Site of upper airway obstruction in preterm infants with problematical apnoea

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Abstract

Airway obstruction is an important factor predisposing to the development of apnoea in preterm infants. An ultrafine fibreoptic scope was used to examine the upper airway of 12 preterm infants with recurrent problematical apnoea. Continuous visualisation of the airway was possible and recorded on to videotape together with simultaneous cardiorespiratory monitoring to detect apnoeic episodes in 12 infants studied. In seven infants obstruction was observed at laryngeal level with the arytenoid masses and aryepiglottic folds closing across the vocal cords. This was not only observed in obstructive apnoea but also during mixed apnoea in periods where no respiratory effort was detectable and again in apparently pure central apnoea. The findings confirm the larynx as an anatomical site of upper airway obstruction. They agree with other indirect methods of assessing airway patency that obstruction has an important role in the pathophysiology of apnoea of prematurity.

It is becoming recognised that obstruction of the upper airway is a common feature in all types of apnoea of prematurity and not limited to the relatively rare obstructive apnoea attacks. Altogether 69.5% of preterm infants with apnoea have periods of airway obstruction when episodes of obstructive and mixed apnoae are taken into account. However this is clearly an underestimate if obstruction is only defined in terms of continued respiratory effort in the absence of airflow at the nose or mouth. Yet it is clear that an external obstruction will often cause preterm infants to become apnoeic even when there are no respiratory efforts against the obstruction. Thus obstruction of the airway can result in a 'central' apnoea as defined by standard cardiorespiratory monitors, with absent airflow and absent respiratory efforts. Clearly an indicator of airway patency would be more useful in defining the role of airway obstruction in apnoea. One approach is to measure tidal flow using a face mask system incorporating a pneumotachograph and sensitive pressure transducer. A cardiac artefact is then transmitted on to the flow trace while the airway is patent but this is lost when the airway obstructs. Using this indirect measure of airway patency obstruction has been detected in about half of apparently central apnoae. An alternative approach to visualise directly the upper airway during apnoeic episodes and so determine its patency.

There are two likely anatomical sites for obstruction of the upper airway in apnoea, the larynx and the pharynx. Evidence exists to support obstruction at either of these sites in preterm infants with apnoea. The aim of this study was to define the site of upper airway obstruction in a group of preterm infants with severe problematical apnoea.

Patients and methods

Twelve preterm infants with severe, problematical apnoea have been studied with a median gestation of 27 weeks (range 24–31) and median birth weight 925 g (range 650–1630). The mean age at study was 30 days and a median postconceptual age of 30 weeks (range 27–36). Two infants were studied on more than one occasion. All but one had required initial ventilation for respiratory distress syndrome, mean duration 6·4 days (range 0–33). At the time of the study recurrent apnoea was a major clinical management problem and although none were oxygen dependant when studied, supplementary oxygen was often required for apnoeic episodes. Episodes of obstruction were often suspected clinically as the apnoeic episodes were sometimes associated with hypoxia and bradycardia often requiring intervention by the nursing staff.

All infants had required treatment before the study for apnoea (table 1) and all were on methylxanthine therapy. Half of the infants required further intubation and ventilation for recurrent severe apnoea after their initial period of ventilation for lung disease. Two were found to be improved when nursed with a soft support under the neck to prevent excessive neck flexion and in three infants constant stimulation was provided by ventilating an air filled mattress.

An ultrafine fibreoptic scope (PF22-Olympus) was used to visualise the upper airway of the infants studied. The scope was originally designed as an angiofibroscope for vascular surgery with an outer diameter of only 2·2 mm. A similar instrument has been used previously with success as a bronchoscope in neonates. The scope has remote control two way angulation through 120° at the tip and can be directed by the operator at the hand piece.

Table 1  Treatment for apnoea

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No (%) of infants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aminophylline/theophylline</td>
<td>12 (100)</td>
</tr>
<tr>
<td>Intubation and ventilation</td>
<td>6 (50)</td>
</tr>
<tr>
<td>Nasal continuous positive airway pressure</td>
<td>7 (58)</td>
</tr>
<tr>
<td>Ventilated mattress</td>
<td>3 (25)</td>
</tr>
<tr>
<td>Neck extension</td>
<td>2 (17)</td>
</tr>
</tbody>
</table>

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Images are relayed to a colour monitor by a small endoscopic camera (OTV-S2 Olympus) connected to the scope and a continuous recording made on to VHS videotape. The fine endoscope tip is introduced intranasally and advanced and directed until located at the site of interest. In this study we have concentrated on the larynx and fig 1 shows the position of the scope relative to the surrounding structures.

Simultaneous cardiorespiratory monitoring was performed to detect spontaneously occurring apnoeas. Respiratory efforts were detected by respiratory inductive plethysmography (Respirtrace system) using only the abdominal band, as previously described, in small preterm infants. Airflow at the nostril was recorded with a self retaining nasal thermistor. Oxygen saturation was also recorded (Ohmeda Biox 3700 pulse oximeter) together with heart rate. All monitor outputs were then recorded onto a four channel tape recorder (Racal Store 4DS) to provide a permanent recording of events.

To enable accurate timing and recognition of apnoeic events and allow direct comparison of the endoscopic view with the monitor recordings, a further modification was made. During a study the outputs of the monitors were continuously printed out on to paper by a four channel chart recorder. This print out was then filmed by a separate free standing TV camera and relayed via a mixing box (modified Sony Video Selector ITP 265AJC) to the same colour monitor displaying the laryngoscopic view (fig 2). This meant that the monitor outputs could be directly visualised alongside the picture of the upper airway and allowed the operator to observe immediately what was happening to the airway during recorded apnoic events. When events were subsequently analysed the split screen view with both respiratory parameters and endoscopic findings were available recorded on videotape as well as the separate permanent recording of the respiratory monitors by the four channel tape recorder.

The procedure was well tolerated by the infants and once introduced the scope appeared

![Figure 1](image1)  
**Figure 1** Position of the fibreoptic scope in relation to upper airway structures.

![Figure 2](image2)  
**Figure 2** System to enable simultaneous visualisation of monitoring recordings and laryngoscopic view.
to cause little discomfort or distress. Positioning of the scope was at times difficult with small movements of the baby or operator resulting in loss of the view and requiring repositioning of the scope. No increase in supplementary oxygen was necessary during the study, as judged by recorded oxygen saturations, except during apnoeic events. If the infant was on feeds these were discontinued one hour before the study and the stomach emptied to prevent aspiration.

The infants were studied in their normal nursing position, usually prone, though some were studied supine with support to keep their neck partially extended. There were no adverse events or complications associated with the procedure.

**Results**

Infants were monitored for a mean time of 79 minutes (range 49-139) with simultaneous laryngoscopic visualisation for a mean time of 43 minutes (range 16-72). We were able simultaneously to record and visualise 14 apnoeic events in seven of the infants studied. The details of the apnoeas are given in table 2. Of the apnoeas recorded eight were mixed (57%), four obstructive (29%), and two central (14%) as defined by the respiratory monitors. The mean duration was 32.25 seconds (range 10.5-72). During 10 of the apnoeas a drop in oxygen saturation of 10% or greater was recorded and half had associated bradycardia of less than 100 beats/minute. No apnoeas were recorded immediately on introduction or positioning of the scope. The apnoeas recorded were not uncharacteristic of the apnoeas the infants were having before the study.

**LARYNGOSCOPIC FINDINGS**

The majority of recording was of normal tidal breathing with cord abduction during inspiration and narrowing of the glottic aperture in expiration (fig 3). The arytenoid cartilages with their coverings and the aryepiglottic folds are prominent structures and actively mobile in the laryngeal movements of normal tidal breathing. Swallows were frequently seen with glottic closure followed by immediate reopening of the airway.

Obstruction was observed to occur at laryngeal level during the apnoeic episodes recorded (fig 4). The prominent arytenoid masses and thick aryepiglottic folds were seen to close across the airway resulting in obstruction. This was similar to that seen during swallowing but the airway patency was not restored despite, at times, respiratory efforts against the obstruction.
tiation. Figures 5 and 6 illustrate two of the apnoeic episodes recorded. The first is an obstructive apnoea with the patent laryngeal opening visualised during tidal breathing. Closure occurs at the start of the episode simultaneously with loss of airflow recorded at the nostril. Respiratory efforts continue to be made against the obstructed airway, as shown by the inductance trace, and in this example eight obstructed breaths are recorded. Airway patency is restored as airflow is again recorded with the resumption of normal respiratory effort waveforms as the obstruction is removed. The episode is associated with desaturation and a small drop in heart rate. Figure 6 is an example of a mixed apnoea with again loss of airflow and laryngeal closure at the onset of the episode simultaneously with loss of airflow.

In this case, however, there were initially no breaths against the obstruction until after about 8 seconds. The apnoea was characterised by restoration of airflow with the resumption of airway patency and intermittent positive pressure ventilation (IPPV) given by bag and mask. The same sequence of events was seen in the other episodes recorded including the apparant central apnoeic episodes with again laryngeal closure at the start of the episode with absent airflow but no respiratory efforts detected by inductance against the obstruction. Termination of the apnoea was characterised by restoration of airflow with the first respiratory effort and reopening of the laryngeal airway. This laryngeal closure appeared to be an active process and not due to a passive collapse of the airway structures. Spontaneous recovery with reopening of the glottis and re-establishment of airway patency was seen in the majority of episodes with the scope and monitoring equipment still in position. Three episodes did require active intervention to terminate, removing the scope and providing IPPV via the bag and mask, but this was not unusual for those particular infants and the apnoeic episodes. Where simultaneous recording and visualisation was possible we did not record any obstructive or mixed apnoea where the larynx remained patent. In six of the apnoeas, either mixed or obstructive, the accumulation of secretions before the onset of, or the clearance of secretions with recovery from, the apnoeic episode was noticed.

Discussion

The suggestion that the larynx may be the site of obstruction in preterm infants with obstructive and mixed apnoea is not new. It is a common observation in apnoeic infants that on direct laryngoscopy the cords often appear tightly adducted making intubation a difficult procedure, whereas one might expect them to lie open in a hypoxic, ‘flat’ infant. Stein- Schneider and Rabuzzi also described the resumption of respiratory efforts against such a closed glottis, as would be the situation in obstructive apnoea. However, it is possible that the introduction of the laryngoscope blade may itself induce glottic closure. This could also occur with our ultrafine scope yet there are a number of points to suggest that this is not the case.

Firstly, we have long periods of recording of normal tidal breathing with the scope in the same position as that during apnoeic episodes. No episodes of apnoea appeared to be precipitated by introduction or positioning of the scope. In five of the babies studied, all with recurrent apnoea, no laryngeal closure was seen for the duration of the study. We have also monitored more mature infants with this system and have failed to see the laryngeal clo-

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**Figure 5** Obstructive apnoea (patient 1). ECG, electrocardiography.

**Figure 6** Mixed apnoea (patient 2). ECG, electrocardiography.
sure as described during these apnoeic episodes. The apnoeas recorded in our infants were typical of the episodes experienced before study and there was no apparent increase in their frequency during the study. We also recorded each 'type' of apnoea as mixed (57%), obstructive (28%), and central (14%) in the subjects and this is not far from the frequency one would expect for spontaneous apnoea particularly in a group where obstructive episodes were suspected.

In the majority of cases the apnoeas resolved spontaneously with the scope in the same position as at the onset of the episode. Research looking at laryngeal reflexes in lambs with tracheostomies showed that stimulation of various regions of the larynx with a probe, although occasionally resulting in swallows, failed to induce changes in respiratory patterns. In contrast very small volumes of hypo-osmolar fluids could produce significant respiratory depression and prolonged apnoea in the same lambs. This perhaps could be studied further in premature infants by spraying local anaesthetic over the laryngeal structures before scopeing but this may itself be detrimental to the baby and make observations difficult to interpret. We feel confident that when performing our studies the scope itself did not precipitate any episodes of apnoea.

There is now clear evidence of a laryngeal chemoreflex in preterm infants. Stimulation of this reflex results in swallowing, airway obstruction, and apnoea. Many features of this airway protective mechanism are similar to spontaneous apnoeas and it has been suggested that an exaggeration of this reflex may be a cause of apnoea of prematurity. Preterm infants respond to fluid bolus volumes of as little as 0.01-0.1 ml introduced into the pharynx. This appears to be a chemosensitive rather than simply a mechanoreceptor response due to presence of the bolus, with the response to water being greater than saline. Electrical stimulation of the superior laryngeal nerve produces glottic closure followed by prolonged apnoea in monkeys with bilateral division of these nerves abolishing the swallowing and respiratory suppression induced by this reflex. Further work in adult cats has shown continuous excitation of the thyroarytenoid muscle, with visible laryngeal adduction, follows electrical stimulation of the superior laryngeal nerve. This is accompanied by cessation of respiration and also suppression of the inspiratory activity of the laryngeal adductors, the post cricoarytenoid muscles. Similar excitation of laryngeal adductors and suppression of adductors occurs with infusion of water or sodium bicarbonate. Infants with malformations of the central nervous system with associated raised intracranial pressure are well documented as having apnoea and airway obstruction as a result of abductor cord paralysis.

Bosma has given detailed attention to the anatomy of the newborn larynx describing it as 'a grossly mobile, enclosing composite of skeleton musculature and a more discretely mobile internal composite'. The latter is composed of the arytenoid, corniculate, aciform, and epiglottic cartilages. He also emphasises 'the dispropor-
of preterm infants to an external obstruction and other indirect indicators of airway patency. Airway obstruction may therefore be a feature of all types of preterm apnoea. This suggests that the classical division into central, mixed, and obstructive apnoea may be misleading as common underlying pathophysiological mechanisms are identified.

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