6 Effects of Insufflation

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6.1 Insufflating Gas Properties

The ideal properties of insufflation gas are:

1. Minimal peritoneal absorption.
2. Minimal physiological effects.
3. Rapid excretion.
4. Noncombustible.
5. Minimal effect after vascular embolization.
6. High solubility in blood.

No gas at present fulfils all of these criteria; however, carbon dioxide (CO_2) could be considered as the closest for endoscopic surgery.

This chapter deals on the effects of insufflated gases in laparoscopic surgery (for thoracoscopic surgery see Chap. 10).

6.2 Gas Delivery Systems

Gas delivery systems are composed of a containment cylinder, insufflator, tubing, filter, and abdominal entry device or port. The cylinders contain the gas as a liquid under pressure of 57 atm (5775.5 kPa). Over time, the cylinders build up inorganic and organic contamination, thus requiring filtration of the gas prior to insufflation of a patient's thorax or abdomen.

6.3 The Jewel-Thompson Effect

The pressure change from the containment cylinder to the insufflator and into the patient's abdomen/thorax causes cooling according to the Jewel-Thompson effect. The temperature of CO_2 gas is about 20.1°C as it enters the abdomen. Gas flow contributes to hypothermia by convection effects. The net effect is a loss of 0.3°C per 60 l of gas insufflated.

6.4 Insufflation Flow Values

Flow should be started at an initial rate of 0.5 l/min to rule out any obstruction. Once the pneumoperitoneum/pneumothorax has been established the insufflation rate can be changed to a higher setting of approximately 0.5–2 l/min to speed up the process. When the limit is reached, the rate of flow can be decreased to 0.1–0.2 l/min.

6.5 Water Content of Gases

The gases used for pneumoperitoneum have low water content. The water content of CO_2 is less than 200 ppm. Dry insufflation gases cause drying of the peritoneum and result in intact mesothelial cells being lost or desiccated from the peritoneum surface. Continuous or intermittent moistening should be performed in order to preserve peritoneal surface integrity and to decrease the tendency toward adhesion formation.

6.6 Insufflation Pressures

The surgeon decides upon the desired pressures required for the pneumoperitoneum. Although no absolute values can be recommended, pressures in the following ranges are considered to be safe:

1. 6–8 mmHg for infants.
2. 8–12 mmHg for small children.
3. 12–15 mmHg for older children/adolescents.

For thoracoscopic procedures lower pressures between 4–8 mmHg are recommended.

6.7 Dynamic Condition

The inactive and invisible pneumoperitoneum is not a static condition and must not be ignored in endoscopic surgery. The pneumoperitoneum is a dynamic space that affects the patient's condition and specific physiologic cellular processes.

The insufflation gas needs to be:

1. filtered to reduce contamination,
2. heated to reduce hypothermia, and
3. hydrated to preserve cellular integrity and reduce adhesion formation.

6.8 Stress/Immunologic Responses

Changes in systemic inflammatory and anti-inflammatory parameters (mainly cytokines) as well as in stress response parameters are less pronounced after laparoscopic surgery than after conventional surgery. Whether this leads to clinically relevant effects (e.g., less pain, fatigue, and complications) remains to be proven. There is no compelling clinical evidence that specific modifications of the pneumoperitoneum alter the immunological response.

6.9 Physiological Changes From CO_2

Physiological changes during laparoscopic surgery are related mainly to the increased intra-abdominal pressure (IAP) associated with CO_2 insufflation of the abdomen, the patient's postural modifications (head-up or head-down), and CO_2 absorption. During pneumoperitoneum, younger children absorb proportionately more CO_2 than older individuals.

6.10 Cardiopulmonary Effects

Increases in IAP affect both ventilation and circulation. Increased IAP induces a mechanical compression of the diaphragm that reduces pulmonary compliance, vital capacity, functional residual capacity, basilar alveolar collapse, and total lung volume. Pneumoperitoneum in children has a major impact on cardiac volumes and function, mainly through the effect on ventricular load conditions.

6.11 Combustion Under Low Oxygen Content

1. Combustion processes that occur in low-oxygen environments cause elevated carbon monoxide emissions.
2. Peritoneal absorption of carbon monoxide causes carboxyhemoglobin formation.
3. The affinity of carbon monoxide for hemoglobin is 200–240 times greater than that of oxygen.
4. Carbon monoxide can cause cardiac arrhythmias and exacerbate complications.
5. Hence, smoke within the pneumoperitoneum should be intermittently evacuated.

6.12 Venous Blood Return

1. During laparoscopy, both the head-up position and elevated IAP independently reduce venous blood return from the lower extremities.
2. Intraoperative sequential intermittent pneumatic compression of the lower extremities effectively reduces venous stasis during pneumoperitoneum and is recommended for prolonged laparoscopic procedures.
3. The true incidence of thromboembolic complications after pneumoperitoneum is not known.

6.13 Methemoglobinemia

1. Methemoglobinemia may occur during tissue combustion.
2. Methemoglobin is the oxidative product of hemoglobin causing the reduced ferrous to be converted to the ferric form.
3. The difference between methemoglobin and oxyhemoglobin in the ferric state is that methemoglobin is formed from unoxygenated hemoglobin and is not capable of carrying either oxygen or CO_2.
4. This property shifts the oxyhemoglobin dissociation curve to the left, inhibiting oxygen delivery to tissues.

6.14 Intra-abdominal Organ Perfusion

Although in healthy subjects changes in kidney or liver perfusion and also splanchnic perfusion due to an IAP of 12–14 mmHg have no clinically relevant effects on organ function, this may not be the case in patients with already impaired perfusion. In particular, in patients with impaired hepatic or renal function or atherosclerosis, the IAP should be as low as possible to reduce microcirculatory disturbances.

6.15 CO_2 Elimination After the Procedure

The short-lived increase in CO_2 elimination post-desufflation may be related to an increase in venous return from the lower limbs after release of the abdominal pressure. CO_2 absorbed by the peritoneal surfaces can cause hypercapnia, respiratory acidosis, and pooling of blood in vessels resulting in decreased cardiac output. This effect is controlled by the anesthesiologist by increasing minute ventilation to maintain normocapnia.

Recommended Literature

1. Balick-Weber CC, Nicholas P, Hedreville-Montout M, Blanchet P, Stephan F (2007) Respiratory and haemodynamic effects of volume-controlled vs pressure-controlled ventilation during laparoscopy: a cross-over study with echocardiographic assessment. Br J Anaesth 99:429–435
2. De Waal EE, Kalkman CJ (2003) Haemodynamic changes during low-pressure carbon dioxide pneumoperitoneum in young children. Paediatr Anaesth 13:18–25
3. Tobias JD (2002) Anaesthesia for minimally invasive surgery in children. Best Pract Res Clin Anaesthesiol 16:115–130

6.16 Shoulder Pain after CO_2 Insufflation

Several causes of shoulder pain following laparoscopic surgery have been suggested:

1. The effect of CO_2 gas.
2. Peritoneal stretching.
3. Diaphragmatic irritation.
4. Diaphragmatic injury.
5. Shoulder abduction during surgery.

The pain after laparoscopic procedures is usually transient and disappears in a day or two.