Crisis management during anaesthesia: desaturation

S M Szekely, W B Runciman, R K Webb, G L Ludbrook

Background: Desaturation occurs for many reasons under anaesthesia, some rare and obscure, and many potentially life threatening. The rapidity with which the cause is determined and appropriate management is instituted varies considerably between anaesthetists.

Objectives: To examine the role of a previously described “core” algorithm COVER ABCD–A SWIFT CHECK, supplemented by a specific sub-algorithm for desaturation, in the management of incidents of desaturation occurring in association with anaesthesia.

Methods: The potential performance of this structured approach for each of the relevant incidents among the first 4000 reported to the Australian Incident Monitoring Study (AIMS) was compared with the actual management as reported by the anaesthetists involved.

Results: Amongst the first 4000 incidents reported to AIMS there were 584 episodes of desaturation in association with general anaesthesia; 41% were dealt with by COVER, 48% by ABCD, and 11% required a specific desaturation sub-algorithm. Nearly a fifth of all desaturations were caused by endobronchial intubation. Within the specific desaturation subgroup, half were due to pulmonary problems in the form of underlying lung disease, excessive secretions or obesity and a third could not be diagnosed.

Conclusion: Desaturation may have many causes, some of which are obscure, and failure to respond promptly may place the patient at risk. In the face of persistent desaturation, management should consist of hand ventilation with 100% oxygen, completion of COVER ABCD–A SWIFT CHECK, and a return to a supine posture. Blood gases, chest radiography, and bronchoscopy may be required where desaturation is persistent and/or no apparent causes can be found.

METHODS

Of the first 4000 incidents reported to AIMS, those that made reference to desaturation were extracted and analysed for relevance, presenting features, type of surgery, cause, management and outcome. The COVER ABCD–A SWIFT CHECK algorithm, described elsewhere in this set of articles, was applied to each relevant report to determine the stages at which the problem might have been diagnosed and to confirm that activating the COVER portion would have led to appropriate initial steps being taken. As desaturation is not adequately dealt with by this algorithm, a specific sub-algorithm for desaturation was developed and its putative effectiveness was tested against the reports. How this was done is described elsewhere in this set of articles. The potential value of this structured approach—that is, the application of COVER ABCD–A SWIFT CHECK to the diagnosis and initial management of this problem, and the
application of the sub-algorithm for desaturation—was assessed in the light of the AIMS reports by comparing its potential effectiveness for each incident with that of the actual management, as recorded in each report.

RESULTS
Amongst the first 4000 AIMS reports there were 706 incidents containing the keyword “desaturation”. Of these, 86 were excluded because they occurred before induction, in the recovery ward, or under regional anaesthesia. A further 36 did not involve desaturation but mentioned it specifically to exclude it in situations where it would have been expected. Examples are rapidly detected circuit disconnections or successful bag and mask ventilation during a difficult intubation. This left 584 incidents for analysis.

The COVER algorithm
The COVER algorithm adequately diagnosed 237 of the 584 incidents (41%). The distribution of these figures is shown in fig 1. Two incidents were diagnosed by cardiac arrest (C1) and 10 were diagnosed at O (five involved the delivery of hypoxic gas mixtures, four involved preoxygenation or mask ventilation with no gas flow, and one was a common gas outlet disconnection). Over 90% of the COVER incidents were diagnosed at V1 or E1. Most of these would have been detected at the “CHECK” phase—that is, during ventilation by hand and/or checking the position and patency of the endotracheal tube. Most of the V1 incidents involved leaks and disconnects. Common gas outlet disconnects accounted for many of these due to a failure to reconnect the hoses after a change of circuit. This also implies a failure to check the circuit before use as well as a failure to watch respiratory movements in the rebreathing bag during preoxygenation. Either of these manoeuvres would have immediately drawn attention to the disconnection.

There were 138 incidents diagnosed at E1 (checking the endotracheal tube), of which 103 were due to endobronchial intubation. In spite of increased awareness of the problem, endobronchial intubation remains a major cause of desaturation during general anaesthesia. The diagnosis was made very late in some of these incidents, with consequent morbidity for the patient. One patient was reported to have suffered a perioperative infarct, possibly as a result of prolonged ventilation, some with laryngeal masks, some after intubation. Half of these arose in intubated patients, with the degree of straining sufficient to prevent adequate ventilation. Some of these patients desaturated profoundly (50%) and needed to be re-anaesthetised to regain control of the situation. These incidents are dealt with in the form of laryngospasm, aspiration, or difficult intubation. Most of these situations presented no diagnostic challenge but required a sub-algorithm for further management. There were 34 incidents under “B” due to hypoventilation, bronchospasm, or pulmonary oedema. Hypoventilation was responsible for most of these. Many were due to coughing, straining or breath-holding, some with mask ventilation, some with laryngeal masks, some after intubation, and some after extubation. Half of these arose in intubated patients, with the degree of straining sufficient to prevent adequate ventilation. Some of these patients desaturated profoundly (50%) and needed to be re-anaesthetised to regain control of the situation. These incidents are dealt with by specific sub-algorithms that are covered in other papers in this series.

Desaturation algorithm
There remained 66 incidents (11%) in which neither COVER nor ABCD had adequately managed the problem. These were

---

**Table 1** Causes of desaturation in which neither COVER nor ABCD adequately dealt with the problem

<table>
<thead>
<tr>
<th>Causes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excessive secretions</td>
<td>11</td>
</tr>
<tr>
<td>Underlying lung disease</td>
<td>11</td>
</tr>
<tr>
<td>Obesity syndrome</td>
<td>10</td>
</tr>
<tr>
<td>Monitor error</td>
<td>5</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>4</td>
</tr>
<tr>
<td>Suspected embolism</td>
<td>4</td>
</tr>
<tr>
<td>Could not determine</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>66</td>
</tr>
</tbody>
</table>
**DESMATURATION**

**EMERGENCY MANAGEMENT**

Complete COVER ABCD—A SWIFT CHECK (1)*
Hand ventilate with 100% oxygen
Confirm the FiO2 is appropriate
Confirm the ETCO2 is appropriate, if it is low consider:
  * Anaphylaxis → page 48**
  * Pneumothorax → page 46**
  * Air (or other) embolism → page 44**
Auscultate again, specifically exclude endobronchial intubation (2)

**FURTHER CARE**

Reassess the situation
If persistent/unstable desaturation consider:
  * Completing/abandoning surgery
  * Chest X-ray, blood gases
If stable and well saturated, see (5) on page 17*
  * Wake the patient up and extubate
If unstable or desaturated, see (5) on page 18*
  * Admit to ICU/HDU

**NOTES:**

If was judged that correct use of the algorithm would have led to earlier recognition of the problem and/or better management in 16% of the 584 relevant incidents reported to AIMS.
(1) The use of COVER ABCD accounted for 88% of applicable incidents reported to AIMS.
(2) Use of the desaturation sub-algorithm accounted for a further 9% of applicable incidents.
(3) Endobronchial intubation was the commonest cause of desaturation in anaesthetised patients reported to AIMS. It should be specifically excluded early. Further details may be found in (6) below.
(4) 2% of incidents were due to bronchial plugs or excessive bronchial secretions, which can produce marked desaturation, especially in young children. A shunt effect is produced, which may be unmasked by abolition of hypoxic pulmonary vasoconstriction with induction of anaesthesia.
(5) “Obesity syndrome” refers to the rapid desaturation which may be seen at induction when anaesthetising obese patients, or those with tightly distended abdomens, and accounted for 2% of relevant incidents. Drug-induced abolition of hypoxic pulmonary vasoconstriction and an acute reduction in functional residual capacity resulting in sudden V/Q mismatching is thought to be the cause. The lithotomy and Trendelenberg positions, spontaneous ventilation and hyperventilation all may exacerbate the problem, resulting in sudden desaturation at the start of a case and progressive desaturation during the maintenance phase.
(6) 0.8% of incidents involved suspected gas embolism.
(6) 1% of incidents involved unusual causes of pulse oximeter malfunction, including acute tricuspid incompetence, polycythaemia and methaemoglobinemia. Acute tricuspid incompetence may lead to the oximeter sensing the venous pulse. A large plethysmographic wave form and a saturation of 70-75% is commonly seen. Arterial saturation, when directly measured, may be quite adequate. Polycythaemia may lead to artefactually low saturation readouts with high directly measured arterial oxygen saturations or tensions. Methaemoglobinemia, depending on its extent, will cause the saturation to approach 85%.

These notes comprise a reverse side of a page of the Crisis Management Manual12.
* Numbers in brackets refer to Notes in right hand panel.
** Page references refer to the Crisis Management Manual12.

---

**REVIEW AND TREAT OTHER POSSIBLE CAUSES**

**Underlying cardiopulmonary problems**

If bronchial secretions or plugs are suspected (3)
  * Posture and suction ETT/bronchi
  * Give a “long slow blow” especially in children
If cardiovascularly stable consider PEEP/CPAP
If acute shunt is suspected (4)
  * Ensure the patient is supine and level
If a pneumoperitoneum is present, deflate the abdomen
Consider gas embolism (5)

**Pulse oximeter malfunction (6)**

Consider: polycythaemia, methaemoglobinemia, acute tricuspid incompetence, probe sited distal to an AV fistula.

The sub-algorithm forms a facing page of the Crisis Management Manual12.*

---

**Incidents**

In incidents in which desaturation occurred with no obvious cause from equipment, airway, circulation, etc. By definition, this was a more challenging group of incidents. The main causes of desaturation unaccounted for by COVER or ABCD are shown in table 1.

**Secretions (n = 11)**

Most of these incidents had one or more of the following features: heavy smoker (including recent ex-smoker), recent upper respiratory tract infection, child requiring grommets (middle ear ventilation tubes) or adenoidectomy, Down’s syndrome or other congenital neurological conditions.

Bronchial plugs or excessive secretions can produce a shunt effect which may be unmasked by the abolition of the homeostatic mechanism of hypoxic pulmonary vasoconstriction with the induction of anaesthesia, resulting in marked desaturation. Also included in this category was the case of a child undergoing nephrectomy for a perinephric abscess in whom the sudden deterioration was later explained by the finding that the abscess had extended into the lung and ruptured during surgery, soiling the bronchial tree with copious amounts of purulent fluid.

**Underlying lung disease (n = 11)**

All of these patients had some lung pathology that was either undiagnosed or underestimated before surgery. For example, a baby with known bronchopulmonary dysplasia and subglottic stenosis was turned on his side for insertion of a spinal with no monitoring in place. When the spinal block was completed and the child turned supine again, he was found to be profoundly cyanosed (SpO2 50%). Care with preoperative evaluation and anaesthetic technique may have averted some of these problems.

‘‘Obesity syndrome’’ (n = 10)

This refers to the rapid desaturation that may occur when obese patients or those with tightly distended abdomens are anaesthetised. It is exacerbated by spontaneous ventilation and by the lithotomy position. All of the patients in this category were obese and all but two were in the lithotomy position.

**Monitor error (n = 5)**

There were five incidents in which the reported desaturation was spurious. In one the oximeter showed marked desaturation, both with a finger probe and an ear probe, but a simultaneous blood gas analysis showed a Po2 of 458. A falsely low reading occurred in a patient with polycythaemia and one in a patient who was very cold. The remaining false readings occurred in a patient with tricuspid incompetence in whom the oximeter was sensing a venous pulse, and in a patient with an old arteriovenous fistula.

---

**Figure 3** Desaturation.
Cardiovascular \( (n = 4) \)
There were four incidents in which desaturation occurred in conjunction with hypotension and arrhythmias. In one of these it was felt that the child may have reversed the flow across his known atrial septal defect, and in another a coarctation of the aorta was diagnosed in the recovery ward.

Suspected embolism \( (n = 4) \)
There were four cases in which the most likely diagnosis was an embolism, one of fat and three of gas. In each case a fall in saturation was associated with hypotension and a moderate to severe fall in end-tidal carbon dioxide. One of the cases occurred during hydrogen peroxide irrigation of a freshly curetted frontal lobe abscess cavity, one occurred during a laparoscopic cholecystectomy, and one during a nephroureterectomy.

Don’t know \( (n = 21) \)
Many of these were complex incidents involving already sick patients where the underlying problem was never resolved. In some the information provided by the reporter was inadequate while, in others, no conclusions were possible despite detailed reporting of the incident.

When the potential effectiveness of the structured approach, represented by the COVER ABCD–A SWIFT CHECK algorithm and the special sub-algorithm for desaturation (fig 3), was compared with that of the actual management as documented in each of the 584 relevant reports it was considered that, properly applied, the structured approach would have led to a quicker and/or better resolution of the problem in 16% of the incidents. A further 42% of all incidents required other specific sub-algorithms to manage the problem, such as laryngospasm, difficult intubation, and aspiration/regurgitation.

There were a significant number of incidents in which use of the structured approach was deemed not to have outperformed the actual management described, in which the COVER algorithm had effectively been used by the reporting anaesthetist.

Within the subgroup of 66 incidents that required the specific desaturation sub-algorithm, it was felt that 15% of these would have been better handled by correct application of the algorithm. In most incidents this referred to failure to clearly work through a logical sequence, ventilate by hand on 100% oxygen, suction the airway, or check blood gases. There was a haphazard approach to finding a cause, an acceptance that desaturation had occurred and the fraction of inspired oxygen increased with no further attempt to elucidate a cause. In 14% it was not possible to determine what the cause of the desaturation was because of inadequate information in the reports. Overall, the majority of incidents in this subgroup were handled well even if the underlying cause could not be found. There were no incidents where use of the desaturation sub-algorithm was thought to have been likely to make the situation worse.

DISCUSSION
Desaturation is a common occurrence during general anaesthesia. It occurs for many reasons related to anaesthetic equipment and to the patient. There have been very few

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Timing of desaturation: number of incidents by cause and phase of anaesthetic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Induction</td>
</tr>
<tr>
<td>COVER</td>
<td>59</td>
</tr>
<tr>
<td>A:</td>
<td></td>
</tr>
<tr>
<td>Laryngospasm</td>
<td>37</td>
</tr>
<tr>
<td>Aspiration/regurgitation</td>
<td>19</td>
</tr>
<tr>
<td>Difficult intubation</td>
<td>37</td>
</tr>
<tr>
<td>B:</td>
<td></td>
</tr>
<tr>
<td>Hypoventilation</td>
<td>7</td>
</tr>
<tr>
<td>Bronchospasm</td>
<td>5</td>
</tr>
<tr>
<td>Pulmonary oedema</td>
<td>0</td>
</tr>
<tr>
<td>C:</td>
<td></td>
</tr>
<tr>
<td>Hypotension</td>
<td>1</td>
</tr>
<tr>
<td>Bradycardia</td>
<td>0</td>
</tr>
<tr>
<td>Myocardial ischaemia</td>
<td>0</td>
</tr>
<tr>
<td>D:</td>
<td></td>
</tr>
<tr>
<td>Drugs</td>
<td>7</td>
</tr>
<tr>
<td>“A”:</td>
<td></td>
</tr>
<tr>
<td>Anaphylaxis</td>
<td>3</td>
</tr>
<tr>
<td>Embolism</td>
<td>0</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0</td>
</tr>
<tr>
<td>Water intoxication</td>
<td>0</td>
</tr>
<tr>
<td>Desaturation</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>197</td>
</tr>
<tr>
<td>Percentage</td>
<td>34%</td>
</tr>
</tbody>
</table>
Key messages

- There were 584 analysable episodes of desaturation (15%) among the first 4000 incidents reported to AIMS.
- Another 86 occurred before induction, in recovery, or under regional anaesthesia; these are excluded from this series.
- With half of the incidents analysed, desaturation was the first warning, emphasising the importance of pulse oximetry.
- Almost a fifth of all the desaturation incidents were caused by endobronchial intubation. This cause was often associated with late diagnoses and consequent patient morbidity.
- Profound desaturation occurred in some intubated patients in association with coughing, straining, or breath holding.
- Sixty six incidents (11%) were not managed adequately by the core algorithm COVER ABCD. The most common causes in this group were excessive secretions (e.g. in heavy smokers), underlying lung disease, and obesity syndrome.
- 15% of the 66 incidents would have been better handled by correct application of the specific sub-algorithm for desaturation.
- Most desaturation incidents (52%) occurred during the maintenance phase.
- In all desaturation situations, ventilation with 100% oxygen represents good practice. Always attempt to maintain oxygenation while a cause for the desaturation is being sought.

ACKNOWLEDGEMENTS

The authors would like to thank all the anaesthetists in Australia and New Zealand who contributed to the 4000 incident reports upon which this and the other 24 papers in the Crisis Management Series are based. The coordinators of the project also thank Liz Brown for preparing the draft of the original Crisis Management Manual; Loretta Smyth for typing; Monika Bullock RN for earlier coding and classifying of data; Dr Charles Bradfield for the electronic version of the algorithms; Dr Klee Benveniste for literature research; and Drs Klee Benveniste, Michal Kluger, John Williamson and Andrew Paix for editing and checking manuscripts.

Authors’ affiliations

S M Szekely, Senior Staff Specialist, Department of Anaesthesia and Intensive Care, Royal Adelaide Hospital and University of Adelaide, Adelaide, South Australia

W B Runciman, Professor and Head, Department of Anaesthesia and Intensive Care, University of Adelaide and Royal Adelaide Hospital, Adelaide, South Australia

R K Webb, Senior Staff Specialist, Department of Anaesthesia and Intensive Care, The Townsville Hospital, Douglas, Queensland, Australia

W B Runciman, Professor and Head, Department of Anaesthesia and Intensive Care, University of Adelaide and Royal Adelaide Hospital, Adelaide, South Australia

R K Webb, Senior Staff Specialist, Department of Anaesthesia and Intensive Care, The Townsville Hospital, Douglas, Queensland, Australia

The resulting structured approach to managing clinical desaturation, as appears in the Crisis Management Manual, is detailed in fig 3. Finally, it is important that a full explanation of what happened be given to the patient and the problem clearly documented in the anaesthetic record. If a particular precipitating event was significant or a particular action was useful in resolving the crisis, this should be clearly explained and documented.
REFERENCES

Crisis management during anaesthesia: desaturation

S M Szekely, W B Runciman, R K Webb and G L Ludbrook

Qual Saf Health Care 2005 14: e6
doi: 10.1136/qshc.2002.004374

Updated information and services can be found at:
http://qualitysafety.bmj.com/content/14/3/e6

These include:

References
This article cites 9 articles, 4 of which you can access for free at:
http://qualitysafety.bmj.com/content/14/3/e6#BIBL

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections
Articles on similar topics can be found in the following collections
QSHC Crisis management in anaesthesia (26)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/