New Anesthesia Delivery Systems
What Do I Need to Know About My New Machine?

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New Anesthesia Delivery Systems
What Do I Need to Know About My New Machine?

Answer:
A great deal, and more than most of us know.
Anesthesia Delivery System, past
1846 Morton Ether Inhaler

Ether Dome at MGH - some of you will visit tonight
1846 version
keep upright
use two hands
This 1850 version worked horizontal with no hands required
Open Circuit Inhaler

Open Circuit = Non-rebreathing
Patient breathes in the ether vapor, breathes ether out (and it is discarded)
Breathes in new ether vapor
Breathes it out again (discarded)
Blood picks up enough to anesthetize the brain
Partial Rebreathing

Don’t throw all the exhaled vapor away
Reuse it
Somehow
Rebreathe vapor
Absorb CO2
1890 added a Breathing Circuit
1950 added a work surface
1960 added calibrated Vaporizer:

Vernitrol®

Copper Kettle®
1965 added Direct Reading Vaporizers

Tec 3.. Vapor 19..
Then, Drawers, Common gas outlet
1970, Mechanical Ventilator
Electronics in the ADS

Boston Anesthesia System
1976
Prototype
Electronic
ADS
(MGH)
Boston
Anesthesia
System
Electronic, with agent injector vaporizer
1990
Integrated Monitors and Data Recording
Ohmeda (now GE) Central Display ADS
BWH Clinical Partner
~ Year 1998

New Clinical Demands
Better ventilation for difficult patients
  FGF-independent ventilation
  Compensate for circuit leaks
  Compensate for circuit compliance
ICU Modes (Pressure, Synchronization)
  GE SmartVent®, Draeger E-Vent Piston
Electronic Vaporization (GE)
Automatic Pre-Use Check (GE, Draeger)
GE-Datex-Ohmeda Aestiva

Draeger Fabius GS

1998 State-of-the-art
GE-Datex-Ohmeda ADU - had been ahead of its time

Electronic Ventilation

Electronic Gas Delivery

Electronic Vapor Delivery
2010 state-of-the-art

GE Aisys

Draeger Apollo GS
2010 not-quite state-of-the-art
A few other brands

Also, not state-of-the-art
Datascope AS 3000
Penlon Prima SP3
Spacelabs
Blease-Sirius
Beyond state-of-the-art

Draeger Zeus ADS

Not in USA
Set $F_1O_2$
Set $F_E$Agent
Press start

Integrated IV pumps
Also with target control

US FDA was opposed
US FDA may be receptive
Anesthesia Delivery System (ADS)

Life Support with oxygen
spontaneous breathing
mechanical ventilation

Inhalant Drug Delivery
Gas
Vapor
Oxygen and Gas Delivery

- Mechanical
- Physical knobs
- Rotameters,
- GE Aestiva, Aespire
Oxygen and Gas Delivery

Mechanical
Physical knobs
Rotameters, Digital meters
Draeger Fabius

Draeger Apollo
Oxygen and Gas Delivery

Mechanical
Physical knobs

Rotameters, Digital meters

Draeger Fabius
Flashes at 12.1 LPM
Turn knob for 25 LPM

Draeger Apollo
Oxygen and Gas Delivery

Electronic
Virtual knobs
Digital meters
GE Avance, Aisys

% Oxygen in FGF
NOT inspired - be careful

GE Avance, Aisys
Common Outlet for FGF

Common Outlet is absent or hidden on all new machines
FGF reaches breathing circuit by a pipe or hose
Advanced Ventilation Modes
Better ventilation for difficult patients

FGF-independent ventilation
Compensate for circuit leaks
Compensate for circuit compliance
ICU Modes (Pressure, Synchronization)

GE SmartVent®, Draeger Piston
New Ventilation Mode

Pressure-cycled, Volume-controlled

GE calls it Pressure Control Volume Guarantee
   PCV - VG

Draeger calls it Volume Ventilation with Auto-Flow
   V V - Auto Flow

Pressure Ventilation but delivers the Tidal Volume you set
Useful in Laparoscopy where compliance changes
but, you want constant tidal volume
and, you want constant-pressure breaths

High-end machines only
   No:  GE Aestiva, Aespire       Draeger Tiro, Fabius
   Yes: GE Avance, Aisys          Draeger Apollo
Vaporizers
Vaporizer Types

Mechanical
- Penlon Signa for isoflurane, sevoflurane
- GE Tec 3,4,5,7 for isoflurane, sevoflurane
- GE Tec 6 for desflurane (electro-mechanical)
- Draeger Vapor 19, 2000 for all agents
- Direct-reading, temperature-compensated

Electronic
- GE Aladin for all agents
Electronic vs Mechanical Vaporizers

More accurate with changing gas composition
Maintains dial concentration at high FGF (15 LPM)
Compensates for altitude with desflurane
Captures & displays agent use data

But
Electronic failure terminates agent delivery
Only one vaporizer, so can’t switch to another agent
Does not allow FGF < 0.2 LPM for closed circuit
Desflurane & other vaporizers must be removed to fill
Breathing Circuits
The Circle-Absorber System and Fresh Gas Flow

- Fresh Gas Flow (FGF)
- CO₂ Absorbant
- Ventilation Flow
- Exhaust
- Expired
- Sampled & measured I, E
- 200 mL/min
- Inspired
Low FGF

Saves money because of less waste
Limits our ability to control inspired concentration
Therefore limits control of expired conc. and brain conc.

Lunch workshop today with Gas Man will show this
Better ventilation for difficult patients
FGF-independent ventilation
Corrects for circuit leaks
Corrects for circuit compliance
< 2000, Standard Anesthesia Ventilators

Tidal Volume and FGF were interdependent

Increase FGF and Tidal Volume increased
by the amount of fresh gas that flowed during inspiration
Fresh Gas Flow Independent of Ventilation

1998 - WYSIWYG What You Set Is What You Get
Set Tidal Volume - patient receives what you set

Two ways to achieve this

Fresh Gas Compensation
  Active, feedback control of inspired tidal volume
  GE

Fresh Gas Decoupling
  Passive separation of FGF during inspiration
  Draeger
GE-Datex-Ohmeda Aestiva and all other models

Pneumatic (oxygen)-driven bellows

Inspiratory and Expiratory Flow Sensors

Feedback from flow sensors to bellows drive

Bellows stops pushing when Measured Inspired Tidal Volume = Set Inspired Tidal Volume

If you press the Flush button Bellows stops Next breaths are confused

GE has many alarms that stop ventilation
All GE models have similar differential-pressure flow sensor
Variable-Orifice flow Sensor (VOS)

Accurate over a wide range of flow
Each one is calibrated in GE factory
Variable-Orifice flow Sensor (VOS)

This is what makes the SmartVent™ smart
This is GE’s core technology
Variable-Orifice flow Sensor (VOS)

Accurate over a wide range of flow
Each one is calibrated in GE factory

One drop of water will make this fail
Water Management is important
Use an HME or HMEF

Heat and Moisture Exchanger
between patient and circuit
Piston
Draeger Fresh Gas Flow Decoupling

Mechanical Ventilation
Piston displacement is constant and provides constant Tidal Volume
Fresh Gas fills the reservoir bag during inspiration (“decoupled”)
Piston draws in Fresh and Exhaled gas during “refill” in expiration
Piston is ready to give the next breath
Implications of “Decoupling”

Collateral damage
Reservoir bag is in the circuit during ventilation
Adds a second sequential mixing chamber
Old gas stays in-play even when FGF is high
This does not matter much during induction
This matters a lot during emergence
In emergence we desire Inspired agent concentration = 0
Even with bag ventilation expired gas contaminates inspired
Example
Fabius, End of case, VCV, FGF = 12 LPM
Inspired does not fall to zero
Draeger has difficulty clearing the last bit of agent

Malignant Hyperthermia Preparation
Target is $F_{1,\text{Agent}} < 5$ ppm
Most ADSs require 10 minutes
Fabius and Apollo require 1 hour
(Inspired Charcoal agent absorber can overcome this)

Draeger has difficulty clearing the last bit of agent

Malignant Hyperthermia Preparation
Target is $F_{1\text{Agent}} < 5\text{ ppm}$
Most ADSs require 10 minutes
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(Inspired Charcoal agent absorber can overcome this)

Fabius and Apollo are similar
Draeger has not solved it yet

GE breathing circuits are faster

Induction

Emergence
Draeger Fabius and Apollo
GE Circuit configuration superimposed on Draeger Circuit
GE Circuit

Pneumatic bellows ventilator
Sevoflurane Induction

High FGF and vaporizer setting
Second Breath, Inspired = Vaporizer setting
GE Graphics don’t show this well

Hidden here
And, often the I and E scales don’t match
So, the agent trend graphs are confusing.
Tight control of inspired is most important during emergence
6 hour graphic trend
Zoom in to 1 hour trend
Better to understand this with slow wave (3 min)
Summary of what you need to know

GE Circuit is fast
Draeger Circuit is slow - use very high FGF for emergence

GE Ventilation Control depends on flow measurements
water can make it fail. HME is mandatory

Draeger Ventilation Control depends on piston motion
piston needs replacement every 3-5 years

GE Ventilator ends inspiration when \( P = P_{\text{max}} \) setting, failing and alarming
Draeger Vent continues inspiration when \( P = P_{\text{max}} \) setting, succeeding & alarming

GE Flush will confuse ventilator for the next few breaths of feedback control
Draeger Flush is OK any time during mechanical ventilation

GE Graphic trends have poor resolution and sometimes have erroneous scales
Draeger Graphic trends have good resolution and good scales

GE offers electronic vaporizers with accuracy but a total failure mode
Draeger mechanical vaporizers do not fail but do not record and display agent use

GE does not return sampled gas to the breathing circuit
Draeger returns sampled gas to the breathing circuit and allows true closed circuit

Neither GE nor Draeger has a convenient Fresh Gas Outlet you can connect to
Thank you
Additional answers
Draeger Fabius and Apollo

Constant Volume FGF Decoupling COSY-2.5

Ventilator
Fresh gas

Fresh Gas Decoupling

Circuit Insp Valve

I E select

I E

setting Pmax/ Peep

Circuit Exp Valve

APL Bypass

Absorber

Bag

Scavenging
Inspiration

Piston pushes gas into lungs

FGF flows through absorber to reservoir bag

Draeger Fabius and Apollo
Expiration Phase 1

lungs empty and fill reservoir bag and Piston

FGF fills Piston

Draeger Fabius and Apollo
Expiration Phase 2 lungs are empty

FGF and Reservoir Bag fill Piston

Draeger Fabius and Apollo Passive at FRC
GE Circuit configuration superimposed on Draeger Circuit
GE Circuit

Pneumatic bellows ventilator
Actual GE Circuit (Avance) Fresh Gas Delivery

FGF enters adjacent to the Inspiratory Valve
Better to understand this with slow wave (3 min)
Hot wire Anemometer is cooled by flow

Used to Display, not to control tidal volume.

Calibrate for heat conductivity.
Set Desflurane Y/N