

# Impact of the patient's body position on the intraabdominal workspace during laparoscopic surgery

Jan Paul J. Mulier · Bruno Dillemans ·  
Sebastiaan Van Cauwenberge

Received: 27 August 2009 / Accepted: 18 November 2009 / Published online: 7 January 2010  
© The Author(s) 2010. This article is published with open access at Springerlink.com

## Abstract

**Background** The effects of the patient's body position on the intraabdominal workspace in laparoscopic surgery were analyzed.

**Methods** The inflated volume of carbon dioxide was measured after insufflation to a preset pressure of 15 mmHg for 20 patients with a body mass index (BMI) greater than 35 kg/m<sup>2</sup>. The patients were anesthetized with full muscle relaxation. The five positions were (1) table horizontal with the legs flat (supine position), (2) table in 20° reverse Trendelenburg with the legs flat, (3) table in 20° reverse Trendelenburg with the legs flexed 45° upward at the hips (beach chair position), (4) table horizontal with the legs flexed 45° upward at the hips, and (5) table in 20° Trendelenburg with the legs flat. The positions were performed in a random order, and the first position was repeated after the last measurement. Repeated measure analysis of variance was used to compare inflated volumes among the five positions.

**Results** A significant difference in inflated volume was found between the five body positions ( $P = 0.042$ ). Compared with the mean inflated volume for the supine position ( $3.22 \pm 0.78$  l), the mean inflated volume increased by 900 ml for the Trendelenburg position or when the legs were flexed at the hips, and decreased by 230 ml for the reverse Trendelenburg position.

**Conclusions** The Trendelenburg position for lower abdominal surgery and reverse Trendelenburg with flexing of the legs at the hips for upper abdominal surgery effectively improved the workspace in obese patients, even with full muscle relaxation.

**Keywords** Intraabdominal pressure · Intraabdominal volume · Laparoscopy · Patient's body position · Surgery

During laparoscopic surgery in obese patients, sufficient intraabdominal workspace is important for the surgeon. Therefore, most surgeons request that their patients receive muscle relaxants, although the resulting effect on increasing workspace is not always sufficient [1]. Chassard et al. [2] proposed performing laparoscopy without muscle relaxation for gynecologic operations, but the resulting effect on the surgical workspace was not measured.

In a recent review examining the physiologic effects of pneumoperitoneum, the issue of workspace was not addressed [3]. Most surgeons use an inflation pressure of 15 mmHg. Higher intraabdominal pressures suggested by Adams et al. [4] to improve workspace might affect hemodynamic stability [5], catecholamine output [6], autonomic system function [7], and splanchnic circulation [8]. Sandhu et al. [9] and Chok et al. [10] tried to work with lower inflation pressures to reduce carbon dioxide (CO<sub>2</sub>) absorption, decrease postoperative pain [11], and facilitate lung ventilation [12, 13], but this is not possible if the workspace becomes too small.

The influence of body position and pneumoperitoneum has been investigated in relation to hemodynamic function [14–18] and respiratory function [12, 13, 19]. Body position may influence the abdominal inflation volume and thus

---

J. P. J. Mulier (✉)  
Department of Anaesthesiology, AZ Sint Jan Brugge-Oostende  
AV, Ruddershove 10, 8000 Brugge, Belgium  
e-mail: Jan.Mulier@azbrugge.be

B. Dillemans · S. Van Cauwenberge  
Department of General Surgery, AZ Sint Jan Brugge-Oostende  
AV, Ruddershove 10, 8000 Brugge, Belgium

could improve or worsen the surgical workspace. We hypothesized that body position may influence the volume of CO<sub>2</sub> that can be inflated at the same abdominal inflation pressure. This study aimed to measure the abdominal inflation volume at a preset pressure of 15 mmHg for five different table and body positions of patients with a body mass index (BMI) greater than 35 kg/m<sup>2</sup>.

## Materials and methods

This study investigated 20 patients with a BMI greater than 35 kg/m<sup>2</sup> scheduled for bariatric laparoscopic surgery with approval of the hospital ethics committee and the oral patient's informed consent. The patient was asked to void before coming to the operating room, and the stomach was emptied with a gastric tube after induction of anesthesia.

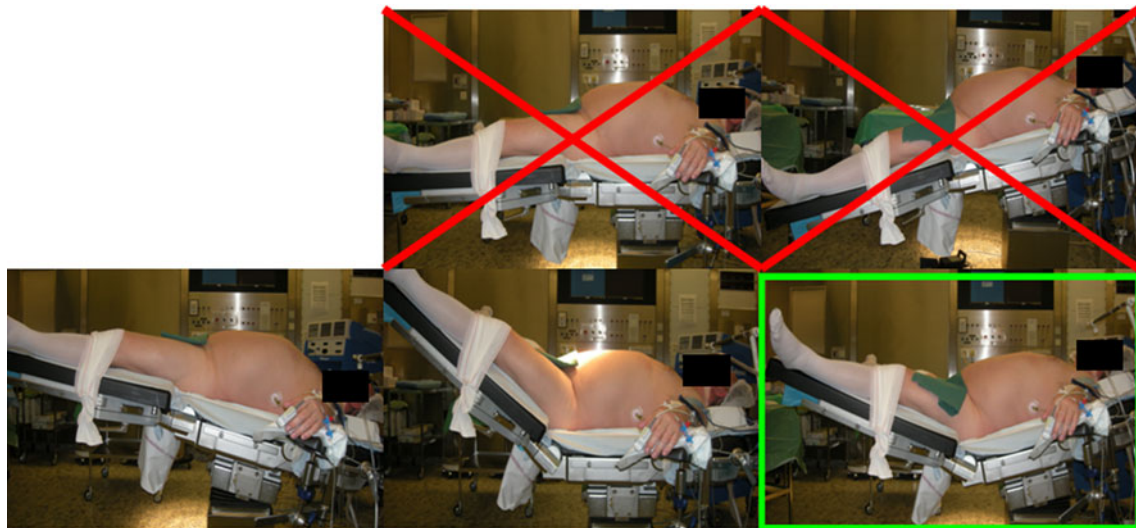
Anesthesia was induced with propofol (Diprivan) and sufentanil (Sufenta) as clinically required. Desflurane was given in an oxygen–air mixture of 1 minimum alveolar concentration. At anesthesia induction, 20 mg of cisatracurium was given, then infused at 8 mg/h during the measurements. Muscle relaxation was controlled by train-of-four stimulation. The patient was volume-control ventilated, and the settings were adapted to achieve an end-tidal partial pressure of CO<sub>2</sub> (PCO<sub>2</sub>) of 40 mmHg before the measurements.

The table was positioned horizontally with the patient's legs flat. The patient's abdomen was inflated with CO<sub>2</sub> through a Veress needle to an intraabdominal pressure of

15 mmHg. One trocar was placed, and its intraabdominal location was verified with the laparoscope. The abdomen was deflated and manually palpated to release all CO<sub>2</sub>. The following body positions, as shown in Fig. 1, were investigated in a random order: (1) table horizontal with the legs flat (supine position), (2) table in 20° reverse Trendelenburg with the legs flat, (3) table in 20° reverse Trendelenburg with the legs flexed 45° upward at the hips (beach chair position), (4) table horizontal with the legs flexed 45° upward at the hips; and (5) table in 20° Trendelenburg with the legs flat.

The patient was positioned in the five body positions, and the first body position was repeated after the last measurement. Each time, the abdomen was inflated with an Olympus UHI-3 inflator (Tokyo, Japan) through the trocar at a high flow (maximum, 12 l/min) and a pressure setting of 15 mmHg. When this pressure was reached, the flow was stopped, and the inflated volume and abdominal pressure were measured. The abdomen was deflated and manually palpated before the next position and measurements.






Continuous data were reported in terms of mean and standard deviation, and ordinal data were reported in terms of number and percentage. Repeated measure analysis of variance was used to compare inflated volumes among the five body positions. For the first and sixth body positions (identical), a paired *t* test was performed to determine whether the inflated volume changed during the measurements (e.g., due to a change in the patient's characteristics or insufficient deflation).



**Fig. 1** Three of the five investigated positions: (1) position C (beach chair position): table in 20° reverse Trendelenburg with the legs elevated at 45°; (2) position D, horizontal, legs up: table horizontal with the legs elevated at 45°; and (3) position E (Trendelenburg

position): table in 20° Trendelenburg with the legs flat, increasing the abdominal workspace. For upper abdominal surgery, the beach chair position is ideal, and for lower abdominal surgery, the Trendelenburg position is ideal. Position D disturbs the surgical access

**Table 1** Inflated volume and pressure for different body positions

	A Supine 	B Reverse trendelenburg 	C Beach chair 	D Horizontal, legs up 	E Trendelenburg 
IAP (mmHg)	14.0 ± 0.3	13.9 ± 0.5	14.0 ± 0.3	13.9 ± 0.2	14.1 ± 0.5
IAV (l)	3.22 ± 0.78	2.99 ± 0.69	3.76 ± 0.90	4.13 ± 0.84	4.14 ± 0.60
Minimum IAV (l)	2.00	1.99	2.39	3.05	3.33
Maximum IAV (l)	4.41	4.00	5.00	5.43	5.11
Patients with IAV < 3 l: n (%)	8 (40.0)	10 (50.0)	4 (20.0)	0 (0)	0 (0)

IAP intraabdominal pressure, IAV intraabdominal volume

Positions: A (supine: table horizontal with the legs flat), B (reverse Trendelenburg: table in 20° reverse Trendelenburg with the legs flat), C (beach chair: table in 20° reverse Trendelenburg with the legs elevated at 45°, D (horizontal, legs up: table horizontal with the legs elevated at 45°, E (Trendelenburg: table in 20° Trendelenburg with the legs flat)

## Results

The mean age of the patients was  $46.2 \pm 8.1$  years, and their mean body mass was  $41.3 \pm 3.2$  kg/m<sup>2</sup>. Seven of the patients were men (35%). The mean difference in the inflated volumes between the first and sixth measurements was 0.16 l ( $P = 0.46$ ).

Table 1 lists the mean intraabdominal pressure as well as the mean, maximum, and minimum intraabdominal volumes for the five body positions. The number of patients whose intraabdominal volume did not reach 3 l is given for each body position. The intraabdominal volume differed significantly ( $P = 0.42$ ) among the five body positions, whereas the intraabdominal pressure showed no significant difference. The mean inflated volume increased by 900 ml when the patient's body was placed in Trendelenburg position or when the legs were flexed at the hips. The inflated volume decreased by 230 ml when the patient's body was placed in reverse Trendelenburg position. Flexing of the legs with the table in reverse Trendelenburg position created the beach chair position and improved the intraabdominal volume by 770 ml.

## Discussion

The first inflation through the Veress needle was not used for analysis. The next inflations were through the trocar, with the inflated volume measured when the flow stopped at the preset pressure. Because trapping of intraabdominal gas could affect measurements at subsequent inflations, abdominal massage was performed after each deflation to minimize such trapping.

Carbon dioxide absorption during inflation could affect the inflated volume. Tan et al. [20] measured CO<sub>2</sub>

absorption during pelvic laparoscopy and found a maximum absorption of  $42.1 \pm 5.1$  ml/min. In our study, the inflation period at high flow was less than 2 min. If we assume a linear pressure-related absorption, 2 min multiplied by 40 ml and divided by 2 for average pressure gives a maximum absorption of 40 ml. Because such absorption affects measurements in all body positions, it was not taken into account in our comparisons. Carbon dioxide leak during inflation also could increase the inflated volume. Only one trocar was placed, and the measurements were performed before the operation started. We previously verified the stability of CO<sub>2</sub> inside the abdomen and demonstrated no significant loss to leakage or absorption over a period of 5 min when one trocar was used [21].

During the measurements, the abdominal wall was not touched, and no medication boluses were given. Nitric oxide was not used during the measurements to prevent volume increase by nitric oxide diffusion. At the first laparoscopic view before any measurements, correct positioning of the trocar and the gastric tube was verified. Lung ventilation was kept constant during the measurements. The depth of anesthesia was measured by entropy, and no additional anesthetic was needed during the measurements to maintain entropy below 40%. Muscle relaxation was controlled with train-of-four stimulation, and no extra doses of muscle relaxant were needed during the measurements to maintain train-of-four stimulation at zero.

Body position during surgery is dictated by the surgical approach. Upper abdominal surgery usually requires reverse Trendelenburg position, whereas lower abdominal surgery requires Trendelenburg position. The minimum insufflation volume needed for optimal performance of upper or lower abdominal surgery has not been investigated to date. Sandhu et al. [9] compared low and standard intraabdominal pressures (without measuring the exact

workspace) and found that whereas a low pressure of 7 mmHg provided adequate workspace in most patients, 2 of 70 patients (2.9%) required higher intraabdominal pressure. These authors explained the cause for this as obesity of the two patients without giving more data.

Only one study, conducted by Valenza et al. [22], measured the effect of body position on intraabdominal pressure. In that study, abdominal volume was not measured. These authors measured pressure without indicating whether volume was held constant. Intraabdominal pressure increased when the patient's body position was changed from horizontal to beach chair before and during pneumoperitoneum. Before pneumoperitoneum, the intraabdominal pressure was high ( $\sim 20$  cm H<sub>2</sub>O), and it increased to 30 cm H<sub>2</sub>O during pneumoperitoneum. These values are sufficiently high to be questionable, and the inflation pressure used to reach these values was not given. The pressure of 30 cm H<sub>2</sub>O (22.1 mmHg) is higher than the maximum pressure of 20 mmHg the inflator can reach. The study did not indicate whether the inflator was kept operating or stopped during changes in body position.

The validity of using urinary bladder pressure as a substitute for intraabdominal pressure is questionable. In a previous study, we found no correlation between bladder compliance and abdominal compliance, and bladder pressure measurements were consistently higher than abdominal pressure when the bladder was filled with more than 50 ml [23]. The beach chair position might have a separate effect on bladder compliance. Valenza et al. [22] found on the contrary an increase in intra abdominal pressures in the beach chair position. This is however also in contradiction with his own measurement of lower airway pressures.

This study was performed with obese patients because the required workspace volume for these patients is more problematic. It is not clear whether nonobese patients would show the same differences, but they are interesting to analyze also given the impact on surgical workspace. The physiologic mechanism explaining these effects has not been analyzed to date. As clinical procedure moves from Trendelenburg to reverse Trendelenburg position, the diaphragm moves upward [24], which may explain the volume rise. Flexing the legs could shorten the distance between the sternum and the pubis, thus lowering the tension on the musculus rectus. This is a hypothetical explanation not verified to date.

Below an inflation volume of 3 l, our bariatric surgeon requests more workspace. If 3 l is taken as the minimum intraabdominal volume needed to perform laparoscopic upper abdominal surgery, 10 of our 20 patients had an insufficient workspace in reverse Trendelenburg position compared with 4 of 20 patients in the beach chair position. This shows that body position helps to improve the surgical workspace when it is otherwise not sufficient.

For laparoscopic bariatric surgery, the Trendelenburg position is never used. Opposite upper abdominal surgery, like bariatric surgery, requires reverse Trendelenburg position, never, until currently, with the legs flexed. Flexing the legs at the hips creates the beach chair position. This is the most effective method for improving the workspace by 770 ml after full muscle relaxation.

The beach chair position did not disturb the surgeon, who stayed between the opened and elevated legs when performing laparoscopic upper abdominal surgery. In our high-volume bariatric center, we have completely standardized the laparoscopic Roux-en-Y gastric bypass procedure [25]. The beach chair position is an essential part of this standardized technique, and it also is used for other types of bariatric procedures.

Not only the inflated volume but also the intraabdominal displacement of fat has an impact on surgical visibility. However, this is difficult to evaluate objectively because it is observer and procedure dependent and therefore not measured in this study.

Mulier et al. [26] developed a mathematical model of the abdomen that allows calculation of abdominal compliance. In their study, only inflated volume was analyzed, and compliance was not measured because surgeons are interested only in the workspace. Theoretically, it might be interesting for physiology to analyze the impact on abdominal compliance in a future study.

## Conclusion

Flexing the legs in the Trendelenburg position and also in the horizontal and reverse Trendelenburg positions improved the inflated volume by at least 770 ml. Therefore, the beach chair position is ideal for upper abdominal surgery, and the Trendelenburg position is ideal for lower abdominal surgery.

**Disclosures** Jan Paul J. Mulier, Bruno Dillemans, and Sebastiaan Van Cauwenberge have no conflicts of interest or financial ties to disclose.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution Noncommercial License which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.

## References

1. Mulier JP, Dillemans B, Sablon T, Danneels I (2006) Effect of muscle relaxants on the abdominal pressure volume relation. *Eur J Anesth* 23:S42
2. Chassard D, Berrada K, Tournadre J, Boulétreau P (1996) The effects of neuromuscular block on peak airway pressure and

- abdominal elastance during pneumoperitoneum. *Anesth Analg* 82:525–527
3. Nguyen NT, Wolfe BM (2005) The physiologic effects of pneumoperitoneum in the morbidly obese. *Ann Surg* 241:219–226
  4. Adams JB, Moore RG, Micali S, Marco AP, Kavoussi LR (1999) Laparoscopic genitourinary surgery utilizing 20 mmHg intraabdominal pressure. *J Laparoendosc Adv Surg Tech A* 9:131–134
  5. Kitano Y, Takata M, Sasaki N, Zhang Q, Yamamoto S, Miyasaka K (1999) Influence of increased abdominal pressure on steady-state cardiac performance. *J Appl Physiol* 86:1651–1656
  6. Barczyński M, Herman RM (2002) Influence of different pressures of pneumoperitoneum on the autonomic system function during laparoscopy. *Folia Med Cracov* 43:51–58
  7. Mikami O, Fujise K, Matsumoto S, Shingu K, Ashida M, Matsuda T (1998) High intraabdominal pressure increases plasma catecholamine concentrations during pneumoperitoneum for laparoscopic procedures. *Arch Surg* 133:39–43
  8. Blobner M, Bogdanski R, Kochs E, Henke J, Findeis A, Jelen-Esselborn S (1998) Effects of intraabdominally insufflated carbon dioxide and elevated intraabdominal pressure on splanchnic circulation: an experimental study in pigs. *Anesthesiology* 89:475–482
  9. Sandhu T, Yamada S, Ariyakachon V, Chakrabandhu T, Chongruksut W, Ko-Iam W (2009) Low-pressure pneumoperitoneum versus standard pneumoperitoneum in laparoscopic cholecystectomy: a prospective randomized clinical trial. *Surg Endosc* 23:1044–1047
  10. Chok KS, Yuen WK, Lau H, Fan ST (2006) Prospective randomized trial on low-pressure versus standard-pressure pneumoperitoneum in outpatient laparoscopic cholecystectomy. *Surg Laparosc Endosc Percutan Tech* 16:383–386
  11. Esmat ME, Elsebae MM, Nasr MM, Elsebaie SB (2006) Combined low-pressure pneumoperitoneum and intraperitoneal infusion of normal saline for reducing shoulder tip pain following laparoscopic cholecystectomy. *World J Surg* 30:1969–1973
  12. Rauh R, Hemmerling TM, Rist M, Jacobi KE (2001) Influence of pneumoperitoneum and body positioning on respiratory system compliance. *J Clin Anesth* 13:361–365
  13. Liem TK, Krishnamoorthy M, Applebaum H, Kolata R, Rudd RG, Chen W (1996) A comparison of the hemodynamic and ventilatory effects of abdominal insufflation with helium and carbon dioxide in young swine. *J Pediatr Surg* 31:297–300
  14. Guenoun T, Aka EJ, Journois D, Philippe H, Chevallier JM, Safran D (2006) Effects of laparoscopic pneumoperitoneum and changes in position on arterial pulse pressure wave form: comparison between morbidly obese and normal-weight patients. *Obes Surg* 16:1075–1081
  15. Hirvonen EA, Poikolainen EO, Pääkkönen ME, Nuutinen LS (2000) The adverse hemodynamic effects of anesthesia, head-up tilt, and carbon dioxide pneumoperitoneum during laparoscopic cholecystectomy. *Surg Endosc* 14:272–277
  16. Junghans T, Böhm B, Gründel K, Schwenk W, Müller JM (1997) Does pneumoperitoneum with different gases, body positions, and intraperitoneal pressures influence renal and hepatic blood flow? *Surgery* 121:206–211
  17. Meininger D, Westphal K, Bremerich DH, Runkel H, Probst M, Zwissler B, Byhahn C (2008) Effects of posture and prolonged pneumoperitoneum on hemodynamic parameters during laparoscopy. *World J Surg* 32:1400–1405
  18. Mertens zur Borg IR, Lim A, Verbrugge SJ, IJzermans JN, Klein J (2004) Effect of intraabdominal pressure elevation and positioning on hemodynamic responses during carbon dioxide pneumoperitoneum for laparoscopic donor nephrectomy: a prospective controlled clinical study. *Surg Endosc* 18:919–923
  19. Fahy BG, Barnas GM, Flowers JL, Nagle SE, Njoku MJ (1995) The effects of increased abdominal pressure on lung and chest wall mechanics during laparoscopic surgery. *Anesth Analg* 81:744–750
  20. Tan PL, Lee TL, Tweed WA (1992) Carbon dioxide absorption and gas exchange during pelvic laparoscopy. *Can J Anaesth* 39:677–681
  21. Mulier JP, Dillemans B, Luyten A, Vannieuwenhuizen R (2007) Is CO<sub>2</sub> leakage or absorption important during measurement of the abdominal pressure volume relation in a pneumoperitoneum? *Eur J Anesth* 24:S43
  22. Valenza F, Vagginelli F, Tiby A, Francesconi S, Ronzoni G, Guglielmi M, Zappa M, Lattuada E, Gattinoni L (2007) Effects of the beach chair position, positive end-expiratory pressure, and pneumoperitoneum on respiratory function in morbidly obese patients during anesthesia and paralysis. *Anesthesiology* 107:725–732
  23. Mulier J, Dillemans B, Segers G, Casier I, Akin F (2008) The urinary bladder compliance is different from the abdominal compliance. *Eur J Anesth* 25:S44
  24. Perilli V, Sollazzi L, Bozza P, Modesti C, Chierichini A, Tacchino RM, Ranieri R (2000) The effects of the reverse Trendelenburg position on respiratory mechanics and blood gases in morbidly obese patients during bariatric surgery. *Anesth Analg* 91:1520–1525
  25. Dillemans B, Sakran N, Van Cauwenberge S, Sablon T, Defoort B, Van Dessel E, Akin F, Moreels N, Lambert S, Mulier J, Date R, Vandelanotte M, Feryn T, Proot L (2009) Standardization of the fully stapled laparoscopic Roux-en-Y gastric bypass for obesity reduces early immediate postoperative morbidity and mortality: a single center study on 2606 patients. *Obes Surg* 19(10):1355–1364
  26. Mulier J, Dillemans B, Crombach M, Missant C, Sels A (2009) On the abdominal pressure volume relationship. *Internet J Anesthesiol* 21:1