Best evidence topic - Pulmonary

Is the preservation of the phrenic nerve important after pneumonectomy?

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Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was: is the preservation of the phrenic nerve important after pneumonectomy? Altogether more than 49 papers were found using the reported search, of which four represented the best evidence to answer the clinical question. The authors, journal, date and country of publication, patient group studied, study type, relevant outcomes and results of these papers are tabulated. We conclude that care should be taken to preserve the integrity of the phrenic nerve wherever possible. The abnormal diaphragmatic motion which occurs as a consequence of phrenic nerve damage significantly reduces expiratory lung volumes, gas exchange and exercise capacity in already compromised patients. Phrenic nerve injury can also lead to a prolonged need for mechanical ventilation; this alone carries a risk of complication, such as infection. Plication of the paralyzed hemi-diaphragm has proved effective in reducing respiratory insufficiency after pneumonectomy. The aim of this is to fix and flatten the diaphragm, thus mimicking the role of a functioning phrenic nerve. Furthermore, the function of a preserved phrenic nerve remains normal for up to 11 years post pneumonectomy. Therefore, deterioration in function may highlight a recurrence in disease or a change in the post pneumonectomy space.

Keywords: Pneumonectomy; Phrenic nerve

1. Introduction

A best evidence topic in cardiac surgery was written according to a structured protocol. This is fully described in ICVTS [1].

2. Three-part question

In [patients undergoing a pneumonectomy], is [preservation of the phrenic nerve] important for [postoperative pulmonary function]?

3. Clinical scenario

During a right sleeve pneumonectomy for a primary lung cancer, the surgeon notes that the tumour has extended into the mediastinum, and it may be necessary to resect a section of the phrenic nerve. The question arises as to the importance of phrenic nerve preservation. You thought that it was advantageous to have an elevated, paralyzed hemi-diaphragm post pneumonectomy but your colleague says that this has a significant negative effect on contralateral lung function postoperatively. You resolve to check the literature.

4. Search strategy

Medline 1950 to May 2007 using OVID interface [Phrenic nerve.mp OR exp Phrenic nerve/] AND [Pneumonectomy.mp OR exp Pneumonectomy/]..

5. Search outcome

Forty-nine papers were found using the reported search. From these, four papers were identified that provided the best evidence to answer the question. These are presented in Table 1.

6. Results

Ugalde et al. [2] performed a retrospective cohort study to investigate ipsilateral diaphragmatic motion and lung function in long-term pneumonectomy patients. They found that out of 88 patients, 44 had abnormal diaphragmatic motion, as assessed by magnetic resonance imaging (MRI) during deep breathing. Abnormal diaphragmatic motion, secondary to intraoperative damage to the phrenic nerve, was then correlated against a series of key outcomes to evaluate to what extent, if any, it impacted upon residual lung function.

The following clinical characteristics were identified as being associated with an increased likelihood of abnormal...
Table 1. Best evidence papers

<table>
<thead>
<tr>
<th>Author, date and country, Study type (level of evidence)</th>
<th>Patient group</th>
<th>Outcomes</th>
<th>Key results</th>
<th>Comments</th>
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<tr>
<td>Ugalde et al. (2008), Ann Thorac Surg, UK, [2] Retrospective cohort study (level 2b)</td>
<td>117 patients were identified who had undergone pneumonectomy for lung cancer between January 1992 and September 2001 and were alive in 2006</td>
<td>FEV, (% of predicted value)</td>
<td>FEV, was 18% decreased (68, S.D. 17–50, S.D. 10)</td>
<td>This retrospective trial showed that abnormal diaphragmatic motion due to phrenic nerve injury during pneumonectomy reduces postoperative pulmonary function.</td>
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<td>Of these 117, 88 patients were available for study from March to December 2006</td>
<td>FVC (% of predicted value)</td>
<td>FVC was 25% decreased (86, S.D. 18–59, S.D. 23)</td>
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<td>FEV/FVC</td>
<td>FEV/FVC ratio 5% increased</td>
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<td>DLCO % of predicted value</td>
<td>DLCO 7% decreased (61, S.D. 12–54, S.D. 11)</td>
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<td>TLC % of predicted value</td>
<td>16% decreased (72, S.D. 12–56, S.D. 10)</td>
<td>Abnormal diaphragmatic motion also reduces exercise tolerance to a lesser extent, however, it was concluded that the 6-min walk test was more representative of general cardiovascular fitness.</td>
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<td>De Troyer and Vanderhoeft (1982), Chest, USA, [3] Case-control study (level 3b)</td>
<td>Ten patients were identified who had undergone pneumonectomy an average of eight years before. The reason for pneumonectomy was either bronchial carcinoma (8) or lung abscess (2)</td>
<td>Phrenic nerve conduction time (ms)</td>
<td>Mean conduction time for control subjects was 7.0 ms (5.5–9.5 ms, S.D. 0.9)</td>
<td>This case-control trial showed that phrenic nerve function in patients who had not sustained phrenic nerve injury during pneumonectomy remains normal up to 11 years after pneumonectomy.</td>
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<td>Patients were compared to a control group of 31 people who had no evidence of neuromuscular or intra-thoracic disorders</td>
<td>Assessed by the Newsom–Davis method* Method records the time interval between phrenic nerve stimulation and the onset of diaphragmatic muscle action potential</td>
<td>Conduction time within the patient group was all within the control range i.e. the same range of results as the people who had not undergone pneumonectomy.</td>
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<td>Therefore, an increase in phrenic nerve conduction time (i.e. reduced function) past 10 ms, late after pneumonectomy, is more likely to indicate recurrent disease rather than damage due to pneumonectomy.</td>
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<td>Takeda et al. (1994), Ann Thorac Surg, UK, [4] Case report (level 4)</td>
<td>A 62-year-old male who underwent a right sleeve pneumonectomy for a squamous cell carcinoma which was invading the phrenic nerve</td>
<td>Tidal volume (ml)</td>
<td>Increased from 415 to 450</td>
<td>Phrenic nerve injury may lead to respiratory failure due to respiratory muscle fatigue (the rib cage and accessory muscle must overcome paradoxical diaphragmatic motion)</td>
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<td>Post pneumonectomy the patient required prolonged mechanical ventilation due to diaphragmatic paralysis and subsequently underwent plication of the right hemi-diaphragm</td>
<td>Frequency (breaths/min)</td>
<td>Decreased from 27 to 19</td>
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<td>Minute ventilation (l/min)</td>
<td>Decreased from 11.1 to 8.6</td>
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<td>Trans-diaphragmatic pressure swing (cm H₂O)</td>
<td>Increased from 8.2 to 11.1</td>
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<td>Gastric/oesophageal pressure ratio</td>
<td>Increased from –0.37 to 0.73</td>
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<td>Work of breathing per litre of ventilation (J)</td>
<td>Decreased from 0.87 to 0.56</td>
<td>Plication of a paralysed hemi-diaphragm reduces the work of breathing and increases respiratory mechanics in post pneumonectomy patients.</td>
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<td>Bergland et al. (1984), Scand J Thorac Cardiovasc Surg, [5]</td>
<td>Canine model initially used involving four dogs who underwent a right pneumonectomy and phrenic nerve sacrifice.</td>
<td>Tidal volume (%)</td>
<td>50% decrease without plication 0% decrease with plication</td>
<td>Paradoxical ventilation is a recognised complication after pneumonectomy, and is due to phrenic nerve damage.</td>
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<td>Respiratory rate (%)</td>
<td>42% decrease without plication 5% decrease with plication</td>
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diaphragmatic motion: younger patients who had a right pneumonectomy, a higher cancer stage and had undergone an extensive pneumonectomy. After an average follow-up time of 9.3 years, patients with abnormal diaphragmatic motion had a decreased forced expiratory volume in 1 s (FEV₁) (18%), forced vital capacity (FVC) (25%), diffusing capacity of the lung for carbon monoxide (DLCO) (7%) and total lung capacity (TLC) (16%) when compared to predicted values from patients with normal diaphragmatic motion post pneumonectomy. In addition, the FEV₁/FVC ratio was increased by 5% indicating a restrictive pattern of respiration.

Abnormal diaphragmatic motion was further differentiated into a paralyzed diaphragm (n=22) and paradoxical movement (n=22). However, the results showed no significant difference in postoperative FEV₁ between the two groups. Exercise capacity was also shown to be reduced (386 min, S.D. 80 compared to 407 min, S.D. 97).

De Troyer and Vanderhoeft [3] studied the effect pneumonectomy had on long-term phrenic nerve function. Nerve conduction times, i.e. the interval between nerve stimulation in the neck and the onset of diaphragmatic muscle action potential, were obtained in accordance with the Newsom–Davis method. Comparisons of these nerve conduction times were then made between the long-term pneumonectomy patients (n=10) and a control group (n=31). None of the pneumonectomy patients had any phrenic nerve damage from their operations, or any evidence of recurrent disease at the time of the study. The control group was assessed for neuromuscular and intrathoracic disorders which may have affected nerve conduction times. Neither was present.

The results showed that phrenic nerve conduction times (on the operated side) in the patient group fell within the control range of 5.5–9.5 ms for every patient but one. Within the control group the average conduction time was 7.0 ms (S.D. 0.9 ms). This suggests that phrenic nerve function remains normal up to 11 years post pneumonectomy.

In 19 control subjects phrenic nerve conduction time was measured bilaterally, however, no significant difference was found between the left and right phrenic nerve. The mean conduction time for the right was 6.9, S.D. 0.9 ms and for the left was 7.1, S.D. 0.8 ms. Incidentally the paper found huge inter-person variability with regard to the amplitude of the diaphragmatic action potential, yet this did not positively correlate with conduction times. Takeda et al. [4] reported on the effects of plication of a paralyzed hemi-diaphragm after a right sleeve pneumonectomy.

Prior to plication the patient described required prolonged ventilation due to respiratory insufficiency, which had arisen after phrenic nerve paralysis. The result of this paralysis was a paradoxical breathing pattern, marked dyspnoea and hypercapnoea. Plication resulted in a fixed and flattened hemi-diaphragm and markedly improved respiratory mechanics. The frequency of breathing (27–19 breaths/min), minute ventilation (11.1–8.6 l/min) and work of breathing (0.87–0.56 J) all decreased - alongside a significant increase in tidal volume (415–450 ml), trans-diaphragmatic pressure swing (8.2–11.1 cm H₂O) and gastro-oesophageal pressure ratio (–0.37 to 0.73).

Bergsland et al. [5] had a similar result. They illustrated that diaphragmatic plication after a radical intrapericardial pneumonectomy helps to prevent respiratory insufficiency, a known complication after phrenic nerve sacrifice.

Using a canine model, a right radical pneumonectomy was performed on four dogs, followed by diaphragmatic plication in two of them. In the dogs who did not receive plication a pattern of severe paradoxical breathing developed.

This modified technique for radical pneumonectomy, i.e. diaphragmatic plication after all phrenic nerve sacrifices, was used by Bergsland et al. successfully in over 20 patients. No respiratory insufficiency was observed.

7. Clinical bottom line

Care should be taken to preserve the integrity of the phrenic nerve wherever possible. The abnormal diaphragmatic motion which occurs as a consequence of phrenic nerve damage significantly reduces expiratory lung volumes, gas exchange and exercise capacity in already compromised patients. Phrenic nerve injury can also lead to a prolonged need for mechanical ventilation; this alone carries a risk of complication, such as infection.

Plication of the paralyzed hemi-diaphragm has proved effective in reducing respiratory insufficiency after pneumonectomy. The aim is to fix and flatten the diaphragm, thus mimicking the role of a functioning phrenic nerve.

Furthermore, the function of a preserved phrenic nerve remains normal for up to 11 years post pneumonectomy. Therefore, deterioration in function may highlight a recur-
rence in disease or a change in the post pneumonectomy space.

References


