The desaturating intubated neonate: is DOPE enough?

Neonatal staff are often asked to review mechanically ventilated infants who significantly desaturate. A systematic assessment is used to ascertain the cause and commonly doctors are taught to use the acronym DOPE (displaced, obstructed, pneumothorax and equipment failure) as an aide-mémoire to the assessment. This article questions how the availability of continuous waveform monitoring alters the systematic assessment of the desaturating infant.

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Key points

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1. The cause of a desaturation event can be difficult to ascertain.
2. It is important to have methodology for assessing a ventilated infant with significant desaturation.
3. An approach to diagnosing the cause of desaturation and consequent management on the neonatal unit is suggested.

Desaturation, a decrease in oxygen concentration in the blood, occurs frequently in ventilated neonates.[1] Although most desaturations resolve quickly, it is not uncommon for neonates to have a profound desaturation that requires further assessment and intervention.

The acronym 'DOPE' has become popular for assessing desaturating intubated patients.[2] Standing for displaced tube, obstructed tube, pneumothorax and equipment failure, DOPE provides a useful checklist for the acute, severe desaturation, but can be limited in scope. This article will discuss the causes of significant desaturations and review the newer available tools to help assess the infant and diagnose the cause. A systematic approach to managing the desaturating infant is proposed.

Causes of desaturation

Equipment

The basic function of a ventilator is to deliver a set amount of oxygen at a set pressure. If the delivery of either of these fails, an infant is likely to desaturate. These problems can be classified in three ways:

1. User error

Settings may be inappropriate, eg inadvertent reduction of peak inspiratory pressure (PIP), respiratory rate (RR) or flow settings may result in hypoventilation and acute atelectasis. The correct fraction of inspired oxygen (FiO_2) settings should not be assumed.

2. Sensor failure

Many ventilator modalities require appropriate response to sensor feedback, including rate triggering and targeting PIP in volume guarantee (VG) ventilation. If sensor malfunction occurs, either the RR or PIP may be insufficient for the infant's needs.

3. Mechanical factors

Gas delivery to the ventilator rarely fails on the neonatal intensive care unit, however this can be more likely in transport settings. Most commonly, gas delivery to the endotracheal tube (ETT) may fail. The cause of this is usually due to a disconnection or leak within the ventilator circuit. As this is proximal to the ETT flow sensor, it will not register as a leak, but as a failure to reach the desired PIP. Common sites for these leaks are at humidifier ports or condensation traps.

Endotracheal tube

1. A displaced ETT

A displaced ETT may not be easy to identify: it may have relocated too far down the trachea into a main bronchus or displaced upwards leading to a leak at the vocal cords or an unplanned extubation.

2. An obstructed ETT

The ETT may be in the correct position but obstructed. This could be internal (eg secretions, blood, an incompletely withdrawn suction catheter) but a kink in the tube, compression from a fixation device or a displaced ETT at the carina of the trachea can also present as obstruction.

The infant

Desaturations originating from the infant may be acute, gradual or fleeting. Changes in lung compliance may occur acutely (eg a pneumothorax or pulmonary haemorrhage) or may evolve over hours as

seen in pneumonia or respiratory distress syndrome. An important group is infants whose lungs acutely de-recruit due to an event such as airway suctioning. In these circumstances, lung compliance significantly worsens and the set PIP may no longer be adequate to generate appropriate tidal volumes.

Dynamic events that acutely come and go usually represent splinting of the chest wall, often in an agitated infant. Transient loss of respiratory drive (apnoea) while on low ventilator rates may present with a desaturation if the ventilator back-up rate is too low. Sustained loss of drive may occur with opiates or general deterioration.

Tools for assessment

The monitor

It is the monitor that usually alerts staff to a desaturation event and as such, it is important to assess and exclude a poor oximeter trace. Association with bradycardia suggests the episode is significant and requires prompt attention.

History

Find out how the infant has been and if anything happened prior to desaturation. Interventions, such as moving the infant or handling the ETT, may have resulted in dislodgement of the ETT. Vomiting may represent aspiration of milk contents, or may be the outcome of an unplanned extubation with resultant gastric distension. Recent suctioning can cause atelectasis or dislodge secretions leading to obstruction. With closed-system suctioning, the catheter may not have been suitably withdrawn from the ETT.

The ventilator

Depending on the ventilator used, differing amounts of information will be available. The authors' unit uses the Dräger Babylog VN500 but for the purpose of this article, the common tools found on most ventilators will be reviewed. Data are available in the form of alarms, numerical data and waveforms. It is important the clinician is aware which modality is being used, particularly whether VG ventilation is being employed.

1. Alarms

A disconnection alarm suggests an opening in the circuit, which must be remedied immediately. An airway obstruction alarm results from a lack of flow at an airway flow sensor and usually signifies a problem at or beyond the ETT, rather than a ventilator issue.

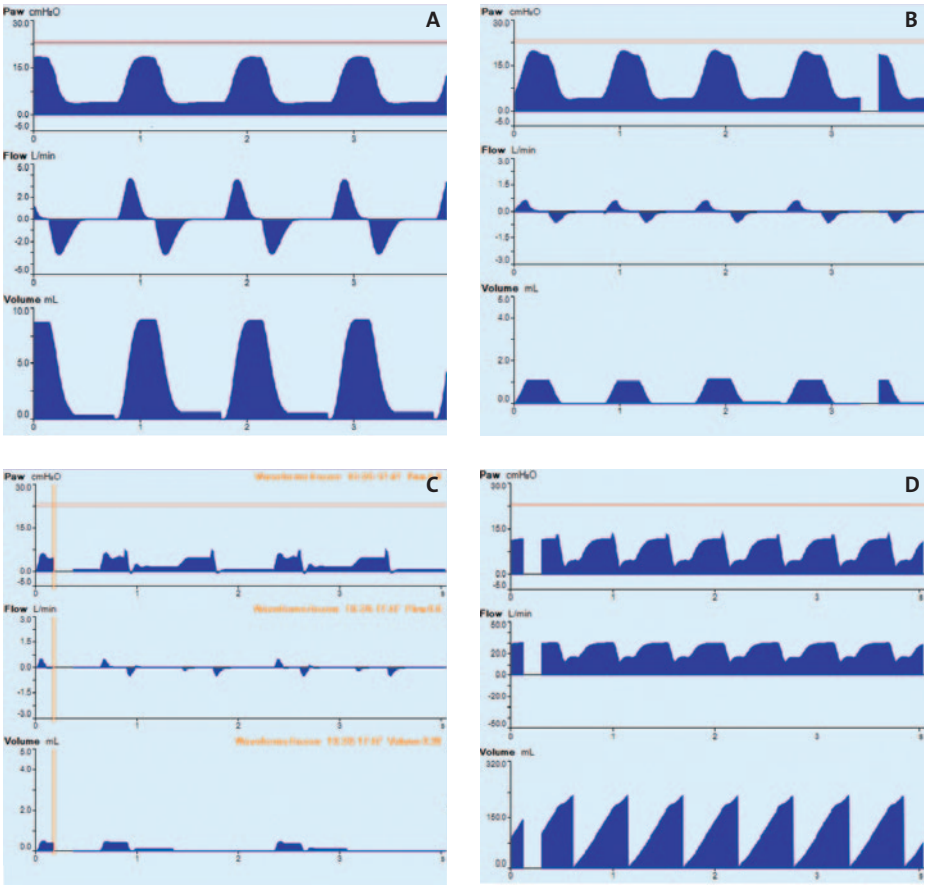


FIGURE 1 A) Normal pattern waveforms: the top waveform shows the set pressures are being delivered. The middle waveform shows inspiratory (above the line) and expiratory (below the line) flow. The bottom waveform shows that appropriate tidal volumes are generated. B) A problem with the infant or a blocked ETT: set pressures are being delivered but there are no (or reduced) flow and volumes waves. The lungs are not inflating meaning either the tube is completely blocked or there is poor lung compliance, eg chest splinting, lung collapse. C) A problem with the equipment or the circuit. Little pressure and little flow are delivered despite the PIP set at 26. This usually means there is a break in the circuit or ventilator error. D) Likely extubation or disconnection of the ETT. There is inspiratory flow only, with no expiratory flow. Most likely, the infant has extubated or there is a disconnection between the flow sensor and the ETT. This is usually accompanied by 100% leak.

2. Numerical data

Numerical data can be extensive and potentially bewildering. Key figures are: PIP, tidal volume, leak, resistance and FiO_2. Failure to achieve the target pressure indicates ventilator or circuit compromise and should prompt an alternative means of ventilation (eg Neopuff/Tom Thumb infant resuscitators).

If VG ventilation is being used and tidal volume is not achieved, the normal response is for the ventilator to increase pressures to the maximum allowed. If appropriate PIP is insufficient to deliver the set tidal volume, the problem is with the ETT or the infant. On the other hand, failure to reach the maximal PIP suggests ventilator compromise.

Ventilators may indicate the percentage of leak around the ETT. Leaks can be due to the ETT being too small for the infant, but very large leaks or 100% leaks should prompt the clinician to assess the tube position and exclude extubation. It is important to remember that this leak measurement refers to the leak beyond the flow sensor and not that of a leak in the ventilator circuit.

Trends in resistance can be helpful in determining if suction is required. A gradual increase in resistance suggests obstruction with secretions, which may be improved with suction.

3. Waveforms

Waveforms show the pressure being delivered, the flow to and from the ETT past the flow sensor and the volume entering and leaving the infant. Waveforms

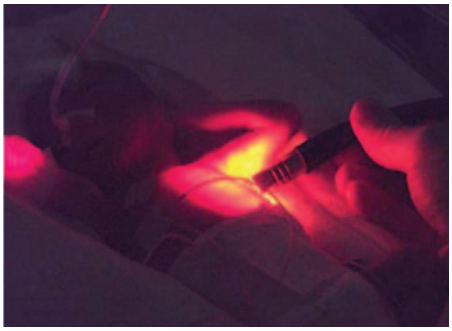


FIGURE 2 The use of cold light for diagnosis of pneumothorax.

can identify problems such as obstruction, disconnection, extubation and splinting (**FIGURE 1**).

Examination

Inspect the position of the ETT. Check that the measured length of the tube is the same as previously documented or at an appropriate length for the infant's size. Look to make sure there is nothing obstructing the tube such as a kink in the ETT.

Examine the chest looking at chest movement. Auscultate over each lung, the stomach and over the mouth. Air entry louder on one side may suggest a displaced tube, a pneumothorax or unilateral collapse. Air entry louder over the stomach or audible at the mouth would be suspicious of a dislodged ETT.

Interventional assessment

The following interventions may help to determine the cause of desaturation:

1) Suctioning

Suctioning will show if there are any secretions or blood blocking the ETT. If an obstruction is present and removed, this can resolve the desaturation. Nursing staff may have already performed this before asking for a review, but suction may need to be repeated, especially if thick secretions are present.

2) End-tidal carbon dioxide (CO_2) detector

If there are doubts about the tube being in the trachea, a CO_2 detector can be put into the circuit. If CO_2 is detected, the tube is very likely to be in the airway. The authors have found these devices more useful during intubation than when assessing a desaturating intubated infant as a blocked ETT, low tidal volume, high leak or low cardiac output can all provide a negative response.[3]

3) Cold light

The use of a cold light can be extremely helpful in the diagnosis of a pneumothorax.[4,5] The side of the chest with the pneumothorax will transilluminate brightly compared to the opposite side unless there are bilateral pneumothoraces (**FIGURE 2**).

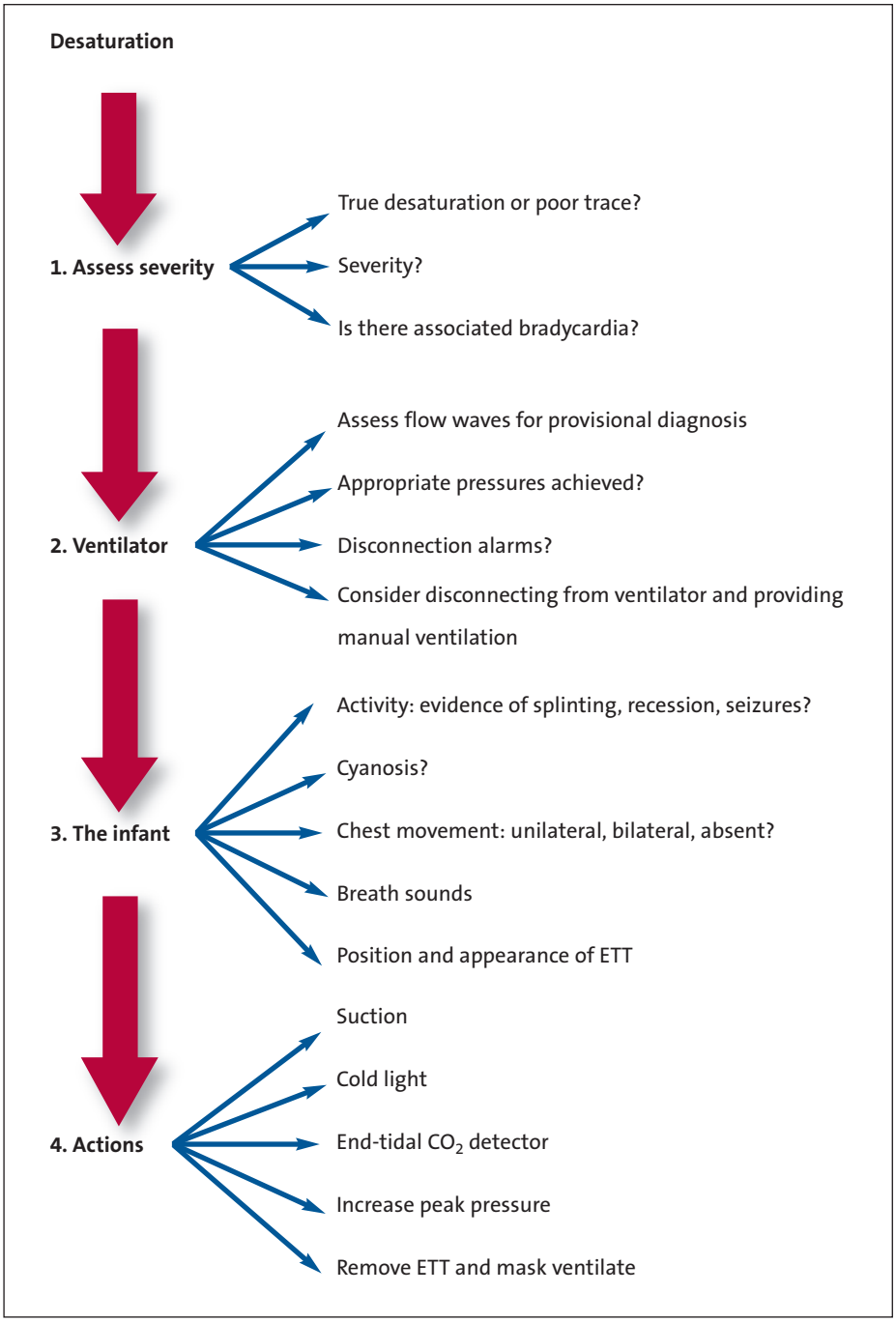


FIGURE 3 A stepwise approach for assessing the desaturating infant. Look for evidence of either gradual or acute deterioration. If acute, determine any manoeuvres that were conducted prior to the event. Key: ETT = endotracheal tube.

A considered approach

Having reviewed the causes for desaturation and the tools available to assess the infant, a logical approach to assessing the desaturating infant is proposed in **FIGURE 3**. Interpretation of findings from the stepwise approach are summarised in **TABLE 1**.

The stepwise assessment can be performed quickly and should help to identify most causes of a significant desaturation event. Example case studies can be seen in **FIGURE 4**. Often, infants in incubators are covered and it is easier and quicker to look at the monitors and ventilator first, before inspecting and handling the infant. Once the infant is stable and the desaturation has resolved, a full clinical assessment to look for any new pathology such as sepsis or abdominal distension should be performed. A chest X-ray may be necessary.

	ETT position	Pressure waves	Flow wave	Breath sounds/chest movement
Extubation	Altered/no change	Achieved	Inspiratory only	Reduced/absent
Blocked tube	No change	Achieved	Reduced/absent	Reduced/absent
Splinting	No change	Achieved	Reduced/absent	Reduced/absent
Pneumothorax	No change	Achieved	No change/reduced	Reduced/absent on affected side
Equipment failure	No change	Reduced/absent	Reduced/absent	Reduced/absent

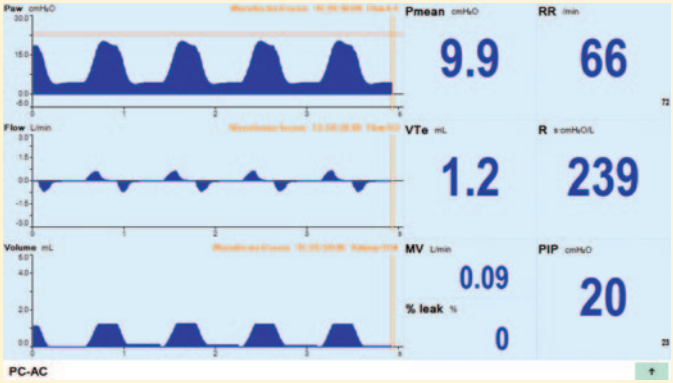
TABLE 1 Interpretation of findings from the stepwise approach to assessing the desaturating infant. Key: ETT = endotracheal tube.

Example case study 1

An eight-day-old infant born at 25 weeks' gestation has an increasing FiO_2 and is desaturating in 100% oxygen. The infant was reintubated four hours previously following an accidental extubation. The nurse looking after him says that he has sternal recession. His monitor reads 80% oxygen saturation with a good trace and a good heart rate.

The ventilator shows appropriate pressure waves, but reduced flow waves and tidal volume, suggesting a problem with the infant or the ETT. On inspection there is no obvious obstruction of the ETT but the tube appears to have slipped to 8cm at the lips. Examination of the infant reveals reduced air entry to the left lung, good air entry at the right with minimal noise at the mouth or stomach.

A provisional diagnosis of unplanned advancement of the ETT is made and the tube is pulled back to the original position allowing the tidal volumes to recover and the air entry to equalise. As there is an appropriate improvement, progression to cold light examination is not required.



Example case study 2

A two-day-old infant born at 26 weeks' gestation has desaturation and bradycardia. The nurse says she was changing the infant's nappy when she desaturated and, despite increasing the FiO_2, she continued to deteriorate. The monitor shows a blood oxygen saturation (SpO_2) trace at just 50%. The heart rate is 70.

The ventilator monitor shows inspiratory flow only, suggesting an extubation or disconnected ETT.

On inspection there is no obvious obstruction and the ETT looks secure at the mouth. On examination there is minimal chest movement and air entry sounds louder over the stomach than the lungs. The diagnosis is an unplanned extubation, therefore the ETT is removed and the infant is mask-ventilated. The heart rate and saturation quickly improve and the infant is re-intubated.

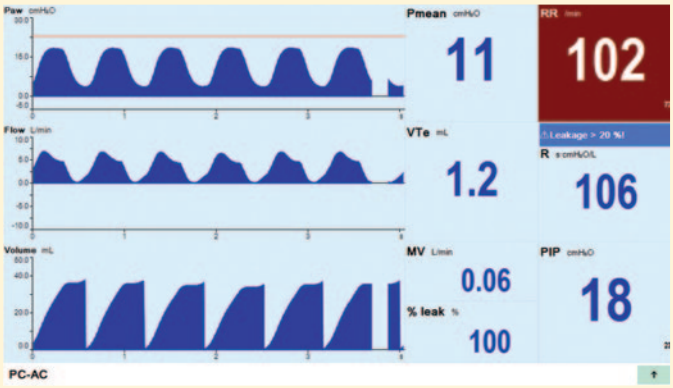


FIGURE 4 Example case studies.

Summary

The acronym DOPE is a useful aide-mémoire for the common acute causes of a desaturating infant although it is not a comprehensive tool. The cause of desaturation can be difficult to diagnose but advancements in ventilator technology offer greater information to aid clinicians. The use of waveforms and trends on the ventilator are helpful tools to use alongside clinical assessment. The suggested approach to assessing a desaturating infant should not take any longer than DOPE, but should improve diagnosis and consequently lead to appropriate management.

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