The term *minimally invasive surgery* conjures up an image of innovation and cutting-edge technology that differs in a fundamental way from conventional surgical methods. Novel procedures have been introduced that have a spectrum of complications and contraindications that differs distinctly from that of the conventional method and requires a modification of standard anaesthetic management. These, obviously, deserve to be dealt with in detail in a book on perioperative management from the more comprehensive viewpoint of the anaesthetist. But all attempts at a general definition of which procedures should be included show how elusive the term actually is. If one takes it to describe procedures that do not require large incisions or extensive tissue destruction, it would include such diverse operations as circumcisions, cataract extractions or transurethral bladder surgery – none of which belong in this book. What then is the characteristic, the common denominator of what we generally refer to as “minimally invasive”? The answer lies in the context: minimally invasive does not refer to the magnitude of invasiveness as an absolute measure, but rather to the invasiveness compared with that of the conventional procedure. Add to this the element of novelty and a particular relevance for anaesthesia and one has a fairly good description of the scope of this book.

Minimally invasive surgery has virtually revolutionized the surgical therapy of a large variety of diseases in the space of just a few years. While progress in the more spectacular surgical specialties, such as heart surgery, organ transplantation, or separating Siamese twins, captures the public imagination to a greater degree, these benefit only a small segment of the population. Endoscopic surgery, on the other hand, has changed the management of some of the most frequently performed surgical procedures, the most notable among these being gall bladder surgery. The continuing interest in endoscopic surgery is not only due to its aesthetic and cosmetic advantages, but also to the potentially smoother postoperative course, with fewer complications and a swifter return of the patient to his normal daily life. However, in order to exploit this potential to its fullest, perioperative anaesthetic management must adapt to the altered requirements of the new techniques.

Most, but not all, of these procedures are performed through small incisions with the aid of an endoscope. This has led some, particularly in the UK, to prefer the term “minimal access surgery”. The endoscope most frequently used is the laparoscope, and the procedures are sometimes referred to collectively as laparoscopic surgery, even though the operation site might be in the retroperitoneum or the mediastinum. Since these are the operations that started the present fascination with minimal invasiveness, and are also the ones whose anaesthetic management differ most from conventional operations, they shall be dealt with first in this introductory chapter.

Laparoscopy itself is not a new technique, but one that has been in use since the beginning of the 20th century, although it was mainly used only for diagnostic purposes. The urologist Georg Kelling examined the peritoneal cavity of a dog in 1901 with the aid of a cystoscope, and called the procedure “koelioskopie”, the term by which it is still known in France.1 In 1910, Jacobaeus described the first major series of such examinations in humans, in whom he studied both the peritoneal and the thoracic cavities.2 He coined the terms “Laparoskopie” and “Thorakoskopie” to describe the two techniques. Kalk improved the optical instruments and used two trocars instead of only one.3 In 1938, Janos Veress introduced the insufflation needle that still bears his name (Figure 1.1).4 The introduction of automatic insufflation devices resulted from the innovative...
Surgical working conditions were improved greatly by attaching a video camera to the endoscope and transmitting the view to a television monitor. This allowed the surgeon to stand in a normal position, and also made it possible to train several assistants simultaneously.

Gynaecologists, above all Semm and Lindemann, were the ones who pioneered the development of a technique with which intra-abdominal operations could be carried out without having to make a large abdominal incision. This led to a marked increase in the number of laparoscopic operations in the 1970s, when laparoscopic ligation of the Fallopian tubes became a normal method of contraception.

The first laparoscopic cholecystectomy, which might be regarded as the birth of minimally invasive surgery as we understand it, was performed by Philippe Mouret in Lyons in March 1987. From this moment on, the technique spread worldwide, despite the controversy it ignited and the vigorous initial resistance from parts of the surgical establishment. In time, other surgical specialties, such as urology, gynaecology and thoracic surgery, developed their own applications for the endoscopic technique and the cholecystectomy was joined by numerous other indications and operations.

One salient feature of the boom in laparoscopic surgery was the dramatic increase in the average duration of the operations due to the shift in the spectrum of surgical procedures. While the usual maximum duration of the typical diagnostic or sterilization procedure was less than 20 min, the average duration of laparoscopic operations is now 60–120 min, with some even lasting many hours. A second feature of the rapid expansion was that the indications widened to encompass a completely different patient population; whereas laparoscopic surgery had been formerly performed mainly on healthy young women, all age groups were now represented, from the hypotrophic, premature neonate to the nonagenarian. The method was also no longer restricted to large medical centres, but had spread with incredible speed on a broad front with even small- and medium-sized hospitals taking advantage of the new techniques. These factors meant that every anaesthetist was likely to be required to deal with laparoscopic operations of varying difficulty at some point.

**Laparoscopic operations**

In the short time since the first laparoscopic cholecystectomy was performed, development has advanced at such a rapid pace that there is now almost no surgical procedure that has not at least been attempted with endoscopic methods. Certain standard laparoscopic operations have become part of the repertoire of nearly every moderately well-equipped clinic. There is then the shifting group of laparoscopic operations that are routinely performed in specialized centres, and although no longer regarded as investigational, nevertheless require the experience of specialists. And then there is a continuously growing list of laparoscopic procedures that stand more or less at the cutting edge of medical science – some of which find their way into clinical routine, while others are dropped as not practicable. Laparoscopic operations routinely offered by many hospitals include cholecystectomy, appendectomy, tubal ligation, treatment of ectopic pregnancies, minor urological operations and many others. Other operations such as hernia repair, laparoscopically-assisted vaginal hysterectomy, enucleation of myomas, ovarian cysts, etc. have also become standard.

Some hospitals perform extensive abdominal and thoracic operations endoscopically, including major bowel resections, pancreatectomy, splenectomy and even oesophagectomy. A wide range of urological operations such as nephrectomy, adrenalectomy or radical prostatectomy with retroperitoneal lymphadenectomy are performed endoscopically. Paediatric urology is another field in which endoscopic operations are becoming very common.

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**Table 1.1 Selected endoscopic operations**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Where conducted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholecystectomy</td>
<td>General hospitals</td>
</tr>
<tr>
<td>Hernia repair</td>
<td></td>
</tr>
<tr>
<td>Appendectomy</td>
<td></td>
</tr>
<tr>
<td>Tubal ligation</td>
<td></td>
</tr>
<tr>
<td>Uterine myomas</td>
<td></td>
</tr>
<tr>
<td>Cryptorchism, orchidopexy</td>
<td></td>
</tr>
<tr>
<td>Ectopic pregnancy</td>
<td></td>
</tr>
<tr>
<td>Oophorectomy etc.</td>
<td></td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>Specialized centres</td>
</tr>
<tr>
<td>Gastric surgery</td>
<td></td>
</tr>
<tr>
<td>Splenectomy</td>
<td></td>
</tr>
<tr>
<td>Bariatric surgery</td>
<td></td>
</tr>
<tr>
<td>Lung surgery</td>
<td></td>
</tr>
<tr>
<td>Coronary artery surgery</td>
<td></td>
</tr>
<tr>
<td>Thoracic sympathectomy</td>
<td></td>
</tr>
<tr>
<td>Oesophagectomy</td>
<td></td>
</tr>
<tr>
<td>Nephrectomy, kidney</td>
<td></td>
</tr>
<tr>
<td>Adrenalectomy</td>
<td></td>
</tr>
<tr>
<td>Radical prostatectomy</td>
<td></td>
</tr>
<tr>
<td>Hepatic resection</td>
<td></td>
</tr>
<tr>
<td>Retroperitoneal and pelvic lymphadenectomy</td>
<td></td>
</tr>
</tbody>
</table>

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are divided regarding the question of whether laparoscopic surgery of malignant tumours is contraindicated,30,32,33 while another controversy involves the question of whether laparoscopic surgery is contraindicated during pregnancy.34–36 Obesity was once considered almost an absolute contraindication against laparoscopic surgery, but has now morphed into a strong indication.37,38 Even weight reduction surgery in the morbidly obese is thought to have a lower total risk of serious complications when performed laparoscopically. Table 1.1 presents an overview of the range of endoscopically performed operations. This list is neither comprehensive nor final, as new techniques are constantly being added, and interventions regarded as investigational at best today, will have become routine operations tomorrow.

Technical aspects of laparoscopic surgery

Laparoscopic operations are basically very standardized procedures that begin and end with a set sequence of events. A brief description of these phases will help to understand the contribution required of the anaesthetist and also to understand the pathology of a number of potentially lethal complications that can occur during laparoscopic surgery, most of which are caused by faulty surgical technique or malfunctioning equipment. These points will be taken up in more detail in the following chapters.

In the first step of the operation, the abdomen is inflated by leading gas into the abdominal cavity under pressure to create a pneumoperitoneum. This is sometimes referred to as a capnoperitoneum43 in order to call attention to the particular problems that arise from using carbon dioxide (CO2) as the insufflation gas (see Chapter 2). The surgeon lifts the ventral wall of the abdomen and introduces a specially designed safety needle through a small incision in the navel (Figure 1.2) for the initial inflation phase. The abdominal muscles must be well relaxed for this manoeuvre to succeed. This needle, known as a Veress needle after its inventor, is about 3–4 mm in diameter, and has a blunt, spring-loaded obturator that protrudes past the tip of the needle (see Figure 1.1). When the needle meets firm resistance, as for example when it is pushed through fascia or muscle, the tip of the obturator is pressed back, exposing the sharp tip of the needle. After the needle penetrates the peritoneum, the obturator tip springs forward, preventing the needle from damaging the intestines or other intra-abdominal organs. Once the correct intra-peritoneal position of the Veress needle has been confirmed, insufflation is started slowly and the patient is monitored closely. The gas flow rate is then increased and the abdomen inflated to a pressure of about 12 to 15 mmHg. IAP is kept constant with an electronically controlled insufflator (Figure 1.3) at a level sufficient to maintain optimal operating conditions for the surgeon (usually about 10–15 mmHg). Neuromuscular block must be sufficient during this period to keep the abdominal cavity compliant, and to prevent its being compressed by the return of muscular tension.

The typical adverse events that can happen during this phase of the operation is the insufflation of gas into preperitoneal tissue or directly into a blood vessel. The former is not infrequent, but is rarely serious, and requires no particular action on the part of the anaesthetist. Intravascular gas insufflation, on the other hand, can be extremely serious and requires rapid, deliberate action to avoid a lethal outcome (see Chapters 2 and 6).

When the abdomen has been sufficiently inflated, the Veress needle is removed and replaced with a larger trocar introduced through the same incision (Figure 1.4). The primary complication of this manoeuvre is injury to large vessels, such as the aorta or the iliac vessels,44,45 or perforation of hollow viscera. Safety trocars with a sharp tip that retracts itself automatically once it has passed the peritoneum are now available. The obturator in the trocar is then removed and a laparoscope is introduced through the sleeve and used to guide the placing of the following trocars, the number and location of which vary according to the operation. The first trocar is used for intraoperative

Figure 1.2 Blind introduction of the Veress needle.
insufflation and it can become dislodged with resulting insufflation of gas into preperitoneal tissues. The anaesthetist is frequently the first to notice this problem when end-tidal CO₂ concentrations start to rise. Statistics on the mortality associated with laparoscopy are available from 1949 to the present. In the period from 1949 to 1977, when it was primarily a diagnostic procedure, there was a mortality rate of 0.09% of a total of 265,900 laparoscopies performed. From 1983 to 1985, the rate had fallen to 0.024% of almost 250,000 operations. In the US in the year 1977–1978, a mortality rate of 0.04% was registered for 750,000 sterilizations, which were carried out by laparoscopy as well as laparotomy. Of the cases resulting in death, 16 occurred in connection with laparoscopy, of which six were classified as anaesthetic complications. Even for the very short surgical procedures evaluated in this study, the risk of death was low but not negligible, considering that the patients were healthy and young. The expanding range of indications with operations having an order of magnitude increase in duration, and the inclusion of patients from extreme age groups and high-risk patients with serious pre-existing pathologies will obviously increase the risk of morbidity and mortality. The realization of this fact should act as a clear warning against incautiously equating minimal invasiveness of the operation with minimal risk to the patient, and should induce the anaesthetist to do his or her utmost to contribute towards minimizing this risk. The most important factors that the anaesthetist has to take into account during laparoscopic operations are the pathophysiological changes due to gas insufflation, the risk of intravascular gas injection and the occasionally extreme position of the patient.

There are other entire groups of minimally invasive operations that are not performed by laparoscopy and thus are not associated with the problems of the pneumoperitoneum and CO₂ insufflation. They will be described in detail in their respective chapters and are therefore only mentioned shortly at this point. Among these are thoracoscopic surgery, minimal access cardiac and coronary surgery, endoscopic laser surgery of the aerodigestive tract and endoscopic neurosurgery. Thoracoscopic operations differ less from their conventional counterparts than the laparoscopic operations do from theirs, and anaesthetic management will not require the same extent of adaptive modifications. The peripheral lung is easily accessible with an endoscope, and thoracoscopic operations, such as wedge resection or lobectomy, ablation of blebs and others have become common. The mediastinum can be approached either by the traditional suprasternal access or through the pleural cavity after allowing the lung to collapse. Cardiac and coronary artery surgery can be considered minimally invasive if they avoid using a midline sternotomy or extracorporeal circulation, the two factors that contribute most to the invasiveness of the conventional methods. Endoscopic laser surgery of the aerodigestive tract allows operations that are not possible by any other...
means. Tissue trauma can be extensive when considered in relation to the narrow anatomy of the larynx, but postoperative recovery is rapid and usually uneventful. Endoscopic and microsurgical procedures in neurosurgery are truly much less invasive than their conventional counterparts and do not generally require any modification of anaesthetic management.

The following chapters will deal with important anaesthesiological aspects of modern minimally invasive surgery, be it endoscopic surgery of the abdomen or thorax, endoscopic laser surgery of the larynx and adjacent structures, or endoscopic neurosurgery. They are designed to offer the anaesthetist the specialised theoretical and practical knowledge which he or she needs to meet the particular challenges of these operations, and to provide competent anaesthetic care with optimal risk reduction for the patient.

References


The physiological consequences of laparoscopic–endoscopic surgery are primarily due to the effects of increased intra-abdominal pressure (IAP) and the systemic absorption of the insufflated gas. The magnitude of these changes is modulated by the position of the patient and the choice of insufflation gas.

Operations in the peritoneum, uterus or bladder require active expansion of the pre-existing cavity by the application of exogenous pressure. This is usually unnecessary for thoracoscopy, where the self-retracting tendency of the lungs is exploited and reinflation of the lungs is prevented by a selective ventilation, such as with a double-lumen endotracheal tube. In operations on organs surrounded by connective tissue, such as in the retroperitoneum (nephrectomy, adrenalectomy, lymphadenectomy), the groin (hernia repair), or in the mediastinum, an artificial cavity must be created with insufflated gas or with the aid of a dilation balloon. The specific effects of these measures will occur in addition to the already ongoing changes resulting from anaesthesia and surgery.

Circulation

During laparoscopic surgery, the circulation undergoes typical changes of cardiac output (CO), blood pressure, venous pressure and cardiac filling pressures that are the result of the complex interactions between anaesthesia, patient position, pressure changes in the body cavities and neuroendocrine reactions. Depending on the circumstances, the effects of these factors can either reinforce each other or they can cancel each other out.

Increased IAP and the patient’s position (supine, head-down Trendelenburg, or head-up reverse Trendelenburg) are – given constant arterial carbon dioxide (CO₂) tension – the main determinants governing circulatory changes during laparoscopy. These two factors must be considered separately, since they can either reinforce or oppose each other, depending on body position. If ventilation is not adjusted properly, CO₂ retention will occur causing initial stimulation and then, ultimately, depression of the circulation, depending on the extent of the resulting hypercapnia and acidosis (see the following text).

Cholecystectomy is one of the most common laparoscopic operations, and a discussion of the effects of laparoscopic surgery on the circulation should be begin with this operation that is typically performed with the patient in the reverse Trendelenburg, head-up position. Joris and co-workers describe the typical haemodynamic course of a laparoscopic cholecystectomy in healthy patients in a 15–30° head-up position. After induction of anaesthesia in the supine patient, there is usually a parallel reduction of CO and mean arterial pressure (MAP). Changing from the supine to the reverse Trendelenburg position induces a further fall in blood pressure and CO accompanied by a decrease in right and left ventricular filling pressures, measured as right atrial pressure (RAP) and pulmonary capillary wedge pressure (PCWP).

Inflating the abdomen with the patient in this position causes an initial increase in MAP, RAP and PCWP with a decrease in CO. Systemic blood pressure gradually returns to the baseline level at anaesthesia induction, RAP and PCWP increase to above their initial levels, while CO decreases still further. There is a sharp rise in peripheral systemic vascular resistance (SVR), which is partly responsible for the observed increase in blood pressure. The changes in MAP and central venous pressure (CVP) are significantly less when the abdominal cavity is expanded with an external lift and not by increasing IAP. This situation lasts only for about 15–20 min, after which CO returns to the baseline level before insufflation, blood pressure remains constant, and SVR decreases slightly, while RAP and PCWP still remain elevated. Since the reduction of CO lasts only such a short time, it may be easily missed if measurements are not timed properly. This could be a reason for the contradictory results of various studies. Figure 2.1 summarizes the behaviour of CO in the studies of Joris et al. and Reid et al. The reasons for the gradual normalization of CO are not entirely clear. Some authors see it secondary to a reduction in afterload, while others consider positive inotropic effects subsequent to sympathetic nervous system activation by absorbed CO₂ to be the decisive factor. As described in more detail below, CO does not recover if nitrous oxide (N₂O) rather than CO₂ is used for insufflation.
This argues in favour of hypercapnia-induced activation of the sympathetic nervous system as the force driving haemodynamic normalization.

The increases in RAP and wedge pressure measured against atmosphere are the consequence of increased IAP, an increase which is transmitted into the thorax.4 This should not automatically be assumed to reflect a rise in cardiac filling, since in the Trendelenburg position, intrathoracic pressure increases to an equal or even greater extent, so that effective transmural atrial pressures may even decrease4 (Table 2.1). This is supported by the echocardiographic study of Cunningham et al.,6 which shows a decrease in end-diastolic left ventricular volume. In the head-up position, gravity-induced reduction of venous return causes the initial decrease in CO. Increasing IAP during pneumoperitoneum reduces blood flow in the inferior vena cava with venous congestion and blood pooling in the lower extremities and a further reduction in cardiac filling volumes (Figure 2.2).7,8 A more recent model uses the Starling resistor concept to explain the behaviour of pressures and blood flow in the intrathoracic and intra-abdominal inferior vena cava.9 Elevated IAP in patients with ascites is known to cause narrowing of the cephalad portion of the intra-abdominal vena cava,10 and this is also observed during pneumoperitoneum.11 Increasing IAP in

Table 2.1 Changes in right atrial filling pressures in animal studies and in patients after creation of pneumoperitoneum under different conditions. There is a consistent reduction of transmural pressures that reflects reduced cardiac filling

A. Studies in dogs after creation of pneumoperitoneum with CO2 or N2O with different IAP4

<table>
<thead>
<tr>
<th>Duration (min)</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>IAP (mmHg)</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>30</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Right atrial pressure (RAP)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>6.5 ± 3</td>
<td>12.5 ± 7</td>
<td>14.3 ± 8</td>
<td>14.6 ± 9</td>
<td>15.9 ± 11</td>
<td>6.0 ± 3</td>
</tr>
<tr>
<td>N2O</td>
<td>6.0 ± 3</td>
<td>13.1 ± 7</td>
<td>13.0 ± 9</td>
<td>14.1 ± 8</td>
<td>16.8 ± 11</td>
<td>6.4 ± 3</td>
</tr>
<tr>
<td>Intrathoracic pressure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>3.8 ± 2</td>
<td>11.6 ± 6</td>
<td>12.8 ± 5</td>
<td>14.0 ± 6</td>
<td>15.1 ± 7</td>
<td>3.9 ± 2</td>
</tr>
<tr>
<td>N2O</td>
<td>3.8 ± 2</td>
<td>11.6 ± 6</td>
<td>12.2 ± 7</td>
<td>13.1 ± 9</td>
<td>15.9 ± 10</td>
<td>4.5 ± 2</td>
</tr>
<tr>
<td>Transmural atrial pressure (RAPtm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>2.7 ± 1.2</td>
<td>0.9 ± 0.5</td>
<td>1.5 ± 0.9</td>
<td>0.6 ± 0.3</td>
<td>0.9 ± 0.5</td>
<td>2.1 ± 1.2</td>
</tr>
<tr>
<td>N2O</td>
<td>2.2 ± 1.1</td>
<td>2.1 ± 1.1</td>
<td>0.8 ± 0.3</td>
<td>1.0 ± 0.5</td>
<td>0.9 ± 0.4</td>
<td>1.9 ± 0.9</td>
</tr>
</tbody>
</table>

B. Patients in reverse Trendelenburg position and CO2 pneumoperitoneum with constant IAP of 14 mmHg.5 Intrathoracic pressure increased (ΔITP) during the study

<table>
<thead>
<tr>
<th>Duration (min)</th>
<th>0</th>
<th>5</th>
<th>15</th>
<th>30</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>5.0</td>
<td>11.0</td>
<td>10.0</td>
<td>10.0</td>
<td>8</td>
</tr>
<tr>
<td>ΔITP</td>
<td>0</td>
<td>9.4</td>
<td>9.6</td>
<td>8.7</td>
<td>0</td>
</tr>
<tr>
<td>RAPtm</td>
<td>5</td>
<td>1.6</td>
<td>0.4</td>
<td>1.3</td>
<td>8</td>
</tr>
</tbody>
</table>

4 Adapted from Ivankovich et al.26
5 Adapted from Joris et al.1
Changes of IAP and blood flow in the inferior vena cava (IVCF). RAP increases with increasing IAP (abscissa). However, transmural filling pressure (RAP\text{transmural}) decreases significantly, while IVCF is also reduced. (Adapted from Ref [26].)

Figure 2.2

$SV = f(L) \frac{dZ}{dt} Z_0^{-1}$

or, with older systems, with the function

$SV = f \left[ \left( \frac{L}{Z_0} \right)^2 \left( \frac{dZ}{dt} \right) \right]_{\text{min}}$

The distance between the upper and lower electrodes ($L$) enters into the calculation to the third or second power, so that minor deviations in the distance between the electrodes result in large errors. For example, a 6% decrease in $L$ results in a 17% reduction in the calculated SV. A deviation of this magnitude is conceivable.
in the head-down position and with increased IAP, since the combined effects of gravity and pneumoperitoneum would widen the lower thorax aperture and would thus bring the upper and lower electrodes closer together. Moreover, the basic impedance of the thorax, $Z_0$, will also be altered to an unknown degree by the shift of diaphragm, liver, spleen and other abdominal organs into the measurement area. Using only a very low IAP (5–8 mmHg) and taking the altered baseline impedance into the equation, as in the study by Ekman et al., the bioimpedance method yields results similar to those of the dye dilution method. This problem is perhaps not as relevant in the head-up position, since the effects of gravity and the pneumoperitoneum tend to balance each other out.

Cardiovascular changes during pneumoperitoneum are not only due to the increased IAP, but are also caused by the systemic effects of the absorbed CO$_2$ and the vegetative reactions to peritoneal irritation. The studies cited so far only investigated the cardiovascular effects of CO$_2$ as insufflation gas, but using N$_2$O for inflation instead of CO$_2$ changes the pattern of cardiovascular effects. Comparing the results of these studies helps to delineate the causative factors.

Ivankovich and co-workers directly compared the haemodynamic changes induced by a pneumoperitoneum with either CO$_2$ or N$_2$O in dogs. Although they described the changes as essentially identical, they did observe that after 20 min at an IAP of 20 mmHg CO had decreased by 57% with CO$_2$ and by only 47% with N$_2$O, while vascular resistance had increased by 148% with CO$_2$ and only by 93% with N$_2$O (Table 2.2).

![Figure 2.3 Haemodynamic changes during pneumoperitoneum with CO$_2$: (a) in head-up reverse Trendelenburg position, or (b) in head-down Trendelenburg position. T: Trendelenburg position; rT: reverse Trendelenburg head-up position; ITP: intrathoracic pressure; AVP: vasopressin; NA: norepinephrine; ↑ increase; ↓ decrease; ↑→ no change or only slight increase. (For abbreviation see text.)](image)