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Morphological changes in the ventilated lung after thoracic surgery

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There are many studies of single lung ventilation (SLV), which are mostly limited to reducing lung damage by changing ventilation strategies or comparing differences in lung damage caused by different lung isolation devices. There is no study comparing the morphological changes of ventilated lungs using different strategies of artificial lung ventilation. The aim of the study was to examine pathomorphological changes in the ventilated lung during thoracic surgery using SLV. A randomized study was performed on 40 patients who underwent thoracic surgery using SLV. After signing the informed consent, the patients were divided into two groups. In the control group (40 patients) with ventilation "by volume" (VCV), in the study group - ventilation "by pressure" (PCV) with the addition of PEEP 5 mm. During surgery in the thoracic cavity with the help of SLV performed transbronchial biopsy of the parenchyma of the ventilated lung to study the pathomorphological changes after ventilation with different modes. The biopsy was performed using a bronchoscope, which was inserted through the endotracheal tube into the lung, opposite the side of the operation (after the end of SLV and "inclusion" of the collapsed lung). The morphological changes caused by the ventilator were investigated. Pathomorphological examination of the non-collapsed lung (which participated in gas exchange during SLV) was as follows: the control group found significant changes in the alveolar wall with its edema, thickening of the interstitial lung, vascular occlusion, severe inflammatory cell infiltration and damage to alveolar structures. The alveoli collapsed and disappeared. The alveolar structures of the study group were better than the control group: pulmonary interstitial and alveolar exudates, as well as inflammatory cell infiltration were significantly reduced compared to those in the control group. The results of the study suggest that the use of PCV with "moderate" PEEP can significantly improve oxygenation and reduce acute ventilatory injury of the lungs compared to VCV during SLV.

Keywords: lung morphology, single lung ventilation.

Introduction

Single lung ventilation (SLV) is a common method of artificial lung ventilation used in thoracic surgery [4]. It is also well known that SLV is one of the most complex intraoperative methods of respiratory support for anesthesiologists [24]. It should provide the most comfortable surgical field, maintaining proper gas exchange and minimizing damage to the two lungs [17]. Achieving this largely depends on how well the unventilated lung is isolated from the other lung. To ensure sufficient space during surgery, it is recommended to use a complete collapse of the lung. Therefore, an endotracheal tube with a double lumen is usually used. However, this traditional method of ventilation can cause an imbalance of ventilation flow, thereby increasing the number of pulmonary bypass surgery and leading to hypoxemia (occurs in 9-27% of patients) [23]; and can also lead to

secondary lung injury. Lung damage caused by ventilator induced lung injury (VILI) [1] has a negative effect [13, 27] and a significant impact on the prognosis of recovery of the patient after surgery [3, 9].

The occurrence of hypoxemia in SLV mainly depends on the correct location of the double lumen tube, the underlying disease and comorbidities, the establishment of the necessary mode of artificial ventilation and the experience of the anesthesiologist in thoracic anesthesiology [12, 15]. Significant hypoxemia [21] is observed in 5-20% of patients who underwent SLV due to increased mismatch of ventilation-perfusion ratio and intrapulmonary shunting [6].

There are many studies of SLV that are mostly limited to reducing lung injury by changing ventilation strategies or comparing differences in lung injuries caused by different

lung isolation devices [6, 8, 18], but there is no study comparing morphological changes in ventilated lungs using different modes of artificial lung ventilation.

Therefore, *the aim* of the study was to study pathomorphological changes in the ventilated lung during thoracic surgery using SLV.

Materials and methods

A randomized study was performed on 40 patients operated on the thoracic cavity using SLV. After signing the informed consent, the patients were divided into groups. In the study group (40 patients) performed artificial lung ventilation "by volume", in the study group - artificial lung ventilation "by pressure" with the addition of PEEP 5 mm wg. During surgery in the thoracic cavity using SLV performed transbronchial biopsy of the parenchyma of the ventilated lung to study pathomorphological changes after ventilation with different modes. The study was approved at a meeting of the Bioethics Committee.

The biopsy was performed using a bronchoscope, which was inserted through the endotracheal tube into the lung, opposite the side of the operation (after the end of SLV and "inclusion" of the collapsed lung). The morphological changes caused by the ventilator were investigated.

Pathological examination of lung tissue: lung biopsy was fixed in 10% neutral formaldehyde for 24 hours, followed by dehydration and fixation in paraffin. The tissue was cut into sections 5 μ m thick, which were stained with hematoxylin and eosin. Histopathological changes in lung tissue were studied under a light microscope (Olympus, Tokyo, Japan) and evaluated in four categories: 1) alveolar hyperemia, 2) hemorrhage, 3) neutrophilic infiltration or aggregation of the alveolar or vascular wall, or 4) thickening and thickening hyaline membrane. The calculation was performed on a scale of 0-4 points according to the severity of the lesion; 0 points: no or very light lesions; 1 point: light lesions; 2 points: moderate lesions; 3 points: severe lesions; 4 points: very severe lesions. The sum of all scores was taken as a general assessment of acute lung injury (ALI) [26].

The author's package MedStat (Lyakh Yu.E., Guryanov V.G., 2004-2012) was used for statistical calculations, and the Mann-Whitney test was used to compare the obtained results.

Results

Pathomorphological examination of the non-collapsed lung (which took part in gas exchange during SLV) showed that the control group revealed significant changes in the alveolar wall with its edema, thickening of the interstitial lungs, vascular occlusion, severe inflammatory infiltration of cells and damage to the alveolar structure (Fig. 1) as a result of which some alveoli collapsed and disappeared (Fig. 2). Atelectasis of a part of alveolus with existence in their gleam of single alveolar macrophages is also noted (Fig. 3). Edema and intraalveolar hemorrhages were found

Fig. 1. A fragment of the lung parenchyma with a site of pronounced emphysematous transformation of the alveoli. 1 - emphysematous changes, 2 - destroyed alveolar wall. Control group. Hematoxylin-eosin. x40.

Fig. 2. Emphysematous changes in the lung parenchyma: a significant expansion of the lumen of the alveoli with the destruction of part of adjacent alveoli walls. 1 - the lumen of the alveoli, 2 - the destroyed wall of the alveoli. Control group. Hematoxylin-eosin. x200.

Fig. 3. A fragment of the lung parenchyma with atelectasis of the alveoli. In the lumen of the alveoli single alveolar macrophages. 1 - alveolar macrophage. Control group. Hematoxylin-eosin. x200.

Fig. 4. Fragment of the lung parenchyma with the phenomena of alveolar atelectasis, intraalveolar hemorrhage, edema. 1 - atelectasis of the alveoli, 2 - hemorrhage, edema of the alveolar wall. Control group. Hematoxylin-eosin. x200.

Fig. 5. A fragment of the lung parenchyma with normal histological structure. 1 - the lumen of the alveoli, 2 - the wall of the alveoli. The study group. Hematoxylin-eosin. x200.

Fig. 6. A fragment of lung tissue with a relatively preserved configuration of the alveoli. In the lumen of the alveoli weakly basophilic exudate. 1 - lumen of the alveoli, 2 - exudate. The study group. Hematoxylin-eosin. x200.

in atelectasis alveoli (Fig. 4).

Thus, hyperemia and marked hemorrhages were observed in the lung tissue. In alveolar cavities the big infiltration by erythrocytes and inflammatory cells was found. The alveolar wall was hyperemic, thickened, with serous exudation and the formation of a transparent membrane.

Alveolar structures in the study group were more preserved than in the control group; most often the lung parenchyma was of normal histological structure (Fig. 5), exudates of the pulmonary interstitial and alveolar cavities, as well as inflammatory cell infiltration were significantly reduced compared with those of the control group, in the lumen of the alveoli observed weak basophilic exudate (Fig. 6).

Score ALI in each group: control group: 11.13 ± 0.78 points; study group: 6.942 ± 0.523 points ($p < 0.05$).

Discussion

Excessive dilation of the alveoli during mechanical ventilation, which occurs when overstretched during SLV, can cause inflammatory reactions in the ventilated lung and initiate a cascade of inflammation [10, 14]. Pulmonary shunting, high airway pressure, ischemic-reperfusion injury and ventilatory imbalance can damage the alveolar capillary endothelium and stimulate alveolar macrophages to release large amounts of proinflammatory mediators [7].

Due to the imbalance of the ventilation/perfusion ratio during SLV, hypoxemia can occur, causing the release of a large number of inflammatory mediators, increasing the permeability of the pulmonary capillaries [11] and increasing the water content in the lungs on the destroyed side, eventually to acute lung injury (ALI). The main pathological changes are severe pneumonia, neutrophil aggregation, edema of the interstitial space of the lung, damage to the endothelial cells of the pulmonary capillary, the integrity of the cells of the alveolar epithelium and the penetration of protein-rich fluids into the alveolar cavities.

Due to pathomorphological observation this study revealed edema of the alveolar wall, thickening of the interstitial space of the lungs, significant inflammatory infiltration of cells in the alveolar cavities and damaged alveolar structure.

G.F. Nieman and co-authors [19] also suggested that mechanical ventilation can lead to lung damage due to collapse and re-expansion of the operated lung during SLV. High oxygen pressure in hypoxic-ischemic lung tissue can lead to the production of reactive oxygen species, cell damage and local leukocyte infiltration. The number of oxygen free radicals is proportional to the duration of SLV [5, 20]. It has been reported [22, 25] that re-expansion of the operated lung may lead to increased expression of inflammatory mediators [2].

In our study, significant hemorrhages with hyperemia of lung tissue, as well as infiltration of alveoli by leukocytes and erythrocytes were also found after SLV. However, when using the developed ventilation methods, these changes

were minimal and morphological examination of lung tissue revealed that its appearance was as close as possible to physiological.

Our study has successfully shown that the use of SLV "with controlled pressure" and "moderate" PEEP can significantly improve oxygenation and reduce acute ventilatory damage.

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Conclusions

The results of the study indicate that the use of SLV "with controlled pressure" and "moderate" PEEP can significantly improve oxygenation and reduce acute ventilatory damage to the lungs compared to SLV "by volume".

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МОРФОЛОГІЧНІ ЗМІНИ У ВЕНТИЛЬОВАНІЙ ЛЕГЕНІ ПІСЛЯ ТОРАКАЛЬНИХ ОПЕРАЦІЙ

Сидюк А.В., Сидюк О.Є., Крпельницький В.О., Клімас А.С.

Існує багато досліджень однолегеневої вентиляції (ОЛВ), котрі здебільшого обмежуються зменшенням пошкодження легень шляхом зміни стратегій вентиляції або порівняння відмінностей у пошкодженнях легень, спричинених різними пристроями ізоляції легень. Немає жодного дослідження, в якому би порівнювали морфологічні зміни вентильованих легень з використанням різних стратегій штучної вентиляції легень. Метою дослідження було вивчення патоморфологічних змін у вентильованій легені під час торакальної операції з використанням ОЛВ. Було проведено рандомізоване дослідження на 40 пацієнтах, котрі перенесли операції на грудній порожнині з використанням ОЛВ. Після підписання інформованої згоди пацієнти були розділені на дві групи. У контрольній групі (40 пацієнтів) з вентиляцією "за об'ємом" (VCV), у досліджуваній групі - вентиляцією "за тиском" (PCV) з додаванням PEEP 5 мм. Під час хірургічного втручання в грудній порожнині за допомогою ОЛВ виконали трансбронхіальну біопсію паренхіми вентильованої легені для вивчення патоморфологічних змін після штучної вентиляції легень з різними режимами. Біопсію виконували за допомогою бронхоскопу, котрий заводили крізь ендотрахеальну трубку в легеню, протилежну стороні оперативного втручання (після закінчення ОЛВ та "включення" колабованої легені). Досліджували морфологічні зміни, спричинені апаратом штучної вентиляції. Патоморфологічне дослідження легень, що не була колабована (котра брала участь в газообміні під час ОЛВ), було таким: контрольна група виявила значні зміни в альвеолярній стінці з її набряком, потовщенням інтерстиціальної легені, оклюзією судин, важкою запальною інфільтрацією клітин та пошкодженням альвеолярних структур. Альвеоли зруйнувались і зникли. Альвеолярні структури досліджуваної групи були кращими, ніж контрольної групи: легеневі інтерстиціальні та альвеолярні екsudати, а також запальна клітинна інфільтрація були значно зменшені порівняно з такими у контрольній групі. Результати дослідження дозволяють припустити, що використання PCV з "помірним" PEEP може значно покращити оксигенацію та зменшити гостру вентиляційну травму легень порівняно з VCV під час ОЛВ.

Ключові слова: морфологія легень, однолегенева вентиляція.