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Alveolar recruitment maneuver and perioperative ventilatory support in obese patients undergoing abdominal surgery

Manobra de recrutamento alveolar e suporte ventilatório perioperatório em pacientes obesos submetidos à cirurgia abdominal

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ABSTRACT

The development of abdominal surgery represents an alternative therapy for the morbidly obese; however, patients undergoing this surgical procedure often experience postoperative pulmonary complications. The use of alveolar recruitment maneuvers and/or perioperative ventilatory strategies is a possible alternative to reduce these complications, focusing on the reduction of postoperative pulmonary complications. In this review, the benefits of perioperative ventilatory strategies and the implementation of alveolar recruitment maneuvers in obese patients undergoing abdominal surgery are described.

Keywords: Respiration, artificial; Obesity/surgery; Postoperative period; Postoperative complications; Pulmonary alveoli/physiopathology; Respiratory mechanics; Anesthesia

Conflicts of interest: None.

Submitted on September 09, 2013
Accepted on December 12, 2013

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DOI: 10.5935/0103-507X.20130053

INTRODUCTION

Morbid obesity is considered an epidemic of global proportions. The origin of this problem is multifactorial and includes biological factors related to physical inactivity and to inadequate dietary patterns that are associated, in turn, with psychosocial factors related to the lifestyle adopted by the population.[1] According to the Ministry of Health in Brazil, 15% of the population is obese; however, overweight individuals represent 48% of the population.[2,3]

An alternative for the treatment of patients with morbid obesity is bariatric surgery. However, this procedure often results in postoperative pulmonary complications. The complications in the postoperative period are associated with a variety of factors, such as the supine position, muscle paralysis, and pneumoperitoneum, which results in reduced functional residual capacity (FRC) and increased volume of airway closure, thus causing atelectasis.[4,5]

Perioperative pulmonary complications are significant causes of morbidity and mortality,[6] may persist for up to 2 weeks, and include the accumulation of carbon dioxide (CO_2), atelectasis, and bronchopulmonary infiltrates.[7]

Some ventilatory strategies have been proposed and used to improve gas exchange during anesthesia and in the immediate bariatric surgery postoperative period. Among these strategies is the alveolar recruitment maneuver (ARM),[8] which is used in mechanical ventilation (MV). In MV, the application of high levels of inspiratory pressure results in the expansion of collapsed alveoli to increase the arterial pressure of oxygen (PaO_2). This strategy aims to improve gas exchange, providing a more homogeneous ventilation of the lung parenchyma.[9-11] The response after the use of ARM varies according to the nature, stage, and extent of pulmonary changes.[12]

The ARM most commonly described in the literature is sustained inflation, with a rapid increase in pressure to 40cmH_2O that is applied for a period of 60 seconds.[13] Various types of recruitment maneuvers are described in the literature: (1) prolonged recruitment maneuvers with low pressure and increased positive end-expiratory pressure (PEEP) to 15cm H_2O, associated with expiratory pauses of 7 seconds twice per minute for 15 minutes;[14] (2) incremental increases in PEEP, limiting the maximum inspiratory pressure;[15] and (3) ventilation with constant controlled pressure with PEEP staggering.[16] However, regardless of the mechanism, the ARMs increase oxygenation, promoting improved ventilatory mechanics and the repair of damage to the lung epithelium.[17,18]

Few studies have compared the use of ARM to ventilatory strategies aimed at alveolar derecruitment in obese patients undergoing abdominal surgery, which hampers evidence-based decision-making by clinicians. The objective of the present study was to present a literature review of the use of ARM and the perioperative ventilatory strategies aimed at derecruitment in obese patients undergoing bariatric surgery with respect to the improvement of gas exchange and respiratory mechanics and the reduction of postoperative pulmonary complications.

METHODS

This is a review conducted using the LILACS, MedLine, and PubMed databases. The period considered was 2007-2013. Terms such as "obese patients", "laparoscopic bariatric surgery", "bariatric surgery", "perioperative period", "recruitment maneuver", and "alveolar recruitment" were used. The selected studies addressed the topic of "abdominal surgery in obese patients", the surgery's pulmonary complications, the effectiveness of the ARM, and perioperative ventilatory strategies.

RESULTS

A total of 39 articles were identified in this review. After their analysis, 15 studies addressed the topic of alveolar recruitment, ventilation strategies, and abdominal surgery in obese patients. The articles selected are presented in table 1. The sample size varied between 30 and 66 individuals of both genders, with a mean age ranging between 32 and 43 years old, who were undergoing abdominal surgery, perioperative ventilatory strategies, and alveolar recruitment maneuvers.

DISCUSSION

Obesity can impair lung function due to the effects on the respiratory mechanics, airway resistance, pulmonary volumes, and respiratory muscles, and obesity is recognized as an independent risk factor for postoperative pulmonary complications.[19]

During general anesthesia and the immediate postoperative period, obese patients are more likely to develop postoperative pulmonary complications such as atelectasis and exhibit impaired pulmonary function compared to non-obese individuals.[20] Therefore, the prevention of atelectasis is of utmost importance in this population because atelectasis affects respiratory mechanics, the volume of airway closure, and the oxygenation index (PaO_2/FiO_2).[20]

Morbid obesity can promote a restrictive syndrome due to the accumulation of thoracic and abdominal fat, decreasing pulmonary volumes, expiratory reserve volume, and FRC due to reduced thorax wall movement, decreased pulmonary compliance, and increased airway resistance. Thus, anomalies in ventilation/perfusion appear, causing hypoxemia at rest and in the supine position, most likely due to the closure of small airways observed in this type of patient.[21]

Considering these factors, different ventilatory strategies have been investigated to improve respiratory function in anesthetized obese patients. The ARM mechanism consists of sustained pulmonary inflations and the use of PEEP and has been suggested to improve oxygenation subsequent to anesthesia in obese patients.[21,22]

In the study performed by Talab et al.,[20] three different PEEP values (0,5 and 10cmH_2O) were evaluated after the ARM was performed (PEEP 40, maintained for 7-8 seconds) to determine which strategy was safer and more effective in preventing atelectasis in patients undergoing bariatric surgery. The results revealed that the patients in the group undergoing ARM and PEEP maintained at 10cmH_2O after the maneuver exhibited a better oxygenation index in the

Table 1 - Clinical studies analyzing alveolar recruitment and perioperative ventilatory support

Author	Year	Sample (N)	Sample characteristic	Objective	Intervention	Conclusion
Ahmed et al.[27]	2012	G1=20 patients G2=20 patients G3=20 patients	Age between 20 and 50 years, BMI>35kg/m², undergoing laparoscopy bariatric surgery	To determine the effects of single or repeated ARM followed by PEEP used to prevent atelectasis in the postoperative period	Group I: control group Group II: ARM (40cmH_2O for 7 seconds) and posterior ventilation with PEEP of 10cmH_2O Group III: ARM (40cmH_2O for 7 seconds, repeated every 30 minutes, repeating up to 90 minutes) and posterior ventilation with PEEP of 10cmH_2O	Repeated ARM with posterior maintenance of PEEP of 10cmH_2O maintained increased PaO_2, PaO_2/FiO_2 and static pulmonary compliance in obese patients undergoing bariatric surgery
El Sayed et al.[31]	2012	G1=19 patients G2=19 patients G3=18 patients	Patients with ASA grade II and III, morbidly obese (BMI> 50kg/m²) patients with grade II and III ASA, undergoing laparoscopic bariatric surgery	To study the efficacy and safety of two different levels of PEEP after ARM in patients undergoing laparoscopic surgery and to evaluate the use of NIV post-extubation compared with conventional therapy (O_2)	Group I: ARM (40cmH_2O for 15 seconds) and PEEP of 10cmH_2O, O_2 was used after extubation Group II: ARM (40cmH_2O for 15 seconds) and PEEP of 15cmH_2O, O_2 was used after extubation Group III: ARM (40cmH_2O for 15 seconds) and PEEP of 15cmH_2O, NIV was used after extubation	The ARM with PEEP of 40cmH_2O, for 15 seconds, followed by the use of PEEP of 15cmH_2O improves pulmonary compliance and oxygenation in morbidly obese patients undergoing bariatric surgery. Furthermore, NIV after extubation was effective in maintaining oxygenation and preventing of alveolar derecruitment
Futier et al.[30]	2011	G1=22 patients G2=22 patients G3=22 patients	Obese patients with BMI>40kg/m² and ASA grade II and III who were undergoing laparoscopic gastrectomy	To determine whether NIV improves arterial oxygenation and end expiratory volume in comparison with conventional oxygenation and to determine if the NIV followed by ARM after endotracheal intubation improves oxygenation and respiratory function compared with isolated NIV	Group I: pre-oxygenation with O_2 100% and spontaneous ventilation Group II: SP followed by NIV; Group III: ARM followed by NIV	NIV improves oxygenation and reduces atelectasis in obese patients compared with conventional pre-oxygenation. NIV combined with ARM is more effective in improving respiratory function after intubation
Hemmes et al.[29]	2011	G1=450 patients G2=450 patients	Patients scheduled for non-laparoscopic abdominal surgery at high or intermediate risk of postoperative pulmonary complications	Comparison of two ventilation protocols	Group I: conventional ventilation with PEEP of 2cmH_2O Group II: PEEP of 12cmH_2O which was increased in 4 every 3 breath cycles up to 30-35cmH_2O; then, returning to PEEP of 10cmH_2O	These patients exhibited an improvement in oxygenation and respiratory mechanics in the short term.
Remístico et al.[8]	2011	G1=15 patients G2=15 patients	Men and women between 20 and 65 years old undergoing laparoscopic gastroplasty surgery	To assess the impact of ARM on the incidence of postoperative pulmonary complications in patients undergoing bariatric surgery	Group I: conventional mechanic ventilation Group II: ARM (PEEP of 30cmH_2O and peak pressure of 45cmH_2O for 2 minutes after the pneumoperitoneum abdominal deflation	The patients who received ARM exhibited better spirometric values, reduction of the incidence of pulmonary complications in thoracic radiography and improvements in range of BORG
Futier et al.[26]	2010	G1=30 patients G2=30 patients	Obese patients with BMI>35kg/m² and healthy individuals with BMI<25kg/m² who were scheduled for performing laparoscopic surgery	To investigate the effects of PEEP at end-expiration on respiratory mechanics and oxygenation in healthy individuals and obese patients during laparoscopic surgery	Group I: healthy individuals Group II: obese patients The protocol consisted of PEEP of 10cmH_2O in the case of pneumoperitoneum followed by ARM with PEEP of 40cmH_2O for 40 seconds and maintenance of PEEP of 10cmH_2O	Both groups exhibited improved respiratory mechanics as well as oxygenation, demonstrating that the use of such protocols can avoid the deleterious effects of pneumoperitoneum.
Weingarten et al.[28]	2010	G1=20 patients G2=20 patients	Patients older than 65 years undergoing open bariatric surgery	To test the hypothesis that ARM improves oxygenation and the ventilatory mechanics of patients undergoing abdominal surgery and to compare a group which used this strategy with a control group	Group I: conventional ventilation Group II: used PEEP of 20cmH_2O during the maneuver and then PEEP of 12cmH_2O	ARM is tolerated for patients in abdominal surgery and improves oxygenation during the surgery, and PEEP of 12cmH_2O promotes this effect

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Author	Year	Sample (N)	Sample characteristic	Objective	Intervention	Conclusion
Almarakbi et al.[24]	2009	G1=15 patients G2=15 patients G3=15 patients G4=15 patients	Patients between 18 and 60 years old, ASA grade II, BMI>30kg/m², undergoing laparoscopic bariatric surgery	To evaluate the best intraoperative strategy for maintaining PaO_2 and static compliance	Group I: vented with PEEP of 10cmH_2O throughout surgical procedure Group II: ARM (40cmH_2O for 15 seconds) and PEEP of 5cmH_2O throughout surgical procedure Group III: ARM (40cmH_2O for 15 seconds) and PEEP of 10cmH_2O throughout surgical procedure Group IV: ARM repeated every 10 minutes (40cmH_2O for 15 seconds) followed by PEEP of 10cmH_2O throughout surgical procedure	The repeated use of ARM followed by PEEP of 10cmH_2O increased compliance, PaO_2 and decreased $PaCO_2$. Moreover, the beneficial effects on the oxygenation continued during the recovery period
Cakmakkaya et al.[32]	2009	20 patients	Obese patients undergoing open abdominal surgery	To test the hypothesis that ARM applied before extubation can improve pulmonary compliance	To perform ARM with PEEP of 40cmH_2O for 10 seconds	The respiratory mechanics do not completely reverse the basal levels after deflation; however, the pulmonary compliance was completely restored using ARM.
Reinius et al.[22]	2009	G1=10 patients G2=10 patients G3=10 patients	Patients with ASA grade II-III, BMI>40kg/m², aged between 25 and 54 years undergoing bariatric surgery	To assess the effect of general anesthesia in three different ventilation strategies in the reduction of atelectasis and improved respiratory function	Group I: conventional ventilation with PEEP of 10cmH_2O Group II: ARM (PEEP of 55cmH_2O, for 10 seconds) followed by zero PEEP Group III: ARM (PEEP of 55cmH_2O, for 10 seconds) followed by PEEP of 10cmH_2O	ARM followed by PEEP of 10cmH_2O reduces atelectasis and improves oxygenation in obese patients for a long period, whereas mechanical ventilation with PEEP of 10cmH_2O or ARM alone did not improve the respiratory function
Souza et al.[25]	2009	G1=14 patients G2=17 patients G3=16 patients	Patients diagnosed with grade III obesity undergoing bariatric surgery	To compare two techniques of ARM and assess its response through the PaO_2/FiO_2 relationship as well as the [PaO_2+$PaCO_2$] sum in grade III obese patients	Group I: conventional ventilation with PEEP of 5cmH_2O Group II: ARM with progressive increase of PEEP to 10, 15 and 20cmH_2O, pause of 40 seconds, and maintenance of each value of PEEP for 2 minutes Group III: ARM with sudden increase of PEEP to 30cmH_2O for 40 seconds every 2 minutes	The technique of ARM with a sudden increase of PEEP to 30cmH_2O exhibited a better response in the PaO_2/FiO_2 relationship compared with the other groups
Sprung et al.[33]	2009	G1=9 patients G2=8 patients	Morbidly obese patients (BMI>40kg/m²) undergoing open bariatric surgery	To investigate whether ARM reverses atelectasis in patients sedated with desflurane undergoing bariatric surgery	Group I: ventilation with PEEP of 4cmH_2O Group II: starts ventilation with PEEP of 4cmH_2O, after 3 breaths, PEEP of 10cmH_2O, 3 breaths PEEP of 15cmH_2O and 20cmH_2O maintained for 10 respiratory cycles	Use of increasing amounts of PEEP is an effective method to improve oxygenation in patients undergoing bariatric surgery
Talab et al.[20]	2009	G1=22 patients G2=22 patients G3=22 patients	Obese patient with BMI between 30 and 50kg/m², aged between 20 and 50 years, undergoing laparoscopic bariatric surgery	To assess the safety and effectiveness of ARM according to the different PEEP used in the postoperative of bariatric surgery to prevent pulmonary atelectasis	Group I: ARM (PEEP 40, for 7-8 seconds) and ventilated with PEEP 0 Group II: ARM (PEEP 40, for 7-8 seconds) and ventilated with PEEP 5cmH_2O Group III: ARM (PEEP 40, for 7-8 seconds) and ventilated with PEEP 10cmH_2O	ARM followed by ventilation with PEEP of 10cmH_2O is effective in preventing atelectasis and is associated with better oxygenation, shorter stay in the recovery room, and decreased postoperative pulmonary complications in obese patients undergoing bariatric surgery
Chalhoub et al.[23]	2007	G1=26 patients G2=26 patients	Morbidly obese patients (BMI>40kg/m²) undergoing open bariatric surgery	To assess the effect of ARM followed by different values of PEEP on PaO_2 values in morbidly obese patients undergoing bariatric surgery	Group I: conventional ventilation with PEEP of 8cmH_2O Group II: ARM (PEEP of 40cmH_2O, for 15 seconds) followed by ventilation with PEEP of 8cmH_2O	The addition of ARM followed by ventilation with PEEP of 8cmH_2O improves PaO_2 in the intraoperative period in morbidly obese patients during the open bariatric surgery

G - group of studied patients; BMI - body mass index; ARM - alveolar recruitment maneuver; PEEP - positive end-expiratory pressure; ASA - American Society of Anesthesiologists; NIV - non-invasive mechanic ventilation; PAO_2 - oxygen arterial pressure; FIO_2 - oxygen inspired fraction; SP - support pressure.

intraoperative and postoperative periods, as well as a decreased incidence of pulmonary atelectasis and minor complications compared to the other groups. However, the study by Reinius et al.[22] analyzed the effects of three different ventilation strategies in anesthetized patients undergoing bariatric surgery to determine which strategy was most effective in reducing atelectasis. The patients were divided into a conventional ventilation group (PEEP 10cmH_2O) and groups of individuals undergoing ARM (PEEP 55cmH_2O for 10 seconds) followed by zero PEEP (ZEEP) or PEEP of 10cmH_2O. Corroborating the findings of Talab et al.,[20] it was observed that ARM followed by PEEP of 10cmH_2O reduced atelectasis and improved oxygenation in obese patients, thus indicating that the maintenance of optimal PEEP after the maneuver improves its benefits.

When comparing patients that used ARM with those who did not, with both groups being ventilated with PEEP of 8cmH_2O during the surgical procedure, it was observed that the addition of ARM followed by ventilation with PEEP of 8cmH_2O improved PaO_2 in the intraoperative period in morbidly obese patients during open bariatric surgery.[23] However, when the goal is to improve PaO_2 and pulmonary compliance during surgery and throughout the postoperative period, Almarakbi et al.[24] demonstrated that ARM repeated every 10 minutes (40cmH_2O for 15 seconds) followed by PEEP of 10cmH_2O throughout the surgical procedure resulted in increased compliance, increased PaO_2, and the reduction of $PaCO_2$. Moreover, the beneficial oxygenation effects persisted during the recovery period.

Another important factor related to ARM is its gradual or sudden application. This relationship was explored in the study by Souza et al.,[25] which demonstrated that the technique of ARM with sudden increases in PEEP to 30cmH_2O resulted in the best response in the PaO_2/FiO_2 relationship compared to the gradual increase of PEEP. However, Futier et al. compared a ventilatory strategy associated with the use of ARM in healthy and obese subjects undergoing abdominal surgery. Patients in both groups were intubated and ventilated with 8mL/kg controlled volume and PEEP equal to zero. The ventilation protocol used 0.5% FiO_2. Pneumoperitoneum was induced, the PEEP was raised to 10cmH_2O for 10 minutes, and ARM was performed with PEEP of 40cmH_2O for 40 seconds followed by PEEP of 10cmH_2O. The authors reported improvements in respiratory function and oxygenation in both groups, indicating that the use of such protocols can avoid the deleterious effects of pneumoperitoneum.[26]

The use of ARM during and/or after bariatric surgery has been shown to be beneficial in several studies. The maintenance of its effects depends on repetition; thus, increasing the frequency of the maneuver is necessary. Based on this fact, Ahmed et al. aimed to evaluate the effect of ARM repetition with respect to oxygenation and the reduction of atelectasis. To do so, 60 patients were randomly allocated into 3 groups: conventional ventilation, single ARM (40cmH_2O for 7 seconds), and ARM repeated every 30 minutes. All groups were treated with PEEP set at 10cmH_2O. In addition to improving gas exchange and respiratory mechanics, repeated ARM maintained its beneficial effects during the postoperative period.[27]

The optimization of PEEP may be an important factor during the perioperative period. This is clear in the study by Weingarten et al.,[28] which tested the hypothesis that the optimization of PEEP improves oxygenation in patients over 65 years old undergoing abdominal laparoscopic surgery. These researchers compared a group that performed this strategy to a control group that received conventional ventilation. A tidal volume of 10ml/kg and PEEP ventilation was applied in the control group. A tidal volume of 6mL/kg and PEEP of 4cmH_2O was applied in the group undergoing this strategy, with PEEP adjusted in three steps: PEEP was raised from 4cmH_2O to 10cmH_2O for three breaths cycles, followed by three cycles of 15cmH_2O and then ten cycles with PEEP of 20cmH_2O. After performing this maneuver, PEEP was maintained at 12cmH_2O until the end of the surgical procedure. The authors demonstrated that this ventilation option is tolerated by patients undergoing abdominal surgery. Moreover, this approach results in improved arterial oxygenation. Corroborating this finding, Hemmes et al. compared conventional ventilation with PEEP of 2cmH_2O to a group treated with the following: initial PEEP of 10cmH_2O, PEEP raised in intervals of 4cmH_2O to 30cmH_2O and then maintained for three breath cycles, and return to PEEP of 10cmH_2O. The authors reported an improvement in oxygenation and respiratory mechanics in the short term in these patients.[29]

The application of ARM during surgery can result in short-term effects. Testing this hypothesis, Ahmed et al., conducted a study with three groups of obese patients undergoing bariatric surgery, comparing a conventionally ventilated group with a group receiving ARM with PEEP of 40cmH_2O and a third group receiving the same maneuver repeated 30 and 90 minutes after surgery; both of the ARM groups used PEEP of 10cmH_2O until the end of the procedure. The authors demonstrated that ARM improved gas exchange; however, the repetition maintained adequate gas exchange and also resulted in better compliance.[27]

One of the factors that may be related to a reduction of the ARM effect is pulmonary derecruitment. The studies by Futier et al.[30] and El-Sayed et al.[31] aimed to determine whether the use of noninvasive ventilation (NIV) after extubation in obese patients who had received ARM would be effective in oxygenation maintenance. Both studies reported that the use of NIV after extubation in this patient population improved oxygenation and pulmonary compliance and prevented alveolar derecruitment. Another possible alternative to modify the outcomes after extubation would be to perform ARM before extubation. It was with this objective that Cakmakkaya et al. tested the hypothesis that the application of ARM before extubation could improve pulmonary compliance. ARM was used with PEEP of 40cmH_2O for 10 seconds in patients undergoing open abdominal surgery. The authors demonstrated that there was an improvement in the pulmonary compliance of these patients.[32]

Clinically, the studies demonstrate that perioperative ventilatory strategies and ARM are good alternatives in improving ventilatory mechanics and gas exchange in obese patients. However, these studies demonstrated the need for adequate PEEP after the use of these ventilation strategies. Most studies demonstrated that PEEP of 10cmH_2O is a good alternative for maintaining the effects achieved with the ARM and that the use of non-invasive ventilation may be an alternative after extubation for such patients.

The studies presented in this review suggest that ARM is an effective technique when performed to prevent pulmonary complications in obese patients undergoing abdominal surgery. ARM is associated with better oxygenation and respiratory mechanics and a reduction in pulmonary complications in the postoperative period in obese patients undergoing bariatric surgery. However, recent studies are highly heterogeneous, which hinders the analysis of the results and the performance of meta-analysis. The absence of randomized and controlled trials with adequate sample sizes increases the risk of bias, such as allocation concealment, bias of detection, attrition, and selection of results, thereby limiting the results presented here. Furthermore, using the studies included in this review, it is not possible to analyze clinical outcomes such as the length of stay or mortality. In addition, some factors related to ARM remain to be further elucidating, including (1) the PEEP values used, (2) the optimal PEEP after ARM, (3) the timing of ARM to avoid derecruitment, (4) the target number of repetitions of ARM, and (5) the safety of the maneuver with respect to clinical outcomes.

FINAL CONSIDERATIONS

Several studies have addressed the effect of alveolar recruitment maneuver and ventilatory strategies that aim to prevent derecruitment during anesthetic procedures in obese patients undergoing abdominal surgery. The alveolar recruitment maneuver seems to be a viable strategy for the prevention of pulmonary complications such as atelectasis and the improvement of gas exchange and respiratory mechanics.

RESUMO

O desenvolvimento da cirurgia abdominal proporcionou uma alternativa terapêutica para obesos mórbidos; entretanto, os pacientes submetidos a esse procedimento frequentemente apresentam complicações pulmonares pós-operatórias. Uma possível alternativa para a redução dessas complicações é a utilização da manobra de recrutamento alveolar e/ou estratégias ventilatórias perioperatórias, com foco na redução das complicações pulmonares pós-operatórias. Nesta revisão, são descritos os benefícios de estratégias ventilatórias perioperatórias, assim como a realização de manobra de recrutamento alveolar em pacientes obesos submetidos a cirurgia abdominal.

Descritores: Respiração artificial; Obesidade/cirurgia; Período pós-operatório; Complicações pós-operatórias; Alvéolos pulmonares/fisiopatologia; Mecânica respiratória; Anestesia

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