

Inhalation Anesthesia Kinetics for Clinicians

a Gas Man® Workshop

CRASH 2009

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Brigham and Women's Hospital
Harvard Medical School
Med Man Simulations, Inc., a non-profit charitable organization

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Ready

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Gas Man® and Med Man Simulations Inc. are a tax-exempt nonprofit charitable organization
I am a frequent speaker for Baxter and Abbott
I have performed funded research on Isoflurane, Sevoflurane, and Desflurane

**Now or later, download Gas Man
software demo**

<http://gasmanweb.com>

Gas Man® Simulations





CONCEPTS taught with Gas Man

- 1. Tissue tensions** (partial pressures) equalize (=)
Tissue concentrations equilibrate (≠)
- 2. The One Compartment Model**
Step Response is an exponential
Lung wash-in from circuit (exponential - $\tau = 0.5$ min)
Brain wash-in from blood (exponential - $\tau = 3$ min)
Breathing circuit wash-in (exponential - $\tau = 8$ L Vol / FGF)
- 3. Sequential Compartments**
delays add to each other
Breathing circuit + Alveoli + Brain

The Alveolar Tension Curve

A. Initial Rise - Alveolar Wash-In

B. Knee - Equilibration with Blood

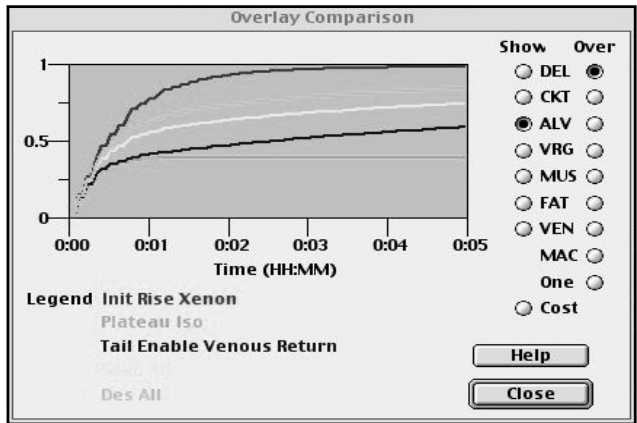
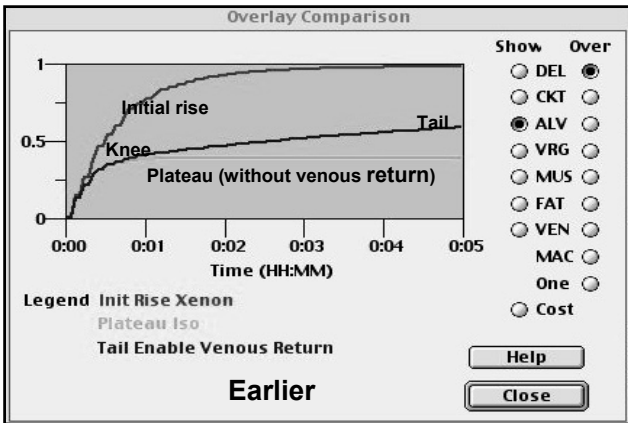
C. Tail - Venous Return

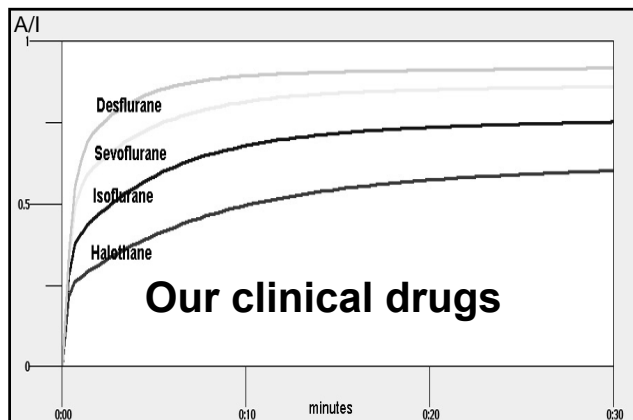
The Alveolar Tension Curve

A. Initial Rise - Alveolar Wash-In
Inspired Tension
Alveolar (lung) ventilation
Alveolar volume (FRC)

B. Knee - Equilibration with Blood
Alveolar ventilation
Cardiac output
Blood/gas solubility

C. Tail - Venous Return
Tissue blood flows
Tissue volumes
Tissue/blood solubilities





Blood / Gas Partition Coefficients

are the key to
Inhalation Anesthesia Kinetics

Blood / Gas Partition Coefficient - $\lambda_{B/G}$

Blood / Gas Solubility Ratio

Blood / Gas Solubility

Solubility

$\lambda_{B/G}$

=

Blood / Gas Partition Coefficients $\lambda_{B/G}$

Diethyl Ether	12.0
Methoxyflurane	10.2
Halothane	2.4
Enflurane	1.9
Isoflurane	1.3
Sevoflurane	0.67
Cyclopropane	0.47
Nitrous Oxide	0.47
Desflurane	0.42
Xenon	0.13
Helium	0.037
Nitrogen	0.014

Blood / Gas Partition Coefficients

Why should we care about them

?

Blood / Gas Solubility

Determines how closely Expired Approaches Inspired

Blood / Gas Solubility

Determines
how closely
Expired
Approaches
Inspired
Concentration, Partial Pressure,
Tension

Blood / Gas Solubility

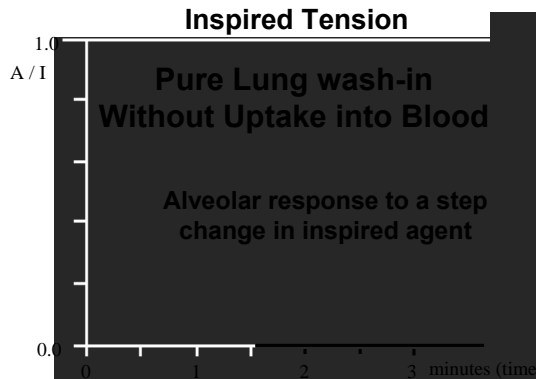
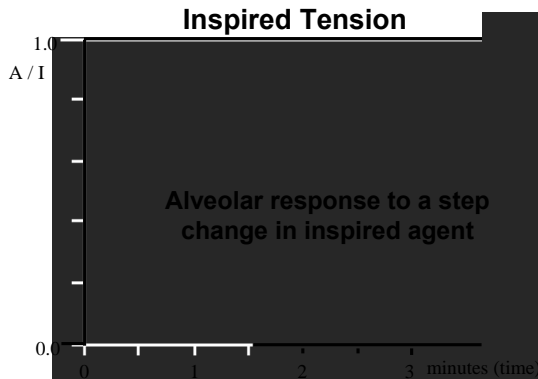
Determines
how closely (not how fast)
Expired
Approaches
Inspired
Concentration, Partial Pressure,
Tension

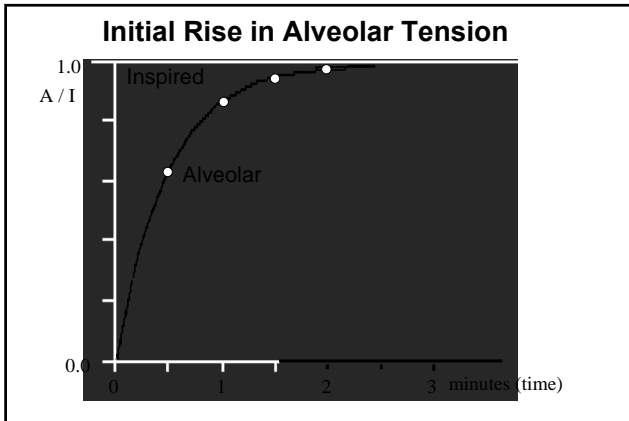
We see this by reviewing the

Alveolar Tension Curve

Alveolar Tension Curve

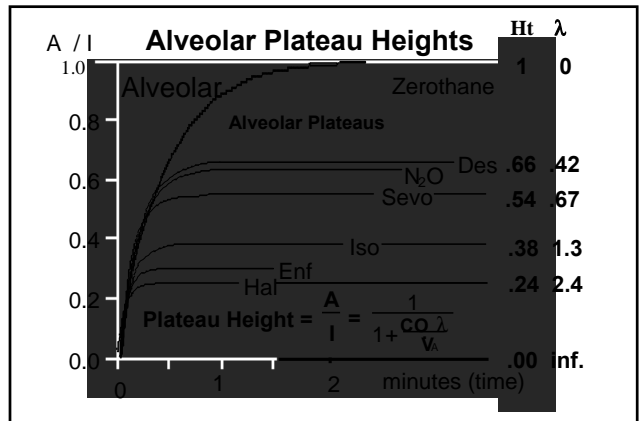
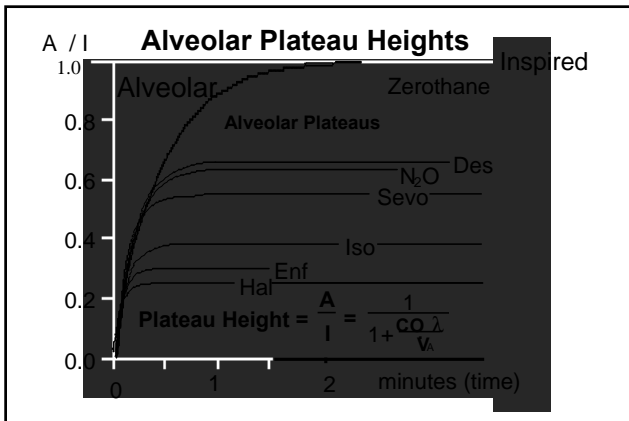
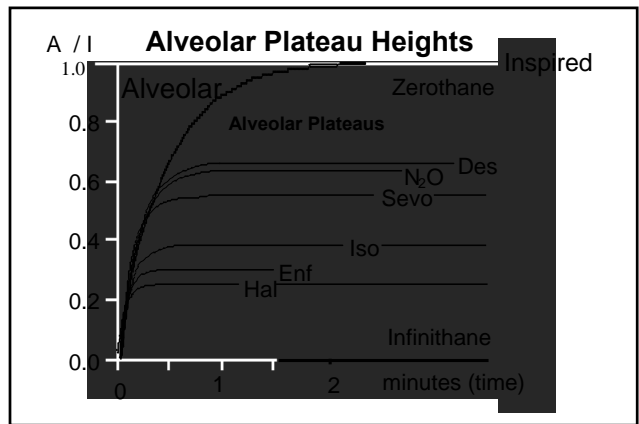
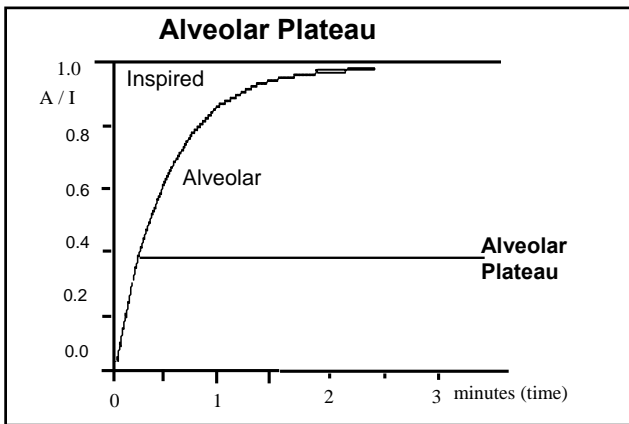
Alveolar response to an Inspired Step
=
The time course of alveolar tension - P_A
in response to a step change in
inspired tension - P_I
 $P_I \rightarrow P_A$

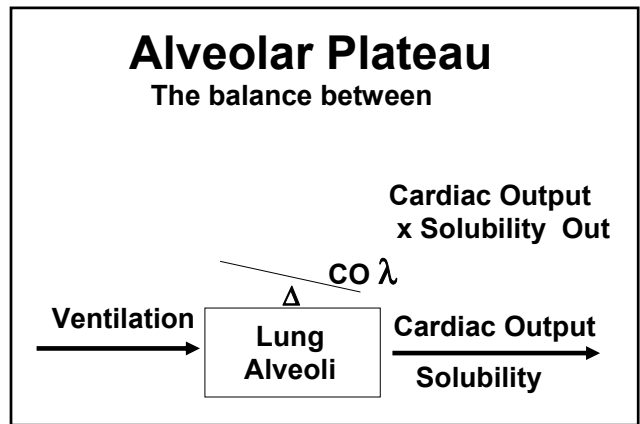
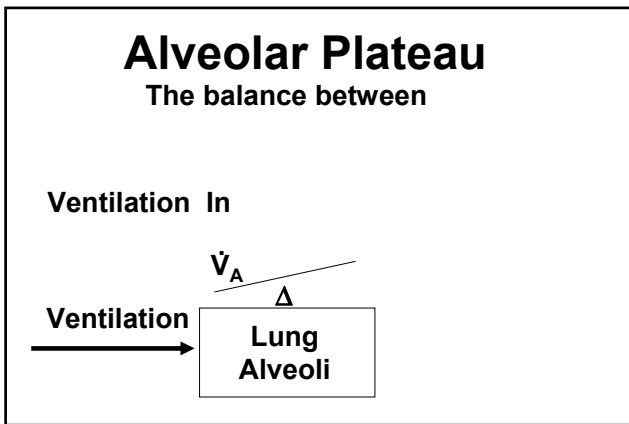
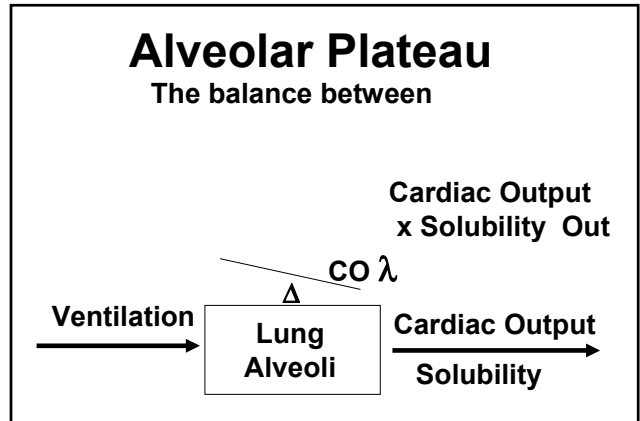
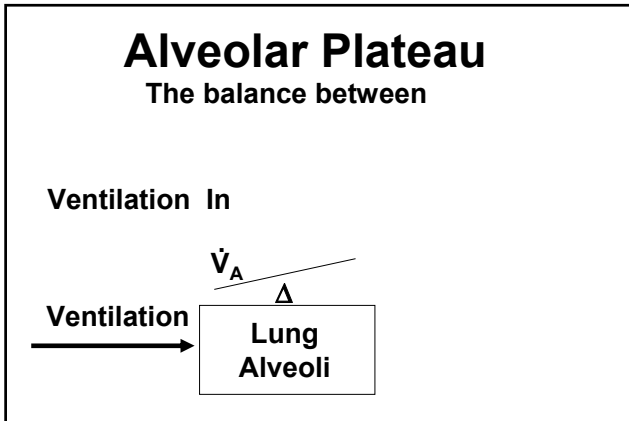




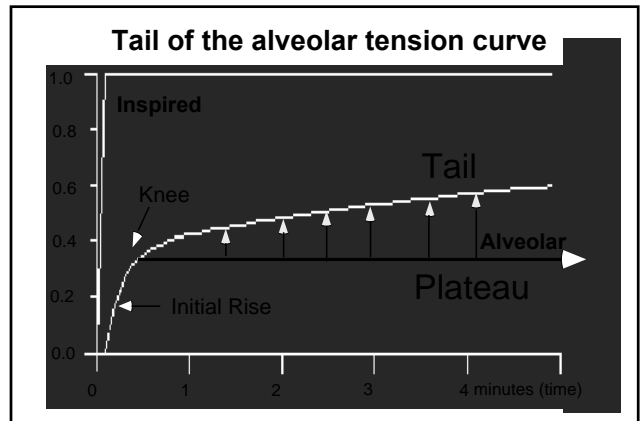
Add uptake into blood

Uptake into blood produces an alveolar tension plateau



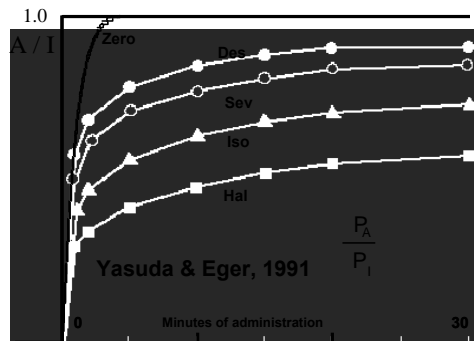


Venous Return converts Plateau into Tail



Next, Real drugs and real curves

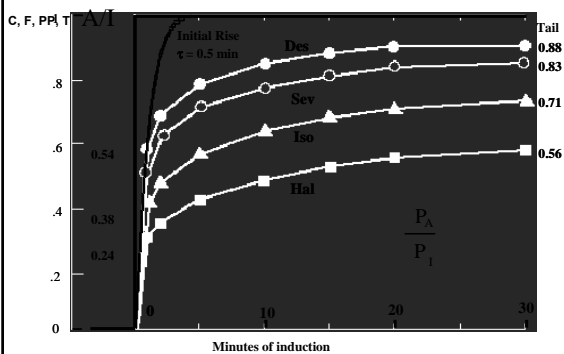
Real drugs and real curves



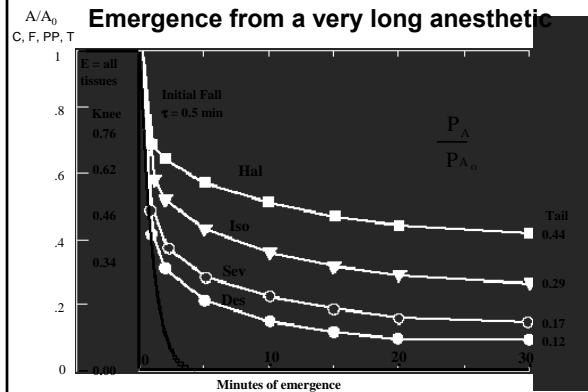
Wake
Up
!

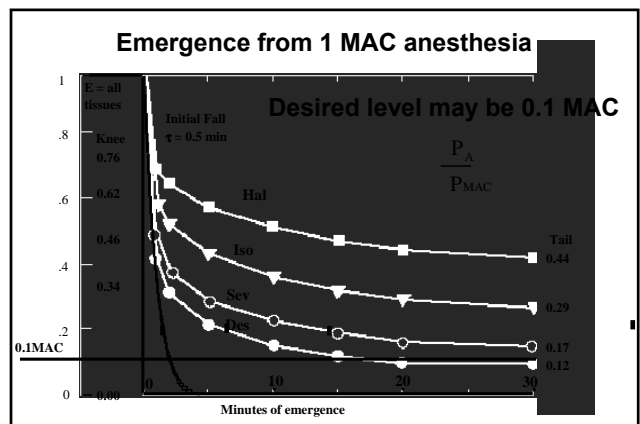
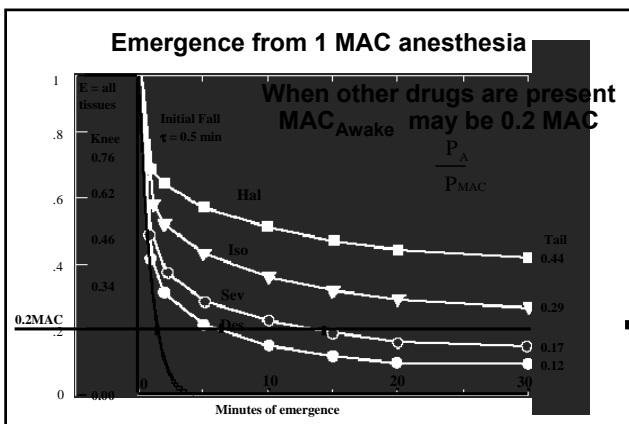
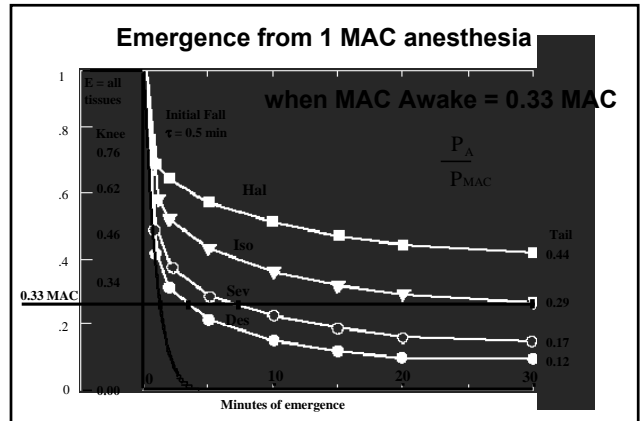
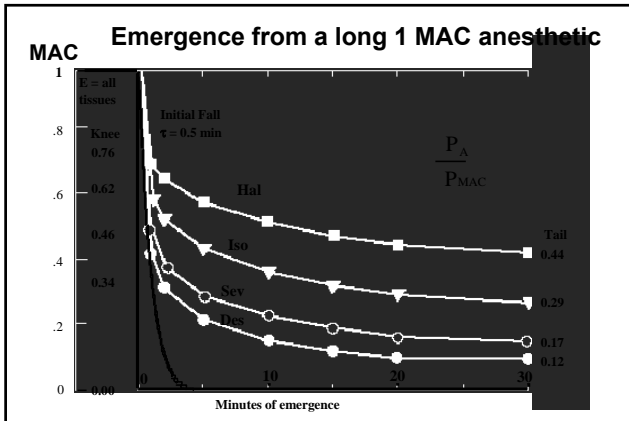
The kinetic relationship between
Induction and
Emergence (Wake Up)
Alveolar concentration curves

Induction (open circuit, again)



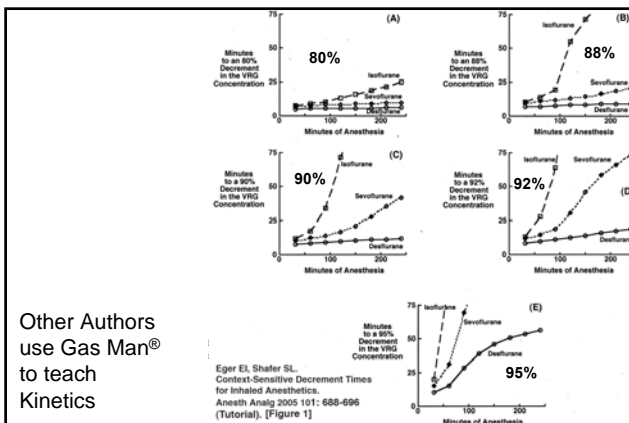
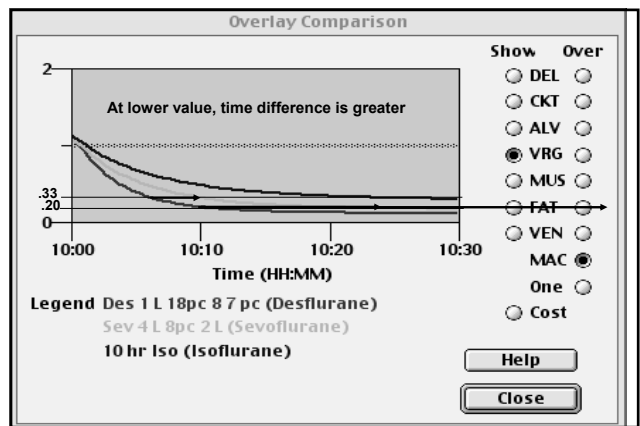
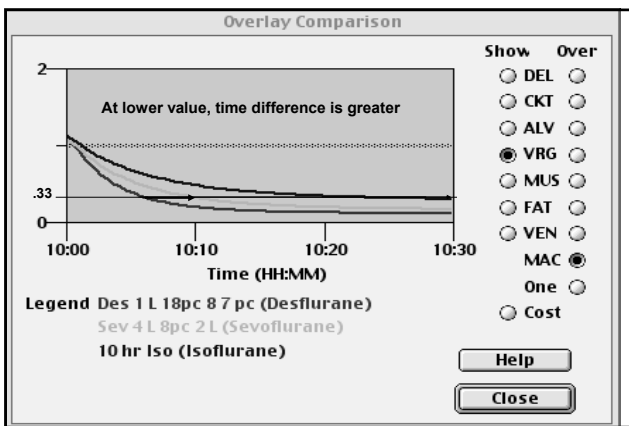
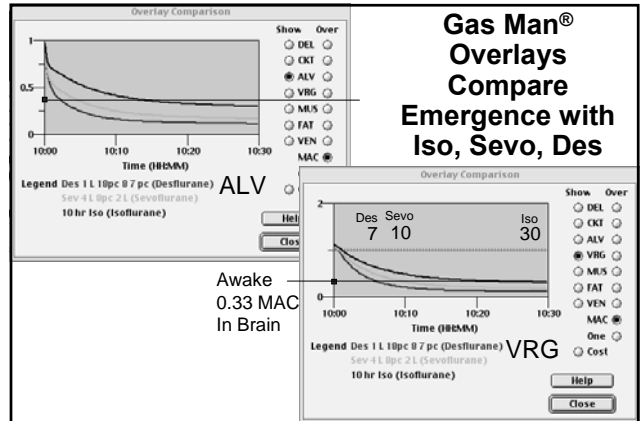
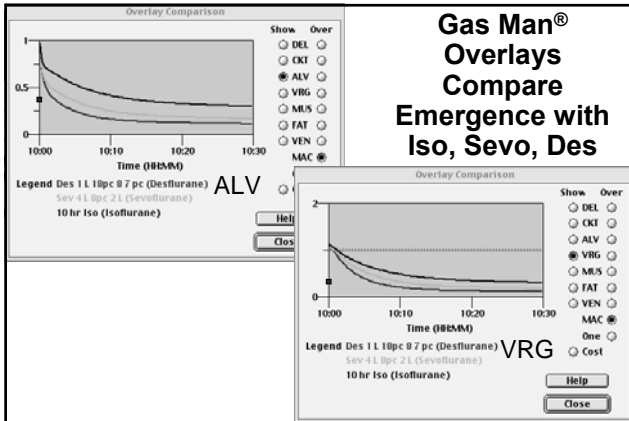
Emergence from a very long anesthetic





Enough of going to sleep
It's now time to
**Wake
Up
!**

Gas Man®
Overlays
Compare
Emergence with
Iso, Sevo, Des



Other Authors use Gas Man® to teach Kinetics

Add a few minutes to all I have said

Brain Time constant causes delay

Brain/Blood Solubility determines delay

Brain Time Constant (τ_{Brain})

<u>Agent</u>	<u>Minutes</u>
Ether	1.7
Hal	3.1
Enf	2.3
Iso	2.6
Sevo	2.7
N2O	1.4
Des	2.0
Xenon	2.1
N2	1.1

Other Clinical Topics of interest

Low FGF

Economic advantage of low solubility

If expired is close to inspired, then
when we lower FGF
the expired gas that the patient breaths
contains enough anesthetic
to not lower the inspired concentration much

Thus, low solubility promotes low FGF

Gas Man, again?

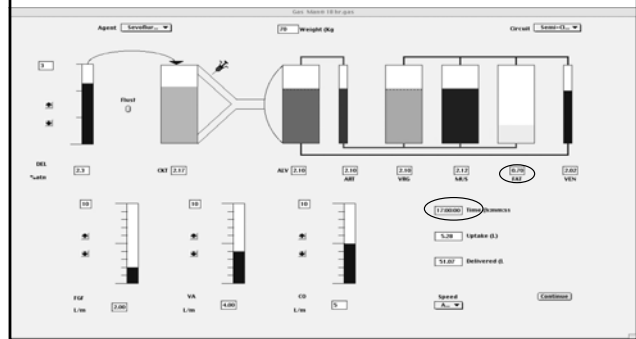
Other Clinical Topics of interest

Fat patients

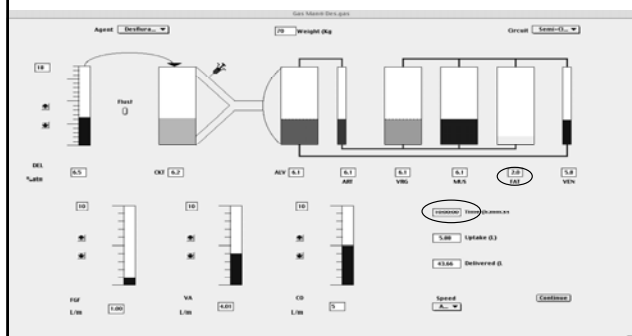
Gas Man[®] shows
Fat reaches 1/3 MAC
after 17 hours for Sevoflurane
after 10 hours for Desflurane

The level of 1/3 MAC is important,
this is the level when fat no longer assists wake
up,
instead it hinders it.

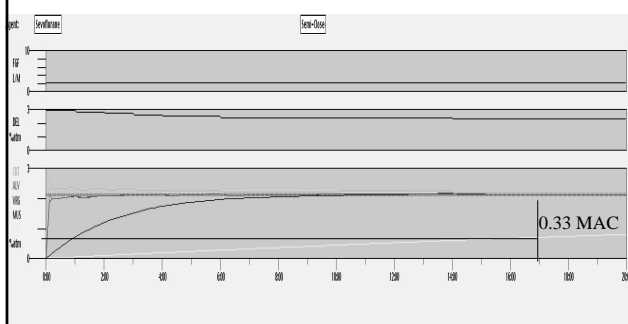
After 17 hr of Sevo at 1 MAC Alveolar
Fat tension reaches 1/3 MAC



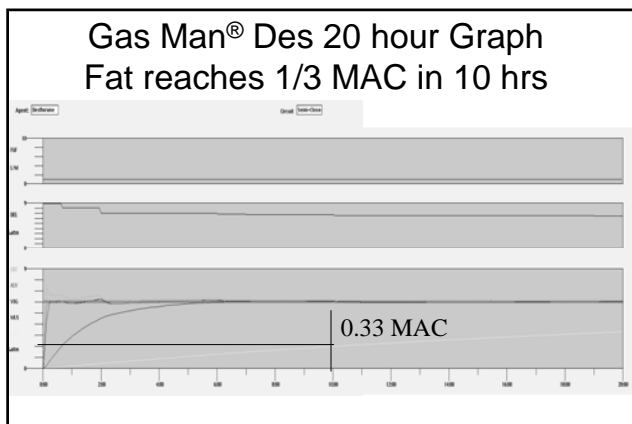
After 10 hr of Des at 1 MAC Alveolar Fat tension reaches 1/3 MAC



Gas Man® Sevo 20 hour Graph Fat reaches 1/3 MAC in 17 hrs



Gas Man® Des 20 hour Graph Fat reaches 1/3 MAC in 10 hrs



It's not fat solubility that determines wake up

**Blood/Gas Solubility alone
Explains the observed differences among drugs**

Other Clinical Topics of interest

Sevoflurane overpressure

Sevoflurane Kinetics

What makes Sevoflurane special

Overpressure Analogy

Accelerate from a STOP sign

Press accelerator pedal to floor
"Pedal to the metal"

Foot off gas pedal at desired speed
Every 16 year old can do it !

As much as the vaporizer allows.

Maximum Effect - Vaporizer to the Top & high FGF

Agent Name	Max Set	Alveolar (30 s)*		Clinical
		%	MAC	
N2O	75	51	0.5	Slight effect
Enf	5	1.7	1.0	Small effect
Hal	5	1.5	1.7	Mod eff, Peds
Iso	5	2.2	1.9	More Potent
Des	18	12.7	2.1	No! Symp. act
Sevo	8	4.8	2.3	Very Potent

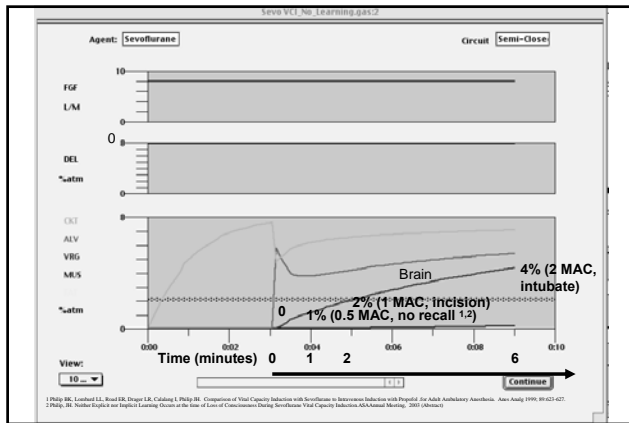
* Gas Man: VA = 4.0, CO = 5.0 Open Circuit

Other Clinical Topics of interest

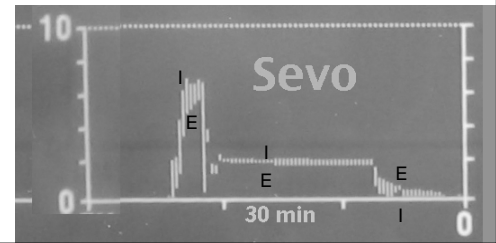
Gas Man shows VCI

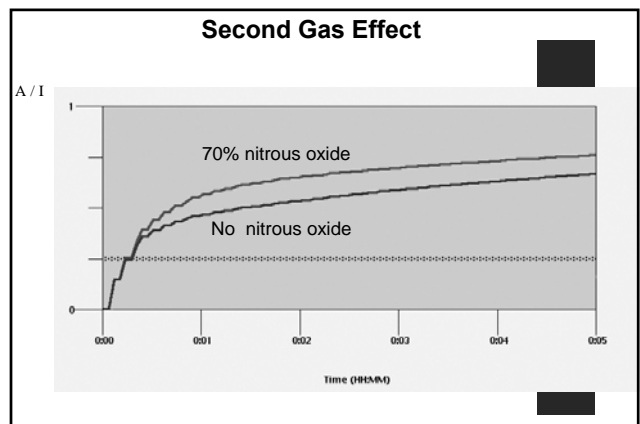
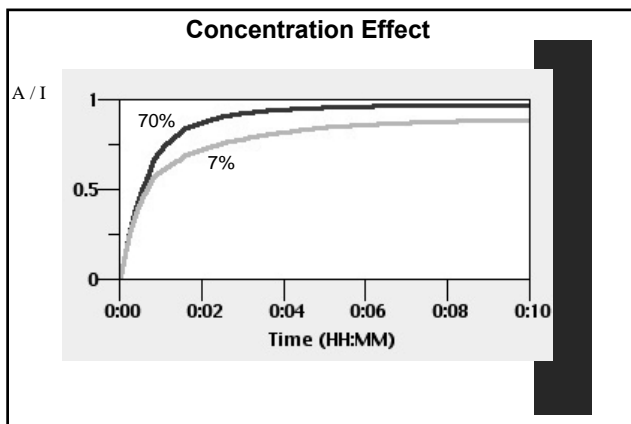
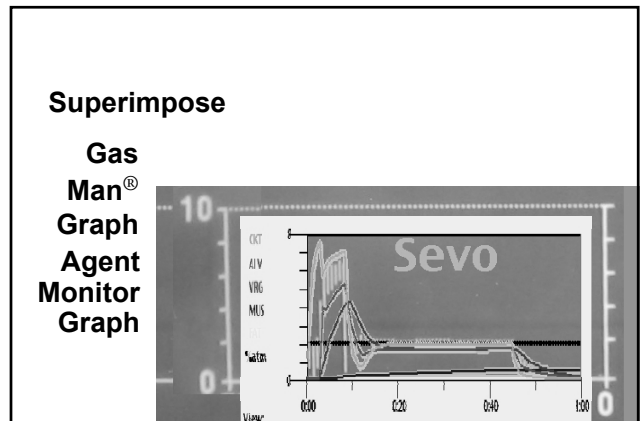
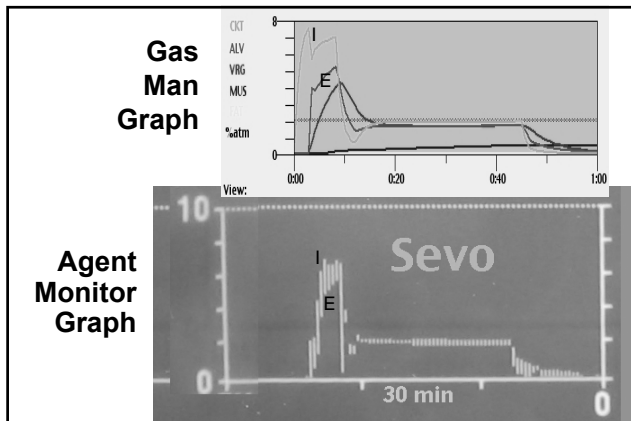
**Gas Man® shows
Single Breath Induction
How and why it works**

Use Gas Man



Agent
Monitor
Graph





Thank you

End

