

Volatile Agents at Sea Level and Altitude

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VOLATILE AGENTS AT SEAL LEVEL AND ALTITUDE

Summary - there are several types of vaporizers whose different characteristics have an impact on anesthesia practice

Objectives

- 1 Different Agents use different Vaporizers
- 2 Physics of Liquids and Vapors is simple to apply; liquid evaporates to vapor
- 3 Factors important to vaporizer design are Vapor Pressure, Sensitivity of Vapor Pressure to Temperature, MAC, Blood/Gas Solubility
- 4 Variable-bypass vaporizers (Tec3,4,5,7, Vapor 19) anesthetize slightly better at altitude while constant concentration systems (Tec 6 and nitrous oxide flowmeter) anesthetize in proportion to barometric pressure.

Vaporizers

Vapor Definition

Vapor

is the

Gaseous Phase

of a substance that is a

Liquid at Room Temperature

and Pressure

Anesthesia Vaporizers

Facilitate Phase Transition

from Liquid to Gas

Allow control of drug administration

to the Fresh Gas Flow and

to the Breathing Circuit

Phase transition Liq -> Gas

Vapor / Liquid
Volume Ratio

Latent Heat of Vaporization

Vaporizers provide
Latent Heat of Vaporization
Heat required to
Vaporize or
Boil

Latent Heat of Vaporization = 40 cal / g

Each anesthetic agent has a Vapor Pressure (P_v)

P_v is the Saturated Vapor Pressure (SVP)

P_v is the partial pressure of the Liquid

P_v is a function of Temperature only

P_v rises with Temperature

P_v is not a function of Atmospheric Pressure

But, if $P_v > P_B$ then pure Vapor (Gas)

If $P_v < P_B$ then Liquid with vapor above

Copper Kettle/Vernitrol Vaporizer Equation

Flow rate x of oxygen (F_{Ox}) enters the vaporizer. Flow rate x of oxygen leaves along with flow rate y of vapor (F_{vap}). Flow rate y satisfies the following equation.

$$y/(x+y) = P_v / P_b; \quad F_{vap} / (F_{vap} + F_{Ox}) = P_v / P_b \quad (1)$$

where P_v equals vapor pressure of agent and P_b equals total pressure which equals barometric pressure.

Therefore, solving eqn 1 for y as a function of x and P_v and P_b ,

$$y = P_v (x+y) / P_b$$

$$P_b y = P_v (x+y)$$

$$P_b y = P_v x + P_v y$$

$$y (P_b - P_v) = P_v x$$

$$y/x = P_v / (P_b - P_v) =$$

$$y/x = 1 / (P_b/P_v - 1)$$

In another form,

Multiply by $F_v = P_v/P_b =$ vapor fraction

$$y/x = F_v / (1 - F_v)$$

Variable-Bypass Vaporizer
Ohmeda Tec 3,4,5,7and Draeger Vapor 19

Tec 5 Vaporizer

Available for
Halothane
Enflurane
Isoflurane
Sevoflurane

Tec 5 Vaporizer cut-away

Tec 5 Temperature compensation

Flow Capability - Tec 4 Output vs FGF

Flow Capability - Tec 4 Output vs FGF

Desflurane is different

Desflurane Vaporizer

Could use conventional vaporizer

Need to cool agent

To a vapor pressure like other agents

Instead - Engineering and Safety Choice - cooler may fail

Heat liquid to guarantee vapor (gas)

Meter vapor into Rotameter Flow

Altitude-independent concentration

concentration = fraction = “%”

Altitude-dependent partial pressure

partial pressure anesthetizes !

Unlike all other vaporizers

Flow Through the Tec 6 Desflurane Vaporizer

Tec 6

Desflurane

Vaporizer

<u>COLOR</u>	<u>MEANING</u>	<u>SOUND</u>
• Green	Operational	Silent
• Red	No Output	Yes
• Red	Low Agent	Yes
• Amber	Warm-up (2 min)	Silent
• Red	Alarm Batt Low	No

Easy-to assemble
Semi-Automatic
Vaporizer Filling System

Tec 6 Front

Tec 6 Left Side

Tec 6 Right Side

Plastic-coated
glass bottle

Vaporizer Order f (Vapor Pressure)

Vaporizer Order MAC

Vaporizer Order l & Plateau

Vapor / Liquid
Volume Ratio

Dimensional analysis for liq -> vap

Given: Molar Volume = 22.4 L at STP

Dimensional analysis for liq -> vap yields:

	GMW	d	0 C
Sevoflurane	200.1	1.52	170
Desflurane	168.0	1.46	195
Isoflurane	184.4	1.50	182
Halothane	197.4	1.87	212
Enflurane	184.4	1.52	184

Temperature-corrected Liquid to Vapor Conversion

	GMW	d	0 C	20 C
Sevoflurane	200.1	1.52	170	182
Desflurane	168.0	1.46	195	208
Isoflurane	184.4	1.50	182	195
Halothane	197.4	1.87	212	227
Enflurane	184.4	1.52	184	198

Altitude Effects are significant

Variable-bypass vaporizers increase concentration greatly and increase partial pressure and anesthetization slightly

Tec 6 Desflurane “Boiling Vaporizer” provides constant fractional concentration and decreased anesthetization in proportion to the decreased barometric pressure.

Variable-Bypass Vaporizer

Ohmeda Tec 3,4,5,7 and Draeger Vapor 19

Altitude Effects are significant

5) Desflurane and N₂O are delivered as concentration

Concentration is Percent or Fraction

Fixed fraction of a rarified atmosphere at Altitude rarifies the anesthetic

Partial pressure and anesthetic effect will diminish with Altitude

6) Other agents are delivered as partial pressure approximately

This means partial pressure should be constant with Altitude

Actually, pp increases a bit with altitude

Because Splitting between Bypass and Vapor is before vapor is added

5,000 ft (0.87 Atm): Iso +7%, Sevo +4%, Des -13%.

10,000 ft (0.74 Atm): Iso +19%, Sevo +10%, Des -26%

See Spreadsheet

Splitting Current

Injecting Liquid Anesthetics into the Breathing Circuit

1 mL Desflurane injected

Desflurane Liquid Injection

Liquid Injection

Liquid Infusion with

Syringe Pump

Get desflurane out of bottle

Syringe must always point up

Desflurane Liquid

Uncommonly used

Used in Closed Circuit

covered in another lecture here

Use at moderate FGF

possibly covered in another lecture here

Vaporizers Summary - 1

- 1) Different Agents use different Vaporizers
- 2) Factors important to vaporizer design are
 - Vapor Pressure,
 - Sensitivity of Vapor Pressure to Temperature,
 - MAC,
 - Blood/Gas Solubility
- 3) Physics of Liquids and Vapors is simple to apply
 - liquid evaporates to vapor
- 4) Place sequential vaporizers carefully
 - Vapor pressure increasing L to R

Vaporizers Summary - 2

- 4) Desflurane is heated but it does not need to be.
 - Refrigerated desflurane could be administered through a standard vaporizer
- 5) Desflurane and N₂O are delivered as concentration
 - Concentration is Percent or Fraction
 - Fixed fraction of a rarified atmosphere at Altitude rarifies the anesthetic
 - Partial pressure and anesthetic effect will diminish with Altitude
- 6) Other agents are delivered as partial pressure approximately
 - This means partial pressure should be constant with Altitude
 - Actually, pp increases a bit with altitude
 - Because Splitting between Bypass and Vapor is before vapor is added
 - 5,000 ft (0.87 Atm): Iso +7%, Sevo +4%, Des -13%.
 - 10,000 ft (0.74 Atm): Iso +19%, Sevo +10%, Des -26%

Vaporizers Summary - 3

- 4) Liquid anesthetics can be injected into the breathing circuit
 - OFF LABEL USE
- 5) The Vapor / Liquid volume ratio is 200 mL Vapor / mL Liquid
- 6) A syringe with liquid agent must point up

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