Capnometry in Emergency Medicine

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Objectives

- Rationale for measuring carbon dioxide (CO_2)
- Physiologic buffer systems
- Current clinical uses
- Potential pitfalls in using capnometry in making clinical decisions

Acid Base Buffer System

- Bicarbonate system is most important clinically
- Venous pH approximately 0.05 units lower (more acid) due to appearance of CO_2 from kidneys to transport to lung for elimination
- Venous is pCO_2 thus higher (also by approximately 5 units)
- In severe illness, arterial pH may fall as low as 6.8 and rise as high as 7.8

Physiologic Buffer Systems

Buffer solutions (ii)

- At pH 7.4, $\frac{[HCO_3^-]}{[H_2CO_3]} = 10^{(7.4-6.4)} = 10$

  i.e. at physiological pH most of the dissolved CO_2 is present as bicarbonate

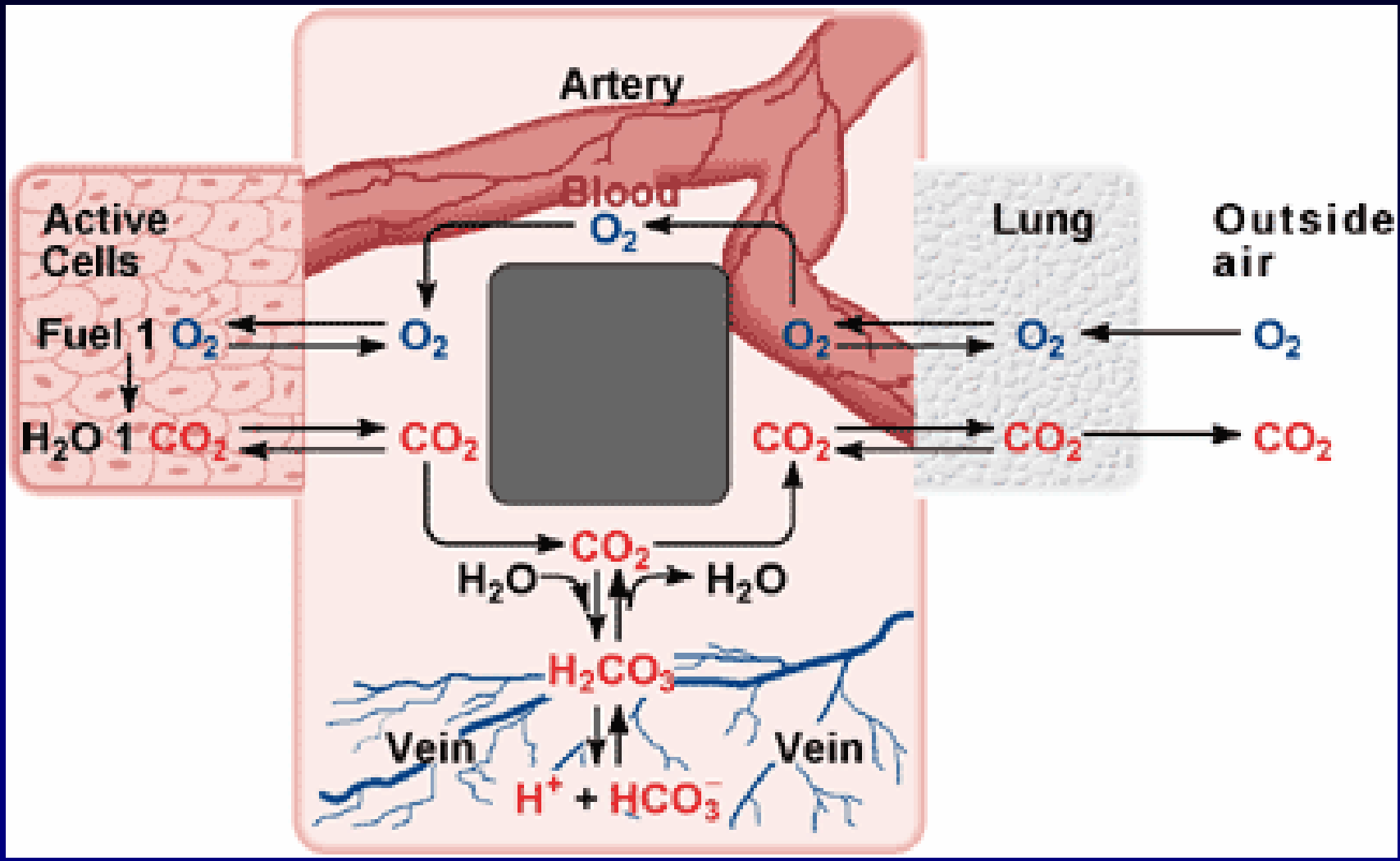
- $H_3PO_4 \overset{2.2}{\rightleftharpoons} H_2PO_4^- + H^+ \overset{6.88}{\rightleftharpoons} HPO_4^{=} + H^+$

  $HPO_4^{=} \rightleftharpoons PO_4^{3-} + H^+$ (12.4)

- At pH 7.4, most phosphate is present as $HPO_4^{=}$, with the remainder largely as $H_2PO_4^-$

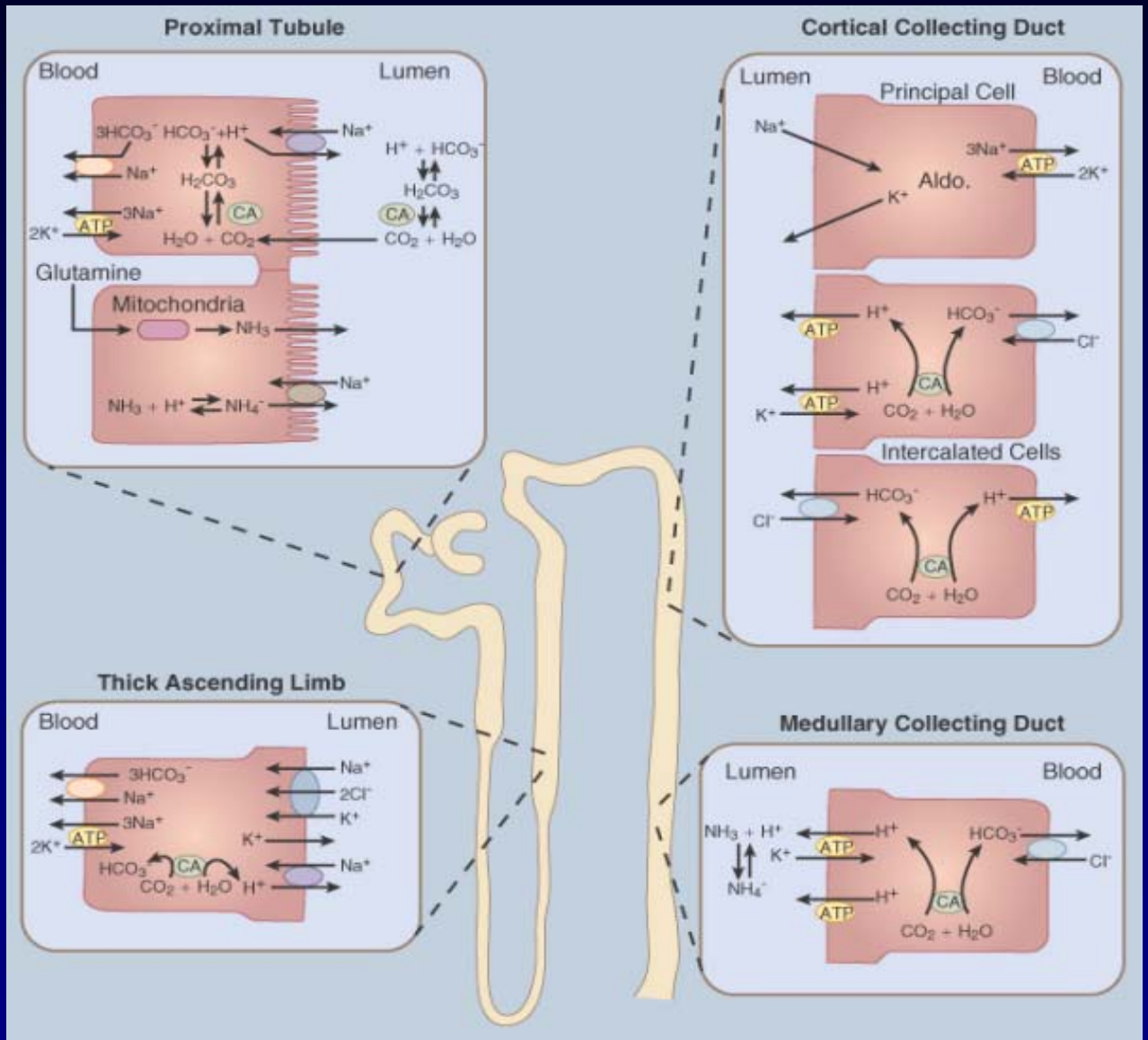
www.vuw.ac.nz/.../courses/221/water/img012.gif

Bicarbonate Buffer – Pulmonary



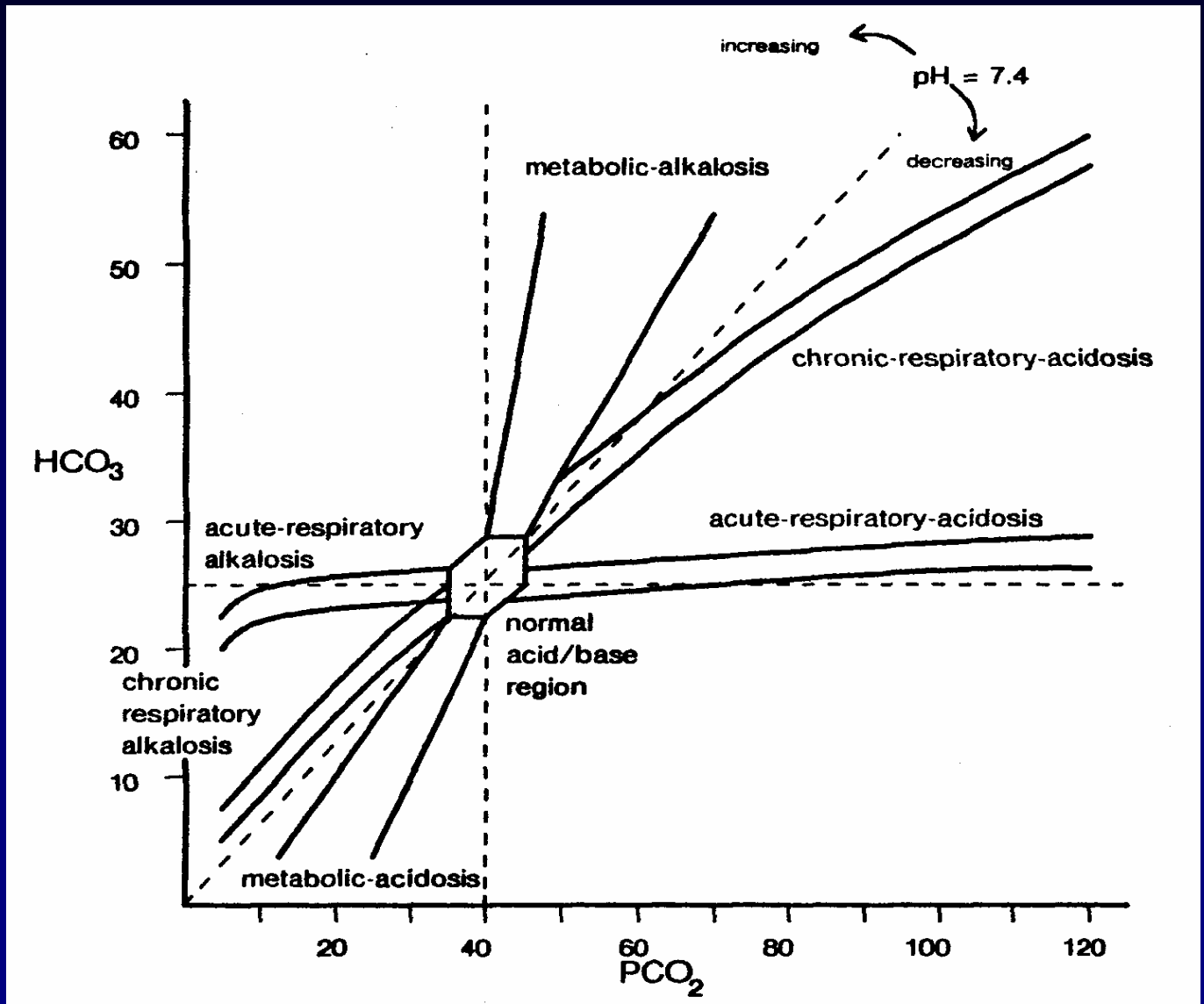
www.wiley.com/.../reviews/pH/bloodbuffer.gif

Bicarbonate Buffer – Renal



Cecil's Textbook of Medicine 2004 WB Saunders

Acid Base Nomogram



groups.csail.mit.edu/.../Patil81_ch1.html

Capnometry – Measure of $pC0_2$

- Static
  - Measure a specific point in time
  - ABG is an example
- Dynamic
  - Measures the wave form
  - May detect underlying pathology

Krauss et al. Annals of EM 2007

Capnometry for Procedural Sedation and Analgesia in the Emergency Department

- History
- Ancient Greeks
  - Combustible engine in body produced kapnos (smoke) in breath
  - Well studied in anesthesiology
  - Used in OR for approximately 35 years
- Modern Capnography
  - Developed by Luft in the 1940s
  - Commercialized in the 1960s and 1970s after development of mass spectroscopy

Terminology (Krauss Ann Emerg Med 2007)

Capnography is the noninvasive measurement of the partial pressure of carbon dioxide in exhaled breath

- Capnometry
  - Displays a number (e.g., $ETC0_2$ end-tidal $C0_2$)
- Capnography
  - Displays the number as well as a wave form
  - Usually displayed as $C0_2$ concentration over time

Phases of the Wave Form (Krauss Ann Emerg Med 2007)

- Phase I
  - Airway dead space is exhaled
  - Dead space contains no $C0_2$
- Phase II
  - Alveolar gas exits the airway
- Phase III
  - Plateau phase with relatively steady concentration of $C0_2$
  - This phase may rise quickly in obstructive lung disease (asthma or COPD exacerbation)
- Phase IV
  - Start of inhalation
  - $C0_2$ decreases to 0 as atmospheric air enters the airway

Capnography Cannulae

Capnometry – Wave Forms

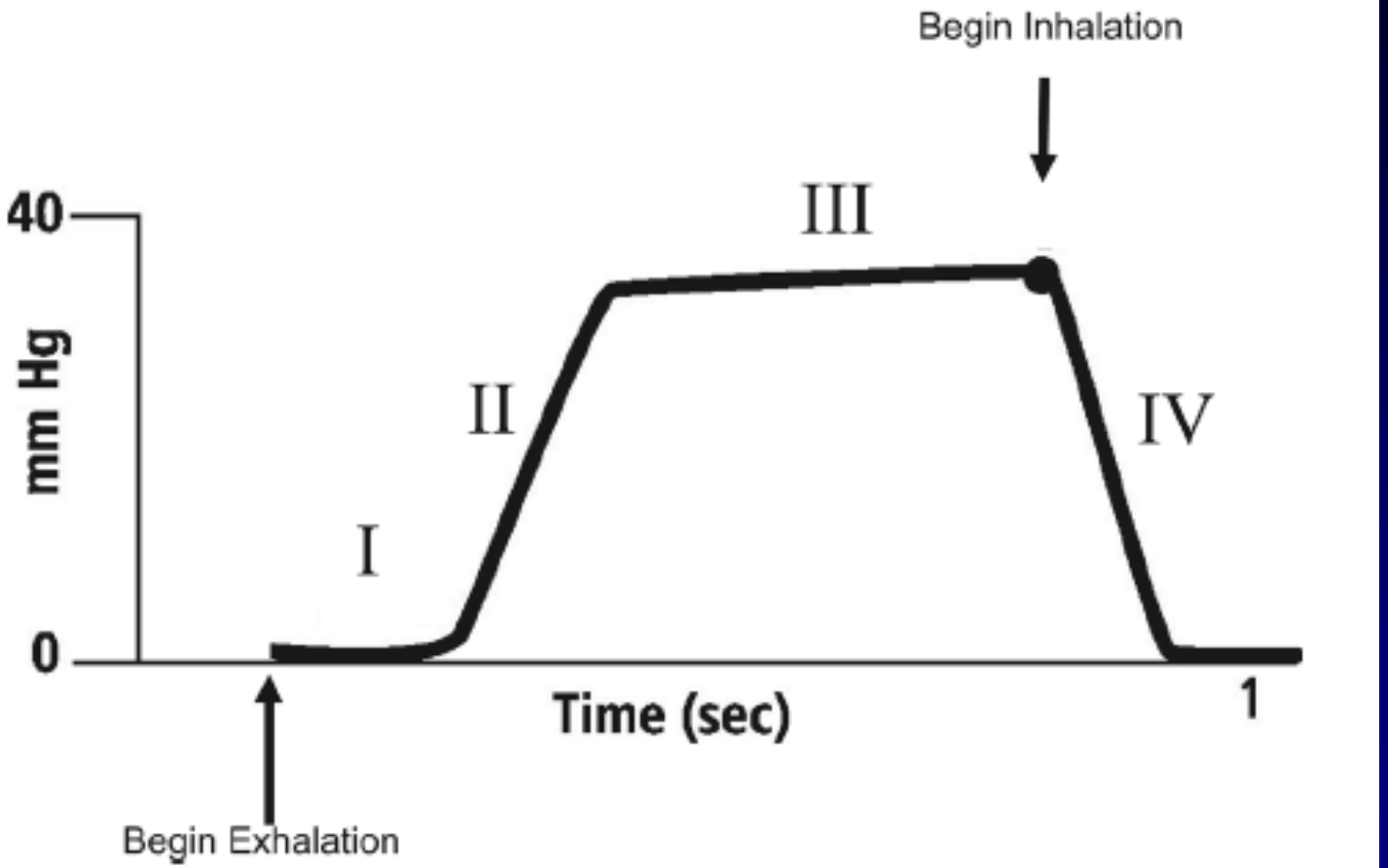
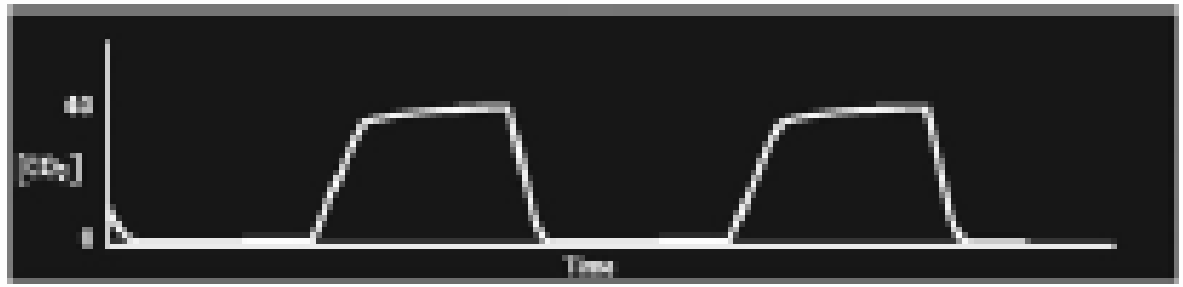
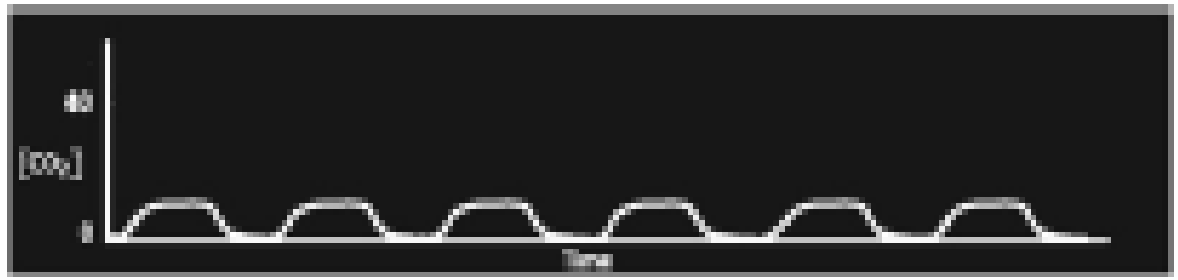


Figure 1. Normal capnogram.

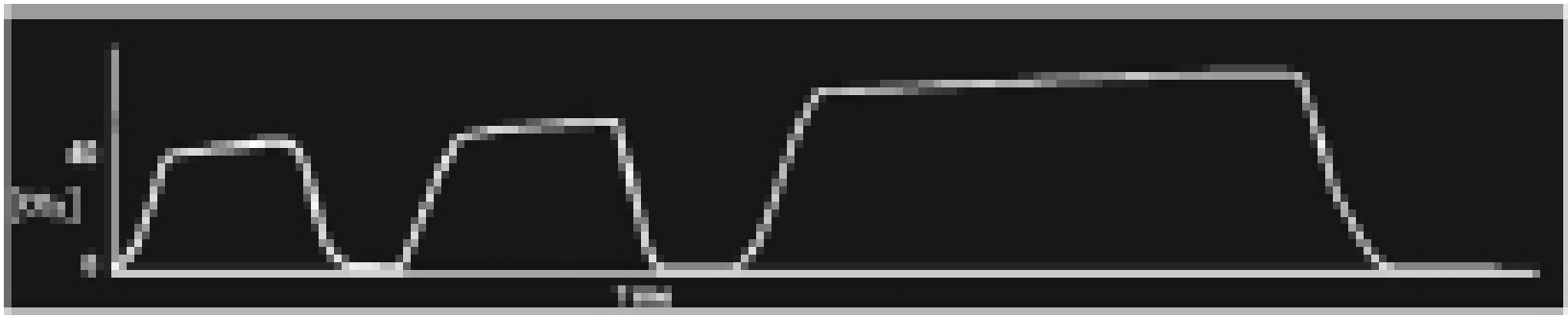
Krauss et al
Ann Emerg Med 2007

Capnometry – Wave Forms

Normal	
Hyperventilation	

Krauss et al
Ann Emerg Med 2007

Capnometry – Bradypnea



Krauss et al

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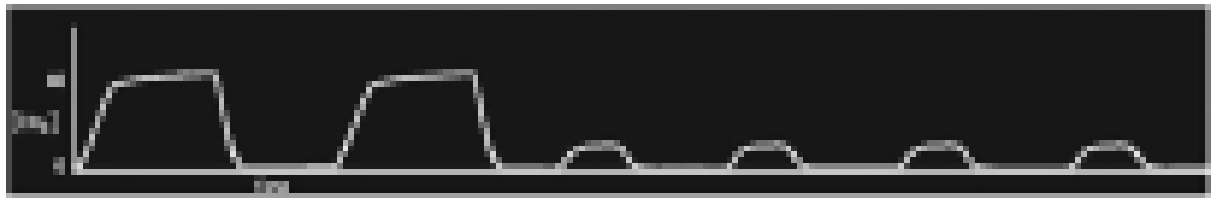
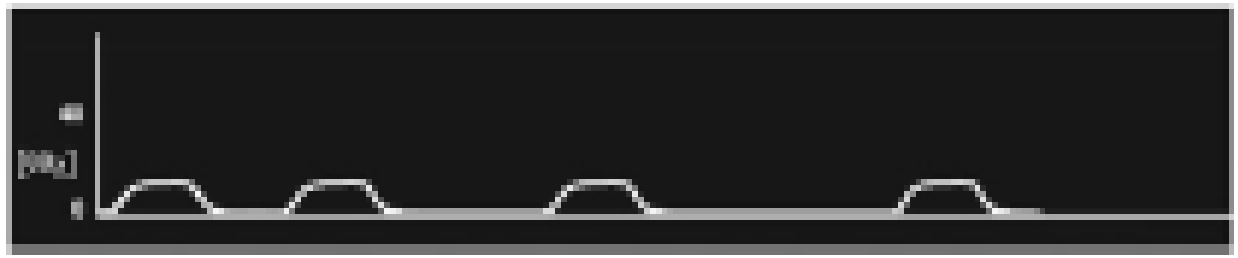
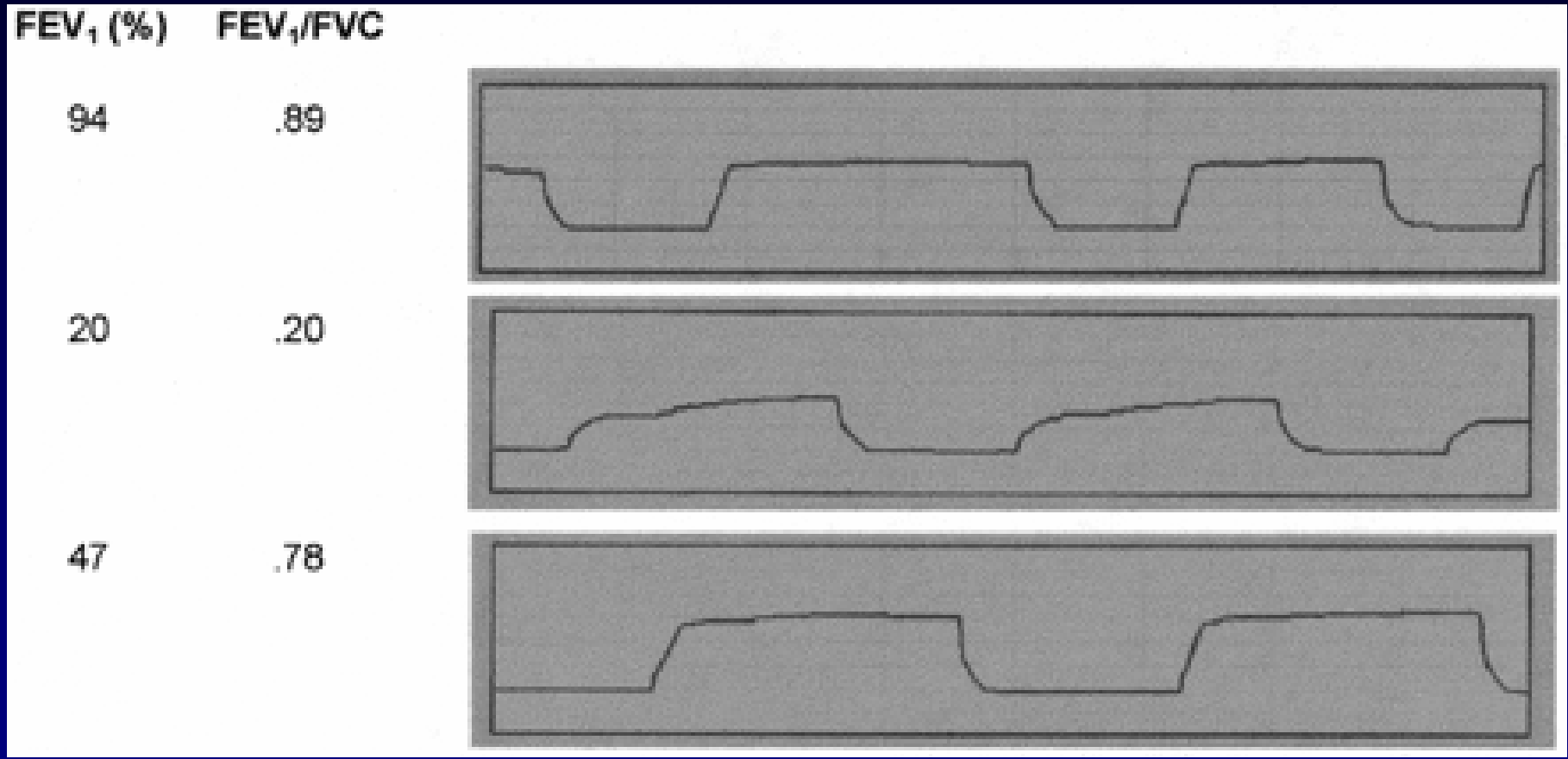
Capnometry – Bradypnea

Hypopneic Hypoventilation (Type 2)	
Hypopneic Hypoventilation with periodic breathing	

Krauss et al
Ann Emerg Med 2007

Capnometry – Bradypnea



Krauss et al
Anesth Analg 2005

Capnometry in Obstructive and Restrictive Lung Disease – Krauss et al. 2005

- Linear phases of the capnogram were identified
  - initial expiratory rise and alveolar plateau
  - Corresponding slopes for each feature, specified in (mm Hg/s) units, were computed from straight lines regressed through the sample points
- Associated angles from the horizontal were calculated
  - The take-off angle of the initial expiratory rise
  - The elevation angle for the slope of the alveolar plateau

Capnometry in Obstructive and Restrictive Lung Disease – Krauss et al. 2005

Total set of six characteristic values for each breath

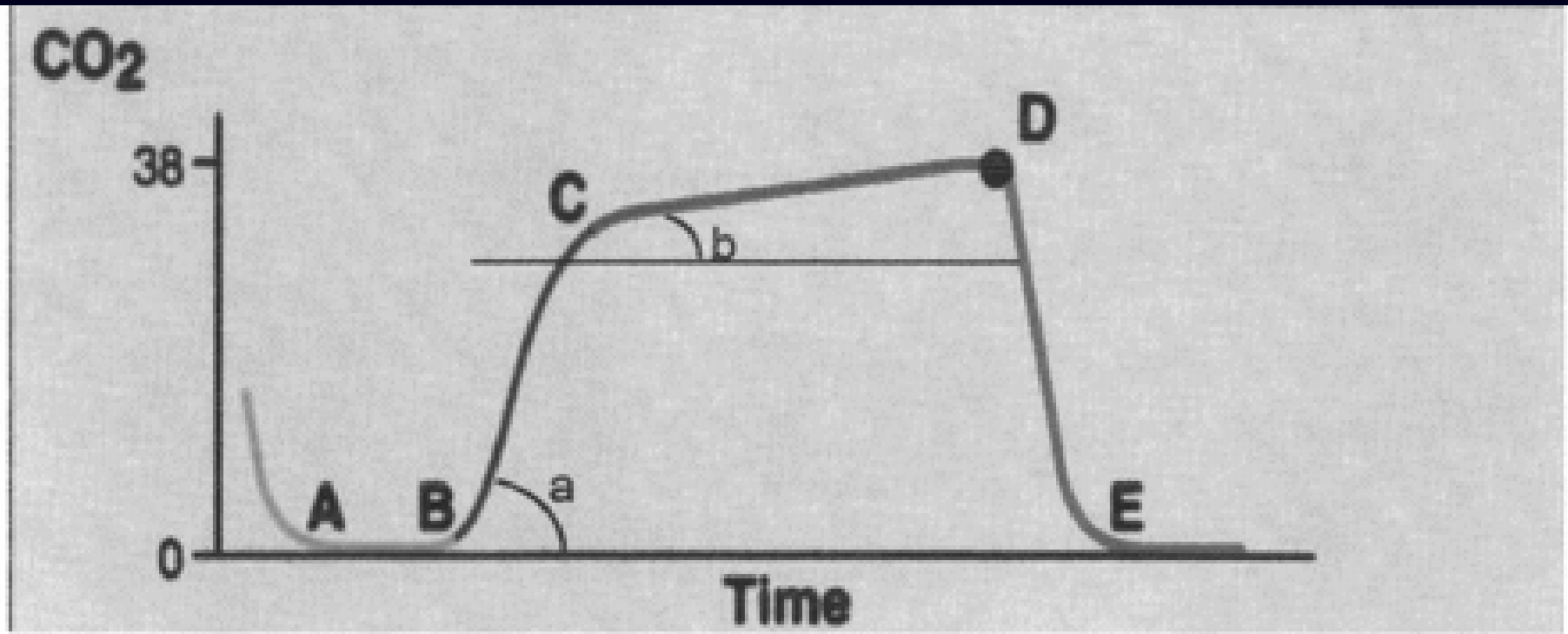
- **ETco2 value**
- **Respıratory rate**
- **Take-off angle**
- **Elevatıon angle**
- **Inspıratory time and expiratory time**

Results – Krauss et al. 2005

- Average take-off angle of ascending phase for severe OD was 7.2 degrees less than for normals
  - **(95% confidence interval [CI]: 4.0, 10.4)**
- Average alveolar plateau elevation angle was 0.8 degrees more for moderate OD than for normals
  - **(95% CI: 0.14, 1.4)**
- Average elevation angle was 3.6 degrees more for severe OD than for normals
  - **(95% CI: 2.9, 4.3)**

Results – Krauss et al. 2005 (Cont.)

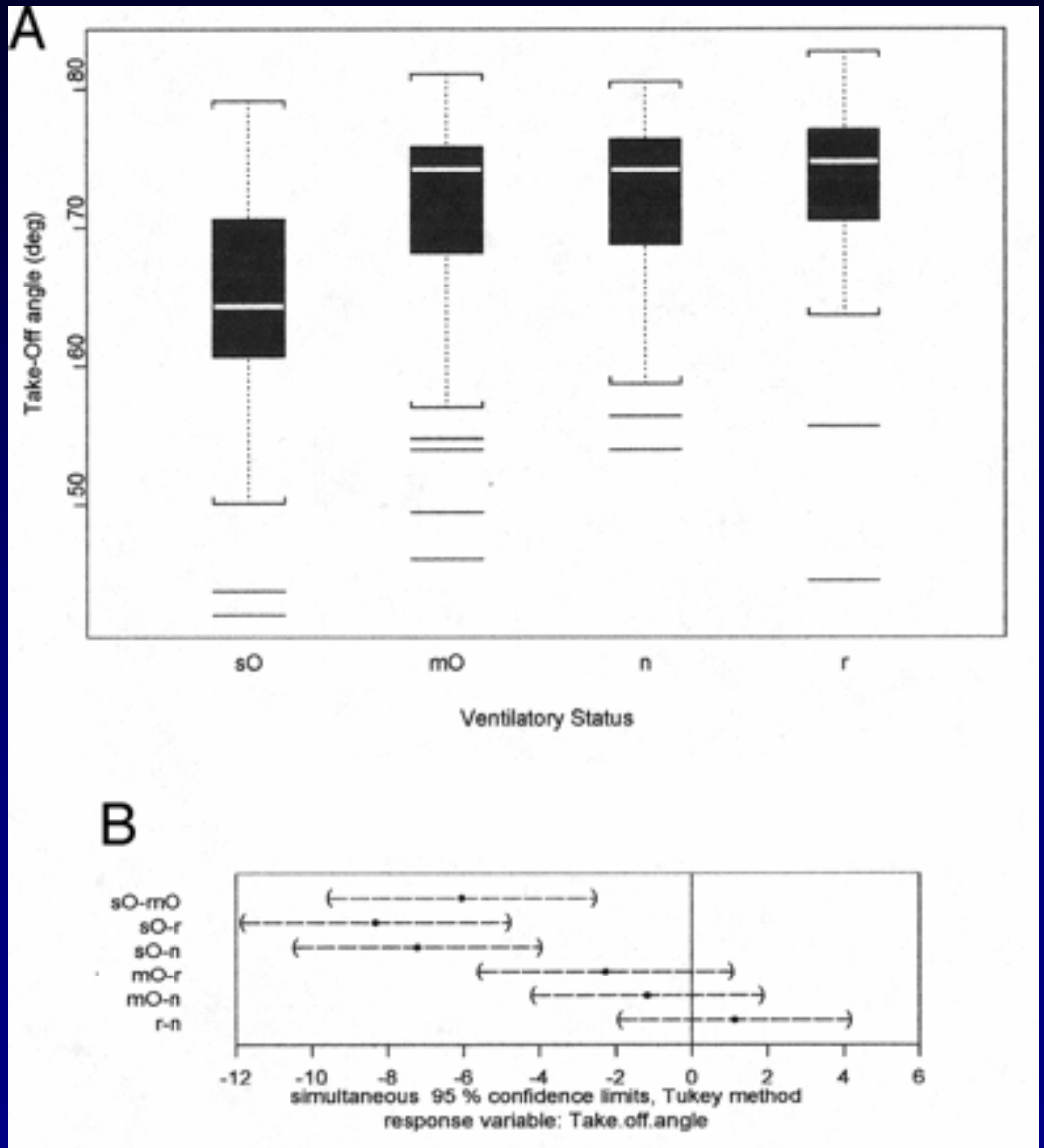
Differences between OD capnograms and normal and RD capnograms, correlating to changes in FEV1, were sufficiently large enough to suggest that the capnogram could be used to discriminate between OD and normal



A – B: Inhalation Trough
B – C: Initial Expiratory Phase
C – D: Expiratory Plateau
D – E: Initial Inhalation Phase
a: Takeoff Angle
b: Elevation Angle

Krauss et al
Anesth Analg 2005

Comparison of Take Off Angles



Krauss et al
Anesth Analg 2005

Tracheal intubation

- **Capnometry helps confirm tracheal tube placement**
- **Many methods of capnometry**
  - Dynamic Capnography
  - Static capnometry
  - Colorimetric indicator
- **Beware false positive with color indicator paper**
- **False positives may result from recent ingestion of a carbonated beverage**

Capnometry – Colorimetric Indicator

Salen et al. – Acad Emerg Med 2001

- **Non-consecutıve study of cardıac arrest patıents**
- **Cardıac sonography and ETC02 performed**
- **Two communıty hospıtals (Bethlehem PA, Newark DE)**
- **102 subjects over 18 months**
- **Survıvors had hıgher medıan ETC02 levels than non survıvors**
  - 36 mmHg for survıvors
  - 14 mmHg for non survıvors
- **In a logıstıc regressıon model**
  - Sonography dıd not statıstıcally predıct survıval
  - ETC02 dıd statıstıcally predıct survıval

Mackway-Jones – Emerg Med J 2003

- Best Evidence Topic Reports
- Reviewed evidence supporting use of colorimetric indicator
- Most studies were anesthesiology driven
- None of the studies were specific to the ED
- Esophageal intubations were sometimes associated with a color change from purple to yellow
- One study documented that this color change was mild and was correctly interpreted.

Li et al. – J Emerg Med 2001

- **Meta-analysis of studies $ETC0_2$ in cardiac arrest**
- **Database included the National Emergency Airway Registry (NEAR)**
- **3 False positives (indicator showed yellow color despite esophageal intubation**
- **Take home message: Use more than one method to confirm tube placement**
- **I always confirm tube placement by laryngoscope**
  - Allows for rapid identification of esophageal intubation
  - Allows for quick placement of tracheal tube if necessary

Summary

- **Capnometry is a useful adjunct for monitoring patients who are critically ill or undergoing sedation analgesia**
- **Capnometry is very user friendly**
  - For physician
  - For patient
- **Important to confirm capnography results with other clinical findings**
- **Further research is needed before capnography can replace current spirometry methods in evaluation of obstructive lung disease**
  - Asthma
  - COPD