## Summary

### What Is The Current Market For Inhalants?

Desflurane is a product that sees a high volume of use in human healthcare due to its very low potency (MAC) and low blood gas solubility. The ability of patients to rapidly exhale desflurane from the body makes it beneficial for short, outpatient surgeries where the patient needs to be fully recovered from inhalant used. The high cost of the electronic desflurane vaporizer (estimated at $8,000.00), the very limited options for mounting the vaporizer on machines and the high cost of the drug itself make this drug a virtual impossibility to be used in veterinary hospitals throughout the country.

Sevoflurane is similar to desflurane in regards to its low potency and low blood gas solubility compared to isoflurane and halothane. Recently there have been significant decreases in the cost of the drug and the available vaporizer options. This reduction in overall price has led to an ever increasing number of veterinarians and technicians that use sevoflurane. Anesthetists have found that the fairly large difference in MAC and Blood Gas Solubility between sevoflurane and isoflurane provides the value of being able to rapidly make changes in anesthetic depth throughout the procedure while using sevoflurane. This maneuverability provides the opportunity to minimize the side effects of the sevoflurane by delivering as little drug as possible while still maintaining the desired depth of anesthesia. The ability of patients to rapidly exhale sevoflurane from the body makes it beneficial for recovery by allowing the side effects of sevoflurane to be quickly eliminated. The speed of full recovery from anesthesia is impacted by the overall anesthetic protocol used.

Isoflurane started to be used in the veterinary market in the 1980s. It is now the most used inhalant anesthetic in the veterinary market. Its original popularity was due to the large difference in MAC and Blood Gas Solubility compared to halothane. Veterinarians and technicians use isoflurane mostly due to familiarity and an overall comfort with how the drug will perform. Anesthetists are cautious in changing the plane of anesthesia and tend to avoid the risk of having the patient in an undesirable depth of anesthesia. The ability to challenge the depth of anesthesia and thus limit the side effects of isoflurane is therefore restricted.

Isoflurane’s ability to be rapidly eliminated from the body is somewhat limited due to its fairly high blood gas solubility. This means isoflurane will not be eliminated from the patient’s body as quickly as desflurane or sevoflurane and the side effects of isoflurane are present longer in recovery. The speed of full recovery from anesthesia is impacted by the entire anesthesia protocol used.

Halothane’s use and availability in the veterinary market was discontinued in the late 1990s and early 2000s. Halothane’s high potency and very high blood gas solubility made it an obsolete product with the availability of sevoflurane and isoflurane.

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### Low Blood Gas Solubility Equates to Quicker Change, Speed. That’s Good Too!

<table>
<thead>
<tr>
<th>Inhalant Anesthetic</th>
<th>Blood Gas Solubility In Dogs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desflurane</td>
<td>0.42</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>0.68</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>1.46</td>
</tr>
<tr>
<td>Halothane (Discontinued)</td>
<td>2.54</td>
</tr>
</tbody>
</table>

Veterinarians are investing thousands of dollars in order to gain the benefits of inhalant anesthetics. The ability to adjust the depth of anesthesia throughout the procedure provides veterinarians and technicians the opportunity to deliver the ideal amount of drug to obtain the ideal outcome for that patient throughout the procedure. The fact that inhalant anesthetics can be exhaled means the body does not need to metabolize the drug and the effects of the drug can rapidly be eliminated from the body along with the side effects.

- A drug should provide the desired effect and be dosed to that desired effect
- The patient should quickly recover from the effects when no longer needed
- The side effects of the drug should go away quickly and not linger
What Is It About Inhalant Anesthetics Anyway?

Inhalant anesthetics are an integral part of a modern day veterinary hospital. Why is it that veterinarians pay thousands of dollars at each treatment area so they can administer one drug? The cost of technician training and continuing education, anesthesia delivery systems, oxygen delivery equipment, the oxygen itself, appropriate gas scavenging, CO₂ absorbent, vital sign and respiratory monitoring systems, routine maintenance of the equipment and the ongoing cost of the inhalant anesthetics themselves is obviously outweighed by the value the use of these drugs brings to the practice.

Even in a small clinic that has one or two anesthetic areas the veterinarian is investing thousands of dollars in the ability to provide general anesthesia that features the use of inhalant anesthetics for his or her patients.

Thirty years ago most patients presented to a veterinary hospital were young healthy animals for simple procedures. Now a large percentage of patients are older or present more complex diseases and conditions leading to higher patient anesthetic risk. The decision you make regarding which inhalant to use now matters more than ever.

The remainder of this document will present information to consider when choosing an agent for your practice.

Global warming potential (GWP) is the capacity of a gas to trap heat. The calculation of GWP is based on the atmospheric life of a gas and its infrared absorption capacity. The GWP of carbon dioxide (CO₂) is considered as reference and is assigned a value 1. Volatile anesthetics are stable halogenated molecules which do not disintegrate in the atmosphere.

Waste anesthetic gases (WAGs) rise up to the troposphere, remain nondegraded for extended periods (sevoflurane – 1.1 years, isoflurane – 3.2 years, desflurane – 14 years, and nitrous oxide – 14 years), and tend to trap the earth's radiant heat. The infra-red absorption potential of all agents is similar but the estimated 100 year-GWP (GWP100) for different volatile anesthetics is sevoflurane 130, isoflurane 510 and desflurane 2540. Desflurane has a high GWP100 because it is likely to remain in the atmosphere for a long period as it’s molecule doesn’t degrade. Out of the WAGs in clinical use, only isoflurane and nitrous oxide can react with the highly reactive ozone in the stratosphere and damage the earth's protective ozone barrier.¹


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What Do The Inhalation Anesthetics Do For You?

General anesthesia can be defined as the use of certain drugs to create unconsciousness that may include an insensitivity to pain and other sensations. This state permits the performance of surgery, painful procedures and diagnostic procedures requiring a lack of movement.

Unconsciousness

Muscle Relaxation

Anesthesia Triad

Analgesia

The role of inhalant anesthetics is to provide unconsciousness. Other drugs are frequently added to the protocol to immobilize, improve muscle relaxation or provide analgesia to lessen the amount of inhalants needed.

A RULE OF THUMB FOR DRUGS

► Most modern drugs are created for a specific effect
► A drug should provide the desired effect and be dosed to that desired effect
► The patient should quickly recover from the effects when no longer needed
► The side effects of the drug should go away quickly and not linger

As long as there is adequate blood flow and breathing, inhalants render the patient unconscious while freely moving in and out of the body. This constant movement provides the ability to change the level of effect without relying on full or even partial metabolism of the inhalant.

The ability to potentially dose to effect throughout the procedure along with rapid exhalation from the body with little to no metabolism is what makes these products so important. No other class of drugs has this ability. This is why you spent the money on all that equipment.

What Is The Difference In Potency Between Inhalants?

The potency or amount of inhalation agent likely needed to obtain a desired depth of anesthesia is called the Minimum Alveolar Concentration (MAC) of each agent. The MAC of modern inhalant anesthetics in dogs has been known for many years but remains a frequently misunderstood characteristic of inhalant anesthetics.

MAC is the average concentration of a particular inhalant that is present in the lungs when 50% of dogs don't respond to pain (no other drugs are present). The variables in response to pain are due to breed, age, fitness, genetics and other factors.

A HIGH MAC VALUE MEANS AN INHALANT IS LESS POTENT. AND THAT’S GOOD!

<table>
<thead>
<tr>
<th>Inhalant Anesthetic</th>
<th>Minimum Alveolar Concentration (MAC) in Dogs</th>
<th>1.5 times (MAC)</th>
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</thead>
<tbody>
<tr>
<td>Desflurane</td>
<td>7.68 - 8.19%</td>
<td>11.52 - 12.29%</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>2.36%</td>
<td>3.54%</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>1.30%</td>
<td>1.95%</td>
</tr>
<tr>
<td>Halothane (Discontinued)</td>
<td>0.87%</td>
<td>1.31%</td>
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Less potent inhalants provide a broader scale of choices. This wider range of deliverable doses makes it easier to accurately deliver the desired dose. More potent inhalants provide a narrow scale that can make it more difficult to titrate the desired amount.

What is most commonly lost in this picture is that the variability of each dog requires administration of the appropriate concentration of inhalant for each individual dog/patient at different times throughout a procedure. Each dog will have their own minimum alveolar concentration (MAC) when it comes to their level of response to pain or other stimulus. If this variability is then coupled with the variability of each dog's sensitivity to the premed and analgesia drugs that may be on board, the need to adjust the amount of inhalant administered to each patient at various times in the case becomes even more important.