Pulmonary stabilisation followed by delayed surgery results in favourable outcome in congenital cystic lung lesions with pulmonary hypertension

Dakshesh Parikh, Madan Samuel

Department of Paediatric Surgery, Birmingham Children's Hospital NHS Trust, Steelhouse Lane, Birmingham B4 6NH, UK

Department of Paediatric Surgery, Box 267, Addenbrookes NHS Trust, Cambridge CB22QQ, UK

Received 23 February 2005; received in revised form 6 May 2005; accepted 29 June 2005; Available online 25 August 2005

Abstract

Objective: Congenital cystic lung lesions associated with fetal hydrops and polyhydramnios are rare, and reported to have greater than 50% mortality, can this be reversed? To propose a period of pulmonary stabilisation and delayed surgery for neonates with congenital cystic lung lesions and pulmonary hypertension. Results: Four neonates with antenatal diagnosed congenital cystic lung lesions with associated fetal hydrops and maternal polyhydramnios, presented with pulmonary hypertension due to lung hypoplasia. Contrast spiral computerised tomography scan was diagnostic. Three had congenital cystic adenomatoid malformation and one extra-lobar pulmonary sequestration with anomalous blood supply from the abdominal aorta. All four were pre-operatively ventilated for 9.8±0.9 days on conventional mechanical ventilators. Definitive surgery was performed at 10.8±0.8 days following stabilisation of lung function (preductal PO2 of greater than 60 torr with a SaO2 of 90–100%) and resolution of pulmonary hypertension with absence of persistent fetal circulation on echocardiography. Optimal timing of delayed surgery was in the range of 216–360 h. All four are thriving with absent respiratory complications. Conclusion: Delayed surgery following pulmonary stabilisation results in favourable outcome.

Q 2005 Elsevier B.V. All rights reserved.

Keywords: Congenital cystic adenomatoid malformation; Pulmonary intralobar sequestration; Pulmonary hypoplasia; Pulmonary hypertension; Congenital diaphragmatic hernia

1. Introduction

Congenital cystic lung lesions especially congenital cystic adenomatoid malformation (CCAM) and/or pulmonary sequestration often present as benign pulmonary mass in infants and children. Large congenital cystic lung lesions can produce,

1. Pulmonary hypoplasia from compression of the contra or ipsilateral pulmonary tissue
2. Polyhydramnios from compression of the oesophagus
3. Nonimmune hydrops, placentomegaly and death in utero from displacement of the heart and compression or distortion of the vena cava.

Hence death in utero or at birth, in such fetuses and neonates is often from 'Hydrops' and 'Pulmonary Hypoplasia' [1,2]. Hydrops occurs in 45% of fetuses with CCAM and is reported to be associated with combined fetal and postnatal mortality rates of 68–89% [1,3]. Mortality rate is less than 10% when fetal hydrops is not present. Polyhydramnios and hydrops develop together, but either may occur independently. Polyhydramnios alone is reported to be associated with 50% mortality [3]. In centres with the provision for 'Fetal Surgery' emergency resection of the cystic lobe in utero (fetal pulmonary lobectomy) has proved to be successful with normal postnatal growth and development [4,5]. However, fetal intervention may not be necessary in all cases of cystic lung lesions as there is the possibility of regression and gross reduction in size to the point that they may not be detected at birth [6,7]. Postnatal symptoms and mortality of fetuses with congenital cystic lung lesions, hydrops and polyhydramnios during the neonatal period are due to compression of the normal lung parenchyma on the opposite side with concurrent ipsilateral and/or contralateral lung hypoplasia and pulmonary hypertension. The purpose of this paper is to present our success of adopting pulmonary stabilisation prior to delayed surgery in postnatal management of neonates with cystic lung lesions and pulmonary hypertension.

2. Material and methods

Between March 1996 and January 2003, 4 consecutive neonates with antenatal diagnosis of polyhydramnios, fetal hydrops and cystic lung lesions were treated successfully at the Birmingham Children's Hospital NHS Trust. Antenatal...
3. Results

3.1. Antenatal scans

Serial antenatal ultrasound scans of 4 consecutive fetuses showed the presence of polyhydramnios and hydrops, with associated heterogeneous cystic mass in the right (2) and left (2) side of the chest with hyperechoic rim of lung on the affected side. A presumptive diagnosis of CCAM with hydrops was made and the neonates were born by emergency caesarean section for fetal distress (Fig. 1).

3.2. Postnatal management and outcome

All four neonates, three males and one female, had poor APGARS at birth and were intubated and ventilated on conventional mechanical ventilators (Table 1; Fig. 2). Initial blood gases are summarised in Table 2. Initial echocardiography (ECHO) showed a right-to-left shunting in the foramen ovale and patent ductus, in all four neonates. As the ECHO confirmed the diagnosis of persistent pulmonary hypertension, due to lung hypoplasia, all four patients were managed on mechanical ventilation without deterioration or progression to impairment of oxygenation or increase in the oxygen index (Table 3). Table 3 summarises the period of pre- and post-operative ventilation that was required to stabilise the mild to moderate pulmonary hypertension due to lung hypoplasia.

Chest X-rays in all four neonates showed large cystic cavities occupying the entire affected hemithorax with absence of delineable normal lung tissue on the ipsilateral side. There was shift of the mediastinum to the contralateral side with varying degrees of lung herniation without pneumothoraces (Fig. 2). A contrast spiral computerised tomography scan (CT) was performed in all four neonates. Contrast spiral CT scan showed large multilocular cystic masses with thin walls on the effected ipsilateral side in 3-neonates (Fig. 3) and in the other a large complex mass consisting of solid to cystic tissue with variable definition of margins was delineated. The presumed radiological diagnosis in all 4 neonates was CCAM. Upper gastrointestinal contrast study showed the absence of intestinal anomalies. Serial ECHOs were performed until there was resolution of pulmonary hypertension in all 4 neonates, which occurred at 9.8 ± 0.9 days. Optimal timing of delayed surgery was in the range of 216-360 h at which time ventilatory support had achieved a preductal PO2 of greater than 60 torr with a SaO2 of 90-100% and absence of persistent fetal circulation on echocardiography. Thoracotomy was performed at 10.8 ± 0.8 days. Right middle lobectomy with right upper lobe segmentectomy was performed in the first neonate, and right (1) and left (1) lower lobectomy was carried out in the other two children (Table 3). The fourth child at thoracotomy had extralobar pulmonary sequestration and not CCAM with an anomalous blood supply from the abdominal aorta. The blood vessel was ligated and the extralobar pulmonary sequestration excised (Table 3). Post-operative course and ventilatory requirements are summarised in Table 3. Histology confirmed the diagnosis of macrocystic CCAM (Stocker type 1)[8,9] in three children, which showed multiple large cysts lined by ciliated columnar and focal cuboidal epithelium, with the cyst walls containing smooth muscle, and elastic tissue. Cyst walls also contained cartilage and mucogenic glandular cells with alveolar like structures between the cysts. Pulmonary artery hyperplasia was also noted. The last child had extralobar pulmonary sequestration. Follow-up has been 39.3 ± 29.1 months (Table 3). The first child is thriving with her weight and height on the 10th centile. This child has left lung hypoplasia.

---

**Table 1**

<table>
<thead>
<tr>
<th>CCAM, Fetal hydrops and polyhydramnios (antenatal scans in weeks)</th>
<th>Gestational age at birth in weeks</th>
<th>Birth weight in grams</th>
<th>APGAR score (1 and 5 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 and 30</td>
<td>30</td>
<td>1840</td>
<td>4 and 7</td>
</tr>
<tr>
<td>28 and 33</td>
<td>35</td>
<td>2300</td>
<td>5 and 8</td>
</tr>
<tr>
<td>28 and 33</td>
<td>38</td>
<td>3380</td>
<td>5 and 7</td>
</tr>
<tr>
<td>22 and 33</td>
<td>38</td>
<td>3650</td>
<td>5 and 7</td>
</tr>
</tbody>
</table>

---

**Fig. 1.** Fetal MRI showing a cystic lung lesion.

**Fig. 2.** Post natal chest X-ray showing a left lower lobe cystic mass.
and the right upper segment and lower lobe are normal. The other three are also thriving and developing normally with weight between the 50th and 75th centile and height between the 10th and 25th centile. These three children have ipsilateral lung hypoplasia and normal contralateral lungs; however, they have good exercise tolerance and no respiratory problems to date (Fig. 4).

4. Discussion

4.1. Delayed surgery

Pulmonary insufficiency from hypoplastic lungs, persistent pulmonary hypertension and poor pulmonary compliance with degrees of pulmonary vascular resistance are observed in neonates with congenital diaphragmatic hernia (CDH). Immediate surgical intervention worsens or prolongs pulmonary hypertension, worsens pulmonary compliance, and stimulates release of circulating pulmonary vascular constrictors that further aggravate pulmonary vascular resistance \[10,11\]. In an attempt to improve the overall condition of the infant with CDH a period of medical stabilisation and delayed surgical repair was proposed to improve and allow the evolution of blood gas perfusion capabilities of the CDH lung. Improved respiratory compliance and pulmonary gas exchange with reduced mortality rates (mortality rates have been shown to be reduced from 80 to 39% and 18 to 6%) has been reported when a strategy of pre-operative stabilisation and delayed surgical repair was proposed to improve and allow the evolution of blood gas perfusion capabilities of the CDH lung. Improved respiratory compliance and pulmonary gas exchange with delayed surgical repair for children who were born with CDH and pulmonary hypoplasia and hypertension benefit from pre-operative stabilisation on ECMO \[12\]. Our report clearly defines the optimal timing of surgery (range: 216–360 h). It also shows that delayed surgery allows the normalisation of the pulmonary vascular bed and probable development of decreased sensitivity to the stimuli inducing vasoconstriction, thereby, resulting in a smooth post-operative recovery. Hence immediate postoperative ventilation is essential with gradual weaning as the lung function stabilises, subsequently followed by a period of continuous positive airway pressure to compensate for the honeymoon period were transient pulmonary hypertension may occur, as seen in babies with CDH. Delayed surgery would possibly lower the reported postnatal mortality of 26% in CCAM with pulmonary hypertension \[1-3\].

Table 2

<table>
<thead>
<tr>
<th>PH</th>
<th>PO₂</th>
<th>PCO₂</th>
<th>FiO₂</th>
<th>Peak</th>
<th>Mean airway pressure</th>
<th>Oxygen index</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.16</td>
<td>29</td>
<td>38</td>
<td>40</td>
<td>32</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>7.06</td>
<td>28</td>
<td>35</td>
<td>40</td>
<td>28</td>
<td>18</td>
<td>26</td>
</tr>
<tr>
<td>7.34</td>
<td>29</td>
<td>32</td>
<td>40</td>
<td>30</td>
<td>17</td>
<td>24</td>
</tr>
<tr>
<td>6.99</td>
<td>28</td>
<td>108</td>
<td>100</td>
<td>40</td>
<td>10</td>
<td>36</td>
</tr>
</tbody>
</table>

Oxygen index is defined as the product of the mean airway pressure times the inspired oxygen concentration divided by the arterial PO₂. The oxygen index relates mean airway pressure and inspired oxygen content (FiO₂) with arterial oxygenation (PAO₂) as an indicator of oxygen delivery across the alveolar membrane \(OI = MAP \times F_iO_2 \div PAO_2 \times 100\).

Similarly, it has been shown that babies born with CCAM and pulmonary hypoplasia and hypertension benefit from pre-operative stabilisation on ECMO \[12\]. Our report clearly defines the optimal timing of surgery (range: 216–360 h). It also shows that delayed surgery allows the normalisation of the pulmonary vascular bed and probable development of decreased sensitivity to the stimuli inducing vasoconstriction, thereby, resulting in a smooth post-operative recovery. Hence immediate postoperative ventilation is essential with gradual weaning as the lung function stabilises, subsequently followed by a period of continuous positive airway pressure to compensate for the honeymoon period were transient pulmonary hypertension may occur, as seen in babies with CDH. Delayed surgery would possibly lower the reported postnatal mortality of 26% in CCAM with pulmonary hypertension \[1-3\].

Table 3

<table>
<thead>
<tr>
<th>Pre-operative ventilation (days)</th>
<th>Time of definitive surgery (age in days and weight in grams)</th>
<th>Post-operative ventilation (days)</th>
<th>CPAP (days)</th>
<th>Weaned of support (days)</th>
<th>Follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>10 (2000 g)</td>
<td>7</td>
<td>6</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>9 (2340 g)</td>
<td>5</td>
<td>3</td>
<td>17</td>
<td>36</td>
</tr>
<tr>
<td>8</td>
<td>9 (3400 g)</td>
<td>4</td>
<td>2</td>
<td>15</td>
<td>37</td>
</tr>
<tr>
<td>14</td>
<td>15 (3700 g)</td>
<td>6</td>
<td>4</td>
<td>25</td>
<td>83</td>
</tr>
</tbody>
</table>

CPAP, continuous positive airway pressure.
4.2. Physiological parameters

Neonates with respiratory distress are stratified to mild, moderate and severe pulmonary hypertension by oxygenation index. An oxygen index of $<40$ is considered mild to moderate pulmonary hypertension not requiring extracorporeal membrane oxygenation (ECMO), whereas oxygen index of $>40$ indicates severe pulmonary hypertension requiring ECMO with an expected mortality of 80% [10-12]. Severe persistent pulmonary hypertension with CCAM may require stabilisation on ECMO prior to definitive surgery. In mild to moderate pulmonary hypertension associated with CCAM, high-frequency oscillation may be required to avoid over expansion of the CCAM, although mechanical ventilation was successful in our cohort. Cystic lung lesions associated with pulmonary hypoplasia and hypertension should undergo pre and post-operative ventilation and stabilisation of lung function.

5. Conclusion

Strategy of ‘delayed surgery’ with a period of pulmonary stabilisation for CCAM and congenital cystic lung lesions associated with pulmonary hypertension results in favourable outcome, with absent morbidity and mortality.

References