Functional Residual Capacity Measurement in Normal Cats

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Lung volume is an important division in maintaining sufficient gas exchange. We would like to give here an outline of our research whose objective was to measure the functional residual capacity (FRC), i.e. the intrapulmonary gas volume at the resting expiratory level. In the previous reports [10, 11], FRC measurement in cats using the helium dilution method performed them using tracheotomy. But the tracheotomy can not use clinically. So we performed FRC measurement using the intact method. FRC is composed of the expiratory reserve volume and the residual volume in the trachea-pulmonary system. The elements determining FRC are the recoil of the lung and chest wall.

Ten male and 22 female healthy adult cats, 29-41 cm length (mean, 34.6 cm) measured at shoulder point-buttock point and 1.9-3.9 kg body weight (mean, 2.8 kg), were used in this study. They were normal with regards to hematology, blood chemistry, and plain chest X-ray. The cats were anesthetized with intramuscular injection of ketamine hydrochloride (15 mg/kg) and continuous intravenous infusion of ketamine hydrochloride (0.1-0.2 mg/kg/min). Muscle relaxation was obtained by administration of pancuronium bromide (0.1 mg/kg) before endotracheal intubation was carried out. A pediatric positive pressure artificial ventilator was connected to the endotracheal tube in order to maintain controlled ventilation.

Measurement of the FRC was offered by the closed circuit method using diluted helium gas [3, 4, 5, 7, 10, 11, 15, 16]. Namely, a syringe filled with 9-11% helium was coupled to the subject in a closed circuit at the resting expiratory level, i.e. FRC level, after the helium density was checked with a helium densitometer. After a few minutes of rebreathing with the syringe, we measured the density in the circuit and the volume of the syringe when the helium density had equalized. We then calculated the FRC from the volume and the helium density before and after equalization using the formula: \( F_1 (V_1 + V_E) = F_2 (V_2 + V_E + FRC) \). \( F_1 \): the helian density prior to equalization, \( F_2 \): the helium density after equalization, \( V_1 \): the volume in the syringe before equalization, \( V_2 \): the volume in the syringe after equalization and \( V_E \): the volume (65 ml) of helium in the densitometer previously measured.) Correlation was studied between body length and FRC, and also between body weight and FRC. Statistical significant difference was tested for sex and FRC using Student's t-test.

A positive correlation was observed between body length and FRC \( y = -156.6+7.7x, r=0.80; P<0.01 \) (Fig. 1), and also between body weight and FRC \( y=12+34.9x, r=0.81; P<0.01 \) (Fig. 2). No significant difference in FRC was observed between both sexes \( P<0.05 \) (Table 1). This method was reproducible.

The conventional method used in the measurement of FRC is the body plethysmograph method [12, 16, 19]. This method involves placing the subject in the box and

![Fig. 1. Correlation between functional residual capacity (FRC) and body length.](image1)

![Fig. 2. Correlation between functional residual capacity (FRC) and body weight.](image2)
measuring the changes in thoracic volume induced by respiratory movements. The gas dilution method involves a closed or open circuit, using a gas that does not pass easily from the pulmonary alveolar into the blood or the lung tissue. In the open circuit method [1, 2, 6, 9, 14, 18], the index gas in the lung is washed out and collected in a separate cylinder. The open circuit method has been considered as the expired index gas is not inhaled again. This method of FRC measurement generally uses Nitrogen (N₂) as the index gas. Three methods described above have the following characteristics [13, 17]. The body plethysmograph requires little time for measurement and enables one to measure the lung capacity without communication with the airway, whereas it is of more complex manipulation than the other methods. Gas in the abdominal cavity may also affect the results of the measurement. The open-circuit method is simple but allows for gas to be washed out of the body for dissolved N₂ in blood. Also, this measurement takes a long time. With the closed circuit method, the technique and calculation are relatively simple but each measurement takes time. We used the closed circuit method based on the facts that the technique and calculation was simple and the value was accurate compared to the open circuit method.

There have been a few reports on FRC in cats [7, 10, 11, 12]. Mansell et al. [7] measured FRC in kittens under spontaneous respiration by the helium-dilution method, and there have been other reports of similar measurements in adult cats. Nissel et al. [12] also reported the results obtained by body plethysmograph, and Muza et al. [10, 11] those by the helium dilution method under urethane anesthesia. Our data were taken under controlled ventilation allowing least possibility for variation due to breathing pattern difference. The FRC values obtained in the present study was not comparable to those reported by Nissel et al. and Muza et al. This discrepancy could be explained by the fact that they preformed measurements using tracheotomy. In the present result, FRC increased with body length and with body weight. The data scatter, however, was large and could be secondary to the variability in the chest wall characteristics in cats. Such variation in FRC values may be due to the differences in anesthetic method [2], the body position [6, 8, 9, 15], obesity, age [8], abdominal distension and other factors.

In the present study, we confirmed that FRC measurement in cats using the helium dilution method was simple, reproducible and reliable, and was considered clinically useful. Clinical application includes diagnosis of restrictive lung disease or restrictive conditions. It could also be applied in diagnosis of hyper-inflation of the lungs in airway obstruction.

**Table 1. Average values of functional residual capacity in male and female cats**

<table>
<thead>
<tr>
<th>Sex</th>
<th>No.</th>
<th>Body weight (kg)</th>
<th>Body length (cm)</th>
<th>FRC (ml/kg B.W.</th>
<th>FRC (ml/cm B.L.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>10</td>
<td>3.07±0.78</td>
<td>35.3±3.53</td>
<td>122.2±31.9</td>
<td>0.41±5.68</td>
</tr>
<tr>
<td>Female</td>
<td>22</td>
<td>2.68±0.56</td>
<td>34.4±2.65</td>
<td>104.0±25.2</td>
<td>0.39±7.0</td>
</tr>
</tbody>
</table>

Values are means±SD.

REFERENCES