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Ventilation management of the obese patient undergoing surgery

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2021

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Dissertação de candidatura ao grau de Mestre em Medicina, submetida ao Instituto de Ciências Biomédicas Abel Salazar – Universidade do Porto

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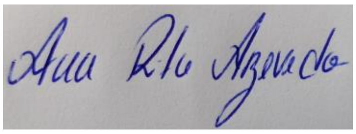
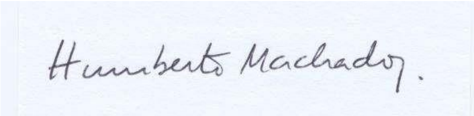
Março 2020



Assinatura do estudante



Assinatura do Orientador

Agradecimentos

O meu sincero agradecimento ao meu orientador, Professor Doutor Humberto Machado, que tão gentilmente aceitou orientar-me neste trabalho e me suscitou o interesse pela temática. Obrigada pela enorme disponibilidade que sempre demonstrou e por todos os conselhos.

Resumo

A obesidade é uma doença cuja prevalência se encontra em crescimento, o que implica, por conseguinte, o incremento do número de pessoas obesas que são submetidas a procedimentos cirúrgicos. As alterações a nível fisiológico que esta população apresenta, em conjunto com as patologias a que se associa, suscitam a necessidade de implementar uma abordagem distinta, não só na sala de operações, mas também no período pré e pós-operatório.

Esta revisão bibliográfica foi, então, realizada com o objetivo de analisar e sistematizar as mais recentes guidelines e práticas médicas no que concerne à ventilação de doentes obesos no período peri-operatório. Deste modo, foi revista informação referente aos últimos 5 anos relacionada com a ventilação no período pré, intra e pós-operatório em doentes obesos. Um total de 41 artigos foram analisados e a sua informação comparada e sistematizada.

Os tópicos abordados foram bastante abrangentes e a sua discussão foi subdividida nos 3 períodos peri-operatórios.

No período pré-operatório, a Síndrome da Apneia Obstrutiva do Sono deve ser rastreada utilizando o score Stop Bang e determinadas medidas gerais deverão ser encorajadas, como a cessação de hábitos tabágicos e de consumo de álcool. A via aérea deve ser estudada, podendo-se recorrer à ecografia, e deve ser considerada a possibilidade de se estar perante uma via aérea difícil, tendo que a sua abordagem ser preparada com antecedência.

No que respeita ao período intra-operatório, deverá ser privilegiada uma posição em que o paciente permaneça com a cabeça mais elevada. Oxigenação apneica com recurso a cânula nasal de alto fluxo poderá ser uma mais valia, uma vez que poderá prolongar o período de apneia segura, manter saturações de oxigénio mais elevadas e facilitar a ressaturação. Adicionalmente, poderá ser utilizada durante a intubação, na qual se deve considerar também a utilização de videolaringoscópio, assim como de um dispositivo supraglótico de segunda geração. Quanto à modalidade de ventilação, frequência respiratória e fração inspirada de oxigénio, estes devem ser individualizados a cada individuo. Não obstante, um rácio ventilatório inverso poderá melhorar a oxigenação. A utilização de manobras de recrutamento e de pressão positiva expiratória final poderá reduzir a formação de atelectasias durante a cirurgia, no entanto, não se verificou qualquer influência no que respeita ao desenvolvimento de complicações pulmonares no período pós-operatório.

Ao longo dos 3 períodos, o recurso a ventilação não-invasiva mostrou ser uma mais valia.

Por fim, é importante realçar que é consistente ao longo dos tópicos abordados a necessidade de individualização, não só ao paciente em si, mas também ao tipo de cirurgia e ao material disponível.

Palavras-chave: Ventilação perioperativa; Ventilação pré-operativa; Ventilação intra-operativa; Ventilação pós-operativa

Abstract

A growing number of obese patients are undergoing surgery. A higher prevalence of co-morbidities leads to a distinct pre, intra, and post-operative approach. This review shows the most recent guidelines and best practices of ventilation management for obese patients undergoing surgery. Available data for the last 5 years, related to the pre, intra and postoperative periods regarding the ventilation management of obese patients was reviewed and forty-one articles were included.

In the pre-operative setting, Obstructive sleep apnea should be accessed through the stop bang score and the cessation of tobacco and alcohol consumption are paramount. The airway should accessed before the surgery and ultrasound may be a great asset in this context.

In the operating room, the body should be in a position with the head up. Apneic oxygenation with a high flow nasal cannula may be a valuable asset in prolonging the period of safe apnea and maintaining higher saturations. Intubation with the use of a videolaryngoscope, as well a second generation supraglottic device, should be considered. Ventilation mode, respiratory frequency and inspired fraction of oxygen should be individualized; however, an inverse ventilation ratio may improve oxygenation. The use of recruitment maneuvers and positive end-expiratory pressure decreases atelectasis formation but did not reduce post-pulmonary complications.

Non-invasive ventilation has proven beneficial throughout the 3 periods.

Nevertheless, it was consistent throughout most of the topics approached, the need for individualization, not only to the patient itself, but also to the type of surgery and the available equipment.

Key-words: Perioperative obese ventilation; Preoperative obese ventilation; Intraoperative obese ventilation; Postoperative obese ventilation.

Abreviations:

BiPAP: *Bilevel positive airway pressure*
BMI: *Body Mass Index*
CPAP: *Continuous positive airway pressure*
EELV: *End-expiratory lung volume*
ERV: *Expiratory Reserve Volume*
FiO_2: *Fraction of inspired oxygen*
FRC: *Functional Residual Capacity*
HFNC: *High Flow Nasal Cannula*
iPEEP: *Intrinsic Positive End-expiratory pressure*
LC: *Lung Compliance*
NIPPV: *Non-invasive positive airway pressure*
NIV: *Non-invasive ventilation*
OHS: *Obesity Hypoventilation Syndrome*
OSA*: Obstructive Sleep Apneoa*
PEEP: *Positive end-expiratory pressure*
Ppeak: *Peak Pressure*
Pmean: *Mean Pressure*
Pplateau: *Plateau Pressure*
PPCs: *Post-operative pulmonary complications*
RM*: Recruitment Maneuvers*
RF: *Respiratory frequency*
TV: *Tidal Volume*

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Introduction

Obesity is a chronic metabolic disease commonly diagnosed and classified according to the Body Mass Index (BMI), since this measure allows to roughly estimate the amount of adipose tissue accumulated in the body. However, it can be a not so useful measure, considering that the distribution of this tissue is also relevant [1]. Central obesity, where it is mostly accumulated in the trunk and has a high intraperitoneal fat content, is the most significant pathophysiologically [1, 2, 3]. This distribution, not only is more associated with the increased inflammatory response seen in obese patients [1, 2], but also with the accumulation of fat tissue around the thorax and the upper airway [1, 4], which generate important anatomical changes in the lung mechanics and can be the basis for other pathologies as Obstructive sleep apnea (OSA) [1]. Therefore, instead of the BMI, it can be used the waist circumference, which can appraise central and abdominal obesity and may be a more useful predictor of outcomes in surgical patients [5, 6].

Obese patients have their pulmonary function impaired [1, 5, 7.] The accumulation of adipose tissue increase the pressure in the thorax and hinder the normal movement of the respiratory muscles, resulting in the decrease of pulmonary volumes, specially Tidal Volume (TV) and Functional Residual Capacity (FRC) to account of a reduced Expiratory Reserve Volume (ERV) [1, 3, 8, 9], and in the decrease in Lung compliance (LC) [4, 5, 7, 10, 11, 12, 13.] Additionally, this pressure is also transmitted to the airway, provoking its narrowing and collapse [1, 4], leading to an increase in intrinsic positive end-expiratory pressure (iPEEP), since part of the air remains trapped inside the alveoli at the end of expiration, originating a dynamic hyperinflation [5, 7, 11.] These collapses contribute to the formation of atelectasis, which obese patients have in higher number than lean patients [14], once the trapped air is reabsorbed [4, 5].

An increase in oxygen (O_2) consumption and carbon dioxide (CO_2) production is also seen [1, 4, 9, 11], not only due to the increased body tissue in general, but also because of the bigger effort needed to breath [1, 3, 5, 7, 12]. Therefore, to maintain normocapnia, it is necessary to increase minute ventilation [1].

All these alterations modify gas exchange as well. Thus, obese patients can have a reduced arterial oxygen partial pressure, increased arterial carbon dioxide partial pressure and an increased alveolar-to-arterial oxygen partial pressure difference [1, 4]. An increased shunt fraction and ventilation perfusion mismatch also contribute to the hypoxemia [1, 4, 7, 10.]

Many others pulmonary dysfunctions emerge associated with obesity. The Obesity-Hypoventilation syndrome (OHS) is characterized by the triad of obesity, sleep-disordered breathing and daytime hypoventilation in the absence of other explanation [1, 3, 5, 7]. This daytime hypoventilation can be explained by the altered respiratory mechanics, by the resistance to leptin that leads to a central hypoventilation and by a defected response to acute hypercapnia in patients with Obstructive sleep apneoa (OSA) [1]. It is important to denote this pathology, owing to its association with singular characteristics: the obstruction in the upper airway tends to be more severe, the respiratory mechanics to be more impaired, the respiratory drive to be more attenuated and the pulmonary hypertension incidence to be augmented [1].

Obstructive sleep apnoea (OSA) is also very common among the obese population [5], due to exerting extra-luminal pressure on the pharynx that elevates the airway collapse [1, 7, 11], and must be taken into consideration, due to its impact in the cardiopulmonary system [15] and its association with a higher postoperative respiratory failure, cardiac events and ICU admission [4, 7]. It is also seen an association with airway hyperreactivity, specifically bronchial, that can be explained by the inflammatory environment induced by the adipose tissue [1, 7].

Thereby, the obese patient undergoing surgery require special care due to all the alterations mentioned above and the additional ones brought about by the anesthesia and the surgery itself. Due to sedation, paralysis and the supine positioning, the anesthetized patient experiences an additional decrease in lung volumes, especially FRC [1, 5, 10], what propitiates the formation of atelectasis [4, 10, 16]. These atelectasis are of major importance, they not only have impact during the surgery, but also in the postoperative period [14], once they impair gas exchange and increase physiological shunt, ventilation-perfusion mismatch and breathing work, also impairing lung mechanics [5, 17]. All these alterations lead to alveolar hypoventilation, hypoxemia and hypercapnia [1] during and after the surgery, considering that these alterations triggered by the anesthesia remain 2-3 days after the surgery [1, 3, 4, 10] and may contribute to the development of postoperative pulmonary complications (PPCs) [10].

Additionally, morphological characteristics of obese patients can negatively interfere with the management of the airway [2], being the difficult airway more frequent [11]. Most of these features are exactly the same as in lean patients, however, occur more frequently or are more prominent in obese patients. Male sex, OSA, particularly if severe [3] and a large neck circumference (above 40 cm) are the risk factor more frequently reported [2].

The prevalence of obese individuals in Portugal, accordingly to a study carried out in 2012 was of 19,9% for males and 19,8% for females [18]. Given this high prevalence and the especial care that obese patients require when undergoing a surgery, the discussion of this subject is of great relevance. Therefore, the aim of this review is to summarize the most recent data regarding the management of ventilation in obese patients undergoing surgery in the pre, intra and postoperative period.

Methods:

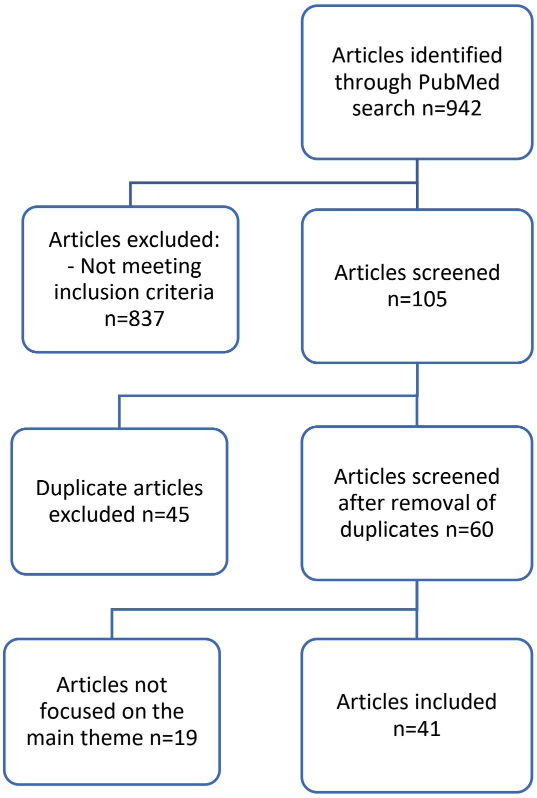

Figure 1- PRISMA flow diagram showing literature search results.

The search for this review was performed on PubMed, during the month of August of 2020, using the query: "perioperative obese ventilation", "preoperative obese ventilation", intraoperative obese ventilation" and "postoperative obese ventilation". The results of this search strategy were limited to meta-analyses, randomized controlled trials, prospective studies and studies in humans, written in English or Portuguese. The analysis also included only articles published in the last 5 years. Initially were identified 942 articles, with the criteria mentioned above, 105 articles were selected. Excluding the repeated ones, 60 articles remain. After the screening of the title and abstract, were selected 41 articles, once the remaining 19 did not focus on the main theme.

Pre-operative care:

Similarly to all patients, obese patients undergoing surgery should be accessed through a thorough clinical history, physical examination and laboratory analysis, with some additional concerns. Frequent pathologies concerning the pulmonary function should be looked upon, namely the Obesity-hypoventilation syndrome and Obstructive sleep apnea syndrome [2] for which can be used the STOP-BANG score [3] ,that has also been study as a tool to predict post-operative pulmonary complications (PPCs) [4].

A few general measures can be taken before the surgery to minimize the risk of adverse events related to obesity and improve operating conditions. Weight loss is one of them, as well as cessation of tobacco and alcohol consumption [2, 3.] The inspiratory muscles can also be strengthened by muscular training, which can also improve postoperative oxygenation [2].

Non-invasive Ventilation before surgery:

Before surgery, the initiation of Non-invasive ventilation (NIV) can be implemented, since it has demonstrated benefits not only on the airway but also in other parts of the respiratory system [1, 2]. This is particularly relevant in OSA patients, once it allows, through mechanical effects, the maintenance of the airway patency [1]. Additionally, to this temporary upper airway dilation, anatomical and functional improvements are also seen and that translates in a decrease in the collapsibility even during the day, however it is only detectable after a relatively long-term usage [1].

Obese patients with symptoms similar to the ones from asthma, like dyspnea and wheezing, may also benefit from NIV [1].

Non-invasive ventilation brings also benefits to patients suffering from OHS, being its first line of therapy. After a short term it improves gas exchange and sleep-disordered breathing, and improves lung volumes and central respiratory drive in response to carbon dioxide when used for longer periods [1]. When OSA is thought to be a major contributor to OHS, Continuous positive airway pressure (CPAP) is preferred, whereas bilevel positive airway pressure (BiPAP) is more useful when a severe restrictive pattern is seen [1].

The use of CPAP also contributes to minimize the cardiometabolic impairment induced by these identities [2], reduce symptoms of sleepiness, improve quality of life measures and cognitive function [1] and decreases the postoperative severe complications incidence [3].

Postoperative planning:

When an obese patient is submitted to surgery, especially a major, revisional or open one, or when is anticipated the necessity of use of parenteral opioids, as well as CPAP or Non-inavaisve positive pressure ventilation (NIPPV), is necessary a more closed monitored postoperative care [2], and it should be planned still before the surgery.

Airway assessment:

One of the major concerns in obese patients undergoing surgery is the airway assessment. This practice is directly dependent on 4 variables: the patients characteristics, particularly relevant in these patients, the anesthetic skills, the duration of the surgery and the devices available [19]. Some morphological features associated with obesity increase the difficulty in ventilation with facial mask and also in tracheal intubation [2, 3, 11, 20]. To assess this difficulty can be used the same predictors used in non-obese patients [2, 21]. It may be considered the degree of mouth opening, thyromental distance, Mallampati score, neck mobility, prognathism, BMI (>30) and the existence of a difficult airway history [11]. Although most of the indicators alone have a poor predictive power, their combination improves their value [22].

Additionally, one review favors the utilization of ultrasound to enhance the preoperative knowledge, once it allows a rapid visualization of structures around the airway and evaluate the dimensions of these structures, the existence of pathologies and their relation to the airway and, at the same time, estimate de endotracheal tube size and evaluate its placement [22]

Sedation:

Preoperative sedation must take into account the risk of hypoventilation in obese patients. Therefore, it must evaluate the risk/benefit and when needed, peripheral oxygenation should be monitored [2]. Also, it is important to highlight that obese patients may have the pharmacokinetics of most drugs altered, thus, the necessary dose may not be the same in these patients [2, 11].

Intra-operatory:

Body Positioning:

The position of the body is also relevant [7]. A position with the head-up, in general, improve respiratory mechanics during induction and intubation, since it decreases the cranial displacement of the diaphragm and the gravitational effect of the abdominal organs exerting pressure in the thoracic cavity [5, 7, 11, 23]. Therefore, a position where the feet are below the head help preserve FRC, improves oxygenation and may prolong the time needed to desaturate [5], increasing the period of safe apnea [2, 8, 11, 23]. These changes are particularly relevant in laparoscopic surgeries, where the abdominal pressure is higher due to the pneumoperitoneum [2]. These benefits are not relevant only during induction and intubation, once it may improve respiratory mechanics also throughout the surgery [11].

The body position can also influence intubation [23]. It can allow a full mouth opening, and a more effective placement of the facemask, and intubation in obese patients, once it allows the alignment of the airway axis, providing a better view [2, 8, 11, 23].

There are various positions where these changes can be achieved, being the Reverse Trendelenburg superior to the back-up position, and both being better than the supine one [9, 11].

Preoxygenation:

The preoxygenation before surgery is of major importance in obese patients, seeing that it was reported that the more severe the obesity, less time is needed to the patient desaturate [1, 20, 23]. Also, the time required to increase saturation after induction is longer than the one seen in lean patients [9]. Therefore, some practices must be considered in order to increase the oxygen reserves, and extend the period of safe apnea (defined as the period of apnea until the peripheral saturation decreases to 95% [12]) [2, 23]. Several studies have demonstrated the advantages of using a font of positive pressure over the standard pre-oxygenation [1, 9, 11, 24 25], and avoidance of high fraction of inspired oxygen (FiO_2), once it promotes the formation of atelectasis [1, 4, 5, 17, 23]. Thus, Non-invasive ventilation (NIV) can be used with this purpose, since it improves arterial oxygenation, decrease the partial pressure of carbon dioxide ($PaCO_2$) and increases lung volumes [2], extending the period of safe apnea and reducing the risk of life-threatening hypoxemia at induction [1, 14].

A recruitment maneuver, in addition to the positive pressure, can also be performed at induction, since it improves oxygenation [9, 23].

Apneic oxygenation:

Following an effective preoxygenation, is possible to maintain oxygenation during longer periods of time when oxygen is administered continuously into de pharynx [9, 23]. This procedure is called Apneic oxygenation, and consists of delivering oxygen to the alveoli while the patient is not being ventilated [12] and it is important to differentiate it from the pre-oxygenation, since it must not be used as one [3].

As carbon dioxide is not fully returned to the alveoli during an apnea, it is created a subatmospheric pressure that pulls the oxygen from the upper parts of the airway [12 23], allowing alveolar ventilation and blood oxygenation. The oxygen supply can be assured by many techniques. One study demonstrated that the oxygenation through nasopharyngeal and standard nasal cannula increased the period of safe apnea during a prolonged laryngoscopy [11], which can increase the rate of the first-pass intubation [12]. Also maintained higher peripheral O_2 saturations during the induction and were able to ressaturate faster after the induction period [12].

A high flow nasal cannula (HFNC) can also be used. It can produce 3 to 5 cmH_2O of PEEP [11] due to its high flow rates and allow the passage of the orotracheal tube through the mouth [3]. The only requirements for this procedure is the patency of the airway, a continuous source of O_2 and an effective preoxygenation [23].

However, is it important to denote the risk of developing respiratory acidosis, since CO_2 levels continue to increase during this time [12].

Intubation:

Intubation is a critical procedure in every patient. All of the scores predicting a difficult intubation include obesity as risk factor [10], being, therefore a practice that requires special attention in these patients.

Similarly to all the procedures taking place in the surgical room, a clear and appropriate strategy, as well as the knowledge of the existing guidelines in case of difficulty, are crucial [2]. Therefore, some practices can be implemented and were associated with an improvement in intubation. The preparation of the material that might be needed, preoxygenation as already discussed in this review, prevention of a collapse, having prepared fluids and vasopressor drugs, rapid sequence intubation and sellick maneuver and the usage of a capnogram for postintubation monitoring are some of them [10].

The laryngoscope used may influence the intubation effectiveness [2]. Videolaryngoscopy can be the first choice in an obese patient when a difficult intubation is predicted or even when it is not predicted [3]. Videolaryngoscopes, when compared to a traditional Macintosh one, may increase the success rate of intubation, improve visualization and decrease the time needed to perform the procedure [2, 19]. However, a study reported an increase in the time needed to perform a videolaryngoscopy when compared to a direct one, despite the improvement in the laryngeal view [8]. Awake flexible fiber-optic intubation can also be used when a difficult intubation is anticipated[2, 3].

To facilitate this procedure, can be used a supraglottic device, especially a second-generation one. They provide a higher oropharyngeal leak pressure, providing a better seal [23] and bringing more safety to ventilation [20] and allow the application of PEEP, gastric decompression and can improve oxygen reserves in morbidly obese patients [23]. These devices, not only can function as a conduit to the insertion of the endotracheal tube, but also as temporary ventilatory devices before intubation, after a failed attempted of intubation [11] or even as a primary airway device during some surgeries [2, 20, 23]. In selected patients, they allow a better postoperative pulmonary performance as long as that they are well fitted to the airway [8].

Ventilatory mode:

Due to the risk of obese patients develop pulmonary complications, the ventilation mode and settings are extremely debated. Protective ventilation has proven an impact on the clinical outcome in the intensive care unit [7, 23] and has been associated with a decrease in the incidence of postoperative pulmonary complications [2, 3, 14]. This strategy is characterized by a low Tidal Volume (TV), appropriate PEEP and low driving pressure [2].

During mechanical ventilation it is important to adjust the settings in order to avoid volutrauma, barotrauma and atelectotrauma, what can be made by using low Tidal Volumes, avoiding high pressures and cyclic closing and reopening of the alveolar units respectively [10]. Additionally, the low Tidal Volumes has shown to reduce postoperative pulmonary complications (PPCs) [7, 10, 26].

It should be denoted that for calculating Tidal Volume should be used the predicted body weight, considering that the excess body weight is due to excess of fat tissue and does not alter the lung size [3, 4, 7, 23, 26, 27]. The optimal value is thought to be between 6 and 8 mL/Kg [3, 5, 10, 14. 26, 28].

The preferential mode that should be used has some contradictions associated, once many studies comparing ventilatory modes show contradictory data [3] and even some trials have reveal no difference between pressure and volume control [7, 8, 25, 29, 30] regarding the oxygenation, mean airway pressure and tidal volume [23]. Some articles defend the preference for pressure controlled mode [4], since it may facilitate the weaning from mechanical ventilation and prevent some types of atelectasis once it allows the maintenence of some muscular effort [5], as well as allow a more homogeneous airflow distribution [7]. Others defend the volume control for being associated with less postoperative complications when compared to pressure controlled [10], however always advocating the individualization in every case [5]. Therefore, in each patient the advantages and disadvantages of each mode should be taken into account [3].

Respiratory frequency:

Regarding the respiratory frequency, it must be taken into account that obese patients have it increased in a basal status [1, 3]. Capnography is often used to guide this setting, however, these patients have a greater expired CO_2/arterial CO_2 gradient, making this approach not so much reliable [3]. Arterial blood gases in repetition can guide the adjustment of RF [3, 26] and it should be individualized accordingly to the patient's overall condition [5].

Positive End-expiratory pressure and recruitment maneuvers:

Beyond the higher level of atelectasis that obese patients experience in their basal states, after induction is seen an increase in the extent of these atelectasis [5, 18]. For this reason, many strategies have been proposed with the intent of prevent their development.

The combined use of Recruitment Maneuver (RM) (temporary application of an end-expiratory pressure significantly higher than plateau pressure [5]), and Positive end-expiratory pressure (PEEP) has the purpose of reopen collapsed lung regions and prevent their re-collapsed respectively [5, 7, 8, 23, 25, 26, 31, 32].

The RM, allowing the alveolar unit to be reopen [3], reverse the atelectasis and improve oxygenation and respiratory function [2], however it has only transient effects [8, 5]. These RM can be achieved by many methods, but the squeezing bag one should be avoided, once it increases PPCs [3]. The timing and number of times a RM should be performed and its combination with PEEP is also very debated [30]. The application of a RM in the beginning of mechanical ventilation right after induction and then when a desaturation occurs is often recommended [2, 10], whereas others defend that they must be repeated throughout the surgery [3].

It is important to denote the importance of PEEP after the recruitment maneuver and its value, once one RCT found no additional benefits of repeated RM if a higher value of PEEP is used [5, 8]. Nevertheless, a study hypothesizing that recurrent RM without PEEP have similar effects in the gas exchange as RM with sustained PEEP, showed that during pneumoperitoneum both strategies had similar effects in improving oxygenation [13]. However, is important to enhance that this study repeated the RM each 30 min.

The application of PEEP can improve respiratory function by decreasing the formation of atelectasis [2, 3]. These advantages are specially seen when applied after a RM [2, 25, 30, 33] ,once it alone seemed to not reduce atelectasis after induction [3, 5, 7, 8, 16]. However, a RCT showed that using a PEEP of 10 cmH_2O alone can preserve oxygenation throughout the surgery as long as it was also used in pre-oxygenation and induction [24].

One of the most discussed topics is the value of PEEP necessary to maintain the alveoli open. The necessary level depends on individual constitution, BMI and positioning, and so can be very different from patient to patient [31]. It is thought that obese patients require higher values of PEEP [30], considering that they present higher pleural pressures [31]. Higher values of PEEP used in order to keep the lung open when controlled by electric impedance tomography and positive transpulmonary pressure at end-expiration, demonstrated an improvement in oxygenation and lung compliance [10]. Another study, who tried to optimize lung compliance through PEEP manipulation, saw that the mean level of PEEP necessary to optimize lung compliance was 10 cmH_2O, what is in agreement with other studies defending that this is the necessary level to prevent atelectasis [26, 28] and maintain oxygenation in obese patients [2, 3, 33]. However even higher levels of PEEP (16-18 mmHg) may be necessary [16]. Nevertheless is it important to underline that if it is accompanied by an increase in driving pressure it may increase the risk of PPCs [2, 7], and has the potential to overdistend the lung [5].

It is important to keep in mind that higher levels of PEEP may have some risks associated, namely hemodynamic instability [7, 14, 21,33], being seen a higher number of hypotensive episodes, higher need for fluids and treatment with vasoactive drugs [3, 13, 23, 28], but also static stress and strain, inflammation and decreased lymphatic drainage when in combination with recruitment maneuvers [32].

Additionally to the improvement seen during surgery, these strategies may also be relevant in the post-operatory period, especially regarding the development of pulmonary complications [13]. The application of a low tidal volume, moderate to high PEEP and recruitment maneuvers was proposed to prevent pulmonary complications [13]. However, it is not clear which of these parameters is the key to the beneficial effects. A meta-analysis has already suggested that is the lower TV the main factor [7, 13, 28], that the combination RM with PEEP did not protect against PPCs [23], and that driving pressure may be the mediator of the effects [13], once changes associated with an increase in driving pressure were associated with more PPCs [13]. One study [13], suggested that a decrease in driving pressure after a RM may not only serve as a protective ventilation strategy, but also cause an improvement in oxygenation, regardless of PEEP. Therefore, some reviews already defend the use of a low driving pressure as part of the protective ventilation strategy [2, 26]. There is not a clear value of driving pressure that should be aimed, however, in lean patients it should be below 13 cmH_2O, having a higher value already demonstrated an increase in the development of PPCS [7, 26]. In obese patients, due to the reduced chest wall compliance it should be below 16 cmH_2O [10].

On the other hand, the alterations seen during the operative time with the strategies mentioned above, are discontinued right after extubation [31]. One study reported a lower End-expiratory lung volume (EELV) after extubation than the one seen before induction, reinforcing the hypothesis of the development and persistence of atelectasis after extubation for more than 24 hours [31]. This fact emphasizes the importance of the post-operative care.

One study used an electrical impedance tomography with the purpose of tritate PEEP and saw an improvement in the oxygenation, ventilation distribution, EELV and lung mechanics [31]. However, the differences seen in the control group vanished in the early post-operative period [31]. Nevertheless, in the control group was used a PEEP of 5 cmH_2O, what can be not sufficient to have an impact in the opening of the lung regions collapsed [2].

Finally, a RCT made with the objective of determine the impact of RM with PEEP in the post-operative period showed that the use of these strategies in order to reduce the formation of atelectasis do not have an impact in reducing PPCs when compared to a strategy of permissive atelectasis [32]. Some previous reviews had already stated that the use of RM and PEEP did not improve clinical outcomes [13 21, 26, 28], and a recent one stated that higher levels of PEEP and RM did not reduce PPCs, and so, individual monitoring should be used when possible [3].

<u>Ratio inspiration-expiration</u>

A few studies that sought to know the impact of different inspiratory-expiratory ratios on respiratory function have been performed.

It has been reported that an inverse ratio ventilation (IRV) (I>E) in a pressure controlled mode can recruit collapsed alveoli and improve oxygenation at lower values of Peak Pressure (Ppeak). However, the value of Ppeak is not negligible and can limit its use in spite of the risk of barotrauma and decrease TV [34]. Therefore, a study sought out to know if the inverse ratio used in volume controlled mode was superior when compared to conventional ratio (1:2) was performed. It showed an increase in PaO2, Mean Pressure (Pmean), what can reduce atelectasis and shunt, and dynamic compliance in the IRV group and also a decrease in Ppeak and Plateau Pressure (Pplateau). Also, it was not shown any effect on the CO2 elimination [34].

The shortened expiratory time may lead to an increase in the air trapped in the alveoli and the generation of iPEEP, what can improve oxygenation and lung mechanics[34].

Additionally, it demonstrated a decrease in the release of inflammatory cytokines, having lower concentrations of TNF-alfa, IL-6, and IL-8 [34]. This decrease is relevant, once obesity represents a high risk for lung injury that is associated with an increase inflammatory response that can be indicated by the increase of these cytokines[34].

<u>Fraction of inspired oxygen</u>:

High values of FiO_2 may prompt the formation of reabsorption atelectasis[4, 11,21, 23,26] and worsen inflammatory lung injury[2], therefore it is advised to use a FiO_2 lower than 0.8 during the surgery[21, 23] and also in the pre-oxygenation[4, 27]. However, during the induction phase a higher value may be beneficial, as long as a positive-pressure ventilation is used, once it can increase the period of safe apnea[26]. In some cases, like a cardiac surgery, higher FiO_2 may be beneficial, as long as PEEP is maintained during the surgery, once it prevents hypoxia, maintain a lower pulmonary vascular resistance and allow higher oxygen tension during extubation [11]. Nevertheless, the adjustment of FiO_2 in order to achieve a physiologic oxygen saturation is also advised[10, 26].

Post-operative:

After surgery is seen a deterioration in the pulmonary function due to anesthesia, pain and surgical manipulation [1, 35], combined with the respiratory dysfunction inherent to the obese patients. This altered respiratory function can promote post-operative respiratory complications, being obesity a risk factor for postoperative hypoxemia [3, 10, 18, 36]. Post-operative pulmonary complications are one of the most frequent perioperative complications [37] and from these, acute respiratory failure is one of the most common [38]. This is probably related with atelectasis-related shunt, and when an open lung strategy is used during surgery, it is possibly due to lung derecruitment [37]. It is important to denote, that this dysfunction is prolonged in time [1, 3, 4, 10], once the diaphragmatic dysfunction, the use of opioids and the immobilization may last for more than the first day after surgery, being PPCs more frequent after the 2nd and 3rd day [35].

Therefore, the implementation of some practices after surgery has been proposed, once intraoperative manipulations failed to show improvement in the post-operative setting.

A meticulous management of the drugs used, adequate analgesia and respiratory physiotherapy can exert benefits in the post-operative setting[3, 26, 35], as well as early mobilization [4].

After surgery, NIV or CPAP in morbidly obese patients may improve lung function and gas exchange [5] and may decrease PPCs [1, 2, 3, 4, 18, 35, 37, 39], meanwhile intraoperative manipulations, as RM or PEEP, did not demonstrate improvement in post-operative hypoxemia [3, 21, 26, 32, 35]. The characteristics of the NIV that are most beneficial is an intensely debated subject.

Non-invasive ventilation can unload the inspiratory muscles and was superior to CPAP regarding the improvement of atelectasis after cardiac surgery, as long as a PEEP higher than 10 cmH_2O is applied [36]. Non-invasive positive pressure ventilation is also recommended for patients with OSA that underwent a bariatric surgery [40]. A review made to assess the safety of immediate NIPPV after a bariatric surgery focusing on the incidence of anastomotic dehiscence did not show any increase in its development, even though caution has been advised with its use [18, 35, 40].

One trial compared BiPAP at individualized pressures with sham BiPAP after a bariatric surgery and demonstrated an improvement in the lung restrictive disease, presenting higher values of Forced expiratory volume in the first minute (FEV_1) and Forced vital capacity (FVC) in the 2nd and 3rd day, as well as higher values of SpO_2 during the 3 days after surgery. Additionally, the BiPAP group showed no PPCs and a trend for early mobilization [35]. However, this trial used a small sample of patients. Another trial shown that the pulmonary function returned more rapidly to the basal state on the third day when NIV with 2 pressure levels was used, as well as fewer PPCs [39].

One trial comparing Boussignac CPAP with the use of a venturi mask, shown an improvement in oxygenation during 24 hours after a use of at least 2 hours, and also a significant difference in alveolar-arterial oxygen gradient, what can be an indicator of a better ventilation/perfusion match, insinuating that may have benefit in prevent additional atelectasis [18].

The use of a high flow nasal cannula (HFNC) has also been proposed for this purpose [2, 4]. This device has the advantages of delivering heated and humidified oxygen at greater flow rates [36, 38], has also the possibility to provide PEEP [4], improving oxygenation by increasing both EELV and TV[36], and decrease both pharyngeal dead space and nasopharyngeal resistance[38], as well as reduce inspiratory muscle effort[36]. It is more beneficial in patients with higher BMI [36]. The value of PEEP that it can generate may not be enough to cause alveolar recruitment but may be sufficient to prevent lung derecruitment [37], being crucial the timing of its initiation. High flow nasal cannula may also improve small airway function and reduce air trapping by improving mucociliary clearance and reduce inspiratory effort [36].

One review, concluded that HFNC in the post-operative period decreased the need for re-intubation and was associated with a significant decrease in the need for escalation respiratory support, although this last one with a low certainty evidence, when compared to conventional treatment [38, 36]. However, it did not demonstrate any difference in other outcomes, as mortality and Intensive care unit and hospital length of stay [38], and was seen a higher improvement in oxygenation with NIV, what the authors conjecture to be attributed to higher levels of PEEP used [36].

However, another controlled trial, when comparing HFNC with conventional treatment after an open lung approach during surgery, demonstrated a decreased in the development of postoperative hypoxemia and postoperative atelectasis when initiated before extubation[37]. When considering these results, it is important to underline the open lung approach, once one study demonstrated that the same strategy did not get the same results after a non-open lung approach strategy and that the patients were encourage to keep their mouth closed [37].

Another study comparing HFNC to NIV did not show any differences in the rates of reintubation or of respiratory therapy failure [3, 36, 38], however the improvement in oxygenation was greater in the NIV group [36]. As HFNC require a lower level of care, its application is easier and more comfortable and has less skin breakdown associated it can be pertinent an alternative [36, 37, 38], having already been proposed instead of NIV in obese patients after cardiothoracic surgery[36]. However, this may not apply to all types of surgeries, as it was mostly demonstrated in cardiothoracic surgery patients, and once it was not exclusive of obese patients [38] more studies are needed.

Pain management:

Besides the surgical trauma, in a laparoscopic surgery, the increased intraabdominal pressure during the procedure and the CO_2 that remains trapped in the abdominal cavity, may contribute the post-operative pain [41]. This pain is of highly relevance once it may contribute to a decrease FRC by preventing cough[4], and so analgesia can decrease the risk of respiratory failure[14]. Additionally, a randomized controlled trial concluded that a RM decreased significantly postoperative pain after a laparoscopic bariatric surgery and decreased the need for opioid medication [41].

Key learning points:

a) Preoperative

1. Obese patients should be accessed by the stop bang score in order to diagnose OSA.
2. General measures should be enforced, namely the cessation of tobacco and alcohol consumption, weight loss and muscular training of the inspiratory muscles.
3. Non-invasive ventilation before surgery has demonstrated benefits not only on the airway but also in other parts of the respiratory system.
4. The airway should be accessed before surgery, the ultrasound can be a valuable asset, and preparation for a potentially difficult intubation should be considered.
5. The postoperative management should be planned still before the surgery.

b) Intraoperative

1. A body position with the head up, not only improves respiratory mechanics, as facilitate ventilation and intubation.
2. Preoxygenation should be performed right before induction and intubation with the use of NIV.
3. Intubation should be carefully planned, the use of a videolaryngoscope should be considered, as well as a second generation supraglottic device.
4. Apneic oxygenation with a HFNC can prolong the period of safe apnea, maintain higher SpO2 during induction and allow a faster ressaturation after induction.
5. Ventilation mode and respiratory frequency should be individualized, the same with FiO_2, although values below 0.8 are often recommended. An inverse ventilation ratio can improve oxygenation. The use of RM and PEEP may prevent atelectasis formation during the surgery, however, did not reduce the development of PPCs.

c) Postoperative

1. Non-invasive ventilation and HFNC can improve oxygenation after surgery and decrease the development of PPCs.
2. An effective pain management can also improve respiratory volumes.

Conclusion

In final analyses, the management of the ventilation in the perioperative period in the obese population has some specificities, that are distinct from the ones seen in the lean population.

Some topics seem to be consensual and to be already implemented in the day-to-day practice, such as the use of Non-invasive ventilation in all steps and the usage of a High flow nasal cannula in the post-operative period.

However, other topics have undergone many advances and the paradigm has changed. For instance, the lack of influence that the use of recruitment maneuvers and positive end-expiratory pressure has on the development of post-operative pulmonary complications, despite the benefits that it may bring to the intra-operative period.

Nevertheless, and not diminishing the importance and validity of the recommendations mentioned in this review, it was consistence throughout most of the topics approached, the need for individualization, not only to the patient itself, but also to the type of surgery and the material available.

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