LUNG FUNCTION IN THE SUPINE AND LATERAL DECUBITUS POSITIONS IN ANAESTHETIZED INFANTS AND CHILDREN

A. LARSSON, C. JONMARKER, S. G. E. LINDAHL AND O. WERNER

In awake adults who assume the lateral position, the upper lung increases in volume but the greater fraction of ventilation goes to the lower lung, the volume of which decreases slightly. The result is a moderate increase in functional residual capacity (FRC) and an uneven pulmonary gas mixing as measured by the nitrogen washout technique [1, 2]. Based on studies in infants with known or suspected pulmonary diseases, it has been suggested that children may exhibit a “reversal of adult pattern” in respect of pulmonary gas distribution [3], but no systematic studies have been undertaken in anaesthetized children with healthy lungs. To test if children differ from adults, we have studied the effects of the lateral position on compliance, FRC and the washout of an insoluble gas in children during spontaneous breathing and mechanical ventilation.

PATIENTS AND METHODS

Twenty-five infants and children, aged 4 months to 9 yr, were studied. Fifteen children (table I) were undergoing abdominal or urogenital surgery and breathed spontaneously. Ten children (table II) were undergoing abdominal surgery or surgery for aortic coarctation involving mechanical ventilation. All children were free from respiratory disease and the two groups were similar in respect of age, weight and height. Compliance and FRC in children with aortic coarctation (patients Nos 21–25, table II) have been reported previously [4].

SUMMARY

We have measured dynamic lung compliance or static lung thorax compliance, functional residual capacity (FRC), and two indices of pulmonary gas mixing (pulmonary clearance delay (PCD) and single breath alveolar mixing efficiency (SBAME)) in 25 children in the supine and lateral decubitus position during nitrous oxide–halothane anaesthesia. Fifteen children (5 month–8 yr) breathed spontaneously and 10 (4 month–9 yr) underwent mechanical ventilation. Tidal volume and rate of ventilation were, respectively, 3.5–6.6 ml kg⁻¹ and 22–46 b.p.m. in spontaneously breathing supine children, and 8.3–15 ml kg⁻¹ and 20–30 b.p.m. in mechanically ventilated supine children, and did not differ significantly in the lateral position. There was no significant change in compliance when the child was turned to the lateral position, but FRC increased from 22 (SD 7) to 25 (8) ml kg⁻¹ (P < 0.01) in the spontaneously breathing group and from 19 (6) to 24 (8) ml kg⁻¹ (P < 0.01) in the other group. In spontaneously breathing children, PCD and SBAME indicated a somewhat impaired pulmonary gas mixing (P < 0.05) after the child had been turned to the lateral position, but no change occurred in the other group. These findings suggest that the distribution of ventilation in anaesthetized children in the lateral position is similar to that reported previously in anaesthetized adults.

Parental consent was obtained and the study was approved by the local Human Studies Committee.

Patients older than 1 yr received a mixture of diazepam 0.5 mg kg⁻¹, morphine 0.15 mg kg⁻¹, and hyoscine 0.01 mg kg⁻¹, rectally 1 h before induction of anaesthesia. Infants (younger than
measurements. Anaesthesia was maintained with
COMPLIANCE, FRC AND GAS MIXING linckrodt or Portex). The cuff was inflated during
was intubated with a cuffed tracheal tube (Mal-
0.01; suxamethonium in 20 children and the trachea
SBAME position. PCD = pulmonary clearance delay [7]; SBAME = single breath alveolar mixing efficiency [8]. *P < 0.05; **P < 0.01; ns = not significant

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (month)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Vent. rate (b.p.m.)</th>
<th>$V_t$ (ml kg$^{-1}$)</th>
<th>$Cl_t$ (ml cm H$_2$O kg$^{-1}$)</th>
<th>FRC (ml kg$^{-1}$)</th>
<th>PCD (%)</th>
<th>SBAME (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>6.5</td>
<td>63</td>
<td>44</td>
<td>43</td>
<td>3.5</td>
<td>13</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>7.6</td>
<td>69</td>
<td>45</td>
<td>44</td>
<td>4.3</td>
<td>15</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>8.4</td>
<td>63</td>
<td>44</td>
<td>46</td>
<td>3.5</td>
<td>18</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>9.7</td>
<td>74</td>
<td>44</td>
<td>45</td>
<td>4.8</td>
<td>16</td>
<td>21</td>
<td>—</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>9.7</td>
<td>73</td>
<td>37</td>
<td>36</td>
<td>5.5</td>
<td>14</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>11</td>
<td>82</td>
<td>33</td>
<td>38</td>
<td>4.1</td>
<td>14</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>7</td>
<td>29</td>
<td>15</td>
<td>94</td>
<td>43</td>
<td>45</td>
<td>3.7</td>
<td>21</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>8</td>
<td>37</td>
<td>12</td>
<td>89</td>
<td>44</td>
<td>45</td>
<td>6.6</td>
<td>30</td>
<td>34</td>
<td>23</td>
</tr>
<tr>
<td>9</td>
<td>51</td>
<td>18</td>
<td>109</td>
<td>23</td>
<td>23</td>
<td>5.8</td>
<td>31</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>10</td>
<td>61</td>
<td>18</td>
<td>109</td>
<td>29</td>
<td>31</td>
<td>4.3</td>
<td>32</td>
<td>38</td>
<td>27</td>
</tr>
<tr>
<td>11</td>
<td>67</td>
<td>20</td>
<td>109</td>
<td>35</td>
<td>24</td>
<td>4.2</td>
<td>29</td>
<td>29</td>
<td>34</td>
</tr>
<tr>
<td>12</td>
<td>77</td>
<td>28</td>
<td>124</td>
<td>29</td>
<td>29</td>
<td>4.0</td>
<td>19</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>13</td>
<td>78</td>
<td>21</td>
<td>116</td>
<td>22</td>
<td>22</td>
<td>4.8</td>
<td>31</td>
<td>33</td>
<td>31</td>
</tr>
<tr>
<td>14</td>
<td>85</td>
<td>25</td>
<td>123</td>
<td>27</td>
<td>28</td>
<td>4.0</td>
<td>28</td>
<td>33</td>
<td>23</td>
</tr>
<tr>
<td>15</td>
<td>94</td>
<td>23</td>
<td>123</td>
<td>28</td>
<td>27</td>
<td>4.5</td>
<td>24</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Mean</td>
<td>42</td>
<td>16</td>
<td>95</td>
<td>35</td>
<td>35</td>
<td>4.5</td>
<td>22</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>SD</td>
<td>32</td>
<td>7</td>
<td>23</td>
<td>8</td>
<td>9</td>
<td>0.9</td>
<td>7</td>
<td>8</td>
<td>12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (month)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Vent. rate (b.p.m.)</th>
<th>$V_t$ (ml kg$^{-1}$)</th>
<th>$Cl_t$ (ml cm H$_2$O kg$^{-1}$)</th>
<th>FRC (ml kg$^{-1}$)</th>
<th>PCD (%)</th>
<th>SBAME (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>4</td>
<td>4.9</td>
<td>63</td>
<td>25</td>
<td>12</td>
<td>—</td>
<td>14</td>
<td>16</td>
<td>45</td>
</tr>
<tr>
<td>17</td>
<td>6</td>
<td>8.2</td>
<td>69</td>
<td>20</td>
<td>15</td>
<td>0.7</td>
<td>13</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>12</td>
<td>82</td>
<td>20</td>
<td>15</td>
<td>0.7</td>
<td>15</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>19</td>
<td>33</td>
<td>14</td>
<td>94</td>
<td>20</td>
<td>13</td>
<td>1.0</td>
<td>25</td>
<td>31</td>
<td>26</td>
</tr>
<tr>
<td>20</td>
<td>43</td>
<td>18</td>
<td>101</td>
<td>20</td>
<td>10</td>
<td>1.0</td>
<td>20</td>
<td>28</td>
<td>22</td>
</tr>
<tr>
<td>21</td>
<td>11</td>
<td>9.6</td>
<td>76</td>
<td>30</td>
<td>11</td>
<td>0.6</td>
<td>11</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>22</td>
<td>20</td>
<td>13</td>
<td>83</td>
<td>27</td>
<td>8.5</td>
<td>0.9</td>
<td>18</td>
<td>19</td>
<td>29</td>
</tr>
<tr>
<td>23</td>
<td>61</td>
<td>19</td>
<td>112</td>
<td>21</td>
<td>9.7</td>
<td>1.2</td>
<td>31</td>
<td>37</td>
<td>17</td>
</tr>
<tr>
<td>24</td>
<td>81</td>
<td>23</td>
<td>120</td>
<td>21</td>
<td>10</td>
<td>1.0</td>
<td>24</td>
<td>29</td>
<td>18</td>
</tr>
<tr>
<td>25</td>
<td>114</td>
<td>33</td>
<td>137</td>
<td>20</td>
<td>8.7</td>
<td>0.8</td>
<td>21</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Mean</td>
<td>40</td>
<td>15</td>
<td>94</td>
<td>22</td>
<td>11</td>
<td>0.9</td>
<td>19</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>SD</td>
<td>37</td>
<td>8</td>
<td>24</td>
<td>4</td>
<td>2</td>
<td>0.2</td>
<td>6</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

1 yr) received no premedication. Anaesthesia was
induced with i.v. thiopentone ($n = 19$) or halothane ($n = 6$). Intubation was facilitated with
suxamethonium in 20 children and the trachea
was intubated with a cuffed tracheal tube (Mal-
linckrodt or Portex). The cuff was inflated during
measurements. Anaesthesia was maintained with
1% halothane and 50–70% nitrous oxide in oxygen. In spontaneously breathing children a
Mapleson D system was used with a fresh gas
flow three times the estimated ventilation. In 12 of
these 15 children anaesthesia was supplemented
with a caudal block using 0.25% bupivacaine
0.5 ml kg$^{-1}$. In the second group of children,
undergoing mechanical ventilation, vecuronium 0.1 mg kg\(^{-1}\) or alcuronium bromide 0.25 mg kg\(^{-1}\) was given to maintain muscle paralysis during measurements. Ventilation was controlled using a Servo ventilator 900C (Siemens–Elema) at 20–30 b.p.m. Positive end-expiratory pressure was not used. The tidal volume was adjusted to give an end-tidal \(P_{\text{CO}_2}\) of 4–5 kPa and the ventilator was set at constant inflation flow. The inflation time was 25 or 33% and end-inspiratory pause time was 0 or 10% of the cycle of ventilation. The pattern of ventilation was unchanged in each child during all measurements, except during measurement of compliance, when a 10% end-inspiratory pause was used in all children.

**Measurements**

Measurements were made after induction of anaesthesia but before surgery. At least 15 min of halothane administration had elapsed before the first set of measurements. Airway flow, oesophageal pressure (\(P_{\text{Oe}}\)), airway (mouth) pressure \(P_{\text{m}}\), and FRC were measured with patients in the supine position and in the lateral decubitus position with the upper arm placed over the head. In the spontaneously breathing group all children were turned to the left side and measurements were made in the following order: supine–left lateral–supine \((n = 7)\); supine–left lateral \((n = 4)\); and left lateral–supine \((n = 4)\). In the group undergoing mechanical ventilation, measurements were made with patients first in the supine position and then in the left lateral (Nos 16–20) or right lateral position (Nos 21–25). In this group, duplicate FRC determinations were made in both positions.

The measurement system is shown in figure 1. In spontaneously breathing children the apparatus deadspace was 8 ml in children less than 10 kg in weight, and 12 ml in children weighing more than 10 kg. In the mechanical ventilation group, apparatus deadspace varied between 8 and 35 ml, because a heat/moisture exchanger was used in some children. Airway flow was measured using a heated Fleisch pneumotachograph No. 00 or 0 (Gould) with a differential pressure transducer (MP 45-1-871, Validyne) or by the standard flowmeter of the ventilator (Nos 21–25). The pneumotachograph signal was zero-adjusted and calibrated before each measurement with a precision pump using 50% nitrous oxide in oxygen. The flowmeter of the ventilator was calibrated against a wet gas meter (Flonic, Schlumberger) during ventilation with 50% nitrous oxide in oxygen. Tidal volume \((V_T)\) was obtained by integration of the flow signal.

In spontaneously breathing children, \(P_{\text{m}}\) and

![Diagram](image-url)
Poe were measured at the tracheal tube connection and in mid-oesophagus, respectively, using pressure transducers (PDCR-75, Druck) calibrated at a pressure of $-20 \text{ cm H}_2\text{O}$. The position and function of the water-filled oesophageal catheter was assessed by occluding the airway at FRC [5]. A ratio of 0.9–1.1 between oesophageal and airway pressure changes at occlusion was considered satisfactory. In mechanically ventilated children $Pm$ was measured in the expiratory tubing with the manometer mounted on the ventilator, as supplied by the manufacturer. The manometer was calibrated against a mercury manometer.

Flow, volume and pressures were recorded on an ink-jet recorder (EM-81, Siemens-Elema) and dynamic lung compliance ($CL$) was calculated from the tracings as:

$$CL = \frac{VT}{\Delta(Poe-Pm)}$$

where $VT$ equals the tidal volume (BTPS), and $\Delta(Poe-Pm)$ the change in pressure during inspiration. The mean value obtained in 10 consecutive breaths was used for the calculations. During mechanical ventilation, breath-by-breath static lung–thorax compliance ($CLt$) was obtained as:

$$CLt = \frac{VT}{(Pi' - PE')}$$

where $Pi'$ equals the airway pressure at the end of the end-inspiratory pause and $PE'$ the airway pressure at the end of expiration. During compliance measurements the end-inspiratory pause was 0.2–0.3 s. $PE'$ was obtained by noting the pressure in the tubing during an “end-expiratory hold”, with both the inspiratory and expiratory valves closed. This function was activated for approximately 1 s. In patients Nos 21–25, in whom airway flow was measured by the flowmeter of the ventilator, compliance of the tubing (0.5 ml/cm H$_2$O) was subtracted from the obtained value.

FRC was measured with a multiple breath washout technique using sulphur hexafluoride ($SF_6$) as tracer gas [6]. Tracer gas concentration is measured in the apparatus deadspace with an infra-red transducer placed over a cuvette with windows (fig. 1). $SF_6$ is washed in through a dispensing device, which mixes $SF_6$ in proportion to inspiratory flow until a stable and uniform alveolar concentration of approximately 0.5% is attained. $SF_6$ washout is started by stopping the tracer gas infusion at the end of inspiration and is considered complete when the concentration is less than 0.001%. Signals representing expired flow and $SF_6$ concentration are fed into a computer (PDP 11/23, Digital Equipment), which calculates FRC as the volume of $SF_6$ washed out divided by the alveolar concentration at the end of the washin period. The value obtained is converted to BTPS and apparatus deadspace is subtracted.

Pulmonary clearance delay (PCD) was calculated as described by Fowler and colleagues [7]. The index compares the average time that a tracer gas molecule remains in the lungs ($T_1$) with the average time that a tracer gas molecule would remain in a uniformly ventilated lung with the same FRC, series deadspace and tidal volume, before being expired ($T_2$). PCD is obtained as:

$$100 \times \frac{(T_1 - T_2)}{T_2}$$

The average time that a tracer gas molecule remains in the lungs is calculated from the washout curve. Calculation of PCD was with an interactive computer program which approximated the curve as the sum of exponentially decaying functions: the computer plotted the washout curve semilogarithmically, and the user indicated how lines should be drawn in order to obtain the exponential curve components. The “peel-off” method was used, that is, the slowest component was first subtracted and the plot was redrawn to identify the remaining component. In all cases, an adequate approximation of the curve was achieved with two components. Single breath alveolar mixing efficiency (SBAME) was calculated by the method of Cumming and Guyatt [8] as the actual volume of tracer gas in the first expiration during washout expressed as a percentage of the “ideal” volume, had gas mixing in the lungs been perfect. The normal values for awake healthy adults in the supine position in our laboratory are 39 (20)% for PCD and 85 (5)% for SBAME. As far as we know, no studies of PCD have been performed in spontaneously breathing, awake children younger than 8 yr and only one study has reported SBAME in children and young adults 5–20 years of age [9]. In that study, SBAME was obtained from an expiration of TLC to FRC using nitrogen as tracer gas. The mean value was 83%.

Arterial oxygen tension ($PaO_2$) was measured in the five children who were to undergo corrective surgery for coarctation of the aorta. In the five remaining children undergoing mechanical ventilation, arterial oxygen saturation ($SaO_2$) was assessed by pulse oximetry.
Statistics

t Test for paired or unpaired data was used when appropriate. Probability values less than 0.05 were considered statistically significant. Regression equations were obtained by the method of least squares. The coefficient of variation for duplicate FRC determinations was obtained as:

$$SD/m = D/m \times \sqrt{2}$$

where $D$ is the absolute value of the difference between the observations and $m$ the mean. Data are given as mean (1 SD) when not otherwise indicated.

RESULTS

The ventilatory rate was greater and the tidal volume smaller in spontaneously breathing children than in the children undergoing mechanical ventilation. In the supine position, FRC was not significantly different in the two groups. The mean value in all patients ($n = 25$) was 21 (7) ml kg$^{-1}$ and the correlation to body weight was:

$$FRC \text{ (ml)} = -86 + 28 \times \text{weight (kg)}, r = 0.92.$$  

In the supine position, PCD values in the two groups were not significantly different, while SBAME was less during spontaneous breathing than during mechanical ventilation ($P < 0.01$).

Spontaneously breathing children (table I)

The order in which supine and left lateral position measurements were obtained did not affect the result. Therefore, the values presented are mean values of measurements obtained in each position.

There was no significant change in breathing rate or tidal volume between the two positions. In the supine position, breathing rate was 35 (8) b.p.m. and $V_T$ was 4.5 (0.9) ml kg$^{-1}$. Correlation between $V_T$ and body weight was:

$$V_T \text{ (ml)} = 3.2 + 4.3 \times \text{weight (kg)}, r = 0.93$$

Ventilation in the supine position was 184 (53) ml kg$^{-1}$ min$^{-1}$ and the correlation to body weight was:

$$\text{ventilation (ml)} = 1028 + 77 \times \text{weight (kg)}, \quad r = 0.74$$

Satisfactory measurements of $C_L$ were obtained in 11 of the 13 children in whom this was attempted. In the remaining two, measurements were discarded because cardiac oscillations made the oesophageal pressure tracings difficult to interpret. $C_L$ supine was 1.1 (0.5) ml kg$^{-1}$ cm H$_2$O and $C_L$ in the lateral position was 1.3 (0.5) ml kg$^{-1}$ cm H$_2$O (ns). FRC supine was 22 (7) ml kg$^{-1}$; it increased by 13% when turned to the lateral position ($P < 0.01$). Both PCD and SBAME indicated significantly more uneven pulmonary gas mixing ($P < 0.05$) when the children were turned to the lateral position. The washout curves obtained in one patient are shown in figure 2.

Mechanical ventilation (table II)

In these children $V_T$ was 11 (2) ml kg$^{-1}$ and ventilation 234 (56) ml kg$^{-1}$ min$^{-1}$. $C_L$ was similar in supine and lateral positions (0.9 (0.2) ml cm H$_2$O kg$^{-1}$). The median coefficient of variation for duplicate FRC determinations was 1.4% (range 0.8–5.3%) in the supine position and 2.3% (range 0.9–3.8%) in the lateral position. FRC was 19 (6) ml kg$^{-1}$ in the supine position and 25 (19)% greater ($P < 0.01$) in the lateral position. The increase in FRC was similar in children placed on their left (Nos 16–20) and children placed on their right side (Nos 21–25) (mean increases 24 and 27%, respectively). Neither PCD nor SBAME changed significantly between the supine and lateral position. In the five children...
COMPLIANCE, FRC AND GAS MIXING

(Nos 21–25) in whom arterial blood was obtained, $P_{A_0_2}$ changed from 23.3 (9.3) kPa supine to 26.7 (9.3) kPa in the lateral position (ns). In the other children (Nos 16–20), $S_{A_0_2}$ was unchanged, at 97% or greater, after the child had been turned to the lateral position.

**DISCUSSION**

The first measurements were made when the child had inhaled 1% halothane for 15 min. Because of the alveolar uptake of halothane, the alveolar concentration during measurements probably varied between 0.6 and 0.7% [10]. However, this small change in alveolar halothane concentration was not expected to influence the results and there were no significant changes in $C_{L}$, FRC or mixing efficiency with time in the seven spontaneously breathing children in whom supine measurements were obtained both before and after the measurement in the lateral position. Furthermore, preliminary studies indicate that FRC changes little with increasing alveolar halothane concentrations in children with an intubated trachea. In two spontaneously breathing children FRC decreased by 2% and 4%, respectively, when the end-tidal halothane concentration was increased from 0.5 to 1.5%.

The effect of the lateral position has been well documented in anaesthetized adults [2,11–13]. The changes occurring in ventilation distribution may be explained by the changes in end-expiratory lung volume: anaesthesia reduces FRC and, because of the S-shaped pressure–volume curve, compliance is also commonly reduced compared with the awake state [12]. The lateral position causes expansion of the upper lung and thus improves compliance of that lung [11–14]. Hence, a greater fraction of the tidal volume is distributed towards the upper lung during both spontaneous breathing and mechanical ventilation. In mechanical ventilation in adults, the change in ventilation distribution between the two lungs is proportional to the change in lung volumes; pulmonary gas mixing, as measured by pulmonary clearance delay, therefore remains unchanged.

However, in spontaneously breathing adults Rehder and Sessler [12] found that lung clearance ratio, another index of pulmonary gas mixing, increased from 2.8 (0.3) supine to 3.2 (0.2) in the lateral position ($n = 9$), $P < 0.05$, suggesting a mismatch between ventilation and lung volume. The reason for this difference in pulmonary gas mixing between mechanical ventilation and spontaneous breathing may be that the lateral position results in cranial shift and, therefore, in a greater preload of the lower diaphragm. Thus the fraction of ventilation to the lower lung does not decrease as much during spontaneous breathing as during mechanical ventilation. Although double-lumen tubes were not used in the present study, the observed changes in FRC and pulmonary gas mixing efficiency are in accordance with these findings, indicating that the lateral position results in similar changes in lung volume and mechanics in anaesthetized children and adults. Davies and colleagues [3] used krypton-81m scanning to assess ventilation distribution in the lateral position in 18 children with known or suspected pulmonary disease and they found that ventilation was distributed preferentially towards the upper lung. The patients were not anaesthetized, but three children required ventilatory support and the diagnoses of the remaining children suggest that most breathed at abnormally low lung volumes. These findings may also be explained by the mechanisms outlined above in anaesthetized patients.

The mean compliance values observed in the present study in supine children agree with previous findings in anaesthetized children without pulmonary disease [15]. There are problems associated with inferring the pleural pressure from oesophageal pressure. First, oesophageal pressure may be determined not only by the pleural pressure, but also by mechanical properties of the oesophagus and the pressure in the space surrounding it [16]. Second, because there exists a pleural pressure gradient [17], the oesophageal pressure may at best represent only a regional pleural pressure, which is probably different in the supine and lateral positions. However, studies in adults and in infants indicate that oesophageal pressure reflects changes in pleural pressure equally well in the supine and lateral positions if the oesophageal catheter is placed accurately as judged by the occlusion test [5,18]. In our patients, $C_{L}$ in the lateral position was not significantly different from $C_{L}$ supine. This may be because a slight increase in compliance of the upper lung was opposed by a slight decrease in compliance of the lower lung. The unchanged compliance and the increased FRC in the lateral position are in contrast to the findings of Helms and colleagues [19] who studied anaesthetized spontaneously breathing children ($n = 9$)
and observed a significant increase in $C_L$, but no change in FRC when turning the child to the lateral position. These authors used a body plethysmograph, and the median age in their series was 7 months, while the median age in our study was 3 yr. Although FRC increased in 13 of 15 spontaneously breathing children in the present study, the mean increase in the five youngest (median age 7 months) was only 9% (ns). The lateral position may thus have a less marked effect in infants, perhaps because of the smaller difference between anterior–posterior and transverse diameters. Also, infants have a compliant chest wall which may cause greater reductions in FRC during anaesthesia [20] and a more marked compression of the lower lung in the lateral position.

Results from two studies in awake children [9, 21] suggest that ventilation may be distributed more unevenly in young children than in adults. This is not supported by the present study in which pulmonary gas mixing in the supine position was generally as good as, or better than, what is commonly observed in healthy adults.

ACKNOWLEDGEMENTS

This study was supported by grants from the Medical Faculty, University of Lund, and from Förenade Liv Mutual Group Life Insurance Company, Stockholm, Sweden.

REFERENCES