SHORT COMMUNICATION

SOME ASPECTS OF PULMONARY FUNCTION AFTER RAPID SALINE INFUSION IN HEALTHY SUBJECTS

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SUMMARY

1. Rapid intravenous (i.v.) infusions of saline were administered to five healthy male volunteers. Measurements were made of static and dynamic lung volumes, ‘closing volume’ and pulmonary compliance before and after infusion; all measurements were made in the seated upright position.

2. Following a 1 litre infusion small decreases occurred in static and dynamic lung volumes in all studies and were associated in each case with an increase in ‘closing volume’. ‘Closing volume’ returned to normal within 1 h of the infusion.

3. After 2 litre infusions more marked decreases in all lung volumes occurred and were associated with variable changes in ‘closing volume’. The pattern of change varied between individual subjects and this is thought to reflect differences in localization within the lungs of the effects of the saline load in different subjects.

4. After 2 litre infusions static compliance was decreased in all subjects during the first 10–15 min. Changes in dynamic compliance showed marked individual variation.

Key words: left ventricular failure, pulmonary oedema, closing volume, respiratory function.

Abnormalities of pulmonary gas exchange are common after acute myocardial infarction in patients in whom clinical signs of airways obstruction are minimal or absent (McNicol, Kirby, Bhoola, Everest, Price & Freedman, 1965). In those patients with clinical signs of left ventricular failure the degree of arterial hypoxaemia has been shown to correlate directly with pulmonary artery pressure (Tattersfield, McNicol & Sillett, 1972). Experimental studies in animals on the genesis of pulmonary oedema have shown that fluid first appears in the perivascular and peribronchiolar connective tissue sheaths and intra-alveolar oedema is a late development (Staub, 1970). Such interstitial fluid accumulation would increase the weight of the lungs and exaggerate the effects of gravity upon small airways in the dependent zones of the lungs. Measurements of ‘closing volume’ which are thought to reflect small airway behaviour.
might be abnormal after acute myocardial infarction and so provide a means of detecting early or minimal pulmonary oedema. In other conditions such as renal failure measurements of 'closing volume' might prove useful for the detection of early pulmonary oedema. To examine this possibility we have measured 'closing volume', static and dynamic compliance and static and dynamic lung volumes in normal subjects after rapid intravenous infusions of physiological saline.

SUBJECTS AND METHODS

Five healthy male subjects aged 27–37 years were studied seated erect. All were non-smokers and their static and dynamic lung volumes were within one standard deviation of predicted mean values given by Cotes (1968). Measurements of forced expiratory volume (FEV₁) and forced vital capacity (FVC) were made with a Vitalograph spirometer and total lung capacity (TLC) was measured with 133 Xenon as that lung volume at the junction of phase 3 and phase 4 of the expiratory trace, results being expressed as phase 4/vital capacity (VC)% (Collins, Clark, McHardy-Young, Cochrane & Crawley, 1973). Measurements of compliance were recorded with an oesophageal balloon (Milic-Emili, Mead, Turner & Glauser, 1964) under quasi-static conditions and at frequencies of 20, 30, 40 and 60 breaths/min. Pulse rate, blood pressure, jugular venous pressure and breath sounds were recorded at intervals throughout each study.

On five occasions in three subjects (1–3) 1 litre of saline (150 mmol/l) was infused via a forearm vein in 10–15 min and measurements were made of static and dynamic lung volumes and 'closing volume'. In four subjects (2–5) similar studies were made before and after the infusion of 2 litres of saline (150 mmol/l) in 20–30 min. Some 2 h after the end of the infusion frusemide (20 mg) was administered intravenously (i.v.), and the studies were repeated 90 min later. On a subsequent occasion in three of these subjects (3–5) measurements of compliance and lung volumes were made at the same intervals after a similar infusion of 2 litres of saline, again followed by intravenous frusemide.

RESULTS

Studies after infusion of 1 litre

In all five studies discernible changes in 'closing volume' occurred after the infusion with a 42% increase in the size of phase 4. This change was associated with small decreases in TLC, FEV₁ and FVC (Table 1A).

Studies after infusion of 2 litres

We had expected the pattern of changes in lung volumes after 2 litre infusions to resemble that which we had observed after 1 litre infusions, showing a similar but greater effect. Our expectations were not fulfilled.

Small decreases in TLC, FEV₁ and FVC occurred after infusion in all subjects and these lung volumes returned towards pre-infusion values by about 60 min after the end of the infusion (Table 1B). This recovery was completed by the administration of frusemide and the associated diuresis.

The effects of the saline infusions on the 'closing volume' trace showed marked individual variations between subjects. In two subjects (3 and 4) phase 4/VC% was increased after infusion and then returned towards pre-infusion values, this latter change being completed
Saline infusion in healthy subjects

by the administration of frusemide. The pattern of the time-course of these changes differed slightly between these subjects. In subjects 2 and 5 the 'closing volume' trace changed after the infusion, the previously horizontal 'alveolar plateau' phase 3 becoming curvilinear and upward sloping. The change occurred at about 45 min after infusion and was resolved within a further 15 min.

TABLE 1A. Aspects of lung function after infusion of 1 litre of saline in five subjects

<table>
<thead>
<tr>
<th>Time after infusion (min)</th>
<th>0</th>
<th>15</th>
<th>30</th>
<th>45</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC 1 BTPS</td>
<td>6.15</td>
<td>6.22</td>
<td>5.91</td>
<td>—</td>
<td>6.41</td>
</tr>
<tr>
<td>(±0.13)</td>
<td>(±0.03)</td>
<td>(±0.18)</td>
<td>—</td>
<td>(±0.10)</td>
<td></td>
</tr>
</tbody>
</table>
| FEV₁ 1 BTPS              | 3.87 | 3.78 | 3.85 | 3.83 | —
| (±0.02)                   | (±0.04) | (±0.21) | (±0.11) |
| FVC 1 BTPS               | 5.11 | 4.83 | 5.0 | 5.0 | —
| (±0.10)                   | (±0.32) | (±0.10) | (±0.25) |
| Phase 4/VC%              | 5.88 | 8.38 | 7.8 | 7.6 | 7.4 |
| (±1.45)                   | (±2.28) | (±2.25) | (±0.28) | (±1.10) |

All values are means ± SEM; BTPS is body temperature and pressure, saturated.

TABLE 1B. Aspects of lung function after infusion of 2 litres of saline in four subjects

<table>
<thead>
<tr>
<th>Time after infusion (min)</th>
<th>0</th>
<th>15–20</th>
<th>25–35</th>
<th>60</th>
<th>90 min after i.v. frusemide (20 mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLC 1 BTPS</td>
<td>6.50</td>
<td>5.75</td>
<td>6.27</td>
<td>6.32</td>
<td>6.45</td>
</tr>
<tr>
<td>(±0.53)</td>
<td>(±0.50)</td>
<td>(±0.51)</td>
<td>(±0.53)</td>
<td>(±0.16)</td>
<td></td>
</tr>
</tbody>
</table>
| FEV₁ 1 BTPS              | 4.03 | 3.80 | 3.58 | 3.94 | —
| (±0.62)                   | (±0.69) | (±0.04) | (±0.48) | (±0.57) |
| FVC 1 BTPS               | 5.08 | 4.65 | 4.83 | 4.80 | 5.03 |
| (±0.30)                   | (±0.43) | (±0.11) | (±0.22) | (±0.33) |
| Phase 4/VC%              | 8.4 | 13.7 | 12.67 | 8.5 | 6.1 |
| (Subjects 2–4)            | (±2.40) | (±6.30) | (±4.16) | (±0.53) | (±1.3) |
| Static compliance        | 0.283 | 0.250 | 0.268 | 0.280 | —
| l/cmH₂O                  | (±0.006) | (±0.063) | (±0.033) | (±0.020) |

All values are means ± SEM.

The static compliance fell during the first 10–15 min after the infusion of saline but the fall was not statistically significant. Dynamic compliance showed marked individual variation in respect to time and frequency after infusion of saline.
Pulse rate, blood pressure and jugular venous pressure did not change in any subject during these studies. No subjective effects were detectable after 1 litre infusions but all subjects experienced sensations of periorbital engorgement and nasal and oral congestion after 2 litre infusions and these symptoms were relieved after the diuresis promoted by frusemide.

DISCUSSION

Marked abnormalities of 'closing volume' occur in normal subjects after rapid intravenous infusions of physiological saline and these abnormalities may persist for as much as 60 min after the infusion. They are accompanied by slight but significant alterations of static and dynamic lung volumes, which are seen for only a short period after the infusion. The differences observed in the effects on 'closing volume' of 1 and 2 litre infusions require some explanation. It is possible that after 1 litre of intravenous saline sufficient increase in peribronchiolar fluid occurs to cause abnormalities of 'closing volume' without altering other aspects of pulmonary function. With the administration of the larger 2 litre infusion accumulation of fluid may affect other parts of the lungs and the degree and duration of such effects varies between individuals. That this may be so is suggested by the abnormalities of phase 3 which occurred in two subjects after a 2 litre infusion. This change could be explained by changes in the pattern of distribution of the inspired bolus of marker gas resulting in failure of the preferential labelling of the upper zones upon which the presence of phase 4 is dependent. Such abnormal distribution and subsequent abnormalities of gas mixing on expiration would occur if the function of larger airways was affected by the increase in pulmonary fluid.

There appeared to be a transient fall in static compliance but no systematic change in dynamic compliance was observed and the patterns of change in individual subjects did not show obvious relationships to the changes in 'closing volume'.

REFERENCES


