



Inhalation Anaesthesia

This is the technique of administering anaesthetic agents via the lungs using a volatile agent being vaporized in a vaporizer by oxygen and then being administered to the patient through an anaesthetic breathing circuit or anaesthetic gas administered through a flowmeter and then passed into the breathing circuit.

Advantages:

- ☛ Recovery from anaesthesia is not dependent on the redistribution of the anaesthetic within the body since primarily exhaled through lungs.
- ☛ Recovery is primarily not dependent upon the body detoxification mechanisms,
- ☛ Anaesthetist has good control over the level of anaesthesia.
- ☛ Recovery is fast.
- ☛ Safe anaesthesia for longer surgical procedures.
- ☛ Oxygen and assisted controlled ventilation is available.
- ☛ Furthermore, should problem arise the inhalant anaesthetic (sevoflurane, isoflurane or halothane) can be eliminated quickly through ventilation.

Disadvantages:

- ☛ It is not suitable for healthy, unpremedicated animals because of the relatively slow speed of induction via inhalant anaesthetic. The induction is also frequently accompanied with vocalization, excitement, defecation, urination, and vigorous struggling.
- ☛ Constant surveillance is required by the anaesthetist.
- ☛ May be inflammable and explosive in nature.
- ☛ May be irritant to the body tissue.
- ☛ The equipment is not easily transported.
- ☛ Trained personals are needed to monitor the patient.
- ☛ Long procedures can cause severe physiological changes.
- ☛ The pungent smell of the isoflurane or halothane may prompt the animal to hold their breath during induction and therefore prevents the uptake of the inhalant anaesthetic and slows the speed of induction.
- ☛ Pollution of the work environment during induction. Waste inhalant anaesthetic gas may cause headaches and other health problems.

Phases of inhalation anaesthesia: Three phases

1. **Pulmonary phase:** The inhalant gas or the vapor is introduced into the lungs and transferred through the pulmonary epithelium to the capillary epithelium of the blood.
2. **Circulatory phase:** The inhalant gas or the vapor is in the circulation and distributed to the body tissues especially CNS.
3. **Tissue phase:** The inhalant gas or the vapor enters the tissues and produce the effect. The vessel rich group of tissues (brain, heart, intestines, kidneys, liver and spleen) and muscle group (skeletal muscles) are the primary tissues involved in the inhalant anaesthesia.



Minimum alveolar concentration (MAC): It is the anaesthetic concentration required to prevent gross muscular movement in 50% of the patients in response to painful (surgical) stimulus. In order to achieve clinical anaesthesia the anaesthetic concentration in the inhalant mixture should be equal to or more than MAC. The clinical signs are due to the action of the inhalant anaesthetics on the CNS and depth of anaesthesia is related to the amount of inhalant anaesthetic made available to the CNS.

Factors that decrease MAC:

- Hypotension
- Anemia (PCV < 13%).
- Hypothermia
- Metabolic acidosis
- Extreme hypoxia (PaO₂ < 38 mmHg)
- Age: old animal require less anaesthetic
- Premedication (opioids, sedatives, tranquilizers)
- Local anaesthetics
- Pregnancy
- Hypothyroidism
- Concurrent use of nitrous oxide

Clinical implications:

- If you anesthetize an anemic patient – you will need less inhalant anaesthetic to maintain this patient.
- If your patient is losing blood intra-operatively – i.e., hypotensive, you will need less inhalant anaesthetic to maintain this patient.
- If you are anaesthetizing a 15 years old dog – less inhalant anaesthetic.
- If you premedicated your dog or cat with acepromazine, xylazine, or morphine etc. before anaesthesia
- If you anaesthetize a pregnant mare
- If you anaesthetize a colic horse (with metabolic acidosis)
- If your patient is getting too cold intra-operatively
- **Factors increasing MAC**
 - Increasing body temperature – increases cerebral metabolic rate of brain
 - Hyperthyroidism
 - Hypernatrimia
- **Factors NOT affecting MAC**
 - Type of stimulation
 - Duration of anaesthesia
 - Species - MAC varies by only 10-20% from species to species
 - Sex
 - P_aCO₂ between range of 14-95 mmHg
 - Metabolic alkalosis
 - P_aO₂ between range of 38-500 mmHg
 - Hypertension
 - Potassium – no effect.

Various inhalant anaesthetics: Volatile or gaseous.

Volatile inhalant anaesthetics:

1. **Ether:** It was synthesized by Valerius Cordus in 1540 in Germany. Also listed as ethyl ether, diethyl ether, sulfuric ether and diethyl oxide.

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H - C - C - O - C - C - H

H H H H

- ☞ It is colorless with pungent smell and has burning taste.
- ☞ It is irritant in nature.
- ☞ The anaesthetic vapors are 2.6 times heavier than air.
- ☞ The liquid ether is lighter than water and also is slightly soluble in water.
- ☞ It is inflammable and explosive in nature.
- ☞ It gets oxidized in the presence of air, oxygen or light and there is production of toxic substances – peroxides and aldehydes. Therefore mostly stored in sealed containers with copper or other metal from inside which can combine with oxygen. Also can be stored in dark amber colored bottles to prevent exposure to light. Stored in cool places but not refrigerator.
- ☞ It is a very good CNS depressant and produces all stages of GA. It blocks sensory pathways to cortex and suppresses cortical activity
- ☞ **Administration:** By all methods of inhalation anaesthesia but closed system is preferred because of its explosive nature. Mostly used for maintenance of anaesthesia since takes very longer time for induction (3-10 min depending upon method of administration, concentration or premedication). Nearly 20% concentration is required for induction which can be fatal to the patient.
- ☞ **Concentration:** For maintenance of anaesthesia is 3.5 to 4.5% by volume in the inhalant mixture. More than 6.7% concentration may cause respiratory arrest. **MAC for ether is 1.92%.**
- ☞ **Clinical effects:**
 1. Struggling is seen for 3 min.
 2. Breath holding is common due to irritation of the respiratory tract mucous membrane.
 3. There is good muscular relaxation due to depression of motor endplate and centrally by suppression of pyramidal and extra pyramidal tracts.
 4. Sometimes there is paralysis of respiratory tract due to sudden inhalation of higher concentration (open/semi open system). Most deaths occur during induction only.
 5. It causes excessive salivation and increase in respiratory tract mucous secretions which interfere with respiration. This effect also lowers the

resistance of the lung tissue to infection and sometimes may lead to post operative pneumonia. This effect can be minimized by atropine sulfate premedication.

6. Oligurea is common due to irritation of the kidney tissue. May be associated with albuminurea and tubular casts.
7. There is a high incidence of post-anaesthetic nausea.
8. Cardiac arrhythmias are frequently seen. Cardiac output is increased during induction due to epinephrine release but in deep anaesthesia there is hypotension and decreased cardiac output.
9. Ether does not sensitize the myocardium to circulating catecholamines.



Advantages:

- a. Good muscle relaxation.
- b. Wide margin of safety.
- c. Respiratory stimulant initially.
- d. Doesn't disturb circulation to greater extent.
- e. Stable, easily stored and inexpensive.
- f. Can be administered with minimum equipment.



Disadvantages:

1. Long induction time.
2. Excitement during induction.
3. Recovery is slow.
4. Irritant, inflammable and explosive.
5. Post anaesthetic nausea.



Contraindications:

- a. Acute/chronic respiratory infection.
- b. Respiratory acidosis.
- c. Kidney, liver diseases.
- d. Shock.

2. Chloroform:



It is heavy, clear, sweet with pleasant odor and noninflammable.



It is non-irritant to skin and mucous membrane.



Agent decomposed by poor quality soda-lime in the presence of heat.



When heated in air – highly toxic phosgene gas is produced. 1% ethyl alcohol is added to prevent phosgene production as there is formation of ethyl carbonate and ethyl chloride.



Chloroform is the most powerful inhalant anaesthetic but has a low safety margin and cardiac arrest may coincide with respiratory failure.



Administration: By open/closed systems.



☞ **Concentration:** 1.35% for light anaesthesia and 1.65% for deep anaesthesia. More than 2% concentration may cause death due to respiratory arrest. The MAC value is 0.77% in dogs.

☞ **Clinical effects:**

1. Deep and accelerated respiration during induction due to struggling. As anaesthesia deepens, respiration becomes slow and shallow.
2. Causes dilatation of the left atrium since first exposed to high concentration of the anaesthetic. Sometimes fatal poisoning of the heart is seen and there is progressive atrial and ventricular dilatation until cardiac failure.
3. Initially there is hypertension due to struggling but as the anaesthesia deepens a decrease in the blood pressure is observed which is due to direct relaxing effect on the blood vessel musculature.
4. Anurea is commonly seen due to decreased kidney function. Later on polyurea and albuminurea are seen in the post anaesthetic period.
5. **Death following chloroform is common.** During induction due to ventricular fibrillation; During prolonged anaesthesia due to respiratory failure and during post anaesthetic period due to central necrosis of the liver and fatty degeneration of heart kidney and liver.

☞ **Contraindications:** cardiac, hepatic and kidney diseases. **Due to its poor safety record it is not used nowadays.**

3. Halothane:

Br F

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Cl F

- ☞ Clear, colorless and non irritant.
- ☞ Noninflammable and non explosive.
- ☞ Slight decomposition when exposed to light. Therefore stored in amber colored bottles and 0.01% thymol is added to it to make it more stable.
- ☞ Not affected by warm soda lime.
- ☞ 4 times as potent as ether and 2 times as potent as chloroform.
- ☞ Recovery is rapid and free from excitement.



☞ Twenty-thirty percent of halothane is metabolized by the liver and the main metabolites include trifluoroacetic acid and bromide ions. The latter have been incriminated as the cause of post-halothane sedation.

☞ Halothane can be used in veterinary patients with some liver dysfunction as long as hypoxia, hypercarbia and hypotension are avoided.

☞ **Administration:** By closed system using precision vaporizers as very costly.

☞ **Concentration:** 2-4% can produce stage III in dogs and small animals (4-10% in large animals). The maintenance concentration is 0.8-2.3% in the inhalant mixture. **The MAC for dogs is 0.86% and for cats is 0.98%.**

☞ **Clinical effects:**

1. Respiration is depressed leading to decreased tidal volume. Sometimes there is apnea. Normally a progressive respiratory acidosis results.
2. Bradycardia is observed and pulse becomes slow.
3. Hypotension is normally recorded following halothane administration which is due to 4 reasons: Ganglionic blocking action; central vasomotor depression; direct vascular smooth muscle depression and direct myocardial depression.
4. Salivary, mucous and bronchial secretions are absent.
5. There is negligible direct effect on the liver and kidney functions. Renal function is depressed, usually due to concurrent hypotension.
6. Halothane sensitizes heart to the action of epinephrine.
7. Deaths have occurred when high concentrations have been given to unpremedicated animals.
8. Laryngospasm may occur in cats.
9. Analgesia offered by halothane is reasonable as is muscle relaxation.
10. The eye is rotated down at a surgical plane of anaesthesia in cats and dogs.
11. Post-anaesthetic shivering is sometimes seen in normothermic animals and the reason for this is unknown. This can be a problem in patients with limited cardiopulmonary reserves because shivering can increase body demand for oxygen 300%.

4. Methoxyflurane:

Cl F H

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Cl F H



- ☞ It is halogenated ethyl methyl ether.
- ☞ It is clear colorless liquid with 'fruity' odor.
- ☞ It is non explosive and non inflammable in nature.
- ☞ Very stable volatile inhalant anaesthetic agent (stable in air, moisture, alkali etc.). However it reacts with metal in anaesthetic circuits and is unstable in light.
- ☞ It is a very poor induction agent. It produces slow inductions and recoveries.
- ☞ **Administration:** By closed system using precision vaporizers as very costly.
- ☞ **Concentration:** 0.4 to 1% in the inhalant mixture for maintenance of anaesthesia.
- ☞ **Clinical effects:**
 1. The compound persists in the blood even 24 hr after anaesthesia.
 2. Causes dose dependant respiratory depression but extremely difficult to produce respiratory arrest.
 3. It causes a dose dependent depression of the cardiopulmonary system although the heart rate and blood pressure generally remains stable due to the release of endogenous catecholamines. The myocardium is sensitized to catecholamines, but not as severely as with halothane.
 4. There is decrease in the tone and motility of GI tract but salivation is not observed.
 5. It causes excellent muscular relaxation.
 6. It is 50-70% metabolized in the liver with the production of renally toxic fluoride ions. It should not be used with renally excreted drugs such as tetracyclines and flunixin. Other metabolites include carbon dioxide, oxalic acid and methodifluoroacetic acid.
 7. The eye tends remains in a central position at surgical planes of anaesthesia in cats and dogs (similar to ether).

5. Enflurane:

F F F

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Cl F F

- a. Mildly pungent, potent, fairly insoluble and stable agent.
- b. Rapid induction and recovery.
- c. The analgesia is considered to be poor and the muscle relaxation becomes poor with increasing concentrations.



- d. At high concentrations (>3.5%) there is increased central stimulation and seizure like activity. Avoid its use in seizure-prone patients.
- e. There is no stimulation of sympathetic tone and there is a dose dependent depression of the cardiopulmonary system.
- f. Enflurane only slightly sensitizes the myocardium to circulating catecholamines, but does so more than isoflurane.
- g. The eye remains central during surgical planes of anaesthesia.
- h. The agent is 2% metabolized by the liver with some free fluoride ions produced.
- i. **The MAC value is 2.1% in dogs, higher than isoflurane or halothane.** It is more expensive than halothane with no real advantages.

6. Isoflurane:

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F C I F

- ☞ This is a newer agent, less potent than halothane or methoxyflurane.
- ☞ Relatively insoluble leading to fast inductions and recoveries.
- ☞ It is non-flammable and has a saturated vapour pressure similar to halothane.
- ☞ It does have a fairly pungent odour and so should be introduced to the patient slowly for a mask induction.
- ☞ Isoflurane is a stable compound which does not break down on contact with soda-lime or in the presence of light.
- ☞ There is a dose dependent cardiovascular depression and very little cardiac sensitization to catecholamines.
- ☞ Isoflurane lowers blood pressure through a decrease in total peripheral resistance rather than through a direct myocardial depression (unlike halothane). There is less disruption of central nervous system autoregulation of blood pressure and so may be indicated for use in head injury patients.
- ☞ Isoflurane has slightly better muscle relaxation than halothane and comparatively less analgesia.
- ☞ Isoflurane does not promote seizure activity.
- ☞ Due to its good cardiac stability, its use is indicated in patients with some cardiac dysfunction. This is especially true for patients with arrhythmias which may worsen with halothane. It is also safer for mask inductions because of little myocardial sensitization to released catecholamines.
- ☞ Isoflurane is 0.2% metabolized by the liver so is safer for patients with serious liver dysfunction.



- ☛ Isoflurane is more of a respiratory depressant than halothane, resulting in hypoventilation and hypercapnia. The alveolar concentration that produces apnea in dogs is 2.4 times MAC.
- ☛ Blood flow to the liver and kidney is reduced, but changes are rapidly reversed during recovery.

MAC for dogs is 1.28% and for cats is 1.63%.

7. **Desflurane:** Totally fluorinated ether. Now released for use in humans. Needs new vaporizer technology which has increased the cost of using desflurane considerably. Desflurane's use in veterinary anaesthesia will be limited by economics. Circulatory and respiratory effects are similar to isoflurane.

MAC in dogs is 7.2%.

8. **Sevoflurane:** Still undergoing toxicity tests regarding breakdown products produced on contact with soda-lime. There are also some fluoride ions on metabolism. Available in Japan for use in humans. Effects are similar to isoflurane.

MAC in cat is 2.58%; MAC in dog is 2.36%.

Gaseous inhalant anaesthetics:

1. Nitrous oxide (N₂O):

- ☛ It is a colorless, sweet, inert and non irritant anaesthetic gas.
- ☛ It is 1.53 times heavier than air.
- ☛ It is non inflammable but supports combustion.
- ☛ Non explosive in nature.
- ☛ It is produced by heating ammonium nitrate to about 250°C and the gas is compressed into liquid form at 40 atmospheric pressure in sky blue cylinders. The liquid continuously vaporizes to form the gas at a constant pressure.
- ☛ The anaesthetic is exhaled unaltered through lungs.
- ☛ It is very good analgesic but very poor anaesthetic. **It is 6.5 times less potent than ether.** The MAC in dogs is 188% and in cats is 255% which is impossible to achieve clinically so anaesthesia is not attainable.
- ☛ **Administration:** By semi closed or closed method with oxygen. Mostly used with volatile anesthetics in 40-70% concentration. Minimum of 30% of oxygen should be there in the inhalant mixture.
- ☛ May cause hypoxia and asphyxia in the animals therefore 100% oxygen is administered to the patient for a few minutes after turning off the nitrous oxide.

2. Cyclopropane (C₃H₆):

- ☞ It is very potent and quick acting gaseous anaesthetic.
- ☞ It is nonirritating but **highly explosive and inflammable** in nature.
- ☞ It is respiratory depressant and causes vasodilation – leading to increased haemorrhage at the operative site.
- ☞ It sensitizes heart to the action of catecholamines.
- ☞ Cyclopropane can cause cardiac arrhythmias especially in the presence of hypercapnia.
- ☞ **Administration:** By semi closed or closed method in 15-20% concentration with oxygen.
- ☞ **Since highly explosive, it is not used now a days.**

3. **Carbon dioxide (CO₂):** It has been used as gaseous inhalant anaesthetic for lab animals like rabbits, rats etc. in 1:1, or 3:2 ratio with oxygen using anaesthetic chambers.

Color code system for gas cylinders:

1. **Oxygen:** Grey/black with white top.
2. **Carbon dioxide:** Grey/black
3. **N₂O:** Light or sky blue.
4. **Cyclopropane:** Orange.

Pin index system: This is a system which has been devised to prevent inhalation of the wrong gas. This is known as “**American Standard Connection No. 860 pin index safety system.**” This system consists of two pins protruding from the yoke of the inhalant anaesthetic machine which must fix into the matching holes of the specific gas (O₂, CO₂ or N₂O) cylinder.

<u>MAC OF VARIOUS INHALATION AGENTS</u>			
AGENT	DOG	CAT	HORSE
HALOTHANE	0.86	0.98	0.88
ENFLURANE	2.2	2.37	2.12
ISOFLURANE	1.28	1.63	1.31
METHOXYFLURANE	0.23	0.23	NA
NITROUS OXIDE	188.0	255.0	NA
DESFLURANE	7.2	NA	NA