Double circuit

Inspiration

Expiration

SINGLE TUBE WITH “TRUE” (EXTERNAL) EXPIRATORY VALVE



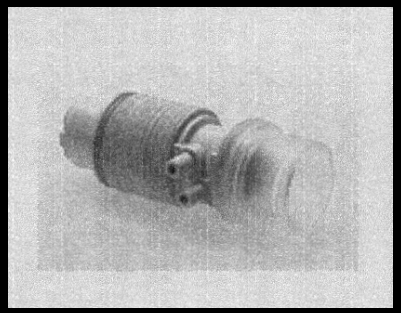
Lofaso F et al Eur Respir J 1998 Jun;11(6):1382-8
Expiratory valves used for home devices: experimental and clinical comparison.

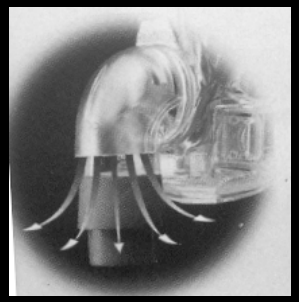
…..differences between home expiratory valve resistances may have a clinically relevant impact on the respiratory effort of patients with a high ventilatory demand.

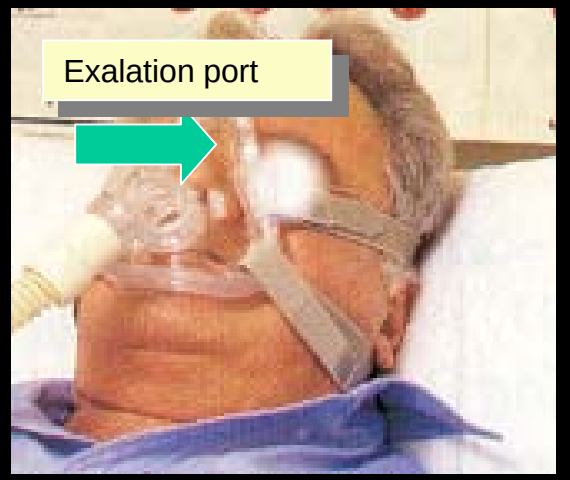
Single circuit with intentional leak

Exhalation devices

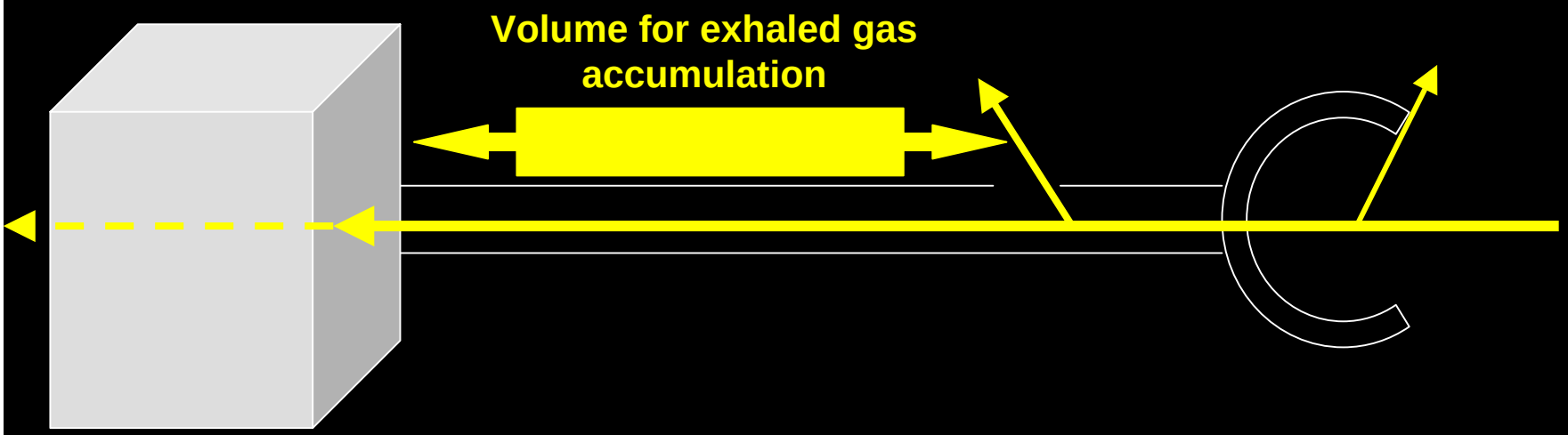
- They are not “true expiratory valves.
- They are positioned either in the mask or the circuit







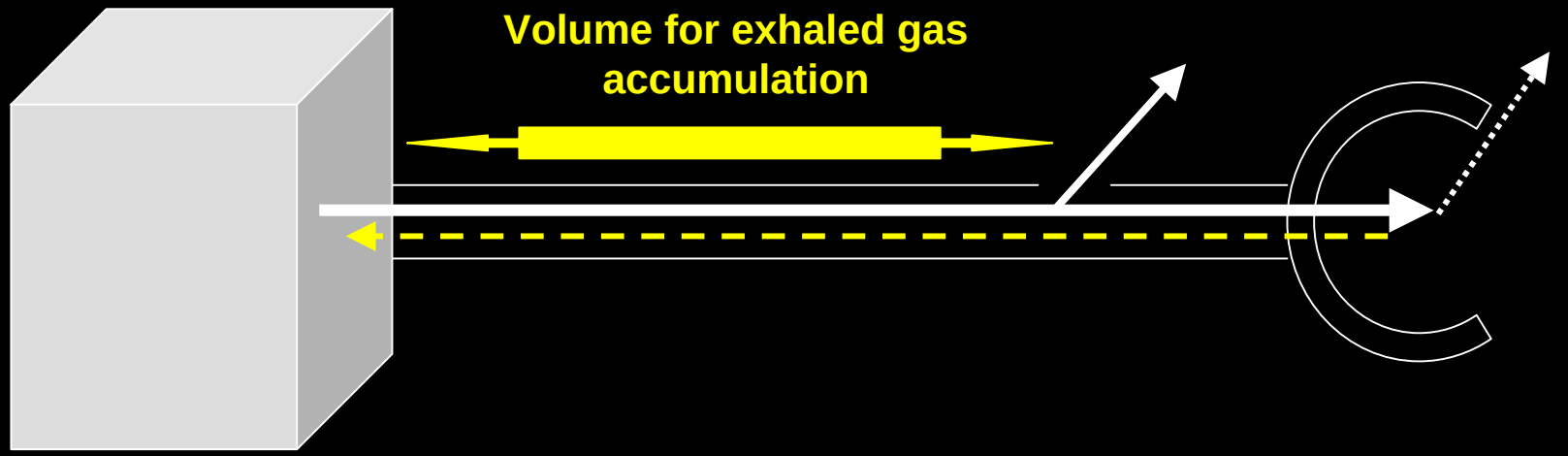
Early expiration



Air flows from the patient

- **Partly throughout the orifice (intentional leak)**
- **Partly around the mask (non intentional leak)**
- **Partly toward the ventilator**

Late expiration



Expiratory flow not high enough to maintain the preset EPAP → flow generated by ventilator which eliminates the exhaled gas accumulated throughout the leak and (sometimes) also around the mask.

Circuit with intentional leaks

- Simpler and lighter
- Usually leaks tolerant (Automatic algorithms of leaks compensation)

Disadvantages

- Need EPAP > 8 to avoid rebreathing may :
  - not always necessary to the patient
  - increase lea

- Do not allow exp.Vt monitoring
- An antisuffucation valve is needed during oronasal NIV

Double circuit or non-rebreathing valve

- Always avoid CO2 rebreathing
- Can be used to invasively ventilate the patients
- Ensure esp.Vt moinitoring (SC with a distal pneumotach)

Disadvantages

- Heavier
- Less leaks tolerant
- Possible increased expiratory valve resistances with SC
  Lofaso F et al Eur Respir J 1998

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  - circuit
  - **Monitoring and alarming**
  - ease of use

NIV is a discontinuous mode of ventilation

- About 40 alarms…in routine practice
- In pediatric, 68% of the alarms were not justified...
- They produce noise louder than 80 dB…
- Sleep deprivation…
- Continuous stress for both nurses and patients…

Cited in MC Chambrin, Intensive Care Med 1999

Monitoring expiratory Vt

Volume delivered = insp V_T + Leaks

- In presence of leaks, insp Vt. shown on the monitor increases while exp. Vt decreases

Exp V_T = insp V_T - Leaks

- -Therefore watch the exp. Vt to determine the true Vt when allowed by the ventilator

Take home message

Choosing the Ventilator

- **Ventilator characteristics**
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  - leaks compensation algorithms
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  - **ease of use**

Intensive Care Med (2009) 35:1687–1691
DOI 10.1007/s00134-009-1580-7

ORIGINAL

Laurence Vignaux
Didier Tassaux
Philippe Jolliet

Evaluation of the user-friendliness of seven new generation intensive care ventilators

Table 2 Difficulty scores given by physicians

Ventilator	Difficulty score
G5	3.8 (2.1)
Evita XL	4.2 (1.5)
Servo i	4.5 (2.5)
EngströmCarestation	4.8 (1.8)
Elysée	5.5 (2.1)
PB 840	6.4 (1.4)
Avea	7.3 (1.9)

Difficulty score: 0 very easy, 10 very difficult
Values mean (SD)

Eur Respir J 2006; 27: 1236–1243
DOI: 10.1183/09031936.06.00078805

Evaluation of the user-friendliness of 11 home mechanical ventilators

J. Gonzalez-Bermejo*, V. Laplanche*, F.E. Husseini#, A. Duguet*, J-P. Derenne*,# and T. Similowski*,#

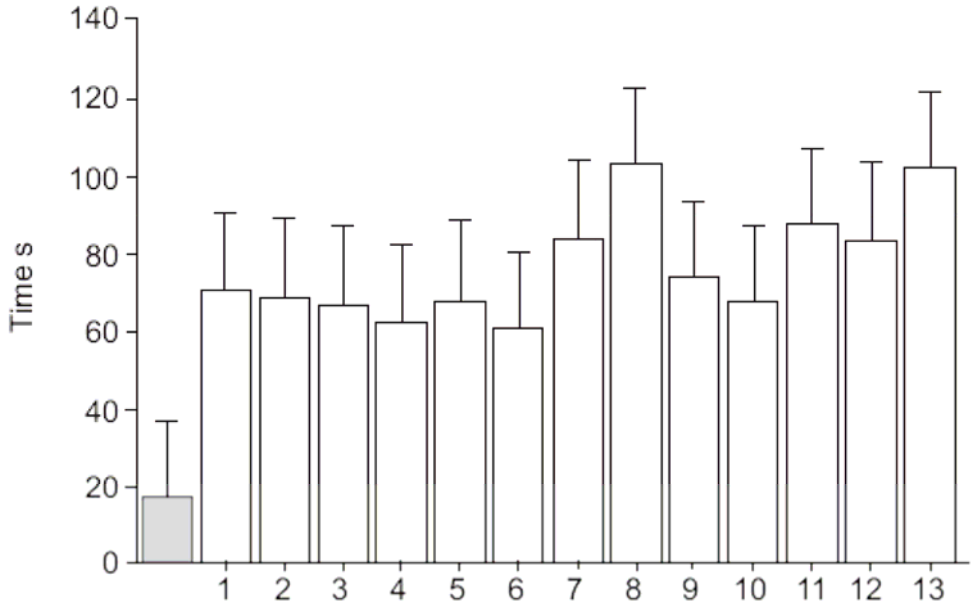
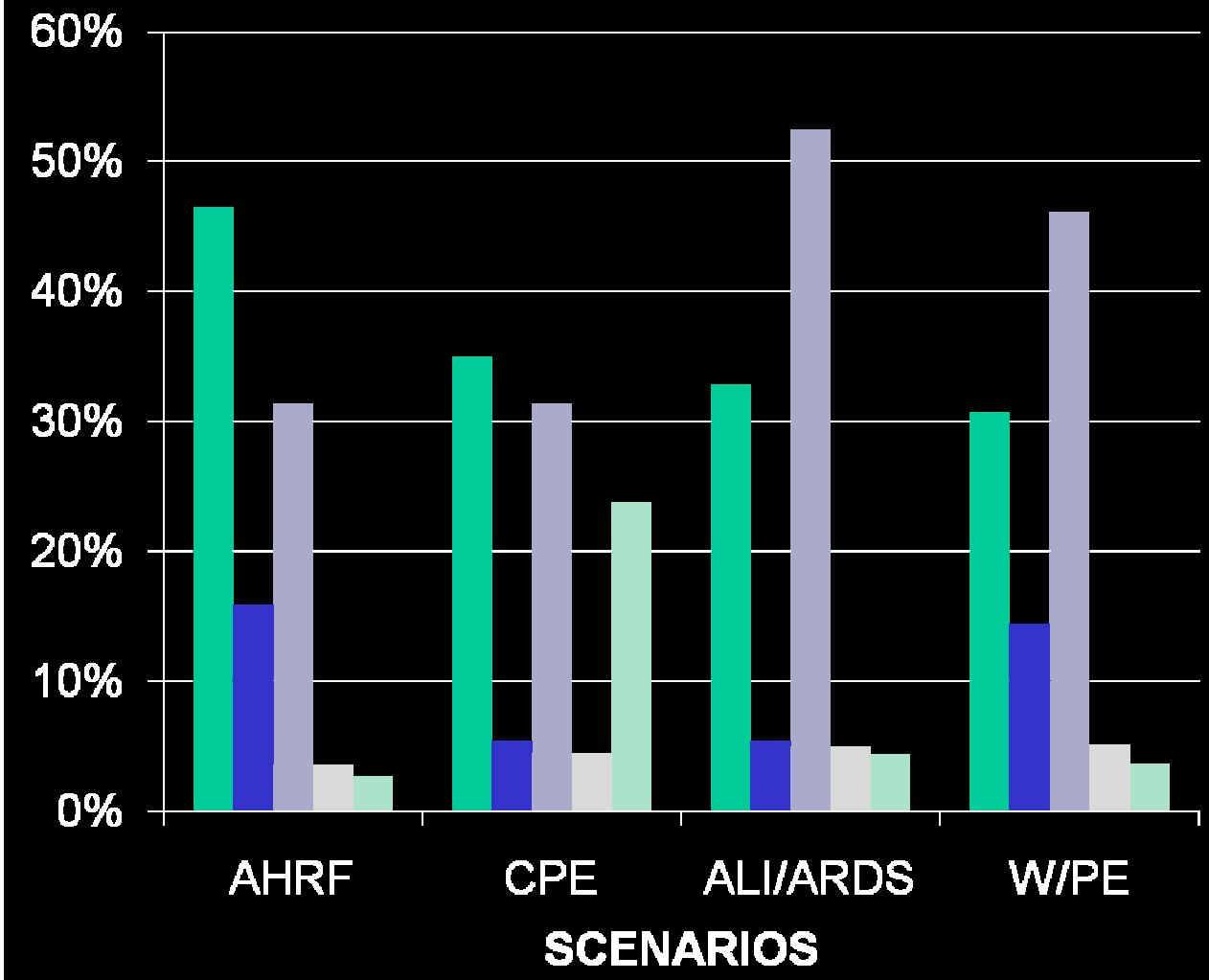


FIGURE 1. Mean time for performing all the tests on all the ventilators by physicians (□) and the technician (■). There were no significant differences between physicians, but all physician times were significantly longer than the technician time ($\leqslant p=0.001$).

Use of ventilators' type in different scenarios



- Dedicated ventilator for acute NIV
- Home care ventilator
- ICU ventilator with NIV
- ICU ventilator without NIV
- Stand-Alone CPAP

Crimi et al ERJ 2010

Summary

- **Gas source= use ventilators with high pressure O2 inlet**
- **Performance= may greatly vary among different ventilators and airleaks inrtefere with several functions**
- **Circuit= each system has pro and contra, but the main goal is to avoid CO2 rebreathing**
- **Monitoring=** Vt monitor is essential to determine the true Vt
- **Ease of use= Still a pending problem !**

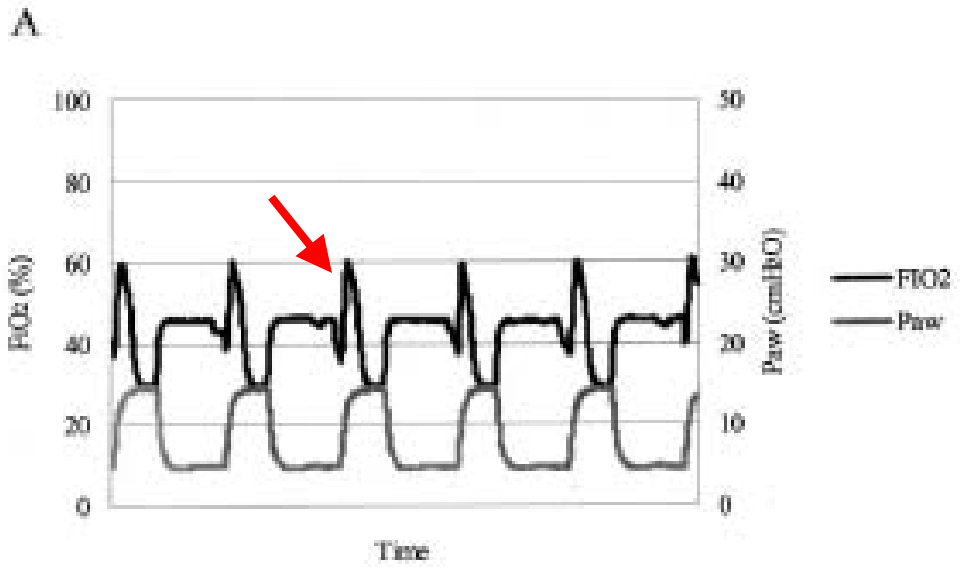


FIGURE 4. *Top, A:* With a moderate leak and oxygen flow of 9 L/min, waveforms for airway pressure (Paw) and FIO_2 measured at the airway opening are illustrated. FIO_2 varied greatly during the ventilatory cycle. *Bottom, B:* Waveforms for airway pressure (Paw) and FIO_2 measured inside the model lung with a moderate gas leak and oxygen flow of 9 L/min. FIO_2 was essentially constant.

Miyoshi E et al Chest 2005

CHEST

Original Research

CRITICAL CARE MEDICINE

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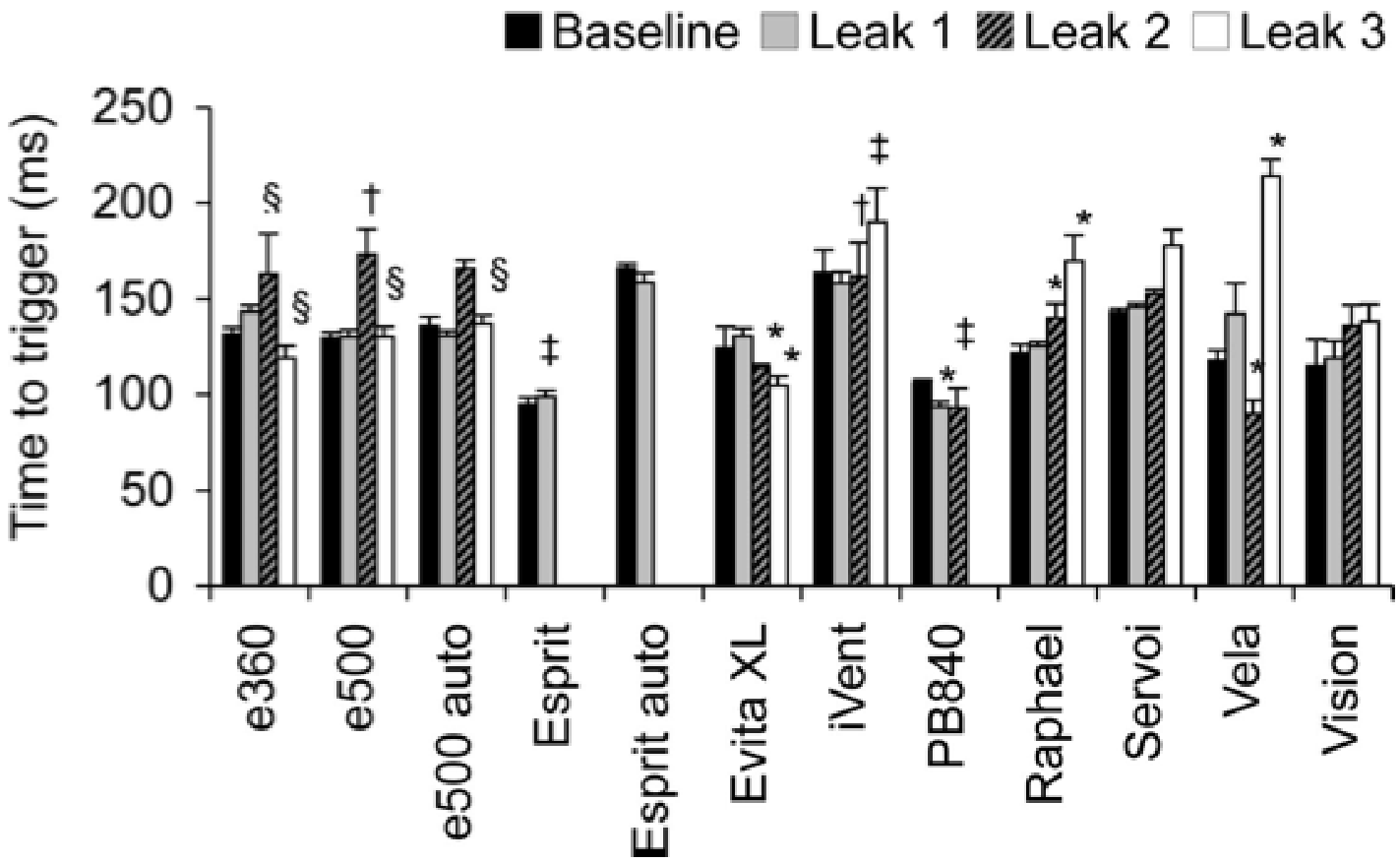

NIV is a specific mode of ventilation

1. Unavoidable leaks
2. Can precede urgent intubation
3. Discontinuous mode