

Apnoea induced by airflow obstruction

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SUMMARY Total obstruction of the airways caused all respiratory efforts to stop on 15 occasions in 10 preterm babies. This was not seen in 60 studies on 38 term babies. These findings suggest that failure to achieve an oral airway may not be the only mechanism by which upper airway obstruction might cause the cot death syndrome.

Although the role of upper airways obstruction in cot death is still only conjectural, evidence has emerged in support of this theory. Swift and Emery (1973) found that if the nares were obstructed in healthy term babies, 87% adopted mouth breathing with no or only transitory difficulty. A further 10% managed to mouth breathe after some initial delay, and the remaining 3% failed to achieve a satisfactory airway after 25 seconds but continued to make quiet respiratory efforts against the obstruction. More recently Steinschneider (1975) reported an increase in the incidence of sleep apnoea and irregular breathing at times when there was an associated upper respiratory tract infection. Other workers (Downham *et al.*, 1975) have found an abnormally high incidence of viral upper respiratory tract infections in babies dying suddenly at home and diagnosed as cot deaths. As a result of these findings it has been proposed that some babies who are obligate nasal breathers fail to establish an adequate oral airway when they have nasal obstruction secondary to an upper respiratory tract infection.

Further evidence on the role of upper airway obstruction in the cot death syndrome was reported by Cross and Lewis (1971). They studied a baby who failed to maintain an adequate tidal volume when the face cuff of the trunk plethysmograph partially obstructed the baby's upper airway. The baby made no attempt to struggle free from the obstruction. Their suggestion was that in some babies there is a progressive and potentially fatal reduction in alveolar ventilation in response to increasing upper airway obstruction.

As part of an investigation into the factors responsible for the formation and maintenance of the functional residual capacity after birth, we have investigated lung function in preterm and term

babies using a total body plethysmograph. Part of the investigation included measurement of the thoracic gas volume (the volume of air in the lungs at the end of a quiet tidal breath). This entails obstructing the baby's airway for several breaths by sliding a shutter system which closes the ports on all tubes leading to an airtight face mask. On occasions this has caused all respiratory efforts to stop. We here describe the types of response observed when the airways are obstructed during the measurement of thoracic gas volume.

Method

The babies were all studied in a specially constructed cylindrical total body plethysmograph with a servo-controlled, external radiant heater, essentially a sophisticated airtight incubator. The babies were all nursed in the right lateral position. No sedation was given at any time. An oesophageal balloon was passed through the mouth so that it lay in the lower third of the oesophagus. This system allowed us to measure tidal flow and by electronic integration, tidal volume, respiratory rate, mouth pressure, oesophageal pressure, and pressure changes within the plethysmograph. As part of the study thoracic gas volume was measured by relating mouth pressure to plethysmograph pressure change while a shutter system, across which all air flowed to and from an airtight face mask, was closed. Further details on the apparatus and technique are given elsewhere (Saunders *et al.*, 1976).

Analysis of the record. The signals were initially recorded on magnetic tape using an SE Ltd. FM tape recorder. The shutter valve was closed on at least three occasions so that the airway was obstructed for periods of 5-15 seconds. The response to airflow obstruction was assessed by analysis of the

oesophageal, mouth, and plethysmograph pressures during the measurement of the thoracic gas volume.

Patients

All babies were thriving at the time of the study. All but one of the babies, who had tachypnoea secondary to a large persistent ductus arteriosus, were free from any clinically obvious cardiorespiratory disease. However, 9 did have periodic breathing and of these, 7 had recurrent apnoeic attacks associated with prematurity. The babies' gestational ages ranged from 26 to 42 weeks and their birthweights from 0.78 to 4.6 kg. The initial studies were carried out between the ages of 2 hours and 49 days, but repeat lung function tests were performed up to the age of 11 months. In this paper the results of 99 studies on 48 babies are considered. Informed parental consent was obtained on all occasions. The project was considered and passed by the Nottingham City Hospital Ethical Committee.

Results

38 babies responded on 66 occasions to closure of the shutter and complete obstruction of their airways by continuing to make respiratory efforts. The pattern most frequently seen is shown in Fig. 1. There was an immediate reduction in respiratory rate and the oesophageal pressure swings progressively increased. Occasionally the shutter closure resulted in a more dramatic and immediate increase

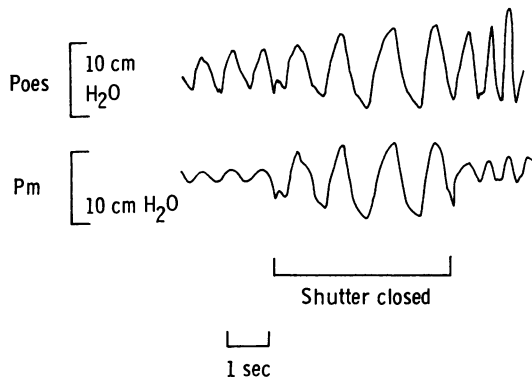


Fig. 1 Oesophageal (Poes) and mouth pressure trace (Pm) before, during, and after shutter closure in a healthy term baby. Inspiratory effort is represented by downward deflection on both pressure traces. The mouth pressure swing before and after the airway obstruction represents the resistance of the face mask system. The respiratory rate falls and the respiratory efforts increase during the period of shutter closure.

in the pressure swings which returned to the previous pattern as soon as the shutter was released (Fig. 2). 4 of these babies were born preterm at 29, 33, 32, and 34 weeks respectively; the remainder at term (Table 1).

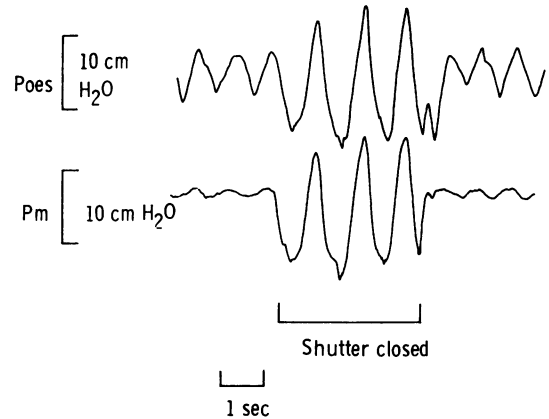


Fig. 2 Oesophageal (Poes) and mouth (Pm) pressure before, during, and after shutter closure in a term baby. The respiratory efforts increase dramatically and immediately in response to airway obstruction.

Table 1 Details of the babies who always continued to make respiratory efforts when their airways were obstructed

	Mean	Range
Gestation (w)	40.1	29-42
Birthweight (kg)	3.36	0.96-4.33
Age when studied (d)	24.0	0.2-300

On a further 15 occasions in 10 babies brief apnoea was induced by shutter closure. On 8 of these occasions the phenomenon occurred each time the shutter was closed, but was seen only intermittently during the remaining 7 tests. 7 of these babies were studied more than once. During a total of 29 lung function assessments these 7 contributed 12 of the total number of apnoeic responses. The pattern of apnoea varied. At 5 of these measurements the baby became apnoeic immediately without any initial respiratory effort. In 23 tests the babies took one or two breaths against the closed shutter before becoming apnoeic (Fig. 3). On only two occasions did the apnoea persist for more than one second after the shutter was released and then for only 5 and 10 seconds respectively.

All babies exhibiting apnoeic responses were born with a gestation of less than 31 weeks and a birthweight of under 1.45 kg (Table 2). The apnoea

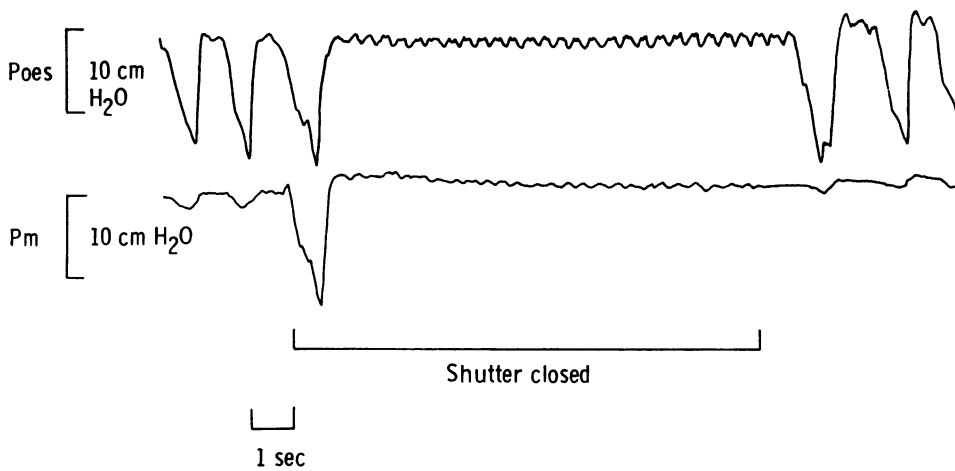


Fig. 3 Oesophageal (Poes) and mouth (Pm) pressure traces before, during, and after shutter closure in a preterm baby. The baby takes a single respiratory effort in response to complete airway obstruction and then becomes totally apnoeic until 1 second after the shutter is released. The small fluctuations in the pressure traces during the period of apnoea are produced by cardiac contractions.

Table 2 Details of the babies who stopped making respiratory efforts when their airways were obstructed

	Mean	Range
Gestation (w)	28.9	26-31
Birthweight (kg)	1.094	0.740-1.420
Age when apnoeic response to shutter closure was seen (d)	33.8	1-117

response to shutter closure was seen as late as 16 weeks in one baby but had disappeared by the age of 10 weeks in the remaining 9. 2 babies in this group showed a normal respiratory response when first studied at 1 and 7 days respectively. 9 of the 10 babies had periodic breathing when studied and of these, 8 at some time had recurrent attacks of apnoea requiring stimulation. At the time of the lung function tests apnoea was a clinical problem in only 3 babies.

Discussion

The response to shutter closure in the 34 term and in 4 of the preterm babies was similar to that reported by Olinsky *et al.* (1974) who found an increase in inspiratory time after airway occlusion. They observed that this increase was most marked in preterm babies. We observed a progressive increase in respiratory efforts in addition to the fall in respiratory rate.

Babies born preterm and who have periodic respirations tend to respond to airway obstruction

by stopping respiratory efforts, the reverse of the normal pattern. The period of airway obstruction was brief, less than 15 seconds, and it would not be ethical to maintain the obstruction for longer, but the findings suggest a mechanism which could explain the high rate of cot death in preterm babies (Carpenter and Emery, 1974).

Steinschneider (1975) has shown that babies are more likely to have periodic respiration when they have relatively mild upper respiratory tract infections. It is also well established that approximately one-third of children dying from cot death have evidence of upper respiratory tract infections (Richards and McIntosh, 1972). It is possible that the combination of periodic respiration and upper airway obstruction in this situation is sufficient to produce fatal apnoea in babies born at term in addition to those born prematurely.

We are grateful to the Action Research for the Crippled Child's fund who have provided financial support for this project.

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