Morphometric indicators for selection of dual endobronchial tube in thoracic anesthesiology

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For the purpose of single-lung ventilation, various methods of lung isolation are used in the world, which is a prerequisite for many thoracic, cardiac and esophageal surgeries. Numerous studies have reported various methods for determining the optimal suitability between the diameter of the tube and the diameter of the left main bronchus for adequate ventilation and gas exchange during operations on the thoracic cavity. However, there is no consensus among anesthesiologists on the choice of tube size for effective lung ventilation and isolation. We have developed a new mathematical formula for determining the appropriate size of the left bilateral luminal endobronchial tube (LDT). The aim of the study was to determine the effectiveness of the developed standardized mathematical formula for determining the appropriate size of LDT for use in thoracic anesthesiology.

The study was performed on 192 patients with diseases of the thoracic cavity (esophagus, lungs, mediastinum), operated on in the thoracoabdominal department of the Shalimov National Institute of Surgery and Tranplantology. A retrospective comparison group - 96 patients after thoracic surgery, which used the choice of LDT size according to the well-known Slinger method “according to the patient’s height”. The study group consisted of 96 patients after thoracic surgery, in which the choice of the size of the bifurcated endobronchial tube was used according to the developed method (according to the formula that evaluates morphometric indicators of height, sex and diameter of the left main bronchus). The application of the proposed method reduces (p = 0.001) the risk of pulmonary complications, HR = 0.39 (95% CI 0.22-0.70) compared to traditional methods. The risk decreased 2.5 times.

Key words: morphometric parameters, formula for determining the size of the bifurcated endobronchial tube.
Bioethics of the State Institution "National Institute of Surgery and Transplantology named after O.O. Shalimov" NAMS of Ukraine Protocol №12 of January 12, 2018, the research methods described in the publication were applied in compliance with human rights in accordance with current legislation in Ukraine, meet international ethical requirements and do not violate ethical norms in science and standards of biomedical research. The study was performed on 192 patients with diseases of the thoracic cavity (esophagus, lungs, mediastinum), operated on in the thoracoabdominal department of the Shalimov National Institute of Surgery and Transplantology. A retrospective comparison group - 96 patients after thoracic surgery, which used the choice of LDT size according to the well-known Slinger method "according to the patient's height" [2]. The study group consisted of 96 patients after thoracic surgery, in which the choice of the size of the bifurcated endobronchial tube was used according to the developed method (according to the formula that evaluates morphometric indicators of growth, sex and diameter of the left main bronchus (DLMB)).

Inclusion criteria were: a patient assigned to open thoracic or video-assisted thoracoscopic surgery under general anesthesia requiring single pulmonary ventilation (excluding emergency surgery); BMI<35 kg / m^2; age>18 years; planned lung isolation with LDT;

Exclusion criteria were: grade 3 and 4 chronic obstructive pulmonary disease, pulmonary fibrosis, documented bullae, severe pulmonary emphysema, pneumothorax; uncontrolled asthma; grade 3 and 4 heart failure, grade 3 and 4 coronary heart disease; previous lung surgery; documented pulmonary arterial hypertension>40 mm Hg (ultrasound assessment); bilateral procedures; isolation of the lungs by a method other than LDT;

Written informed consent was obtained from all patients. Patients in both groups were comparable in age, sex, ASA scale, weight, height, duration of surgery (Table 1), p>0.05 in all indicators.

The diameter of the left main bronchus was measured by computed tomography (CT) at a distance of 1-2 mm from the bifurcation of the trachea. To do this, it is better to use the construction of a 3D model with the help of computer programs (Horos, Radiant), which allow you to get clearer images of the Airways and accurately measure their diameters. Here is a clinical example. Figure 1 shows the measurement of the diameter of the left main bronchus on the image of the CT in the axial section. Figure 2 shows a 3D model of the same patient where

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Control group, n=96</th>
<th>Research group, n=96</th>
<th>The level of significance of the difference, p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>174.5 (168 - 176)</td>
<td>172 (168 - 176)</td>
<td>0.406</td>
</tr>
<tr>
<td>Weight</td>
<td>76 (69.5 - 82.5)</td>
<td>76 (70 - 86)</td>
<td>0.312</td>
</tr>
<tr>
<td>DLMB</td>
<td>1.295 (1.2 - 1.34)</td>
<td>1.29 (1.2 - 1.34)</td>
<td>0.738</td>
</tr>
<tr>
<td>Age</td>
<td>60 (56 - 65)</td>
<td>58 (56 - 64)</td>
<td>0.265</td>
</tr>
<tr>
<td>Ppeak</td>
<td>26 (24 - 28)</td>
<td>10 (9 - 11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pplat</td>
<td>23 (20 - 25)</td>
<td>22 (20 - 24)</td>
<td>0.75</td>
</tr>
<tr>
<td>Pmean</td>
<td>12 (10 - 12.5)</td>
<td>19 (17 - 22)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lung_Compliance</td>
<td>22 (21 - 24)</td>
<td>24 (23 - 26.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CVP</td>
<td>40 (40 - 50)</td>
<td>50 (40 - 50)</td>
<td>0.022</td>
</tr>
<tr>
<td>PAo2_Fio2</td>
<td>220 (220 - 230)</td>
<td>240 (230 - 260)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PAco2_kPa_</td>
<td>43.5 (40 - 45)</td>
<td>38 (36 - 40)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Po2</td>
<td>130 (114 - 140)</td>
<td>140 (132.5 - 150)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>FEV1, %</td>
<td>78 (76 - 86)</td>
<td>82 (78 - 86.5)</td>
<td>0.061</td>
</tr>
<tr>
<td>tOLV</td>
<td>120 (90 - 140)</td>
<td>100 (90 - 120)</td>
<td>0.007</td>
</tr>
<tr>
<td>T body</td>
<td>36.1 (35.8 - 36.5)</td>
<td>36 (36 - 36.3)</td>
<td>0.528</td>
</tr>
</tbody>
</table>

Note: The Mann-Whitney test was used in the comparison.
you can see that the size of the left main bronchus is larger than the axial section.

Such differences are noted by many authors [8, 11, 12], who point to the need to measure several sizes of the left main bronchus, or compare the diameters of cricket cartilage, trachea and bronchi to compare these indicators with the choice of endobronchial tube size.

To study the effectiveness of single lung ventilation, we investigated the following parameters: the number of postoperative pulmonary complications, which are reported to be directly correlated with inadequate single lung ventilation.

EZR v.1.54 statistical software was used for statistical calculations (graphical user interface for statistical software R version 4.0.3, R Foundation for Statistical Computing, Vienna, Austria) [10].

Results
According to the distribution by number of the left bilateral luminal endobronchial tube, the patients of the study and control groups did not differ from each other, p = 0.752 (Table 2).

The main indicator of the effectiveness of using the developed standardized mathematical formula to determine the appropriate size of LDT is the number of pulmonary complications after thoracic surgery. In this study, pulmonary complications developed in 33 (34.4 %) patients of the control group and in 13 (13.5 %) patients of the study group, a statistically significant difference was found at p = 0.001 (Fig. 3).

This is evidence of effective perioperative management of patients with thoracic diseases and shows that clear and consistent use of simple, innovative methods of prevention of postoperative pulmonary complications (such as accurate selection of LDT by several morphometric parameters) in thoracic patients significantly reduces these complications.

Thus, the application of the proposed technique reduces (p = 0.001) the risk of pulmonary complications, HR = 0.39 (95 % CI 0.22-0.70) compared to traditional methods. The risk decreased 2.5 times.

Discussion
One of the difficulties most anesthesiologists encounter in performing lung ventilation is choosing the optimal size of the left bilateral luminal endobronchial tube for each patient [22]. At our institute, this selection is usually based on the method recommended by Slinger [2]. It involves calculating the required number based on the average height and sex of patients. However, this recommendation may not be acceptable to all patients, especially those with tall stature and narrow airways. Therefore, we decided to use an assessment methodology that included not only the sex and height of patients, but also integrated LDT as an indicator. This allowed us to more accurately predict the appropriate size for left-sided LDT.

Different research groups have used different methods to select a bilateral endobronchial tube based on individual anthropometric parameters (eg, sex and height, DLMB) [11, 12, 13, 14, 15]. Based on our review of available sources, no studies have compared the full range of these indicators, and there are no standardized formulas for endobronchial tube selection.

A previous study reported that the use of a method based on gender and height gives an accuracy of 58.3 % [11]. However, when the transverse diameter of the annular cartilage was measured by ultrasound and CT, the accuracy of intubation in the groups of ultrasound and CT was 90.2 % and 94.1 %, respectively (p>0.05). Thus, the authors concluded that the measurement of the transverse diameter of the annular cartilage led to much greater accuracy in choosing the size of LDT than traditional methods. In addition, they reported that this method can significantly reduce postoperative complications. Given that there is no significant difference between the accuracy of ultrasound and CT, their results showed that both of these methods for tube selection can be safely used before intubation in thoracic surgery [23].

A prospective study was conducted to test the hypothesis that a previously developed formula based on height (0.25 x 0.916 height) could predict the exact depth of LDT administration in 66 patients who underwent breast

### Table 2. Distribution of patients on the left bilateral endobronchial tube.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Control group, n=96</th>
<th>Research group, n=96</th>
<th>The level of significance of the difference, p</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>21 (21.9)</td>
<td>21 (21.9)</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>18 (18.8)</td>
<td>20 (20.8)</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>44 (45.8)</td>
<td>34 (35.4)</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>13 (13.5)</td>
<td>21 (21.9)</td>
<td>0.752</td>
</tr>
</tbody>
</table>

Note: Fisher’s exact test or chi-square test is used in the comparison.
surgery. The formula led to optimal LDT positioning without additional adjustments in 45 patients (70 %) [12].

In our study, we used a new approach to compare the set of indicators (sex, height, DLMB), which allowed us to develop a standardized formula for choosing the size of left-sided LDT. Although we used the sex and height of patients to choose the size of LDT, not taking into account DLMB. The advantages of this method are that it is simple and easy to use. However, it has shortcomings that can significantly worsen the prognosis of the postoperative period. These include: the predicted result by this method significantly worsen the prognosis of the postoperative DLMB. The advantages of this method are that it is simple to choose the size of LDT, not taking into account the size was either overestimated or underestimated. This once again confirmed the discrepancy between gender and height, as well as airway diameters.

Conclusions
Thus, the application of the proposed method of LDT selection reduces (p = 0.001) the risk of pulmonary complications by 2.5 times, BP = 0.39 (95 % CI 0.22-0.70) compared to traditional methods.

References
З метою однолегеневої вентиляції в світі використовують різноманітні методи ізоляції легень, яка є передумовою для багатьох грудних, серцевих та стравохідних хірургічних втручань. Численні дослідження повідомляють про різні методи визначення оптимальної придатності між діаметром трубки та діаметром лівого головного бронха для адекватної вентиляції та газообміну під час операцій на грудній порожній. Однак серед анестезіологів немає єдиної думки щодо вибору розміру трубки для ефективної вентиляції та ізоляції легень. Нами була розроблена нова математична формула для визначення відповідного розміру лівосторонньої двопросвітної ендобронхіальної трубки (ЛДТ). Метою дослідження стало визначити ефективність розробленої стандартизованої математичної формули для визначення відповідного розміру ЛДТ для використання в торакальній анестезіології. Дослідження виконано на 192 хворих із захворюваннями грудної порожнини (стравоходу, легень, середостіння), оперованих в торакоабдомінальному відділі Національного інституту хірургії та трансплантології ім. О.О.Шалімова. Ретроспективну групу порівняння становили 96 пацієнтів після торакальних операцій, у котрих використаний вибір розміру ЛДТ за загальновідомою методикою Slinger "за зростом хворого". Групу дослідження становили 96 пацієнтів після торакальних операцій, для котрих був використаний вибір розміру двопросвітної ендобронхіальної трубки за розробленою методикою (за формулою, завдяки якій можна оцінити морфометричні показники зросту, статі та діаметра лівого головного бронха). Застосування запроопонованої методики дозволяє знизити ризик розвитку легеневих ускладнень, ВР = 0,39 (95 % ВІ 0,22-0,70). У порівнянні з традиційною методикою: ризик знизився у 2,5 рази.

Ключові слова: морфометричні показники, формула визначення розміру двопросвітної ендобронхіальної трубки.


