Trendelenburg Position and Morbid Obesity

A Respiratory Challenge for the Anesthesiologist

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In this issue of Anesthesiology, Grieco *et al.*[1] bring evidence that pneumoperitoneum and the Trendelenburg position impose a dangerous stress on the respiratory system of morbidly obese patients undergoing robotic gynecologic surgery. In 22% of patients after Trendelenburg positioning, severe expiratory flow limitation and airway closure were observed, with airway opening pressures ranging between 17 and 32 cm H_2O. The authors warn against the danger of using intraoperative pressure control ventilation, which could produce severe alveolar hypoventilation in patients with airway opening pressures greater than 15 cm H_2O. More generally, the recent development of robotic-assisted surgery is, in obese patients, a serious challenge for the anesthesiologist.

"In bariatric laparoscopic surgery, two specific conditions worsen obesity-related respiratory disorders and increase the anesthetic risk: [pneumoperitoneum and Trendelenburg position]."

Severe and morbid obesity critically affect respiratory physiology. In awake obese patients lying in the supine position, the active contraction of the diaphragm and intercostal muscle opposes active forces against the crushing weight of thoracic and abdominal fat, thereby preserving end-expiratory lung volumes and maintaining lung aeration. After anesthetic induction and muscle relaxation, diaphragm and rib cage respiratory muscles become passive and the lungs are fully subjected to the overwhelming pressure of the abdominal, mediastinal, and subcutaneous adipose tissue (fig. 1). Several physiologic respiratory disorders result[2]: a precipitous fall in transpulmonary pressure in dependent lung regions, atelectasis of the posterior segments of the lower lobes, decrease in end-expiratory lung volume, airway closure, reduction of respiratory compliance, and increased airway resistance. Decreased arterial oxygenation results from increased venous admixture and pulmonary shunt, as attested by the increase in alveolar-arterial gradient of partial pressure of oxygen. As shown in figure 2, most of respiratory disorders worsen exponentially with the body mass index.[3] When body mass index is above 40 kg/m^2, functional residual capacity is more than halved and expiratory reserve volume restricted by two thirds.[4] As a consequence, intraoperative tidal ventilation occurs at very low lung volumes if positive end-expiratory pressure (PEEP) is not enough to re-establish expiratory reserve volume. Noncartilaginous small airways collapse at the end of expiration, resulting either in cyclical opening and closure during tidal ventilation or, if peak inspiratory pressure does not exceed the opening pressure, in persistent closure.[1]

In bariatric laparoscopic surgery, two specific conditions worsen obesity-related respiratory disorders and increase the anesthetic risk. The first is pneumoperitoneum used to facilitate surgical exposure. Intraperitoneal insufflation of carbon dioxide increases the abdominal pressure by 50%. In morbidly obese patients, the abdominal pressure is chronically elevated, reaching 10 mmHg in basal conditions (twice the normal value). After pneumoperitoneum, it increases to 15 mmHg, a high pressure that displaces the diaphragm cranially, increases volume of atelectasis in dependent lung regions,[5] reduces functional residual capacity, decreases respiratory compliance, and increases airway resistance. All these respiratory disorders are partially reversed by PEEP, beach position,[6] and recruitment maneuver.[7] Interestingly, pneumoperitoneum is associated with an improvement in arterial oxygenation, likely resulting from a shift of pulmonary blood flow from lower to

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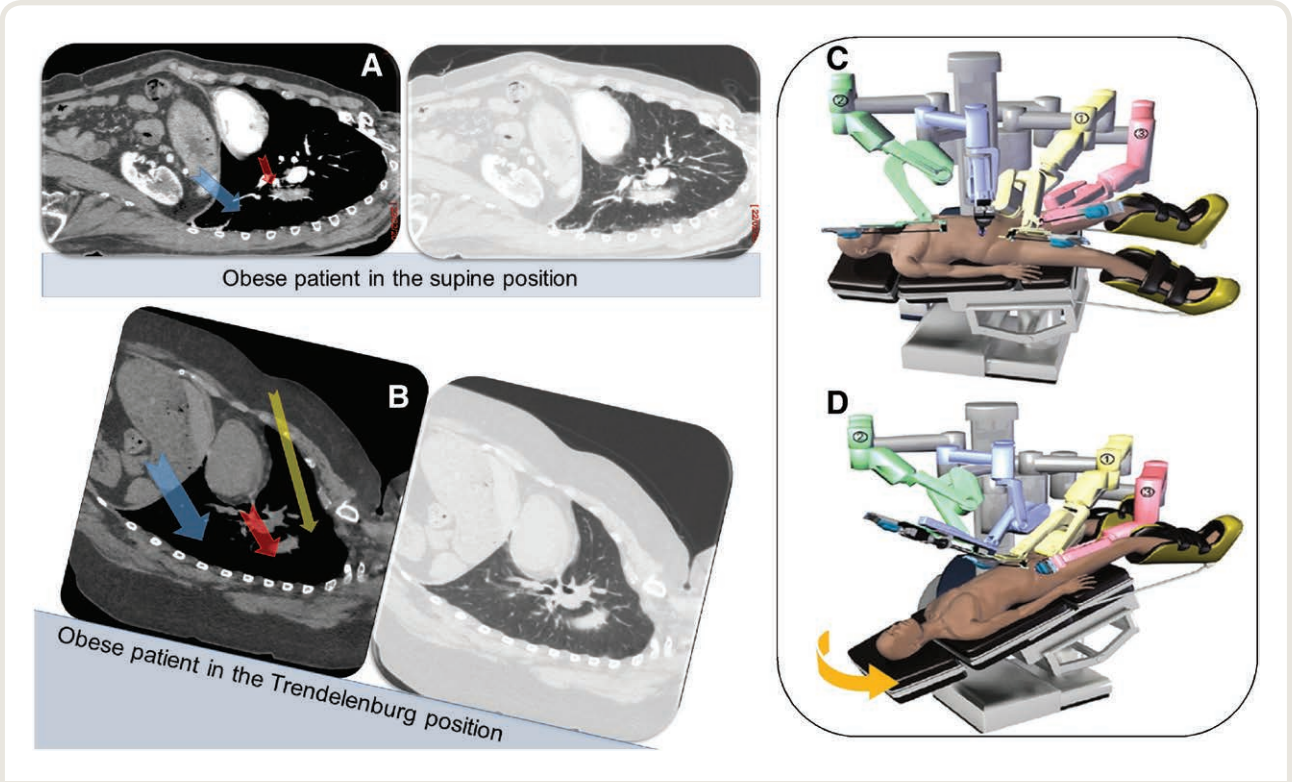

Fig. 1. Respiratory effect of the Trendelenburg position in obese patients during robotic surgery. (*A*) Left sagittal computed tomography section in a morbidly obese patient (body mass index = 42 kg/m^2) lying in the supine position. *Blue* and *red arrows* indicate the direction of the abdominal and heart compression on the left diaphragmatic cupola. (*B*) Left sagittal computed tomography section in a morbidly obese patient (body mass index = 51 kg/m^2), obtained in the supine position and represented in a 30° Trendelenburg position. *Blue, red*, and *yellow arrows* indicate the direction and the strength of the abdominal, cardiac, and subcutaneous compression on the left diaphragmatic cupola. (*C*) Positioning of a nonobese patient undergoing colorectal robotic surgery. For colonic mobilization, the patient is put in the Trendelenburg position at 30° and tilted right side down at an angle of 10° to 15°. (*D*) For rectal dissection, the angle of the Trendelenburg position is increased at 45°. (Figs. *C* and *D* are reproduced from reference 8, with permission of *Surgical Endoscopy*.)

upper lobes which tends to optimize ventilation–perfusion ratio.[6] The second factor influencing respiratory risk is the intraoperative posture implemented to facilitate surgical exposure. In laparoscopic and robotic bariatric surgery, surgical access is obtained through abdominal trocars that replace midline incisions. In upper gastrointestinal surgery, the beach position (inverse Trendelenburg) is recommended because it facilitates surgical exposure by moving the patient's bowel toward the pelvis. In lower gastrointestinal, urologic and gynecologic surgery, 25° to 45° Trendelenburg position is strongly advocated because it provides better exposure of the operative field because the bowels are displaced toward the upper abdomen. In robotic left colon surgery,[8] after 30° Trendelenburg positioning, the patient can be tilted right side down at an angle of 10° to 15° (fig. 1, C and D). Beach position is protective against obesity- and pneumoperitoneum-related respiratory disorders: it partially restores lung volumes, respiratory compliance, and airway resistance, and combined with PEEP and recruitment maneuver, improves arterial oxygenation.[5,7] Trendelenburg positioning is the critical factor that increases the respiratory risk by increasing the pressure on diaphragm cupolas (fig. 1B). It markedly increases peak inspiratory pressure (that may exceed 35 cm H_2O in some patients) and driving pressure that is always above 25 cm H_2O.[9] It dramatically reduces respiratory compliance, sometimes to 20% of normal values, and impairs arterial oxygenation without, however, producing life-threatening hypoxemia.[9] Lateral decubitus position, by shifting the abdominal contents away from the diaphragm, is partially protective against Trendelenburg-induced respiratory disorders. Not surprisingly, Grieco *et al.* have found that occult extended airway closure is observed in 20% of morbidly obese patients after 25° to 30° Trendelenburg positioning.[1]

Facing such a respiratory challenge, what should be the appropriate ventilator management? First, the anesthesiologist should thoroughly evaluate the risk. The latter increases with body mass index and the degree of Trendelenburg positioning. Body mass index greater than or equal to 40 kg/m^2 and tilting angle greater than or equal to 30° put the obese patient at maximum risk. Although steep Trendelenburg is recommended for robotic gynecologic, urologic, and lower gastrointestinal surgeries, lesser degree

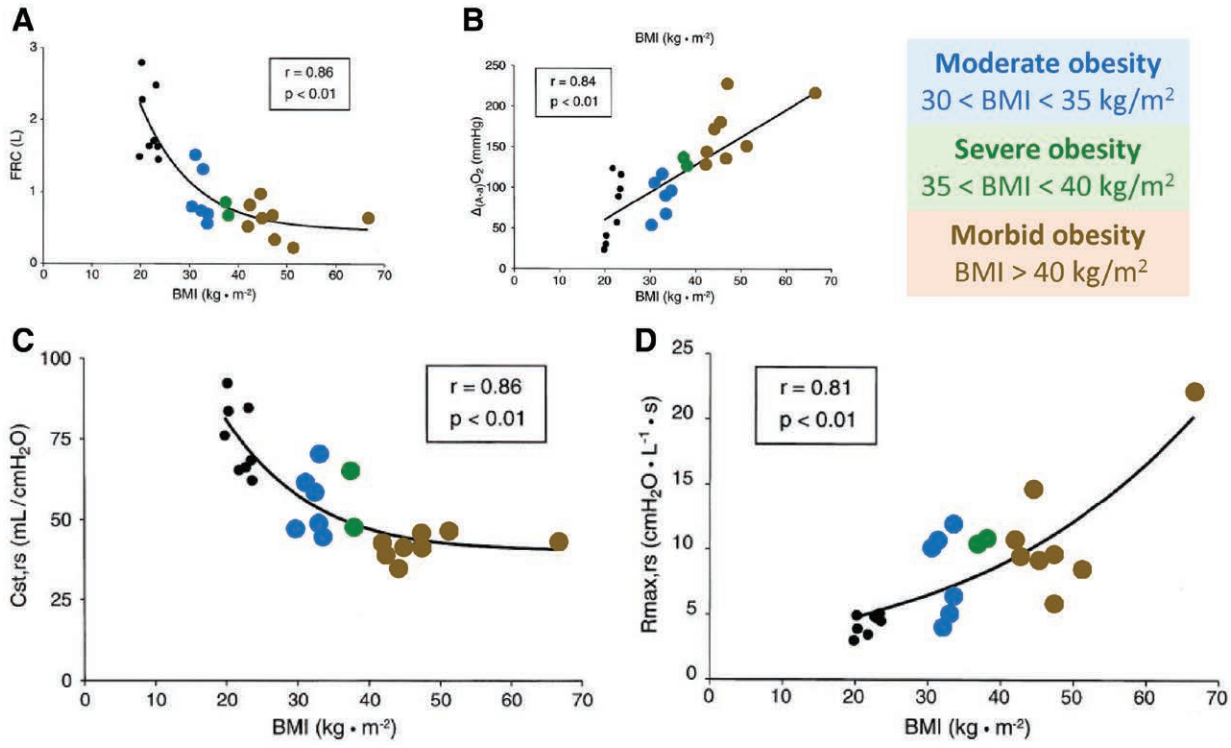

Fig. 2. Effect of body mass index on lung volume (*A*), arterial oxygenation (*B*), and respiratory mechanics (*C* and *D*). BMI, body mass index; FRC, functional residual capacity; Δ (A-a) O_2, Alveolar-arterial oxygen difference; Cst,rs, compliance of the total respiratory system; Rst,rs, resistance of the total respiratory system. (Modified from reference 3 with permission of *Anesthesia & Analgesia*.)

of Trendelenburg positioning (9° to 24°) can be effectively used without compromising surgical exposure.[10] Therefore, in morbidly obese patients, the degree of Trendelenburg positioning should be discussed between the Surgeon and the Anesthesiologist, on an individual basis. Second, intraoperative mechanical ventilation settings should be specifically adapted to the different steps of the robotic procedure.[11] After anesthetic induction, volume-controlled mechanical ventilation should be used with tidal volumes between 6 and 8 ml/kg of ideal body weight[1] (and not actual weight) and PEEP ranging between 5 and 10 cm H_2O.[12] After Trendelenburg positioning, PEEP should be increased above 10 cm H_2O, and targeted to obtain a driving pressure less than or equal to 15 cm H_2O; respiratory rate should range between 15 and 21 breath/min, and FiO_2 should be set as low as possible to avoid resorption atelectasis. Last but not least, periodic recruitment maneuvers should be performed to avoid airway closure and severe aeration loss.[13,14] By preserving lung volumes and avoiding ventilator-induced lung injury, such a protective ventilation strategy should provide adequate intraoperative oxygenation and carbon dioxide elimination while meeting the respiratory challenge of the Trendelenburg position in morbidly obese patients.

Competing Interests

The authors are not supported by, nor maintain any financial interest in, any commercial activity that may be associated with the topic of this article.

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References

1. Grieco DL, Anzellotti GM, Russo A, Bongiovanni F, Costantini B, D'Indinosante M, Varone F, Cavallaro F, Tortorella L, Polidori L, Romanò B, Gallotta V, Dell'Anna AM, Sollazzi L, Scambia G, Conti G, Antonelli M: Airway closure during surgical pneumoperitoneum in obese patients. Anesthesiology 2019; 131:58–73
2. Imber DAE, Pirrone M, Zhang C, Fisher DF, Kacmarek RM, Berra L: Respiratory management of perioperative obese patients. Respir Care 2016; 61:1681–92
3. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, Gattinoni L: The effects of body mass on lung volumes, respiratory mechanics, and gas exchange

during general anesthesia. Anesth Analg 1998; 87:654–60
4. Jones RL, Nzekwu MM: The effects of body mass index on lung volumes. Chest 2006; 130:827–33
5. Valenza F, Vagginelli F, Tiby A, Francesconi S, Ronzoni G, Guglielmi M, Zappa M, Lattuada E, Gattinoni L: Effects of the beach chair position, positive end-expiratory pressure, and pneumoperitoneum on respiratory function in morbidly obese patients during anesthesia and paralysis. Anesthesiology 2007; 107:725–32
6. Andersson LE, Bååth M, Thörne A, Aspelin P, Odeberg-Wernerman S: Effect of carbon dioxide pneumoperitoneum on development of atelectasis during anesthesia, examined by spiral computed tomography. Anesthesiology 2005; 102:293–9
7. Futier E, Constantin JM, Pelosi P, Chanques G, Kwiatkoskwi F, Jaber S, Bazin JE: Intraoperative recruitment maneuver reverses detrimental pneumoperitoneum-induced respiratory effects in healthy weight and obese patients undergoing laparoscopy. Anesthesiology 2010; 113:1310–9
8. Bae SU, Baek SJ, Hur H, Baik SH, Kim NK, Min BS: Robotic left colon cancer resection: a dual docking technique that maximizes splenic flexure mobilization. Surg Endosc 2015; 29:1303–9
9. Blecha S, Harth M, Zeman F, Seyfried T, Lubnow M, Burger M, Denzinger S, Pawlik MT: The impact of obesity on pulmonary deterioration in patients undergoing robotic-assisted laparoscopic prostatectomy. J Clin Monit Comput 2019; 33:133–43
10. Ghomi A, Kramer C, Askari R, Chavan NR, Einarsson JI: Trendelenburg position in gynecologic robotic-assisted surgery. J Minim Invasive Gynecol 2012; 19:485–9
11. Pépin JL, Timsit JF, Tamisier R, Borel JC, Lévy P, Jaber S: Prevention and care of respiratory failure in obese patients. Lancet Respir Med 2016; 4:407–18
12. Jaber S, Coisel Y, Chanques G, Futier E, Constantin JM, Michelet P, Beaussier M, Lefrant JY, Allaouchiche B, Capdevila X, Marret E: A multicentre observational study of intra-operative ventilatory management during general anaesthesia: Tidal volumes and relation to body weight. Anaesthesia 2012; 67:999–1008
13. Futier E, Constantin JM, Pelosi P, Chanques G, Massone A, Petit A, Kwiatkowski F, Bazin JE, Jaber S: Noninvasive ventilation and alveolar recruitment maneuver improve respiratory function during and after intubation of morbidly obese patients: a randomized controlled study. Anesthesiology 2011; 114:1354–63
14. Futier E, Constantin JM, Paugam-Burtz C, Pascal J, Eurin M, Neuschwander A, Marret E, Beaussier M, Gutton C, Lefrant JY, Allaouchiche B, Verzilli D, Leone M, De Jong A, Bazin JE, Pereira B, Jaber S; IMPROVE Study Group: A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. N Engl J Med 2013; 369:428–37