RESOLUTION OF EXPERIMENTAL PNEUMOTHORAX BY ROOM AIR

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ABSTRACT
Observation alone is advised only for primary spontaneous pneumothoraces with less than 20 percent of the lungs collapsed. In such cases, it is the resorption capabilities of the visceral pleura that are solely relied upon.
The aim of the present experimental study was to demonstrate the capabilities of the pleura for pneumothorax resolution by room air.

MATERIAL AND METHODS: The study was conducted with six laboratory animals (New Zealand white rabbits, weighing 2.5-3.5 kg), in which right total pneumothorax was induced. Conventional chest X-rays at intervals of 2 days were used to monitor the changes in the size of the pneumothorax until its final resolution. The size of the pneumothorax was estimated by the Light index.

RESULTS: Total resolution of the pneumothorax occurred within 12 days after it was induced. The average rate of pneumothorax resolution was 6.63% (SEM ± 0.20)/daily.

CONCLUSION: The study imitates initial clinical observation in pneumothorax. Despite the fact that the study demonstrates resolution of total pneumothorax (100%), observation only is inappropriate as a treatment modality in patients with more than 20% collapse of the lung.

Key words: spontaneous pneumothorax, experimental pneumothorax, subpleural bleb, room air

INTRODUCTION
Pneumothorax is defined as collection of air in the pleural space with subsequent collapse of the lungs. This condition is classified according to the causative mechanism: it can be traumatic (secondary to a thoracic trauma), or a spontaneous pneumothorax (without any trauma or other obvious cause). Spontaneous pneumothorax is further classified as primary and secondary. Secondary pneumothorax is a complication of underlying pulmonary disease, most often chronic obstructive pulmonary disease. Primary spontaneous pneumothorax occurs in healthy subjects without any pulmonary disease; it is frequent in thoracic surgery.¹⁻³ The reported incidence of primary spontaneous pneumothorax is 37:100 000 and 15.4:100 000 per year for men and women, respectively.⁴

There are several therapeutic approaches to patients with primary spontaneous pneumothorax: dynamic observation; pleural puncture with air aspiration from the pleural cavity; application of intrapleural drainage; video-assisted thoracic surgery; conventional surgical intervention.¹⁻³,⁵⁻⁸ Dynamic observation in patients with spontaneous pneumothorax is a big challenge for the thoracic surgeon. This approach is advised only in cases of minimal pneumothoraces (up to 20% of the hemithoracic volume), at first manifestations of the condition, when there are no clinical symptoms and if patients refuse flatly any interventions aiming to remove air from the pleural cavity.¹⁻³,⁵ When patients with pneumothorax are only observed, air removal from the pleural space rests only on the resorption capabilities of the visceral pleura.

AIM
The aim of the current study was to demonstrate experimentally the capabilities of the pleura for pneumothorax resolution by room air at room temperature. It is a part of our bigger research on spontaneous pneumothoraces.

MATERIAL AND METHODS
The experimental study was conducted with healthy New Zealand white rabbits weighing 2.5-3.0 kg. Six laboratory animals were used in the study in which
the conventional X-ray performed immediately before induction of pneumothorax was normal.

**Induction of pneumothorax**

The pneumothorax was induced in the right pleural cavity of the laboratory animals. After anesthetizing the animal by intramuscular injection of ketamine hydrochloride (35 mg/kg), the right half of the chest was shaved and disinfected with iodine tincture and ethanol. In the area between the spine and the superior angle of the scapula, following local anesthesia with 0.5% of lidocain, a 3 cm cut of the skin was made. The muscles in 6th or 7th intercostal area were dissected by blunt dissection technique giving access to the endothoracic fascia. Then a multiperforated catheter (angiocatheter – 22-G) prepared in advance was inserted into the right pleural cavity using a metal guide. The guide was removed from the catheter and the latter was connected to a syringe (20 ml). After aspirating to exclude any pulmonary or vessel damage, 20 ml of atmospheric air were insufflated which resulted in total right pneumothorax. The syringe was disassembled from the catheter and was left open for 10 sec, which leads to equalizing of the pleural pressure with the atmospheric pressure. After that the catheter was removed from the pleural cavity and the dissected muscles and the skin cut were sewed with single stitches. Then, chest X-ray was performed, documenting the experimental pneumothorax. For the time of the experiment, the animals were kept in individual cages at room air.

**Monitoring of the resolution of the experimental pneumothorax**

Resorption of the air in the right pleural cavity of the experimental animals was assessed by conventional chest X-ray studies. Imaging studies were performed every other day until total pneumothorax resolution in each animal. The size of the pneumothorax was determined on each of the X-rays using the index of RW Light\(^2,9\) According to the Light index, the size of the pneumothorax can be calculated as percentages of the volume of the corresponding hemithorax using the formula:

\[
\text{Size of pneumothorax (\%)} = \frac{1 - (\text{average lung diameter})^3}{(\text{average hemithorax diameter})^3} \times 100
\]

The rate of air resorption from the pleural space was determined for each animal. The data from the first pneumothorax size measurement (day 2) and the time for its total absorption were used. The speed was presented as percentages of resolved pneumothorax per day. The average rate of pneumothorax resolution for all animals was also been determined. The results are presented as mean plus SEM.

**Experimental animals care**

In the present study we conformed to the rules for treatment of laboratory animals approved and published in the “Guide to the Care and Use of Experimental Animals”. The experimental study was regarded with agreement of the University Ethical Committee. After completion of experiment, the animals were euthanized painlessly with a lethal dose of thiopental (50 mg/kg), injected in the marginal ear vein.

**Results**

A collapse of the lung – total pneumothorax, was established immediately after it was induced in each of the experimental animals included in the study (Fig. 1).

Conventional chest X-rays of the experimental animals demonstrate progressive air resorption from the pleural space (Figs 2, 3).

The changes in size of the pneumothorax and the rate (level) of its resolution (absorption) for each of the animals are presented in Table 1.

In four of the animals complete resorption of the air in the right pleural cavity occurred 12 days after causing the pneumothorax. In the other two animals complete resorption of the pneumothorax was established on day 10 (Fig. 4).

For all animals, using the data in Table 1, the average rate of resolution of the pneumothorax was calculated: 6.63% (SEM – 0.20) per day.

![Figure 1. Conventional chest X-ray of an experimental animal after inducing experimental pneumothorax. [arrows indicate right total pneumothorax (93.6%)]](image-url)
DISCUSSION

Pneumothorax is a common thoraco-surgical condition. It may result from a trauma (a traumatic pneumothorax), or may arise with no apparent cause (a spontaneous pneumothorax). Observation of patients with pneumothorax is a type of nonsurgical initial treatment which is recommended only in specific conditions. The air resorption in such cases from the pleural cavity relies solely on the resorption capabilities of the pleura. Air resorption from the pleural cavity is accomplished by the process of simple diffusion of gases through the semipermeable pleura to the subpleural venous system. In 1954, in clinical conditions, Kircher and Swartzel found that the air in the pleural cavity can be resorbed at a rate of approximately 1.25% of pneumothorax size per 24 hours.\textsuperscript{2,3} R. Hill et al.

Table 1. Changes of size of experimental pneumothorax by days after its creation

<table>
<thead>
<tr>
<th>Rabbit No</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Rate of absorption (% / daily)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>76.5</td>
<td>61.2</td>
<td>46.2</td>
<td>31.8</td>
<td>14.3</td>
<td>0</td>
<td>6.4</td>
</tr>
<tr>
<td>2</td>
<td>78.2</td>
<td>62.6</td>
<td>43.7</td>
<td>29.8</td>
<td>12.9</td>
<td>0</td>
<td>6.5</td>
</tr>
<tr>
<td>3</td>
<td>73.4</td>
<td>59.7</td>
<td>41.8</td>
<td>27.6</td>
<td>13.1</td>
<td>0</td>
<td>6.1</td>
</tr>
<tr>
<td>4</td>
<td>75.1</td>
<td>60.5</td>
<td>45.6</td>
<td>28.5</td>
<td>15.6</td>
<td>0</td>
<td>6.3</td>
</tr>
<tr>
<td>5</td>
<td>71.7</td>
<td>57.6</td>
<td>36.3</td>
<td>17.4</td>
<td>0</td>
<td>x</td>
<td>7.2</td>
</tr>
<tr>
<td>6</td>
<td>72.8</td>
<td>54.9</td>
<td>35.4</td>
<td>16.5</td>
<td>0</td>
<td>x</td>
<td>7.3</td>
</tr>
</tbody>
</table>

Figure 2. Conventional X-ray of an experimental animal two days after inducing a right pneumothorax (78.2%).

Figure 3. Conventional X-ray of an experimental animal on the 6\textsuperscript{th} day after inducing right pneumothorax (46.2%).

Figure 4. Conventional chest X-ray of an experimental animal on the 10\textsuperscript{th} day after inducing right pneumothorax (the air completely resorbed from the right pleural cavity).
present significantly faster pneumothorax resorption in experimental conditions – maximal duration up to 101.8 hours for total pneumothorax.¹⁰,¹¹ The aim of the this study was to assess the capabilities of the pleura for air resorption from the pleural space. We hypothesised that in the described experiment, the reabsorption of air from the pleural space will be faster than the one established in clinical conditions (1.25%/day).

Observation as initial treatment modality is advised only in patients with primary spontaneous pneumothorax, with less than 20% of the lungs collapsed. Primary spontaneous pneumothorax is most often a result of the rupture of subpleural blebs. Blebs are little air collections confined in the visceral pleural layers and localized in the apical segments of the lungs. It is accepted that blebs are paraseptal form of emphysema. In case of rupture of superficially situated alveoli, air penetrates into and is confined in the space between lamina elastica interna and lamina elastica externa of the visceral pleura. The air from the subpleural blebs has no communication with the airways. Therefore, penetration of air into the pleural space following rupture of a subpleural bleb, is a one-time self-limiting process.²,³,¹²,¹³ It has been established that the gaseous composition of the air from the pleural space in patients with primary spontaneous pneumothorax is identical with the one of atmospheric air (oxygen ~ 21 vol.%).²

In the present study we have chosen an experimental model of pneumothorax, which, in our opinion, imitates most closely primary spontaneous pneumothorax – single/ one-time atmospheric air penetration into the pleural space, with no communication with the airways (no lung injury). The choice of rabbit as an experimental animal in the study was determined from the necessity for use of experimental animal with two distinct pleural cavities.

In clinical and experimental conditions it has been established that air resorption from the pleural cavity is accelerated with the increase in oxygen concentration in the inhaled air.²,³,¹⁰,¹¹,¹⁴ Pneumothorax-accelerated resorption in these cases is explained with the increased nitrogen gradient between the air in the pleural space (78.09 vol.%) and the inhaled gas mixture. Obligatory condition for accomplishment of supportive oxygen therapy is hospital admission of patients with spontaneous primary pneumothorax. We used experimental model of pneumothorax imitating clinical variant of observation of patients with pneumothorax in home conditions – room (atmospheric) air.

The rate of pneumothorax resolution depends on the thickness of the visceral pleura. The rate is also proportional to the area of the pleural membrane and the size of the pneumothorax.²,¹⁵ The main factor determining the difference in the rate of air resorption from the pleural cavity in experimental animals (domestic rabbit) and humans is the thickness of the pleural membrane. Gas diffusion is faster through the thinner visceral pleura of experimental animals than through the thicker human pleura. This opinion underlies our working hypothesis, that the speed of pneumothorax resorption in experimental animals will be greater than the one determined in clinical conditions (1.25%/day). The results from the study supported our working hypothesis.

CONCLUSIONS

The present study followed up the changes in the size of experimental pneumothorax which was its aim. It demonstrated the capabilities of the visceral pleura for air reabsorption from the pleural cavity in room air.

This experimental study imitates initial clinical observation in pneumothorax. Despite the fact that the study demonstrates a resolution of total pneumothorax (100%), observation is inappropriate in patients with more than 20% collapse of the lung. In cases of pneumothoraces greater than 20% in size we can assume that there is communication between the pleural space and the airways, a condition requiring obligatory drainage of the pleural cavity.

REFERENCES


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**РЕЗОРБЦИЯ ЭКСПЕРИМЕНТАЛЬНОГО ПНЕВМОТОРАКСА В УСЛОВИЯХ КОМНАТНОЙ ТЕМПЕРАТУРЫ**

**ВВЕДЕНИЕ:** Наблюдение, как начальная форма поведения, допустимо только в случаях пациентов с первичным спонтанным пневмотораксом и при колапсе легкого до 20%. У таких пациентов для устранения воздуха из плевральной полости рассчитывается единственно на резорбтивные возможности висцеральной плевры.

**ЦЕЛЬ:** Демонстрировать возможности плевры резорбировать пневмоторакс в условиях атмосферного (комнатного) воздуха.

**МАТЕРИАЛ И МЕТОДЫ:** Эксперимент ставится на шести подопытных животных с массой тела 2,5 - 35 кг (New-Zealand white rabbits) с вызванным правосторонним тотальным пневмотораксом. С помощью конвенциональных рентгенографий грудной клетки, осуществляемых через два дня, прослеживаются изменения в размерах пневмоторакса до его полной резорбции. Для определения размеров пневмоторакса используется индекс Light.

**РЕЗУЛЬТАТЫ:** Полная резорбция пневмоторакса наступает на 12-ый день. Средняя скорость резорбции пневмоторакса - 6,63% (SEM ± 0,20) в день.

**ЗАКЛЮЧЕНИЕ:** Исследование имитирует начальное клиническое наблюдение при пневмотораксе. Необходимо отметить, что оно демонстрирует резорбцию тотального (100%) пневмоторакса, у пациентов наблюдение как форма поведения допустимо при колапсе легкого до 20%.