The EAES Clinical Practice Guidelines on the Pneumoperitoneum for Laparoscopic Surgery (2002)

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Introduction

Only 15 years after the introduction of laparoscopic cholecystectomy, laparoscopic techniques (used either as a diagnostic tool or as a therapeutic access method) are among the most common procedures in surgery worldwide. However, concerns about higher surgical complications rates (such as vascular and intestinal injuries) compared to conventional techniques and anesthesiological risks have remained. Since the start of the laparoscopic era, numerous studies have described pathophysiological or clinical problems that are related to laparoscopy. Therefore, many technical innovations and modifications have been developed to improve safety and effectiveness of laparoscopy, but not all of them have been studied adequately before clinical use.

With these developments in mind, the European Association for Endoscopic Surgery (EAES) decided to develop authorative and evidence-based clinical practice guidelines on the pneumoperitoneum and its sequelae. The scope of these guidelines covers all important general surgical aspects of the pneumoperitoneum but not special laparoscopic procedures for defined pathologies. They address the pathophysiological basis for the clinical indications, aspects to establish the pneumoperitoneum, and perioperative aspects such as adhesions and pain. In addition, a clinical algorithm was formulated for practical use.

Methods

Under the mandate of the EAES Scientific Committee with the aim to set up evidence-based clinical practice guidelines, we combined the methodologies of a systematic review and a consensus development conference (CDC) because previous CDCs (both within and outside the EAES) had difficulties in identifying all relevant articles [218, 262, 280]. As a framework of the process, the key aspects pertaining to the pneumoperitoneum were precisely formulated in separate questions, which then were answered concurrently by the use of literature and expert evidence.

For the systematic review, one researcher (J.N.) performed comprehensive literature searches in Medline, Embase, and the Cochrane Library. We used the medical subject headings Laparoscopy and Pneumoperitoneum. Our primary intention was to identify all clinically relevant randomized controlled trials (RCTs). However, other trials using concurrent cohorts (CCTs), external or historical cohorts, population-based outcomes studies, case series, and case reports were accepted for a comprehensive evaluation of the pneumoperitoneum and its sequelae (Table 2.1). Included articles were scrutinized and classified by two reviewers (J.N. and S.S.). Furthermore, all panelists were asked to search the literature according to a list of defined questions. The reference lists of all relevant articles were also checked.

For the CDC, the conference organizers in Cologne, together with the scientific committee of the EAES, nominated a multidisciplinary expert panel. The criteria for selection were clinical and scientific expertise in the field of laparoscopy and geographical location within Europe.

Six months before the conference, the questions on laparoscopy were sent to the panelists. In parallel, the questions were answered by literature evidence found in systematic searches. One month before the conference, all answers from the panel and the literature searches were analyzed and subsequently combined into a provisional preconsensus statement and a clinical algorithm. Each panel member was also informed about the identities of the other members, which had not been previously disclosed.

In Maastricht, all panelists (except A.C. and H.J.B.) met for a first meeting on June 13, 2001. Here, the provisional bottom-line statements typed in bold and the clinical algorithm with the grades of recommendation were scrutinized word by word in a 5-h session in a nominal group process. For all statements, internal (expert opinion) and external evidence was compared. The following day the modified statement and the algorithm were presented to the conference audience by all panelists for public discussion (1.5-h session). During a postconsensus meeting on the same day, all suggestions from the audience were discussed again by the panelists, and the statement was further modified. The finalized statement as given later was mailed to all panelists for final approval (Delphi process) before publication.

To increase readibility, a short version of the clinical practice guidelines with a clinical algorithm was prepared (Fig. 2.1). The extended version consists of a detailed appraisal of pathophysiologic background and clinical research evidence. Each recommendation is graded according to its reliability and the rigor of research evidence behind the statement (Table 2.1).

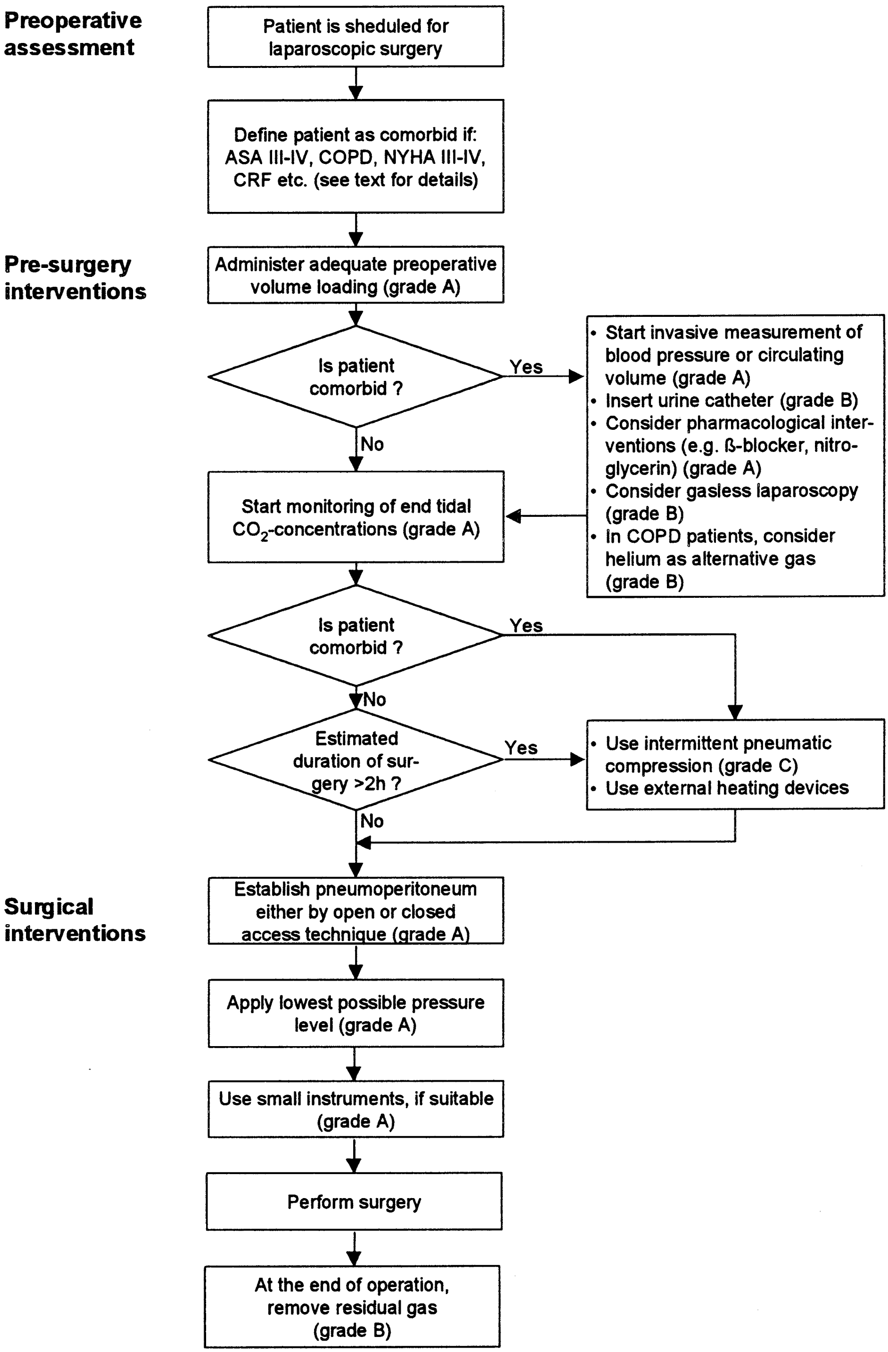

Fig. 2.1. Evidence-based clinical algorithm on the pneumoperitoneum for laparoscopic surgery. The recommendation is graded according to Table 2.1. *Diamond boxes* decision boxes, *square boxes* action boxes [255]

Table 2.1. A method for grading recommendations according to scientific evidence

Grade of recommendation	Level of evidence	Possible study designs for the evaluation of therapeutic interventions
A	1 a	Systematic review (with homogeneity) of RCTs
	1 b	Individual RCT (with narrow confidence interval)
	1 c	All-or-none case series
B	2 a	Systematic review (with homogeneity) of cohort studies
	2 b	Individual cohort study (including low-quality RCT)
	2 c	"Outcomes" research
	3 a	Systematic review (with homogeneity) of case-control studies
	3 b	Individual case-control study
C	4	Case series (and poor-quality cohort and case-control studies)
D	5	Expert opinion without explicity critical appraisal, or based on physiology, bench research, or "first principles"

From Sackett et al. [255]
RCT randomized controlled trial

Pathophysiological Basis for the Clinical Indications

Cardiovascular system

Cardiovascular effects of pneumoperitoneum occur most often during its induction, and this should be considered when initial pressure is increased for introduction of access devices. In ASA I and II patients, the hemodynamic and circulatory effects of a 12–14-mmHg capnoperitoneum are generally not clinically relevant (grade A). Due to the hemodynamic changes in ASA III and IV patients, however, invasive measurement of blood pressure or circulating volume should be considered (grade A). These patients should also receive adequate preoperative volume loading (grade A), beta-blockers (grade A), and intermittent sequential pneumatic compression of the lower limbs, especially in prolonged laparoscopic procedures (grade C). If technically feasible, gasless or low-pressure laparoscopy might be an alternative for patients with limited cardiac function (grade B). The use of other gases (e.g., helium) showed no clinically relevant hemodynamic advantages (grade A).

Pneumoperitoneum decreases venous return, preload, and cardiac output (CO) and increases heart rate (HR), mean arterial pressure (MAP), as well as systemic (SVR) and pulmonary vascular resistence (PVR). These hemodynamic and cardiovascular – changes mostly occur because of increased intraabdominal pressure (IAP) (1b [159, 221, 291]) and the stimulated neurohumoral vasoactive systems [vasopressin and rennin–aldosterone–angiotensine system (RAAS)] (1b [142, 158]), but are independent of type of gas (1b [28]). However, in otherwise healthy patients these changes are not dangerous when IAP does not exceed 15 mmHg (1b [27]).

Increased IAP, up to 12–15 mmHg, decreases venous return, which results in reduced preload and CO, without adequate intravascular volume loading (1b [63, 142, 162, 201, 221]). Additionally, changes in body position, especially head-up tilt position, intensify these negative effects of a pneumoperitoneum (2b [115, 116]), whereas head-down or Trendelenburg position has a positive effect on venous return (1b [162]). Furthermore, the use of positive end-expiratory pressure (PEEP) of 10 H_2O during pneumoperitoneum decreases preload and CO (4 [164]). Pneumoperitoneum increases sympathetic cardiac activity (1b [260]) and induces a hemodynamic stress response by activation of the neurohumoral vasoactive system (i.e., vasopressin and RAAS) resulting in increased HR, increased SVR and PVR, and increased arterial blood pressure (1b [142, 159]). This stress response leads to an increase in oxygen consumption, which might be deleterious for patients with compromised cardiac function. In clinical studies on ASA III and IV patients distinct intraoperative hemodynamic changes during pneumoperitoneum were described (4 [127]), but cardiovascular stability was unimpaired (4 [64, 83, 111, 322]) if appropriate invasive monitoring and pharmacologic interventions were used (4 [79, 292]). In contrast, there are reports of cardiovascular alterations persisting after release of the pneumoperitoneum (4 [108]). Most of these studies used an IAP of 12–15 mmHg without preoperatively volume loading. Without adequate intravascular volume loading a pneumoperitoneum in connection with head-up tilt position decreases CO significantly (up to 50%) (1b [142, 221]). In comorbid patients (ASA III and IV), RCTs with adequate sample size are missing.

In the majority of patients (ASA I and II), the hemodynamic effects of a pneumoperitoneum are without consequences and vanish after desufflation. Therefore, most patients without comorbidities (ASA I and II) do not need invasive hemodynamic monitoring. However, in ASA III and IV patients an invasive monitoring of blood pressure and circulating volume must be considered because only these measures allow early recognition and adequate treatment of severe cardiovascular changes (1b [162]). For intraoperative monitoring, a pulmonary artery catheter or COLD (cardiac oxygenation and lung water determination) monitoring should be applied, because transesophageal echocardiography in patients with cardiac disease has not been proven to be useful (4 [241]). For patients with severley compromised circulation, measurement of the pulmonary artery pressure (PAP) and CO can be necessary. However, interpreting changes in central venous pressure (CVP) and PAP may be difficult (4 [213]). Due to the consecutive increase in intrathoracic pressure during laparoscopy CVP and PAP also increase, but right arterial volume is not decreased. Therefore, CVP may only incorrectly describe the effective circulating blood volume and could be misinterpreted [162].

Since the effects of increased IAP on hemodynamics are volume dependent, adequate preoperative intravascular loading is essential, especially in patients with cardiac diseases, to prevent cardiovascular side effects of a pneumoperitoneum (1b [162]). Another intervention of proven effectiveness that also increases cardiac preload and thereby prevents hemodynamic changes (2b [6]) is intermittent sequential pneumatic compression of the lower extremities to augment venous blood return (1b [273, 274], 2b [273, 274]).

To minimize the effects of hemodynamic stress response on myocardial oxygen consumption, esmolol or clonidine can safely be used (1b [142, 163]) if volume depletion is not present. Intraoperative hemodynamic alterations in patients with underlying cardiopulmonary disease can be effectively controlled by appropriate pharmacological intervention (use of intravenous nitroglycerin) (2b [80]).

Hemodynamic and circulatory changes are independent from the used gas (CO_2 or helium) (1b [28]) but decreased during gasless laparoscopy (1b [5, 91, 159, 201, 22 1]). Therefore, gasless laparoscopy might be an alternative for patients with limited cardiac function. In summary, cardiac diseases are associated with an increased risk of general complications after laparoscopic surgery (and even higher risk after conventional surgery). Since various surgical and nonsurgical treatment options can be recommended to reduce these risks, the presence of heart disease does not principally contraindicate laparoscopic surgery (2b [239, 240]). There is a need for further trials in ASA III and IV patients.

Lung Physiology and Gas Exchange

Carbon dioxide pneumoperitoneum causes hypercapnia and respiratory acidosis. During laparoscopy, monitoring of end-tidal CO_2 concentration is mandatory (grade A) and minute volume of ventilation should be increased in order to maintain normocapnia. Increased intraabdominal pressure and head-down position reduce pulmonary compliance and lead to ventilation–perfusion mismatch (grade A). In patients with normal lung function, these intraoperative respiratory changes are usually not clinically relevant (grade A). In patients with limited pulmonary reserves, capnoperitoneum carries an increased risk of CO_2 retention, especially in the postoperative period (grade A). In patients with cardiopulmonary diseases, intra- and postoperative arterial blood gas monitoring is recommended (grade A). Lowering intraabdominal pressure and controlling hyperventilation reduce respiratory acidosis during pneumoperitoneum (grade A). Gasless laparoscopy, low-pressure capnoperitoneum, or the use of helium might be alternatives for patients with limited pul-

monary function (grade B). Laparoscopic surgery preserves postoperative pulmonary function better than open surgery (grade A).

The specifics of a capnoperitoneum, the IAP and the used gas, result in hypercapnia, respiratory acidosis, reduced pulmonary compliance, and increased airway resistance (1b [224, 307]). Additional changes in body position have minor influences (2b [68]) but could intensify these effects, especially in the head-down position (2b [114, 116]). Relaxation of the diaphragm caused by anesthesia in combination with increased intraabdominal pressure impairs excursion of the diaphragm and leads to compression of the lower lung lobes. These effects result in a decreased tidal volume, ventilation–perfusion mismatch, a decreased shunt volume, increased dead space, and decreased pulmonary compliance (1b [160], 2b [250]). Pulmonary gas exchange during laparoscopy can be optimized by the choice of the anesthetic procedure (1b [93]) and PEEP (5 [183]). Without hyperventilation P_aCO_2 will increase by 8–10 mmHg and pH will decrease (1b [315]) before a steady state is reached. Intraoperatively, pulmonary changes due to capnoperitoneum are compensated by otherwise healthy adults (1b [197]).

Various laparoscopic procedures have been shown to result in better post-operative pulmonary function when compared to their open-surgery counterparts (1b [38, 42, 48, 51, 74, 112, 149, 167, 197, 206, 275, 307]), but clinically more relevant end points such as postoperative pulmonary complications were rarely evaluated or found unchanged in ASA I and II patients (1b [205, 206]). These data generally prove that laparoscopy rather than conventional surgery should be advised for compromised patients, particularly those with obstructive lung disease. This superiority of laparoscopic surgery during the postoperative period is mostly related to its lesser extent of surgical trauma and pain, but laparoscopy has certain effects on ventilation that deserve special attention.

Capnoperitoneum with an IAP of more than 12 mmHg combined with head-down or Trendelenburg position should be avoided because it reduces pulmonary compliance by more than 30% and there is ventilation–perfusion impairment (1b [155, 159, 224] 2b [188, 250, 296]). Hypercapnia and respiratory acidosis can be avoided by controlled hyperventilation (1b [315]). CO_2 storage during pneumoperitoneum can result in postoperative hypercapnic hangover, which has to be particularly considered in cases, of accidential subcutaneous CO_2 insufflation. To recognize these changes intra- and postoperative arterial blood gas monitoring and continous capnometry are generally recommended for comorbid patients [161], particularly those with cardiopulmonary diseases (2b [314]). These patients may also benefit from prolonged postoperative mechanical ventilation [160]. From a more surgical standpoint, gasless laparoscopy or the use of other gases (e.g., helium and N_2O) may have clinically relevant advantages (1b [28, 155, 159, 224]), but the results of randomized trials are inconsistent (1b [92]) and need to be confirmed. Trocar positioning also has a relevant influence on pulmonary function, (1a [167]). Overall, most of the discussed randomized trials included only small numbers of patients, leading to an increased chance of type II error.

It should be mentioned that capnothorax can be a serious, albeit rare, complication that has been encountered in patients after capnoperitoneum (4 [7, 233]). Capnothorax occurs more often after laparoscopic esophageal or gastric surgery but has also been observed after lower abdominal procedures or even hernia repair. Because of the high solubility of CO_2, asymptomatic capnothorax diagnosed by postoperative chest X-ray may be treated conservatively. However, tension capnothorax may occur very rarely. Therefore, symptomatic capnothorax requires immediate drainage.

Venous Blood Return

During laparoscopy, both head-up position and elevated intraabdominal pressure independently reduce venous blood return from the lower extremities (grade A). Intraoperative sequential intermittent pneumatic compression of the lower extremities effectively reduces venous stasis during pneumoperitoneum (grade A/B) and is recommended for all prolonged laparoscopic procedures. The incidence of thromboembolic complications after pneumoperitoneum is not known.

Increased intraabdominal pressure together with reverse Trendelenburg position (head-up position) decreases venous return from the lower extremities by more than 40% (1b [273, 274], 2b [12, 99, 123, 204]) with a concomittant increase in femoral venous pressure (2b [12, 139]). However, it has been hypothesized that the systemic coagulation system is activated by laparoscopic surgery (1b [243], 2b [41, 178]), but controversial data exist (2b [67, 119, 192]). Due to the impairment of lower extremity circulation, the increased venous pressure, and the activation of the systemic fibrinolytic system, the potential risk for deep venous thrombosis (DVT) is increased. Although there are alarming reports about a high incidence of DVT after pneumoperitoneum (4 [230]), the rate of clinically evident postoperative thrombembolic complications after laparoscopic surgery remains unclear [10, 31, 184, 189]. The negative effects of elevated IAP and body position on venous blood return from the lower extremities can partly be counteracted by intermittent sequential compression of the lower limbs in laparoscopic cholecystectomy and colorectal surgery (1b [273, 274], 2b [273, 274]). Whether such compression does reduce thromboembolic event remains to be elucidated in larger trials.

The effects of a low-pressure pneumoperitoneum (5–7 mmHg) and abdominal wall lifting on thromboembolic complications have not been studied, although from a pathophysiologic standpoint a positive effect can be reasonably anticipated.

Perfusion of Intraabdominal Organs

Although in healthy subjects (ASA I and II), changes in kidney or liver perfusion (grade A) and also splanchnic perfusion (grade D) due to an intraabdominal pressure of 12–14 mmHg have no clinically relevant effects on organ function, this may not be the case in patients with already impaired perfusion. Especially in patients with impaired hepatic or renal function or atherosclerosis, intraabdominal pressure should be as low as possible to reduce microcirculatory disturbances (grade B). Patients with impaired renal function should be adequately volume loaded before and during elevated intraabdominal pressure (grade A).

Renal Effects

Randomized clinical trials showed a decrease in renal blood flow (RBF), glomerular filtration rate, and urine output in the initial phase of a pneumoperitoneum (1b [155, 221]). With increasing IAP renal function is gradually depressed (5 [146]). Elevated IAP causes renal dysfunction due to direct mechanical compression of renal parenchyma, renal arteries, and veins (5 [247]). The reduction in RBF and urine output is probably caused by a decrease in CO and/or the compression of the renal vein. In experimental studies, renal vein flow remained decreased for at least 2 h postoperatively (5 [195, 247]). Mediated by humoral factors, a sympathetic reaction induces a constriction of the renal artery. Pneumoperitoneum increases plasma renin activity (PRA) and consequently activates the RAAS, which promotes the renal vasoconstriction via angiotensin II. However, one prospective randomized trial found no signs of a clinically relevant impairment of renal function (1b [26]).

Hepatoportal Effects

When measured with laser Doppler, hepatoportal circulation is gradually decreased with increasing IAP (2b [69], 4 [136, 223]). In elderly patients, splanchnic circulation is very sensitive to elevated pressure (4 [261]). Experimental and clinical studies reported elevated liver enzymes after prolonged laparoscopic procedures and elevated intraabdominal pressure (1b [95], 2b [209]). However, in one RCT no signs of clinically relevant postoperative liver dysfunction were detected (1b [26]).

Splanchnic Effects

Elevated IAP mechanically compresses capillary beds, decreases splanchnic microcirculation, and thus impairs oxygen delivery to the intraabdominal organs. During pneumoperitoneum, a 24% reduction of blood flow in the superior mesenteric artery and the hepatic portal vein was reported (5 [125]). In healthy patients, a high vs low IAP (15 vs 10 mmHg) decreased blood flow into the stomach (54%), the jejunum (32%), the colon (4%), the parietal peritoneum (60%), and the duodenum (11%) (4 [266]). Furthermore, clinical and animal studies noted a decrease in gastric intramucosal pH (1b [157], 2b [69]), which may be the earliest indicator of alterated hemodynamic function compared to traditional measurements, such as CO, SVR, and lactate [154], but conflicting findings exist [69, 187, 223]. The clinical implications of these investigations remain unclear.

Otherwise healthy patients seem to compensate changes in intraabdominal organ perfusion without impairment of organ function. However, in patients with cardiovascular comorbidities or preexisting organ disorders, reduced alteration in organ perfusion could have detrimental effects. Therefore, for these patients careful observation and selection of surgical technique are required.

Several studies of different quality reported that in patients with limited hepatic or renal function, postoperative hepatic and renal function were better preserved by keeping IAP under 12 mmHg and by avoiding a prolonged pneumoperitoneum (1b–4 [69, 125, 154, 266]). Recently, one experimental study investigated the influence of different IAP levels on intra- and extraabdominal tissue blood flow by using color-labeled microspheres and reported, a nonimpaired tissue blood flow during capnoperitoneum of 10–12 mmHg (5 [317]). Esmolol inhibits the release of renin and blunts the pressor response to induction and maintenance of pneumoperitoneum. It may protect against renal ischemia during laparoscopy because urine output under, esmolol therapy was found to be higher (1b [162]). Nonsteroidal antiinflammatory drugs (NSAIDs), widely used in laparoscopic surgery, can cause renal medullary vasoconstriction. Because cases of renal failure after laparoscopic surgery and NSAID therapy were reported, NSAIDs should be replaced by other analgetics wherever possible (5; A.-M. Koivusalo, personal communication).

Stress Response and Immunologic Parameters

Changes in systemic inflammatory and antiinflammatory parameters (mainly cytokines) as well as in stress response parameters are less pronounced after laparoscopic surgery than after conventional surgery (grade A). 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.

The influence of pneumoperitoneum on the function of the immune system and stress response is poorly evaluated because most studies investigate surrogate parameters of the immunological function, such as cytokines and other cell products, and not the cell function itself (e.g., account, ratio, concentration, and activity of immunological cells). The essential clinical outcomes after surgery concerning immunological functions are infections (e.g., sepsis, pneumonia, urinary tract infection, and local wound-related infections) and cancer growth (e.g., metastasis and local tumor spread). However, there is no study in the field of laparoscopic surgery demonstrating an association between changes of intra- and postoperative immune function and the occurrence of clinical complications.

Clinical controlled trials of laparoscopic versus conventional surgery have mostly focused on changes of cytokine levels to describe the influence of pneumoperitoneum on systemic immunological functions. These studies showed differences in serum cytokine levels between laparoscopic and conventional surgery for IL-1(1b [174]), IL-6 (1b [36, 135, 165, 176, 254, 320, 322]), CRP (1b [135, 140, 176, 235, 254, 320], CRP (1b [133, 138, 174, 233, 252, 318]) and cell-mediated immunity (1b [224]) that have not been confirmed by other authors (1b [17, 198], 2b [89]). In RCTs, postoperative immunological functions seemed to be better preserved after laparoscopic compared to conventional procedures (1b [13, 45, 151, 176, 235, 276, 284, 308, 321]); however, some trials found no differences (1b [73, 113, 173, 203, 226, 248, 270, 289, 295]) and one trial even reported a more pronounced immunodepression after laparoscopy (1b [290]). Additional RCTs examined perioperative stress response and found adrenaline (1b [150]), noradrenaline (1b [150]), and cortisol (1b [150, 174, 303]) decreased to a lesser extent after laparoscopic than after conventional procedures, although one study did not confirm this result (1b [112]). By comparisons carbon dioxide insufflation with gasless laparoscopy, similar courses of stress response parameters were found (1b [158, 162]), but conflicting data exist (1b [126]). Since all these studies compared laparoscopic and open surgery, the immunological effects of the pneumoperitoneum and the surgical procedure overlap each other, precluding the quantification of any specific effects.

The influence of the specifics of the pneumoperitoneum (e.g., IAP, gas, and warming and humidified surrounding) on immunological function has only partly been studied in experimental settings. Helium seems to preserve cell-mediated intraperitoneal immunity better than CO_2 (5 [47, 219]) and causes a less pronounced cytokine response and bacterial translocation (5 [194]). In clinical trials, postoperative intraperitoneal cytokine response after warming the insufflation gas was attenuated (1b [244]). Another study suggested a similar stress response (IL-6, CRP, neutrophil elastase, and white cell count) after pneumoperitoneum or abdominal wall lifting (1b [221]). It is questionable whether the specifics of the pneumoperitoneum have clinically relevant effects or even benefits on postoperative immunological function and outcome (e.g., less pain, fatigue, and complications). Thus, additional clinical trials with adequate end points and sample sizes have to be performed to confirm the hypothesis of better preservation of the immune function by minimally invasive surgery.

Peritonitis

Presupposing appropriate perioperative measures (e.g., adequate preoperative volume loading) and hemodynamic stability, there are no contraindications to create a pneumoperitoneum when laparoscopic surgery is applicable in cases of peritonitis (grade B). The results from animal studies on the influence of pneumoperitoneum bacteremia and endotoxemia are controversial.

In experimental studies, a penumoperitoneum seems to increase the risk of bacteremia and endotoxemia [23–25, 77, 101, 214]. Other animal studies demonstrated that the systemic inflammation is higher after laparotomy than after laparoscopy, causing a transient decrease in immunologic defense and possibly leading to sepsis (5 [131, 180]).

With regard to the specifics of a pneumoperitoneum, any increase in IAP seems to further promote bacteraemia (2b [77]), but data are inconsistent. The used gas seems to play only a minor role (5 [105]). A clinical RCT found no difference in the acute phase response and endotoxemia between laparoscopic and conventional gastric surgery in cases of peritonitis (1b [173]). Furthermore, laparoscopic compared to conventional cholecystectomy for acute and gangrenous cholecystitis does not increase the mortality rate (1b [153]), and the morbidity rate seems to be even lower after laparoscopy (1b [153, 182]). Two small conflicting RCTs assessed bacteremia during appendectomy and found 0/11 versus 6/12 and 5/14 versus 5/13 positive blood cultures after open and laparoscopic access, respectively (1b [222, 279]). The hypothesis that in cases of peritonitis laparoscopy leads to a lesser depression of the systemic immune response with better postoperative outcome is unproven.

In conclusion, the decision to perform a laparoscopic procedure in case of peritonitis depends on the extent of peritonitis, the onset of disease, and the general clinical state of the patient. No clinical trials have found any contraindication to perform laparoscopy in case of beginning peritonitis (e.g., perforated appendicitis).

Risk of Tumor Spreading

There is no strong clinical evidence (except case reports) that pneumoperitoneum in patients with intraabdominal malignant disease increases the risk of tumor spread (grade D). The panel considers that there is no reason to contraindicate pneumoperitoneum in these patients, given the fact that an appropriate operative technique is used (grade C). The type of insufflation gas seems to affect intraabdominal tumor growth, whereas intraabdominal pressure is of little im-

portance (grade D). Due to the low level of evidence, patients undergoing laparoscopic surgery for malignant disease should be included in randomized controlled trials or at least in quality registries.

Several animal studies have been conducted to evaluate the pathogenesis of portsite metastasis in laparoscopic surgery, but the experimental models and tumor cell techniques vary considerably (5 [32, 33, 132, 134, 151, 219]). Port-site recurrence is common in small animal models after inoculation of high numbers of tumor cells and more pronounced after capnoperitoneum compared to laparotomy or gasless laparoscopy (5 [132, 134, 219]). IAP has little influence on intraperitoneal tumor growth or the incidence of port-site metastasis, whereas insufflation with helium may decrease subcutaneous tumor growth (5 [132, 134, 219]). In contrast to these findings, intraperitoneal tumor growth is stimulated more by laparotomy than by laparoscopy, gasless laparoscopy, or anesthesia alone without any operative procedure (5[130]).

Port dislocations should be avoided and ports should be irrigated intraperitoneally before they are retracted from the abdominal cavity. Before the tumor is extracted, the incision has to be protected against direct tumor cell contamination. The risk of tumor cell dissemination may be reduced by intraabdominal instillation of cytotoxic solutions at the end of the operation (5 [34]).

Prospective clinical trials failed to show a higher incidence of free intraperitoneal tumor cells (5 [37]) or recurrence in the skin incision (2a [304], 5 [37]) for laparoscopic compared to conventional surgery. A systematic review of clinical trials found no significant differences in overall survival, disease-free survival, cancer-related death, locoregional tumor recurrences, port-site metastasis, or distant metastasis in patients undergoing laparoscopic or conventional colorectal resections (2a [304]). Perioperatively, mobilization of neoplastic cells occurs frequently in patients with colorectal cancer, but the surgical approach does not seem to be a determining factor (16 [18]). Randomized trials with low quality found no wound or port-site metastasis in 91 patients during a mean follow-up of 21.4 months and in 43 patients after long-term 5-year follow-up (2b [57, 169]). Adequately powered RCTs on laparoscopic and conventional resections of colorectal carcinoma are missing, but such trials are currently being performed in Europe, the USA, and Australia. Results of these trials will be available in 2004–2006.

Establishing the Pneumoperitoneum

Creation of a Pneumoperitoneum

For severe complications (vessel perforation) it is impossible to prove a difference between closed- and open-access technique in RCTs; therefore, large outcome studies should be considered. In the RCTs, the rate of major and minor *complications is surprisingly high, which may be due to the definition of a complication or surgical learning curve. Insertion of the first trocar with the open technique is faster as compared to the Veress needle (grade A). The randomized controlled trials comparing closed (Veress plus trocar) versus open approach have inadequate sample sizes to find a difference in serious complications. In large outcome studies there were less complications in the closed group (grade B). Although RCTs found the open approach faster and associated with a lower incidence of minor complications (grade A), the panel cannot favor the use of either access technique. However, the use of either technique may have advantages in specific patient subgroups (grade B).*

Among the various techniques for achieving a pneumoperitoneum and introducing the first trocar, two common methods are usually performed. The first, so-called closed technique requires the Veress needle, which is inserted in the abdominal cavity for CO_2 insufflation followed by blind introduction of the first trocar. The second, so-called open technique was first described by Hasson [110]. This technique begins with a small incision at the umbilical site and subsequently all layers of the abdominal wall are incised. The first trocar is then inserted under direct vision followed by gas insuation.

Table 2.2. Randomized clinical trials of Veress needle or open approach

Reference/ year	No. of patients	Procedure	Access time (min)	Complications	Results
Gullà et al. [103]/2000	262	Diagnostic and operative laparoscopy	Not mentioned	Needle: 11/101 Open: 0/161	Open technique is safer
Saunders et al. [262]/ 1998	176	Diagnostic laparoscopy in abdominal trauma	Needle: 2.7 Open: 7.3	Needle: 0/98 Open: 0/78	Veress technique is faster
Cogliandolo et al. [50]/ 1998	150	Laparoscopic cholecystectomy	Needle: 4.5 Open: 3.2	Needle: 5/75 Open: 5/75	Open technique is faster
Peitgen et al. [231]/1997	50	Diagnostic and operative laparoscopy	Needle: 3.8 Open: 1.8	Needle: 0/25 Open: 0/25	Open technique is faster
Byron et al. [39]/1993	252	Diagnostic and operative laparoscopy	Needle: 5.9 Open: 2.2	Needle: 19/141 Open: 4/111	Open technique is safer and faster
Nezhat et al. [219]/1991	200	Diagnostic and operative laparoscopy	Not mentioned	Needle: 22/100 Open: 3/100	Open technique has fewer complications
Borgatta et al. [30]/ 1990	212	Laparoscopic tubal sterilization	Needle: 9.6 Open: 7.5	Needle: 7/110 Open: 4/102	Open technique is safer and faster

The morbidity associated with the establishment of the pneumoperitoneum and the insertion of the first trocar is estimated to be less than 1% (4 [29, 109, 264]), but the true incidence of visceral and vascular injury for both techniques is unknown. However, major vascular injuries occur most often with the Veress needle (2c [44, 236]). Several RCTs found that the open technique on average causes less complications and is cheaper and faster than the Veress needle technique (1b [30, 39, 50, 104, 220, 232]) (Table 2.2). However, one study on the access technique for percutaneous diagnostic peritoneal lavage in blunt trauma patients showed that the Veress needle technique was faster compared to the open technique (1b [263]). A recent three-armed RCT found it easier to establish the pneumoperitoneum with a new access device (TrocDoc) than with the open technique or the Veress needle (1b [14]). The choice between reusable and single-use instruments was outside our scope. In specific patient subgroups, the access technique has to be chosen according to the patients characteristics (e.g., pregnancy, obesity, and trauma).

Gas Embolism and Its Prevention

Clinically relevant gas embolism is very rare, but if it occurs, it may be a fatal complication (grade C). The true incidence of clinically inapparent gas embolism is not known. Most described cases of gas embolism have been caused by accidental vessel punction with a Veress needle at the induction of pneumoperitoneum. Low intraabdominal pressure, low insufflation rates, as well as careful surgical technique may reduce the incidence of gas embolism (grade D). A sudden decrease in end-tidal CO_2 concentration and blood pressure during abdominal insufflation should be considered a sign of gas embolism (grade C). Due to the low incidence of clinically relevant gas embolism, advanced invasive monitoring (transesophageal Doppler sonography) cannot be recommended for clinical routine (grade B).

The incidence of gas embolism during pneumoperitoneum is estimated to be less than 0.6% (2 [282], 4 [122, 144]). Many case reports have detailed fatal or near-fatal coronary, cerebral, or other gas embolism (4 [102, 152, 172, 231, 238]). In more than 60% of cases, gas embolism occurred during the creation of a pneumoperitoneum.

The usual cause leading to gas embolism was the accidental deplacement of a needle or trocar into a blood vessel. Similarly, any injury to the veins of parenchymal organs can result in direct gas flow into systemic circulation. CO_2 bubbles are capable of reaching the right heart (2b–5 [61, 66, 79, 267]). This is best detectable when patients are studied with transesophageal echocardiography (2b–5 [61, 66]. Transcranial Doppler has shown that CO_2 bubbles may even reach the cerebral circulation (4 [267]). Furthermore, gas emboli are able to escape from venous to arterial circulation through pulmonary arteriovenous shunts (5 [306]) or an open Foramen ovale (4 [190]).

Experimental animal studies have induced gas embolism by infusing air directly into a vein or by lacerating a large intraabdominal vein during a pneumoperitoneum (5 [66, 145, 147]). Increased IAP of more than 20 mmHg in connection with an insoluble gas (helium or argon) enhanced the risk of gas embolism during pneumoperitoneum (5 [146, 148, 251]), suggesting that caution should be exerted when laparoscopic surgery is performed close to large veins (5 [66]). Furthermore, the use of nitrious oxide for anesthesia may increase the risk of developing gas embolism during laparoscopy (4 [200, 242], 5 [147]).

In clinical practice, there are few technical options available to reduce the risk of gas embolism. It is therefore very important that especially the surgeon who creates the pneumoperitoneum be experienced in laparoscopic access techniques. It can be assumed that blunt trocars reduce the risk of accidental vessel puncture (1b [14]).

The most sensitive method to detect gas embolism is transesophageal Doppler monitoring (TEE) (2b [283, 316]). Simple measures to detect clinically relevant gas embolism are electrocardiogram (ECG) and $EtCO_2$ monitoring, which have low costs and require low personal effort. During surgery, decreasing $EtCO_2$ values of more than 3 mmHg could be related with gas embolism and should be clarified immediately (4 [52], 5 [147]). In case of injury of larger veins during abdominal insufflation, ECG and $EtCO_2$ should be closely monitored, especially when gases with low solubility are used. Because of the low incidence of gas embolism, special perioperative monitoring (e.g., TEE) is not indicated.

Choice of Insufflation Pressure

The panel recommends use of the lowest IAP allowing adequate exposure of the operative field rather than using a routine pressure (grade B). An IAP lower than 14 mmHg is considered safe in a healthy patient (grade A). Abdominal wall-lifting devices have no clinically relevant advantages compared to low-pressure (5–7 mmHg) pneumoperitoneum (grade B).

Normal and low laparoscopic insufflation pressure are defined as 12–15 and 5–7 mmHg, respectively. It is important to differentiate between the pressure at induction of the pneumoperitoneum and that during the operation. Initially, the IAP might be increased up to 15 mmHg to reduce the risk of trocar injuries. As already stated, IAP affects the physiology of heart, lung, and circulation. In order to attenuate these possible side effects of high IAP, the intravascular volume should be adequately filled preoperatively (1b [159]) and the insufflation pressure should be selected according to the planned laparoscopic procedure and the patient characteristics. In ASA I and II patients, a low-pressure pneumoper-

Table 2.3. Randomized clinic trials comparing low- and high-pressure pneumoperitoneum

Refrenence/ year	No. of patients/ASA	Pressures compared	Results	Conclusions
Wallace et al. [308]/1997	40/ASA I–II	7.5 vs 15 mmHg CO_2	CI↓, MAP↑, HR↓, end-tidal CO_2↑, pain scores↓	Cardiac changes in both groups similar; postop pain in low-pressure group reduced
Pier et al. [236]/1994	33/ASA I–II	8 vs 15 vs 19 mmHg CO_2	No differences in pain, analgesic use, FEV_1, or VC	Pressure has little effect on pain
Dexter et al. [63]/1999	20/ASA I–II	7 vs 15 mmHg CO_2	MAP↑, HR↑, SV↓, CO↓	High pressure reduces SV and CO more than low PP

All trials were performed on laparoscopic cholecystectomy
CO cardiac output, *HR* heart rate, *MAP* mean arterial pressure

itoneum reduces adverse effects on physiology without compromising laparoscopic feasibility (1b [63, 237, 309]) (Table 2.3). It remains questionable whether these physiologic changes are associated with clinically relevant side effects.

In older and compromised patients (ASA III and IV), the effects of a high vs low IAP have only been studied in nonrandomized clinical trials (2b [64, 83, 111], 4 [257]). In these studies, an elevated IAP (12–15 mmHg) showed considerable cardiac alterations. With the use of invasive monitoring, adequate volume loading, and vasoactive drug, it was possible to keep the hemodynamic and cardiac function stable. Therefore, in ASA III and IV patients, gasless or low-pressure laparoscopy could be alternatives, which should be further tested.

Warming and Humidifying of Insufflation Gas

Warming and humidifying insufflation gas is intended to decrease heat loss. However, compared to external heating devices, the clinical effects of warmed, humidified insufflation gas are minor (grade B). Data on its influence on postoperative pain are contradictory (grade A).

Perioperative hypothermia is related to increased catecholamine and cortisol levels leading to peripheral vasoconstriction and higher arterial blood pressures (2b [86]). Maintaining normothermia generally decreases postoperative cardiovascular morbidity (1b [84, 85]).

General and regional anesthesia essentially determine body core temperature by downregulation of the internal temperature level. Once vasoconstric-

Table 2.4. Pneumoperitoneum and hypothermia; randomized clinical trials

Reference/year	No. of patients, operations	Treatments	Temperature measurement	Pathophysiological results	Clinical results
Dietterle et al. [323]/ 1998	100 vs 100 operative or diagnostic pelviscopic procedures	Body vs room temperature, pressure and humidifying not mentioned	None	None	Gas warming lowers the intensity of diaphragm and shoulder pain and reduces the use of analgesics
Saad et al. [254]/2000	10 vs 10 lap. CCE	37 vs 21 °C. CO_2 IAP 15 mm Hg, humidifying not mentioned	Esophageal thermotip catheter	No differences in body and intraabdominal temperatures and pain scores	Gas warming has no clinically relevant effect
Slim et al. [284]/1999	Double-blind 49 warm vs 51 cold gas, different upper abdominal lap. procedures	37 vs 21 °C, CO_2, IAP 14 mmHg humidifying not mentioned, 20°RT	Subdiaphramatic thermometric probe	Subdiaphramatic temperature equal VAS score for shoulder tip pain higher in the warm group	Gas warming increases postoperative pain (VAS)
Mouton et al. [209]/ 1999	20 vs 20, lap. CCE	34–37 vs 21–25 °C	Esophagus	No difference in core temperature; pain score less in humidified group	Humidified heated gas reduces pain but preserves no heat loss
Nelskylä et al. [215]/ 1999	18 vs 19 women, lap, HE end point: heart rate variability	37 vs 24 °C, CO_2, IAP 12–14 mmHg , humidifying not mentioned	Tympanic and nasopharyngeal	Body core temperature decreases more in the warming group	Heating of insufflation gas does not prevent decrease of body temperature
Puttick et al. [243]/ 1999	15 vs 15, ASA I–II, lap. CCE	37 vs 21 °C, CO_2, mean duration of surgery 32 min	Esophagus	Body core temperature decreases more in room temperature group	Higher cytokine levels in room temperature group; pain scores and consumption not different

Bäcklund et al. [11]/1998	13 vs 13 prolonged lap. Procedures >90 min	37 vs 21 °C, CO_2, IAP 11–15 mmHg , humidifing not mentioned	Swan–Ganz catheter	Core temperature and urine output higher in warm PP	Warm insufflation increases urine output
Ott et al. [226]/1998	Double-blinded multicenter (7) study, 72 women	36 °C and humidified vs 23 °C, CO_2 IAP?	Endotracheal	Warm insufflation: less intraoperative hypothermia, postoperative stay and pain	Gas warming reduces lap. induced hypothermia
Korell et al. [162]/1996	50 vs 53 women, div. laparoscopic procedures	Heated CO_2 (30–32 °C) vs normal CO_2 (23–24 °C)	Flow therme	VAS scores reduced for shoulder and subdiaphragmatic pain	Warm CO_2 reduces postoperative pain
Semm et al. [277]/1994	30 vs 30 lap. pelviscopy	37 °C PP vs 21 °C PP, CO_2 IAP 12 mmHg, humidifying not mentioned	Intraadbominal and rectal probe	37 °C group shoulder tip pain; pain medication and incidence of tachycardia reduced	Warm insufflation reduces shoulder tip pain; pain medication

IAP intraabdominal pressure

tion has occurred, application of warming systems is less effective in compensating heat loss (1b [245]). Therefore, forced-air warmer systems should be applied before heat loss occurs. In contrast, warming and humidifying of the insufflation gas is less important than application of external warming devices before and during anesthesia.

Warming of the insufflation gas reduces postoperative intraperitoneal cytokine response (1b [243]) and reduces postoperative hospital stay (1b [226]) and pain (1b [226, 277, 323]) (Table 2.4). In contrast, a double-blind RCT found an increase in shoulder tip pain after warming the insufflation gas (1b [284]). Other groups found no clinically relevant effects of warming the insufflation gas (1b [198, 215, 254, 311]). Additional humidifying of warmed insufflation gas seems to reduce postoperative pain but has no heat-preserving effect in brief laparoscopic procedures (1b [209]). Since most of the studies have small sample sizes with possible type II error, no firm conclusions can be drawn. Given their possible small effects, the costs of these devices have also to be considered.

Abdominal Wall-Lifting Devices

Abdominal wall lifting as compared to capnoperitoneum results in less impairment of hemodynamic, pulmonary, and renal function (grade A). In ASA and I and II patients, the magnitude of these benefits is too small to recommend abdominal wall lifting (grade D). In patients with limited cardiac, pulmonary, or renal function, abdominal wall lifting combined with low-pressure pneumoperitoneum might be an alternative (grade C). Nevertheless, surgical handling and operative view were impaired in most surgical procedures (grade A).

Gasless laparoscopy has been developed to avoid the pathophysiological side effects of elevated IAP and CO2 insufflation, especially in patients with comorbities (ASA III and IV). However, most RCTs on gasless laparoscopy vs pneumoperitoneum have been performed in healthy ASA I and II patients (Tables 2.5, 2.6). In these patients, gasless laparoscopy results in a more stable hemodynamic and pulmonary function (1b [155, 220, 223]), a concomitant increase in urine output (1b [156, 223]), reduced hormonal stress responses (1b, [156, 223]), less postoperative pain (1b [131, 153]), and less drowsiness (1b [155, 178]). Contrarily, other RCTs found no differences in postoperative pain (1b [102]) and cardiorespiratory functions (1b [200]). Many surgeons encountered technical difficulties due to inadequate visualization (1b [136, 184, 200]). This led to high conversion rates in these trials, one of which was even terminated prematurely [136]. Although gasless laparoscopy may have hemodynamic and cardiovascular advantages in ASA III and IV patients, clinical trials in this group of patients have not been per-

Table 2.5. Randomized clinical trials comparing gasless to low- or high-pressure pneumoperitoneum

Reference/ year	No. of patients, ASA	Pressures compared	Results in experimental group	Conclusions
Lubkan et al. [184]/2000	30, single blind	Laparolift vs 15 mmHg	VAS score for visualization less in gasless patients	Conventional PP provides better view
Ogihara et al. [223]/1999	12, ASA I–II	Gasless vs 13 mmHg CO_2 (Trendelenburg position 15–20° in both groups)	CO_2 group: pulmonary compliance↓, epinephrine↑, norepinephrine↑, dopamine↑, ADH↑, urine output↓	Gasless: lesser hormonal stress responses; better pulmonary function; higher urine output
Schulze et al. [271]/1999	17	Gasless vs 12 mmHg CO_2 (thPDA in both groups)	CO_2 group Blood flow↓, HR↑, MAP↑, CVP↑	No clinically relevant differences; CO_2 group less pain and more fatigue
Vezakis et al. [304]/1999	36, ASA I–II	Gasless vs 8 mmHg CO_2	No changes in postop pain and analgesic consumption	Shoulder pain more frequent
Cravello et al. [53]/1999	103	Gasless vs CO_2 PP (IAP unknown) (8 conversions)	No differences in complication pain medication hospital stay	Gasless technique needs further evaluation
Guido et al. [102]/1999	54	Gasless vs 15 mmHg CO_2	No differences in shoulder, pelvic, and periumbilical pain	Similar pain scores compared to conventional PP
Meijer et al. [200]/1997	20, ASA I–II	Gasless (AWL) +5 vs 15 mmHg CO_2	Gasless surgery lasted longer; CO, RR, and HR equal in both groups	AWL is not recommended for laparoscopic cholecystectomy, view impaired
Koivusalo et al. [156]/1997	30, ASA I–II	IAP 12–13 mmHg CO_2 vs gasless	CO_2 group: MAP↑, pulmonary compliance↓, urine output↓, U-NAG↑, intramucosal pH↓	Gasless: more stable in hemodynamics; protects renal and splanchnic ischemia
Koivusalo et al. [155]/1997	25, ASA I–II	IAP 12–15 mmHg CO_2 vs gasless AWL	Drowsiness shorter	Avoiding CO_2 reduces drowsiness
Johnson and Sibert [136]/1997	18	Gasless vs CO_2 PP (IAP not mentioned)	Increased technical difficulty – poor visualization	CO_2 PP is preferable for routine LTC

Table 2.5 (continued)

Reference/year	No. of patients, ASA	Pressures compared	Results in experimental group	Conclusions
Casati et al. [42]/1997	20	Gasless vs 12 mmHg CO_2	Better pulmonary compliance: oxigenation unchanged	Better lung compliance
Goldberg and Maurser [96]/1997	57	Gasless (laparolift) vs 15 mmHg CO_2; 9/28 converted because of inadequate exposure	Technically difficult; no differences in cardiopulmonary parameters and pain scores	No clinical benefit
Koivusalo et al. [154, 157]/1996	26, ASA I–II	IAP 12–15 mmHg vs laparolift	Maddox–Wing deviation higher in conventional PP group gasless: plasma renin activity↓, diuresis higher	Less right shoulder pain, nausea, and vomiting; smaller neuroendocrine responses; better renal function
Lindgren et al. [178]/1995	25, ASA I–II	PP (IAP 12–15 mmHg + CO_2) vs AWL	CO_2 group MAP↑, HR↑, pulmonary compliance↓	MAP lower; postoperative nausea, vomiting, and right shoulder pain less often

AWL abdominal wall lifting

Table 2.6. Cross-tabulation of current research on the effects of technical modifications of laparoscopy on pathophysiologic and medical outcomes

	Open-acces technique	Smaller trocars (3.5 mm)	Warmed insufflation gas	Helium, argon, or NO_2	Low-pressure laparoscopy	Gasless laparoscopy	Intraperitoneal anaesthetics
Pathophysioloical effects							
Circulatory	(0)	(0)	++ [277]	0 [28]	++ [63, 158, 236, 308]	++ [96, 156, 158, 178, 200, 220, 223]	(0)
Pulmonary	(0)	(0)	?	0 [28]	+ [236]	++ [155, 158, 200, 220, 223]	?
Renal/hepatic/ intestinal	(0)	(0)	++ [11]		+	++ [156, 158, 223]	(0)
Immunological	(0)	?	++ [243]	(0)	(0)	+/0 [220]	?
Hormonal	(0)	?	?	(0)	(0)	++ [156, 223]	?
Body core temperature	(0)	(0)	+/0 [11, 215, 226, 243, 254]	?	(0)	+	(0)
Technical effects	++ [262]	– [276]	(0)	(0)	-/0 [63, 158, 308]	– [96, 136, 184, 200]	(0)
Clinical effects							
Intraoperative surgical in-cidents	+++ [30, 39, 50, 103, -219, -231]	[276]	+	(0)	(0)	?	(0)
Heart and lung complications	(0)	+ [276]	?	(0)	-10	+/0	?
Kidney and liver complica-tions	(0)	(0)	?	(0)	-10	+/0	?
Pain	(0)	++ [22, 35, 276]	+/0 [162, 243, 254, 277, 284]	0 [236]	++ [258, 308]	+/0 [53, 102, 154, 178, 271, 304]	+++ [3, 40, 49, 55, 69, 70, 93, 211, 214, 227, 228, 293, 297, 309]

Table 2.6 (continued)

	Open-acces technique	Smaller trocars (3.5 mm)	Warmed insufflation gas	Helium, argon, or NO_2	Low-pressure laparoscopy	Gasless laparoscopy	Intraperitoneal anaesthetics
Drowsiness and fatigue	(0)	0 [276]	?	(0)	(0)	++ [155, 178, 271]	?
Cosmetic results	?	++ [276]	(0)	(0)	(0)	(0)	(0)
Incisional hernia	?	++	(0)	(0)	(0)	(0)	(0)
Adhesions	(0)	+	(0)	(0)	+	(0)	(0)
Infections	(0)	?	(0)	(0)	(0)	(0)	(0)

+++strong RCT evidence in favour of intervention; ++, some RCT evidence in favour of intervention; +/0, conflicting RCT evidence in favour of intervention; + non-RCT evidence in favour of intervention; 0 some RCT evidence for no effect of intervention; (0) non-RCT evidence for no effect of intervention; – non-RCT evidence against intervention; -/0 conflicting RCT evidence against intervention; – some RCT evidence against intervention; – strong RCT evidence against intervention; ? no valid research evidence available formed. Since gasless laparoscopy also requires excellent surgical expertise, its use should be restricted to certain subgroups of surgeons and patients.

Size of Access Devices

Smaller access devices (≤ 5 mm) in laparoscopy are only feasible in selected group of patients. The use of 2–5-mm instead of 5–10-mm access devices improves cosmetic result and postoperative pain marginally in laparoscopic cholecystectomy (grade A).

Although it has been assumed that smaller access devices may markedly improve the patients outcome of laparoscopic surgery, this has not been shown in valid RCTs (1b [22]). Merely modest advantages have been reported concerning a better cosmetic result (1b [276]) and less postoperative pain (1b [22, 35, 46, 276], 4 [192]) after laparoscopic cholecystectomy. Postoperative pulmonary function and fatigue were unchanged (1b [276]). Other clinical trials found a shorter convalescence by using smaller access devices in laparoscopic procedures (4 [192]). The incidence of postlaparoscopic incisional hernia is less than 1% (4 [165, 169]). Whether smaller access devices prevent incisional hernia has not been clarified (4 [165]). To prove a difference would require a large sample size and an extensive postoperative observation period. Currently, the general use of smaller trocars cannot be recommended due to difficulties in handling and reduced optical quality, especially when using smaller laparoscopes (1b [22, 276], 4 [168]). Recently published RCTs reported a reduction in postlaparoscopic pain when a radially expanding access device was compared to the conventional cutting trocar (1b [19, 80, 170, 318]). No data are available on other clinical effects.

Perioperative Aspects

Adhesions

Some laparoscopic procedures may cause less postoperative adhesions compared to their conventional counterparts (grade B). However, the specifics of a pneumoperitoneum (gas, pressure, temperature, and humidity) seem to have no major effect on the development of postsurgical adhesions (grade D).

Two RCTs found less postsurgical adhesions after laparoscopic compared to conventional surgery (2b [61, 62, 185]), but these studies have methodological flaws (small sample size, unclear allocation concealment, no intention-to-treat analysis, and losses to follow-up). Furthermore, since postsurgical adhesions are usually assessed by means of different scoring systems, it is difficult to compare the results of the trials in between or to rule out observer bias in these unblinded trials.

Pathophysiologically, a reduced peritoneal fibrinolytic activity seems to be the main cause for postsurgical adhesions (4 [116]). Experimental studies indicate that adhesion rates also depend on intraabdominal pressure (5 [317]) and the type of gas used (5 [132, 213]). However, one clinical RCT found no difference in peritoneal fibrinolytic activity in elective laparoscopic compared to conventional colorectal resections (1b [216]). It seems that the specifics of a pneumoperitoneum do not influence generally the peritoneal fibrinolytic activity and the development of postoperative adhesions. Therefore, avoiding local peritoneal damage seems to be the most significant factor to prevent postsurgical adhesions.

Pain, Nausea, and Vomiting

Pain after laparoscopic surgery is multifactorial and should be treated with a multimodal approach (grade A). Shape and size of access devices have to be considered (grade A). Low-pressure pneumoperitoneum, heated and humidified insufflation gas, incisional and intraperitoneal instillation of local anesthetics, intraperitoneal instillation of saline, and removal of residual gas all reduce postlaparoscopic pain (grade B). Inconclusive data and small effect sizes of singular approaches make it difficult to recommend these treatments in general (grade D). No evidence exists that the specifics of a pneumoperitoneum have any effect on postoperative nausea and vomiting.

Although pain after laparoscopic surgery is less severe and of shorter duration than that after open surgery, it still causes considerable discomfort and increased stress response. The etiology of postlaparoscopic pain can be classified into at least three aspects: visceral, incisional, and shoulder pain [21, 140, 300]. Although visceral pain may also depend on the extent of intraabdominal surgery, incisional pain is related to the number and size of access devices and also to the technique of incision closure and drainage. The origin of shoulder pain is only partly understood, but it is commonly assumed that the continual stretching of the peritoneum during and after the pneumoperitoneum is responsible. Clinically, incisional and deep abdominal pain dominate over shoulder pain. However, shoulder pain is specific for laparoscopic surgery. After different abdominal laparoscopic procedures, shoulder pain was noted in 30–50% of cases, which is significantly higher than after the corresponding open procedures (1b [43, 55, 174, 297]). It was suggested that shoulder tip pain is caused mechanically by stretching the diaphragmatic ligaments (1b [308]). The hypothesis of a chemical effect of the pneumoperitoneum with a decrease in intraperitoneal pH could not be verified [233].

The incidence of postoperative nausea and vomiting after laparoscopic procedures ranges from 10 to 60% [81, 201, 312]. After laparoscopic cholecystectomy, nausea and vomiting persisted up to 14 days in some patients [296]. The pathogenesis of postoperative nausea and vomiting is multifactorial, depending on anesthesia, surgery, gender, and perioperative administration of opioids. Several RCTs examined the influence of antiemetics and analgesics on postoperative nausea and vomiting, but this was beyond the scope of this guideline.

Within the past few years, various modifications of the pneumoperitoneum have been developed and clinically tested in order to reduce peritoneal pain after laparoscopic surgery [21, 310]. Here, we focus on those interventions that are directly related to the pneumoperitoneum, thus excluding oral, intravenous, or epidural drug administration and other nonlocal treatments. The intensity of postoperative pain varies largely among different cultures, settings, and individuals.

The following interventions were all shown in RCTs to effectively reduce pain after laparoscopy:

- Reducing IAP (1b [178, 236, 299, 308])
- Using other insufflation gases, such as N_2O, helium, or argon (1b [2, 180, 206, 236, 280])
- Lowering the insufflation rate (1b [16])
- Warming and humidifying the insufflation gas (1b [162, 209, 210, 226, Removal of residual intraabdominal gas at the end of operation (1b [86, 137, 298], 2b [4, 128], 4 [4, 128])
- Intraperitoneal instillation of fluids (1b [233])
- Intraperitoneal instillation of anesthetics (1b [3, 40, 49, 55, 69, 70, 93, 211, 214, 227, 228, 293, 297, 309])
- Reducing the size of trocars (1b [22, 35, 97, 166])
- Injecting anesthetics into the trocar sites (1b [3, 21, 257, 301])
- Omitting drains (which is beyond the scope of this recommendation, since it depends on the type of operation)

The intraperitoneal instillation of anesthetics is well studied. Most RCTs found a significant decrease in postlaparoscopic pain, including shoulder tip pain (1b [3, 40, 49, 55, 69, 70, 93, 211, 214, 227, 228, 293, 297, 309]), whereas other trials found no effect (1b [21, 87, 140, 244, 264, 270]). Since there is also evidence that postlaparoscopic instillation of normal saline or Ringers lactate reduces pain (1b [233]), it is important to distinguish between trials that used placebo controls from those that did not.

Humidifying the insufflation gas reduced postoperative pain in one trial (1b [211]) but increased it in another (1b [284]). After gasless laparoscopy, one double-blind RCT showed that shoulder tip pain (as primary end point) was more frequent than after conventional pneumoperitoneum (1b [304]), a second RCT with a smaller sample size reported the contrary (1b [154]), and a third found no difference (1b [101]).

On the basis of these contradictory results, the panel is not able to favor one treatment option over another. For the multifactorial pathogenesis of postlaparoscopic pain, we assume that a combined therapeutic approach is most effective ([20, 201]). Surgical awareness of this significant patient problem needs to be improved.

Pregnancy

Presupposing obstetrical consultation, laparoscopic procedures during pregnancy should be performed in the second trimester if possible (grade C). Perioperatively, maternal end-tidal CO_2 concentration and arterial blood gases must be monitored to control maternal hyperventilation and to prevent fetal acidosis (grade C). For the establishment of the pneumoperitoneum the open technique should be preferred (grade C). During laparoscopy intraabdominal pressure should be kept as low as possible and body positioning should be considered in order to avoid inferior vena cava compression by the uterus (grade C). Furthermore, pneumatic compression devices are recommended (grade D).

Surgery during pregnancy always carries an increased risk of fetal loss. Therefore, the indication for surgical intervention during pregnancy is generally limited to urgent situations such as acute appendicitis [268] or acute cholecystitis [99, 287]. The incidence of acute appendicitis and acute cholecystitis during pregnancy is similar to that of nongravid females and is estimated to be less than (0.1% (4 [195, 248]). The treatment of acute cholecystitis in gravid women should consider effective nonsurgical therapeutic options (4 [292]). Today, pregnancy should not be seen as an absolute but a relative contraindication for laparoscopic procedures. Because of increased risk for postoperative abortion in the first trimester and hindrance of operation due to the enlarged uterus, surgery during pregnancy should be performed during the second trimester (4 [190, 286]). During pregnancy laparoscopic compared to conventional surgery is preferred because of possibly less fetal impairment due to less postoperative analgetic requirements (4 [176]) and less postoperative maternal respiratory depression (4 [56]). However, increased intraabdominal pressure may decrease maternal respiratory compliance (5 [9, 58]), uterine blood flow (5 [58]), or preterm labor (5 [58, 96]). Furthermore, the use of carbon dioxide seems to increase fetal acidosis (5 [54, 59, 120]), to enhance the risk for fetal loss (4 [8]), and may lead to detrimental side effects if hyperventilation fails (5 [54]). Most of these concerns are based on experimental studies and case reports and should be confirmed by randomized controlled trials. Due to the low incidence of surgical interventions during pregnancy, these studies have to be performed as multicenter trials.

Intracranial Pressure

Increased IAP and head-down position increase intracranial pressure (ICP) (grade A). Therefore, elevated IAP, head-down position, and hypoventilation should be avoided (grade D). In patients with head injury or neurological disorders, perioperative monitoring of ICP should be considered (grade C). Gasless laparoscopy might be an alternative to prevent ICP peaks (grade D).

During pneumoperitoneum, IAP and head-down position increase ICP (5 [75, 117, 142, 207, 252], 4 [123]), enhance cerebral blood flow velocity (4 [1]), and diminish cerebrospinal fluid absorption (5 [106]). Elevated ICP values during laparoscopic surgery return to baseline after desufflation (5 [75]). There is no evidence that elevated ICP during pneumoperitoneum is clinically relevant.

Pathophysiological studies suggested that an increased intraabdominal pressure hinders venous drainage of the lumbar venous plexus followed by a decline in cerebrospinal fluid absorption during abdominal CO_2 insufflation (5 [105, 106]). Furthermore, it was hypothesized that this mechanical effect leads to an increase in ICP and a central nervous system response causing systemic hypertension (5 [15, 251]). However, the exact pathophysiology of increasing ICP during pneumoperitoneum remains unclear. Experimental and clinical studies showed that hemodynamic changes are directly related to the increase in ICP (4 [89, 123], 5 [142, 251]). Therefore, in patients with severe head injuries or conditions associated with elevated ICP, intraabdominal pressure should be as low as possible, sudden IAP peaks should be avoided, and intraoperative ICP monitoring should be considered (4 [127]). Furthermore, gasless laparoscopy could be an option to avoid the effects of IAP on ICP (5 [75, 117]).

The use of carbon dioxide as insufflation gas leads to hypercarbia and acidosis, which possibly influence the intracerebral circulation by vascular autoregulation. CO_2 increases ICP more than do helium and nitric oxide (5 [267]). Hypoventilation and hypercarbia increase ICP compared to hyperventilation and hypocarbia, but during acute elevations of ICP hyperventilation did not decrease ICP effectively (5 [251]). The insufflation gas has fewer effects on ICP than on IAP (4 [74], 5 [60]).

Abdominal Trauma

There are no prospective studies evaluating the specifics of a pneumoperitoneum (type of gas, IAP, and temperature) in patients with blunt or penetrating abdominal trauma (grade D).

Laparoscopy is used as a diagnostic tool in hemodynamically stable patients after blunt or penetrating trauma in order to detect those injuries that require laparotomy or laparoscopic repair (2b [71, 77, 285]). In rare cases of penetrating trauma, the establishment of a pneumoperitoneum led to an insufflation of injured organs or cavities ([119]). Nevertheless, the panel agrees that there is no reason to contraindicate pneumoperitoneum in stable trauma patients.

The use of different intraabdominal pressures, different types of gas, or even gasless laparoscopy has not been evaluated in patients with blunt or penetrating abdominal trauma. Thus, no recommendations are reasonably justifiable. However, one clinical RCT tested which access technique is faster and safer, and found advantages for the closed technique (1b [262]), thus refuting data from nontrauma surgery.

Discussion

After a 2-year break, the EAES has continued its guideline activities, now on an even more evidence-based level and with much more advanced preparation than in the past. We believe that the result of this endeavor can be considered to be a milestone in the societys responsibility of being a bridgetender between primary research and clinical practice and vice versa.

We hope that the reader understands the importance of guideline methodology. In a European survey 2 years ago, many members complained that the EAES consensus panels had always been consisting of the same clique of people. The panel for this guideline still contains many well-known names from the EAES simply because the number of experts in endoscopic surgery is limited, as are resources for guideline development. Wherever interdisciplinary coworking was necessary, experts from other fields were invited to join the panel, although this guideline could have received further benefit from the input of a pediatric surgeon.

The scope of this guideline is broad since the pneumoperitoneum is the key issue in laparoscopic surgery. However, it is impossible for a guideline to answer all relevant points in detail or to discuss the role of the pneumoperitoneum separately for every disease entity. The panel tried to formulate the statements as concise as possible. However, for those issues, for which no strong evidence was found, it was often impossible to recommend any specific option. Those who find such broad statements disappointing should remember that the panel can only judge on the basis of clinical experience and published evidence. Often, a treatment is widely held to be evidence based, although not a single study has ever been performed.

Therefore, one of our aims was to define some implications for future research. A fair amount of RCTs were retrievable to answer the various issues. We consider it unlikely that important studies were missed by our literature searches because we combined various techniques to capture all relevant studies. However, the available studies mostly focused on those questions which can be answered already using a small sample size and short-term observation. Some other statements did not receive grade A because the existing RCTs had methodological flaws. What is of general concern is that such a large proportion of trials assessed pathophysiological rather than clinical outcomes. These trials, albeit randomized, are usually insufficient to answer the clinical questions we had posed. Therefore, the plea for clinically relevant RCTs cannot be reiterated too often. It is a future task to check whether the recommendations have to be modified on the basis of new data.

Developing guidelines is only worthwhile if they are used clinically. Guideline use hinges upon guideline awareness and knowledge. Therefore, the format and dissemination of the current guideline goes beyond simple publication. Since guidelines created on a European level cannot address the local circumstances in every European country or even hospital, the EAES scientific committee recommends the use of the current guideline as a basis for a locally adapted and translated guideline, which could then be implemented at any given level.

The most important factors that have to be considered before adapting this guideline for local use are individual surgical expertise and health care setting. Some surgical techniques that are discussed or even recommended here are probably not practical or affordable for every European surgeon. This is why we decided not to include cost comparisons in this guideline.

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