DOI: 10.56871/RBR.2024.75.27.010
UDC 612.216.3+616-089.5-031.81+612.215

USE OF SPONTANEOUS BREATHING MODES AT VARIOUS STAGES OF GENERAL ANESTHESIA. LITERATURE REVIEW

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For citation: Pyzhov VA, Khrapov KN. Use of spontaneous breathing modes at various stages of general anesthesia. Literature review. Russian Biomedical Research. 2024;9(3):76–86. DOI: https://doi.org/10.56871/RBR.2024.75.27.010

Received: 20.06.2024 **Revised: 26.07.2024** **Accepted: 16.09.2024**

Abstract. Among all the respiratory complications observed in surgical patients in the postoperative period, lung tissue atelectasis is one of the most common. In addition to the use of protective intraoperative ventilation, one of the measures to prevent atelectasis of lung tissue may be to maintain independent breathing throughout, or at certain stages of general anesthesia. Currently, most anesthesia machines have a wide range of ventilation modes, including self-breathing mode with pressure support. When performing respiratory support in this mode, the patient is able to influence all phases of the respiratory cycle, the diaphragm remains functional, which reduces the risk of atelectasis and ventilator-induced dysfunction of the diaphragm. Due to the support pressure applied in response to each breath, the patient does little breathing work, which prevents the development of fatigue of the respiratory muscles. However, anesthesia with preserved spontaneous breathing may be limited by the need to administer high doses of opioids and anesthetics, for example, in highly traumatic surgical interventions, since anesthesia drugs can have a significant effect on the respiratory center. There is sufficient information in the literature regarding the effectiveness of its use at the stage of induction of general anesthesia, in order to better preoxygenation. The use of (PSV, pressure support ventilation) mode in combination with positive end expiratory pressure (PEEP) during preoxygenation improves oxygenation, prevents episodes of desaturation, and lengthens the time of safe apnea. In addition to using this regimen during the induction of general anesthesia, its use may be appropriate at the stage of maintaining anesthesia during operations where the introduction of muscle relaxants is not required, as well as at the final (awakening, extubation) stages of general anesthesia in cases where the main surgical stage requires total myoplegia. The use of pressure support at these stages is less common. However, a number of publications have shown that the use of this regimen during general anesthesia while maintaining independent breathing can lead to improved gas exchange and reduced atelectasis of lung tissue, in addition, make awakening and extubation more comfortable and faster, compared with other approaches to respiratory support during anesthesia.

Keywords: artificial lung ventilation, pressure support ventilation, spontaneous breathing, general anesthesia, awakening

ПРИМЕНЕНИЕ РЕЖИМОВ САМОСТОЯТЕЛЬНОГО ДЫХАНИЯ НА РАЗЛИЧНЫХ ЭТАПАХ ОБЩЕЙ АНЕСТЕЗИИ. ЛИТЕРАТУРНЫЙ ОБЗОР

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Для цитирования: Пыжов В.А., Храпов К.Н. Применение режимов самостоятельного дыхания на различных этапах общей анестезии. Литературный обзор // Российские биомедицинские исследования. 2024. Т. 9. № 3. С. 76–86. DOI: https://doi.org/10.56871/RBR.2024.75.27.010

Поступила: 20.06.2024 **Одобрена: 26.07.2024** **Принята к печати: 16.09.2024**

Резюме. Среди всех респираторных осложнений, наблюдаемых у хирургических больных в послеоперационном периоде, ателектазирование легочной ткани — одно из наиболее часто встречающихся. Помимо применения протективной интраоперационной вентиляции легких, одной из мер профилактики ателектазирования легочной ткани может являться сохранение самостоятельного дыхания на всем протяжении, либо на отдельных этапах общей анестезии. В настоящий момент на большинстве наркозных аппаратов имеется большой спектр режимов вентиляции, в том числе и режим самостоятельного дыхания с поддержкой давлением (PSV, pressure support ventilation). При проведении респираторной поддержки в данном режиме пациент способен оказывать влияние на все фазы дыхательного цикла, сохраняется работоспособность диафрагмы, что снижает риск возникновения ателектазов и вентилятор-индуцированной дисфункции диафрагмы. За счет подаваемого в ответ на каждый вдох давления поддержки, пациентом проделывается незначительная работа дыхания, что предотвращает развитие усталости дыхательной мускулатуры. Однако проведение анестезии с сохраненным спонтанным дыханием может быть лимитировано необходимостью введения высоких доз опиоидов и анестетиков, например, при высокотравматичных оперативных вмешательствах, поскольку препараты для анестезии могут оказать существенное влияние на дыхательный центр. В литературе имеется достаточно сведений в отношении эффективности использования режима PSV на этапе индукции общей анестезии с целью лучшей преоксигенации. Использование режима PSV в сочетании с положительным давлением в конце выдоха (ПДКВ) во время преоксигенации улучшает оксигенацию, предотвращает появление эпизодов десатурации, удлиняет время безопасного апноэ. Помимо использования данного режима во время индукции общей анестезии, его применение может быть целесообразным и на этапе поддержания анестезии во время операций, где не требуется введение миорелаксантов, а также и на завершающих (пробуждение, экстубация) этапах общей анестезии в тех случаях, когда основной хирургический этап требует тотальной миоплегии. Применение поддержки давлением на этих этапах менее распространено. Однако в ряде публикаций было показано, что применение данного режима во время общей анестезии с сохранением самостоятельного дыхания может привести к улучшению газообмена и уменьшению ателектазирования легочной ткани, помимо этого, сделать пробуждение и экстубацию более комфортными и быстрыми по сравнению с другими подходами к проведению респираторной поддержки во время анестезии.

Ключевые слова: искусственная вентиляция легких, вентиляция с поддержкой давлением, самостоятельное дыхание, общая анестезия, пробуждение

INTRODUCTION

Postoperative pulmonary complications (PPCs) are the most common complications following surgical interventions [23], significantly influencing the course of the postoperative period [25]. The share of pulmonary complications in abdominal and vascular surgery accounts for 10–40% of all postoperative complications [12]. Thus, pulmonary complications are the second most frequent after cardiovascular ones during the postoperative period [19].

Among all respiratory postoperative complications, pulmonary atelectasis is one of the most common in surgical patients. Atelectasis determines the risk of hypoxemia and forms the basis for the development of other postoperative pulmonary complications [27]. Atelectasis can persist for several days after surgery, impairing respiratory function and ultimately increasing the duration of hospitalization [14].

In the early 2000s, a whole range of modes which were previously available in ventilator-assisted resuscitation machines became available on the majority of anesthesia-breathing machines, including modes of independent breathing and primarily pressure-supported independent breathing. Despite this, there are no clear recommendations regarding the use of these modes during anesthesia. As a result, habitual forced ventilation modes are preferred by anesthesiologists in most situations. However, a number of studies have shown that the use of pressure support mode during general anesthesia with preservation of independent breathing can lead to improved gas exchange and reduced atelectasis of lung tissue. In addition, it can make awakening and extubating more comfortable and faster than other approaches to respiratory support during anesthesia [1, 2, 6, 28, 48]. Furthermore, the use of PSV (pressure support ventilation) and preservation of spontaneous breathing can potentially reduce the total anesthetic dose during general intravenous anesthesia [6, 28]. In addition, anesthesia with preserved spontaneous breathing is limited by the need to administer high doses of opioids and anesthetics, for example, in highly traumatic surgical interventions, because anesthetic drugs can have a significant effect on the respiratory center.

In addition, this mode can be used to maintain anesthesia during operations that do not require the administration of myorelaxants, according to available data, its use may be appropriate at the initial (preoxygenation before induction of general anesthesia) [7] and final (awakening, extubation) [3, 35] stages of general anesthesia in cases where the main surgical stage requires total myoplegia. In the first case, a higher level of oxygen tension in arterial blood and, as a consequence, a longer time of safe apnea compared to classical preoxygenation is provided [7]. In the second case, independent breathing is initiated after the end of the main stage of surgical intervention, which can reduce the time of awakening and extubation, accelerate the transfer of the patient from the operating room, improve gas exchange, reduce the frequency and severity of cough after extubation, and thus make awakening more comfortable than when using forced ventilation [3, 35].

Thus, the use of independent breathing modes at different stages of general anesthesia can potentially reduce the likelihood of postoperative pulmonary complications (PPC) in the early postoperative period.

IMPACT OF FORCED ARTIFICIAL VENTILATION ON THE RESPIRATORY SYSTEM

Effects on lung tissue

It has been shown in both experimental and clinical studies that artificial ventilation (AV) can exacerbate pre-existing lung damage [8, 27, 42] or even induce it in a healthy individual [39]. Several major mechanisms for the development of ventilator-induced lung injury (VILI) have been identified [8, 14]. Increased airway pressure (barotrauma) and the application of high inspiratory volumes (volumotrauma) can cause damage or destruction of alveolar epithelial cells. In addition to baro- and volumotrauma, ventilator-induced lung injury can result from cyclic opening and closing of the alveoli (atelectotrauma) [8]. All three described mechanisms, namely barotrauma, volumotrauma and atelectrauma, can affect both alveolar epithelial cells and pulmonary capillary endothelium [43], as well as cause interstitial damage by disrupting the intercellular matrix [29]. As a consequence of lung tissue injury, surfactant synthesis and barrier function of the alveolo-capillary membrane are impaired, which leads to the development of interstitial pulmonary edema and extensive atelectasis of lung tissue. Ventilator-induced lung injury is one of the causes of postoperative pulmonary complications (PPC).

Heterogeneity of ventilation in different areas of lung tissue may also occur during general anesthesia. This inhomogeneity may be related to extensive atelectasis due to the effects of anesthetics on the respiratory system, to patient positioning (e.g., Trendelenburg position), to increased intra-abdominal pressure (e.g., when carboxyperitoneum is applied during laparoscopic surgeries) [32], and also as a result of alveolar gas resorption [36], which makes the respiratory system even more vulnerable to the negative effects of ventilatory support.

According to current thinking, in order to prevent all types of damaging effects leading to VILI and, consequently, to reduce the risk of postoperative pulmonary complications, a strategy of protective ventilation should be applied in the operating room [11].

Effects on the respiratory musculare

In addition to negative effects on lung tissue, there is also evidence that mechanical ventilation has a negative effect on diaphragm function, which may lead to ventilator-induced diaphragmatic dysfunction (VIDD) [45].

The first evidence that continuous mandatory ventilation can cause respiratory muscle damage was obtained in animal studies [33]. In more recent studies it was shown that mandatory ventilation leads to atrophy of respiratory muscles (diaphragm to a greater extent) [40]. This theory was confirmed in human studies: analysis of histological data of 13 newborns who were on forced ventilation for 12 days revealed diffuse atrophy of diaphragmatic fibers [22]. Diaphragm atrophy may be the result of decreased protein synthesis and/or increased protein degradation [16].

According to other authors, structural transformation of diaphragm muscle fibers occurs as a result of impaired protein synthesis and degradation (especially myosin heavy chain protein) during mandatory ventilation [40].

In addition to global structural rearrangements, an increase in oxidative stress, reflected by increased protein oxidation and lipid peroxidation, was observed in animals undergoing 6-hour forced ventilation [40]. Moreover, according to some studies, structural damage to some cellular organoids was observed after 48 hours of CMV (continuous mandatory ventilation): destruction of myofibrils, abnormal swelling of mitochondria, lipid droplets and vacuoles [4]. The mechanisms of damage are not completely clear, but may include activation of various proteolysis pathways and oxidative stress.

Interestingly, even minimal patient involvement in ventilation can significantly improve the functional status of the diaphragm. According to Sassoon et al., the decrease in contractility of the rabbit diaphragm after 3 days of artificial ventilation was more pronounced in the group in which CMV was used compared to the group in which assisted continuous mandatory ventilation (AssistCMV) was used and minimal spontaneous respiratory activity was preserved [38].

Taking into account these data, despite the fact that the CMV mode remains the most popular in anesthesia practice, it can be assumed that the use of assisted modes, as well as modes of independent breathing during anesthesia can have a beneficial effect on the respiratory system and reduce the risk of PPC.

INDEPENDENT BREATHING AND GENERAL ANESTHESIA

Numerous studies conducted in the last two decades have led to a better understanding of the pathophysiology of ventilator-induced lung injury that may be responsible for the development of PPC. Consequently, this has resulted in the widespread adoption of protective ventilatory strategies and advanced respiratory monitoring that optimizes ventilation settings [11].

Another, newer area of research related to intraoperative ventilatory support is the study of the association between the use of myorelaxants and the risk of PPC development. The POPULAR research has shown that the use of myorelaxants during general anesthesia leads to an increased risk of PPC. Neither the use of neuromuscular transmission monitoring nor the use of decurarizing agents significantly reduces the risk of these complications [21]. In this regard, it can be assumed that maintaining independent breathing during general anesthesia, where possible, may be one of the options for further improvement of the strategy of protective ventilation.

It is well known that regional distribution of ventilation and perfusion is heterogeneous due to the elastic properties of the lungs, as well as the vertical gradient of pleural, transpulmonary and hydrostatic pressures [41]. The diaphragm displacement is also not homogeneous, and it can be functionally divided into three segments: upper (independent, ventral), middle and lower (dependent, dorsal) ones. The dorsal part makes more movement during spontaneous inspiration than the ventral part, providing better ventilation of dependent lung regions and counteracting the collapse of alveoli due to hydrostatic pressure, leveling the ventilation-perfusion mismatch, and these advantages are maintained even in the supine position [30].

On the contrary, when performing forced ventilation (especially with the use of myorelaxants), a typical redistribution of ventilation occurs: its main part is shifted to the independent and less perfused anterior lung sections, atelectasis formation occurs in the dependent lung regions, which leads to a violation of ventilation-perfusion relations [30]. These effects are primarily associated with changes in diaphragm excursion. During forced ventilation against the background of relaxants, passive displacement of the posterior part of the diaphragm is significantly reduced [5, 6].

The main advantage of maintaining spontaneous breathing during general anesthesia is the preservation of normal work of respiratory muscles and, first of all, the diaphragm. Preservation of tone and active movements of the diaphragm can increase ventilation of the dorsal lung sections, prevent early expiratory airway closure and atelectasis formation, improve ventilation-perfusion relations and gas exchange [37]. The results of the study confirming the benefit of preserving diaphragm performance during general anesthesia with tracheal intubation are indicative. The use of diaphragmatic nerve stimulation, simulating the diaphragm work, accompanied by the use of positive end-expiratory pressure (PEEP) leads to a decrease in the size of atelectasis in dependent parts of the lungs [15].

In addition to the positive effect on pulmonary function, other possible advantages of preserved independent breathing include reduced consumption of anesthetics, as well as reduced time of awakening, extubation and transfer from the operating room [2, 6, 28], no need to use myorelaxants and, consequently, reduced risks associated with their use (postoperative pulmonary complications, allergic reactions) [17, 21].

It should be noted that spontaneous breathing during ventilation also has a number of disadvantages: the possibility of asynchrony, which can lead to baro- or volumotrauma; the need for more careful control of ventilation to ensure timely transfer of a patient to the forced mode due to the effect of narcotic analgesics on respiratory drive, the development of respiratory muscle fatigue and decreased efficiency of independent breathing attempts due to increased breathing [6].

A pressure-supported independent breathing mode can help overcome most of the disadvantages of preserved spontaneous breathing during general anesthesia.

THE USE OF PRESSURE SUPPORT VENTILATION AT DIFFERENT STAGES OF GENERAL ANESTHESIA

Preoxygenation and induction of general anesthesia

The use of pressure support breathing in anesthesia practice is most studied at the stage of induction. Thus, a meta-analysis based on 13 studies performed from 2001 to 2021 showed that the use of noninvasive ventilation in PSV mode immediately before induction of general anesthesia was more effective than the “traditional” method of preoxygenation [7].

A number of studies have compared the safe apnea time when preoxygenation is performed in PSV mode or with masked oxygen delivery [7]. Although there was a difference in the interpretation of the term “safe apnea” between the authors (the lower limit of saturation in the studies differed), according to the results of all studies, the group of preoxygenation in the PSV mode showed a significantly more favorable result than the group of classical preoxygenation.

One of the studies compared the rate of achieving a 90% end-expiratory oxygen level using the pressure support mode and traditional methods of preoxygenation [10]. Patients of the first group achieved the result significantly earlier than the group in which “classical” preoxygenation was performed.

It is logical that higher PaO_2 [10] and lower $PaCO_2$ [9] were observed during preoxygenation using noninvasive ventilation than in the group of standard preoxygenation.

Separately, we would like to note that this technique is most useful in patients with a potentially large volume of atelectatic lung tissue, which include overweight patients. Thus, a study in morbidly obese patients showed that the use of PSV combined with moderate PEEP during preoxygenation significantly improves oxygenation and prevents desaturation episodes compared with standard preoxygenation in the mode of fully independent breathing [13].

The main stage of general anesthesia

In the last 20 years, modern supraglottic airway devices (SGDs) have been widely introduced into clinical practice: laryngeal masks, I-Gel type supraglottic airway devices, etc. [24]. The placement of these devices, designed to ensure patency of the upper airways, does not require the administration of myorelaxants, respectively, and the use of forced modes of ventilation. The traditional method of ventilation in operations of short duration (less than 1 hour) has become the preservation of spontaneous breathing. However, the use of spontaneous ventilation during longer surgical interventions was limited by a high risk of hypoventilation caused by anesthetics. They influenced the breathing pattern and the development of respiratory muscle fatigue, which required transferring a patient to a controlled mode of ventilation [28].

PSV mode on modern anesthesia and respiratory devices made it possible to perform longer surgical interventions in conditions of preserved independent breathing thanks to control of the respiratory volume and reduction of the patient’s work of breathing.

A number of researchers have argued that the use of pressure-support self-respiratory mode offers many advantages over spontaneous breathing without device support or forced ventilation during anesthesia with supraglottic airways. PSV mode significantly reduces work of breathing compared to fully spontaneous breathing and at the same time provides lower airway pressures compared to forced ventilation [6, 28].

When comparing PSV with ventilation in the CPAP mode (continuous positive airway pressure, a mode of independent breathing with constant positive airway pressure), it was found that the former was superior to the latter in terms of respiratory volume, oxygenation indices, and end-expiratory partial pressure of CO_2, which may be associated with improved ventilation and ventilation-perfusion relations in the lungs [46].

However, it should be noted that according to some works, the use of PSV mode, as well as forced ventilation modes, aggravates ventral redistribution of ventilation in comparison with independent breathing without ventilatory support. Such results were obtained in a trial performed using electrical impedance tomography visualizing regional ventilation differences in the lungs [34].

Another study showed that the use of PSV or preservation of spontaneous breathing leads to a shorter time from the moment of anesthetic cessation to awakening, extubation, and transfer from the operating room compared to respiratory support in the mode of volume-controlled mandatory ventilation [6]. Moreover, a significantly higher consumption of anesthetics was noted in the CMV group. However, the group of fully spontaneous breathing showed a significant increase in occlusion pressure 100 ms after the start of inspiration (P0.1), a decrease in minute ventilation, and an increase in end-expiratory carbon dioxide pressure $EtCO_2$ by the end of anesthesia, indicating the development of respiratory muscle fatigue. No such phenomena were observed in the PSV group [6]. The results of the above mentioned research also correspond with the data obtained in a similar research in pediatric patients [28].

A similar research was performed in our clinic. It compared gas exchange parameters by analyzing arterial blood gas composition, airway pressure, and wake-up time in 100 patients who underwent minor traumatic orthopedic interventions on the lower extremities under general combined anesthesia with desflurane. The results of the research demonstrate better indices of arterial blood oxygenation, respiratory mechanics, as well as shorter time intervals before awakening, extubation and transfer to a ward in the group of pressure support mode, which is fully consistent with the above-mentioned foreign researches It should be noted that in both cases the main hemodynamic parameters as well as the level of anesthesia depth remained normal and did not differ significantly between the groups [2].

In addition to practically healthy patients with physical status ASA I-II, participated in the mentioned studies, the PSV regimen also showed its efficacy in patients with moderate obesity (body mass index (BMI) 25–35 kg/m^2) and physical status II–III according to ASA. This category of patients underwent PSV respiratory support, as a result there were observed intraoperative improvement in oxygenation index (PaO_2/FiO_2) and higher values of SpO_2 in the early postoperative period compared to a group receiving pressure-controlled forced ventilation (CMV-PC) [48].

A number of studies have shown that besides general anesthesia with supraglottic airways, PSV may also be useful during anesthesia with tracheal intubation. The use of a pressure-supported independent breathing mode during general anesthesia accompanied by tracheal intubation may also reduce wake-up and extubation time. Interestingly, the level of depth of anesthesia according to BIS monitoring in this study remained normal and did not differ between groups (using PSV and CMV-VC) [1].

When comparing PSV and CPAP modes during anesthesia with tracheal intubation, it was shown that the use of pressure support provides a lower respiratory rate and lower end-expiratory carbon dioxide level, as well as stable respiratory volume [5].

Among other things, the mode of independent breathing with pressure support can be useful for patients coming to an operating room from intensive care units. This category of patients is initially in severe condition and requires pressure assisted ventilation. Thus, it is possible to ventilate these patients in the same mode as in the intensive care unit. This can help prevent deleterious effects of forced ventilation on the compromised respiratory and cardiovascular systems [44].

It should be stated that pressure support regimen during the maintenance phase of anesthesia is evaluated in significantly fewer studies than during the induction phase of anesthesia. Apparently, it seems that using this mode during the maintenance of general anesthesia is less common in clinical practice. In addition, the majority of trials that evaluated the intraoperative use of PSV mode used total intravenous anesthesia, the possibility of such ventilation against the background of inhalation anesthetics was evaluated much less frequently.

Completion of general anesthesia, awakening

The main purpose of using protective intraoperative ventilation is to make intraoperative ventilation safer by reducing the probability of postoperative pulmonary complications; however, it has been shown that all the positive aspects achieved by improving the methods of respiratory support at the initial and main stages of general anesthesia can be lost during awakening and extubation [47]. There are works [18, 31] that demonstrated that atelectasis of lung tissue occurs at the final stage of general anesthesia, despite the protective strategy of artificial ventilation at the main stage. Thus, it was revealed that pulmonary atelectasis occurs in 39% of patients at the time of extubation and full awakening of a patient [31]. In this regard, a study devoted to the influence of ventilation mode on the severity of pulmonary atelectasis after extubation at the end of anesthesia should be noted. According to the data presented, the incidence of postoperative atelectasis in patients who received PSV ventilation before awakening was much lower than in patients breathing independently without device support [18].

Some authors have demonstrated that the pressure support mode used at the end of general anesthesia, at the stage of extubation and awakening can both potentially prevent postoperative pulmonary complications and improve intraoperative gas exchange, as well as significantly improve patient comfort in comparison with other approaches to respiratory support at this stage of general anesthesia [1, 6, 28, 48]. First of all, we are talking about reducing the severity of the cough reflex during extubation. Despite the fact that coughing is a necessary physiological reflex, its severe and prolonged character may cause a whole set of adverse effects, including increased intracranial, intraocular, and intra-abdominal pressures [26]. In addition, severe repetitive coughing leads to a significant increase in blood pressure, depleting coronary blood flow [20].

Many influences can trigger the cough reflex. However, in the case of postextubation cough, it is certain that the main trigger is a mechanical impact of an intubation tube on the airway [26]. Extubation itself is often causes bronchospasm or laryngospasm, which may lead to the development of hypoxemia, directly threatening patient's life.

In recent decades, a considerable amount of studies have been conducted aimed at selecting pharmacologic methods to reduce airway irritation under caused by intubation tubes. These include irrigation of the vocal folds with local anesthetic solution during direct laryngoscopy, its intravenous administration and even injection of local anesthetic solution into the cuff of the intubation tube. Some authors suggest using beta-blockers, calcium channel antagonists, and opioids for this purpose. At the same time, a study by Richardson et al. showed that the use of PSV mode on awakening, immediately before extubation, significantly reduces the severity of the cough reflex caused by the endotracheal tube than the mode of forced ventilation or independent breathing without device support [35].

Our clinic has conducted a study on a similar topic. We evaluated the frequency and severity of postextubation cough, as well as the time of awakening and extubation in patients who underwent routine general surgical interventions under general combined anesthesia with desflurane with tracheal intubation and myorelaxation at the main stage of intervention. Patients who underwent independent breathing with further transfer to the pressure support mode after completion of the main stage of surgical intervention, had severe and moderate coughs much less frequently than patients on forced ventilation during the whole duration of general anesthesia. At the same time, the independent breathing group had shorter time intervals from inhalation anesthetic switch-off to awakening, extubation, and transfer to a ward [3].

Thus, the use of PSV at the final stage of anesthesia can potentially reduce the severity of periextubation irritation of the airways by the endotracheal tube, prevent the occurrence of severe and recurrent cough. This approach to respiratory support at the end of general anesthesia can make this stage more comfortable for the patient, which is an extremely important aspect of modern medicine. However, there is no evidence in the literature whether a pressure support regimen can improve gas exchange in the early postoperative period, reduce the time of awakening, extubation and transfer from the operating room.

CONCLUSION

In summary, the use of pressure support mode in an operating room has quite a few positive effects, which include improved oxygenation, faster awakening, transfer of a patient out of the operating room, and greater comfort of the peri-extubation period. However, we should not forget about some limiting factors that require special attention from the anesthesiologist. First of all, it is the dose of narcotic analgesic, obviously individualized for each patient, at which the respiratory drive capable of maintaining normal ventilation will be preserved.

It is also worth noting that the use of PSV mode in an operating room is not limited to the preoxygenation and induction phase of general anesthesia, which is the subject of most available articles. Such tactics of respiratory support can be successfully and beneficially used at the main stage of general anesthesia. Supraglottic airways can be used if the surgical technique does not require the introduction of myorelaxants, as well as at the final stage of general anesthesia, accompanied by total myoplegia at the main stage.

Obviously, it is necessary to continue studying this approach to intraoperative ventilation and its effect on postoperative pulmonary complications, especially in patients with existing respiratory pathology. In addition, further research of this topic may allow to determine more precisely the limiting doses of narcotic analgesics and anesthetics, to develop additional requirements for intraoperative monitoring. It also seems important to study this approach in more traumatic surgical interventions, taking into account the multimodal approach to intraoperative anesthesia (use of non-opioid analgesics, combined anesthesia).

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data of the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

Competing interests. The authors declare that they have no competing interests.

Funding source. This study was not supported by any external sources of funding.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования.

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