Bilateral diaphragm paralysis after cardiac surgery with topical hypothermia

J Efthimiou, J Butler, M K Benson, S Westaby

Abstract
Bilateral diaphragm paralysis is a rare but important complication of open heart surgery. Two cases were found among 360 prospectively studied patients undergoing open heart surgery during one year. Both patients had insulin dependent diabetes with peripheral neuropathy and this may have contributed to their diaphragm paralysis. The patients were studied postoperatively for one year with measurements of lung function, nocturnal oximetry, diaphragmatic function, and phrenic nerve conduction. Treatment with intermittent positive airway pressure ventilation by nasal mask was effective in both patients. After nine months one patient had recovered completely with normal phrenic nerve conduction and diaphragmatic function; the other continues most of his normal daytime activities, but still requires nasal positive airway pressure ventilation for six hours at night.

In the last two decades unilateral and rarely bilateral diaphragm paralysis have been increasingly recognised as complications of open heart surgery. The diaphragm paralysis has been attributed to cold injury of the phrenic nerve as a result of the topical iced or slush saline used for myocardial protection, though this is debated. Only a few cases of bilateral diaphragm paralysis following open heart surgery have been reported since the original description by Scannell in 1963. Why some patients develop bilateral as opposed to unilateral diaphragm paralysis has never been clearly explained, and no definitive treatment strategy has been agreed.

Intermittent positive airway pressure ventilation delivered by nasal mask is non-invasive and simple to use and has been shown to benefit patients with various neuromuscular disorders causing diaphragm weakness. We present two patients with bilateral diaphragm paralysis following open heart surgery, both with insulin dependent diabetes, who were successfully treated with nasal positive airway pressure ventilation.

Methods
For a prospective study of phrenic nerve conduction before and after elective cardiac surgery we studied 360 consecutive adult patients having open heart surgery. Two of these, both with insulin dependent diabetes, developed bilateral diaphragm paralysis.

Two additional patients, from a further 390 consecutive adult patients studied retrospectively for the year before the prospective study, were also found to have bilateral diaphragm paralysis. One of these latter patients had insulin dependent diabetes with a mild peripheral neuropathy; the other had a right sided diaphragm paralysis before operation as a result of brachial neuritis three years previously. The two patients in the prospective group were studied in detail and form the basis of this report.

Case reports
PATIENT 1
A 57 year old non-smoking man underwent quadruple aortocoronary bypass grafting for angina resistant to medical treatment. He had longstanding insulin dependent diabetes and a peripheral neuropathy (predominantly sensory and affecting only the lower limbs clinically), nephropathy, and retinopathy of two years’ duration. During surgery myocardial protection was achieved during 73 minutes of aortic cross clamping with cold cardioplegia (modified St Thomas’s hospital solution), core cooling to 28°C, and topical hypothermia with iced and slush saline. Weaning from assisted ventilation and extubation took four days. Subsequently, when he had left the intensive care unit, he complained of severe ortho-

Table 1 Postoperative pulmonary function values, mouth pressures, arterial oxygen and carbon dioxide tensions (Pao2, Paco2), and nocturnal arterial oxygen saturation (Sao2)

<table>
<thead>
<tr>
<th>Patient 1</th>
<th>Patient 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting</td>
<td>Supine</td>
</tr>
<tr>
<td>FEV1 (%)</td>
<td>1.10</td>
</tr>
<tr>
<td>FVC1 (%)</td>
<td>1.30</td>
</tr>
<tr>
<td>Pmax (cm H2O)</td>
<td>-45</td>
</tr>
<tr>
<td>Pmax (cm H2O)</td>
<td>75</td>
</tr>
<tr>
<td>Pdi max (cm H2O)</td>
<td>TLC</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Pao2 (kPa)</td>
<td>Sitting</td>
</tr>
<tr>
<td></td>
<td>8.19</td>
</tr>
<tr>
<td>Paco2 (kPa)</td>
<td>3.90</td>
</tr>
<tr>
<td>Lowest overnight Sao2 (%)</td>
<td>Before NPAP 81.0</td>
</tr>
<tr>
<td>Sao2 dips over 4% in 6 hours’ sleep (%)</td>
<td>32</td>
</tr>
</tbody>
</table>

FEV1—forced expiratory volume in one second; FVC—forced vital capacity; Pmax—maximum inspiratory mouth pressure; Pmax—maximum expiratory mouth pressure; Pmax—maximum transdiaphragmatic pressure; TLC—total lung capacity; Sniff—maximum inspiratory sniff; NPAP—nasal positive airway pressure ventilation.

References

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Table 2. Phrenic nerve conduction time and diaphragm compound muscle action potential (CMAP)*

<table>
<thead>
<tr>
<th>Right</th>
<th>Left</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>PATIENT 1</td>
<td>Before operation</td>
<td>8.1</td>
<td>8.2</td>
</tr>
<tr>
<td>1 week after</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>1 month after</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>9 months after</td>
<td>9.8</td>
<td>11.9</td>
<td>350</td>
</tr>
<tr>
<td>PATIENT 2</td>
<td>Before operation</td>
<td>8.3</td>
<td>8.5</td>
</tr>
<tr>
<td>1 week after</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>1 month after</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>9 months after</td>
<td>Absent</td>
<td>Absent</td>
<td>Absent</td>
</tr>
</tbody>
</table>

*Normal ranges: phrenic nerve conduction time 5.6-9.1 ms; diaphragm CMAP 350–1100 μV.

Discussion

Bilateral diaphragm paralysis after open heart surgery is an uncommon complication with few published reports. The incidence of this complication in our unit was two cases in 360 patients studied prospectively over one year.
Both these patients and one of the two patients identified in our retrospective study had insulin dependent diabetes. One of the two patients described by Kohorst et al also had insulin dependent diabetes, further supporting our hypothesis that diabetes predisposes to phrenic nerve cold injury and diaphragm paralysis. All three of our diabetic patients had clinical evidence of peripheral neuropathy, of moderate severity in two. Possibly the phrenic nerves were also affected by subclinical neuropathy, though phrenic nerve conduction time was normal preoperatively. These findings suggest that further work on the sensitivity of diabetic nerves to cold injury is indicated.

Pronounced orthopnoea and abdominal paradox, in association with a fall in vital capacity of about 50% when the patient lies supine, strongly suggests the diagnosis of bilateral diaphragm paralysis.16,17 and led to a positive diagnosis in all our patients. Diaphragmatic screening may be helpful in showing that diaphragm movement is reduced or absent, but paradoxical movement is frequently not present.16

The measurement of phrenic nerve conduction time is a useful technique for assessing phrenic nerve function, time and therefore may be the most sensitive method available for identifying different degrees of phrenic nerve cold injury. The initial absence of phrenic nerve conduction in our patients after surgery suggests that cold injury may result in axonal degeneration or severe demyelination of the phrenic nerves, or both. Evidence of such lesions has been seen at necropsy11 and in experimental models of cold injury in animals.16 Prolongation of phrenic nerve conduction time due to milder degrees of cold injury may occur in up to 40% of patients after open heart surgery (unpublished data), and milder degrees of demyelination may be the best explanation for this.

Considerable morbidity and mortality are associated with bilateral diaphragm paralysis. Respiratory impairment may be well tolerated by day but becomes a serious problem during sleep, especially during rapid eye movement sleep.18,20 Respiratory failure has generally been considered common in patients with bilateral diaphragm paralysis.19 Laroche et al21 however, have recently challenged this point of view and suggested that it is rare unless the other respiratory muscles are also affected. In our patients the other respiratory muscles are unlikely to have been affected and, although respiratory failure did occur, it was mild and seen only when the patient was supine, particularly at night. Death is not uncommon after bilateral diaphragm paralysis, and in three of the 10 previously reported cases the patient died within the first six months after operation, the other seven patients requiring assisted ventilation for four to twelve months before recovering.4,5,8

Negative pressure ventilation has been used to treat bilateral diaphragm paralysis in patients with neuromuscular disorders in the past, but it is often accompanied by complications and is cumbersome to use.22,23 Nasal positive airway pressure ventilation is a relatively new technique, which is simple to use, has few complications, and has been shown to be of benefit to patients with neuromuscular disorders and in hypventilation associated with kyphoscoliosis.8,10,24 After the initiation of nasal positive airway pressure ventilation in our patients the mean overnight SaO2 increased to normal levels and the dips in SaO2 were abolished. After nine months of this treatment one patient had fully recovered and, although the other patient continued to require assisted ventilation he was able to continue most of his normal daytime activities.

We conclude that diabetes mellitus, particularly with peripheral neuropathy, is a substantial risk factor for the development of bilateral diaphragm paralysis after open heart surgery when topical iced or slush saline is used for myocardial protection. We suggest that the latter should be avoided where possible or used in conjunction with a pericardial insulator in patients with diabetes and in those with previous phrenic nerve or diaphragm problems. Nasal positive airway pressure ventilation is a relatively simple and effective treatment. Measurement of phrenic nerve conduction time may be useful in monitoring the recovery of phrenic nerve function after cold injury following cardiac surgery.

9 Rodenstein DO, Stansero DC, Delgust P. Adaptation to intermittent positive pressure ventilation applied through the nose during day and night. Eur Respir J 1989;2:473-8.


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