Crisis management during anaesthesia: pulmonary oedema

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Background: Pulmonary oedema may complicate the perioperative period and the aetiology may be different from non-operative patients. Diagnosis may be difficult during anaesthesia and consequently management may be delayed.

Objectives: To examine the role of a previously described core algorithm “COVER ABCD–A SWIFT CHECK”, supplemented by a specific sub-algorithm for pulmonary oedema, in its management 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: Pulmonary oedema was identified in 35 (<1%) of the first 4000 reports to AIMS. The most frequent presenting sign was hypoxia (46%) and the most specific sign was the presence of frothy sputum (23%). The core algorithm, although successful in the management of the initial physiological upset, was found to be inadequate for the ongoing management of pulmonary oedema. A specific sub-algorithm for the management of perioperative pulmonary oedema was devised, tested against the reports and would have been effective, if properly applied, in the management of all but one of the reported cases.

Conclusion: Successful recognition and management of perioperative pulmonary oedema is likely with the application of the structured algorithm and specific sub-algorithm approach outlined in this study.

Pulmonary oedema is the abnormal accumulation of fluid in the interstitial or alveolar spaces of the lung. It occurs for a number of reasons which can be explained on the basis of a disturbance in the normal Starling equation. It involves changes in hydrostatic or oncotic pressure across the alveolar membrane or in the permeability of the alveolar membrane such that fluid moves across from the capillaries into the alveolar space. Traditional teaching is that pulmonary oedema occurring in patients outside hospital tends to be due to cardiac dysfunction causing back pressure across the pulmonary system, resulting in extravasation of fluid into the alveoli. However, recent evidence suggests that increased afterload as in neurogenic pulmonary oedema may also be important in cardiogenic causes.

In patients undergoing anaesthesia, causes of pulmonary oedema other than cardiogenic are encountered. Decreased plasma oncotic pressure (due to hypoproteinemia), fluid overload, alterations in the permeability of the alveolar-capillary membrane (such as typically seen in acute respiratory distress syndrome (ARDS)), and post-obstructive and neurogenic pulmonary oedema may all occur. In many cases the aetiology is multifactorial with no clear identifiable precipitant. Because recognition may be delayed and management variable, it was decided to examine the place of a structured approach to the diagnosis and management of pulmonary oedema occurring in association with general anaesthesia.

In 1993 a “core” crisis management algorithm, represented by the mnemonic COVER ABCD–A SWIFT CHECK (the AB precedes COVER for the non-intubated patient) was proposed as the basis for a systematic approach to any crisis during anaesthesia where it is not immediately obvious what should be done or where actions taken have failed to remedy the situation. This was validated against the first 2000 incidents reported to the original Australian Incident Monitoring Study (AIMS). AIMS is an ongoing study which involves the voluntary anonymous reporting of any unintended incident which reduced or could have reduced the safety margin for a patient.

It was concluded that, if this algorithm had been correctly applied, a functional diagnosis would have been reached within 40–60 seconds in 99% of applicable incidents, and that the learned sequence of actions recommended by the COVER portion would have led to appropriate steps being taken to handle the 60% of problems relevant to this portion of the algorithm. However, this study also showed that the 40% of problems represented by the remainder of the algorithm ABCD–A SWIFT CHECK were not always promptly diagnosed or appropriately managed. It was decided that it would be useful, for these problems, to develop a set of sub-algorithms in an easy-to-use crisis management manual. This study reports on the potential place of the COVER ABCD–A SWIFT CHECK algorithm in the diagnosis and initial management of pulmonary oedema, provides an outline of a specific crisis management sub-algorithm for this problem, and provides an indication of the potential value of using this structured approach.

METHODS

Of the first 4000 incidents reported to AIMS, those that made reference to pulmonary oedema were extracted and analysed for relevance, presenting features, type of surgery, cause, management and outcome. The COVER ABCD–A SWIFT CHECK algorithm, as presented elsewhere in this series of papers, 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 pulmonary oedema is not dealt with by this algorithm, a specific sub-algorithm was developed (see fig 1) and its putative effectiveness was tested against the reports. How this was done is described elsewhere in this series 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
PULMONARY OEDEMA/ARDS

SIGNS (1)*
Respiratory distress/tachypnoea
Desaturation
Increased inspiratory pressure
Pink frothy sputum and ET T/ILMA (diagnostic)
Crepitations or brachioascarpam

PRECIPITATING FACTORS
Fluid overload (2)
Non cardiogenic:
- Post airway obstruction (3)
- Anaphylaxis
- Neurogenic
- Sepsis
- Pulmonary aspiration
- Multiple organ failure
Cardiogenic (4)

EMERGENCY MANAGEMENT
Titrator: inspired oxygen concentration against SpO2
Head up tilt/sit up
If self ventilating/applied CPAP (5)
Intubate if necessary
IPV and PEEP if intubated
Consider drug therapy: morphine/GTN/frusenide (6)

* Numbers in brackets refer to Notes in the right hand panel.

FURTHER CARE
Consider and investigate likely cause
Review perioperative fluid balance/renal function
Non-cardiogenic: consider post airway obstruction
- Allergy/anaphylaxis → page 48*
- Aspiration → page 16*
- Sepsis → page 64*
- Multiple organ failure, eg major trauma, pancreatitis
- Renal – renal function tests
Cardiogenic:
- ECG
- Cardiac enzymes
- Echocardiogram
- Chest X-ray
Consider admission to high dependency area/CU

The COVER ABCD – A SWIFT CHECK algorithm was successful in the management of the initial physiological upset, however it was considered that the use of this specific sub-algorithm would be required once the initial diagnosis of pulmonary oedema was made.

(1) Hypoxia – 46%; pink frothy sputum – 23%; increased airway pressures – 14%; respiratory distress – 14%; crepitations or wheeze – 9%.
(2) Fluid overload was judged to be the cause in 46% of incidents. 81% of these had pre-existing conditions making them more susceptible to overhydration: age >70, cardiovascular disease or hypertension, renal failure and chronic airflow limitation.
(3) 23% of incidents were judged to be post upper airway obstruction.
(4) 16% were judged to be cardiogenic in origin, eg, valvular heart disease, ischaemia/infarction, cardiac failure, arrhythmia.
(5) CPAP is important specific therapy for pulmonary oedema (in addition to treatment for hypoxia).
(6) Preload reduction:
- Morphine 1mg IV doses
- GTN infusion 50 mg in 500 ml
- Commence at 0.1 ml/kg/hr
- Fluid reduction:
- Frusenide 0.5mg/kg IV if fluid overload (place urinary catheter)
- If hypotensive:
- Adrenaline infusion: start with 0.00015mg/kg/min
- Adrenaline: for easy adult dosing, see page 71*
- Titratin against heart rate and blood pressure

These notes comprise a reverse side of a page of the Crisis Management Manual12.
* Page numbers refer to the Crisis Management Manual12.

Figure 1  Pulmonary oedema/ARDS.

application of the sub-algorithm for pulmonary oedema—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
Pulmonary oedema was mentioned in 37 reports (<1%) but, in two of these, pulmonary oedema was not one of the active problems at the time of the incident. This left 35 reports which constitute the database for this study.

The aetiology of the pulmonary oedema was varied. It was associated with fluid overload in 16 patients (46%), most of whom (81%) had a clinical condition that may have made them more susceptible to fluid overload. These conditions included age >70 years, a past history of cardiac disease or hypertension, renal failure, and chronic obstructive airways disease. It occurred following upper airway obstruction in eight patients (23%), appeared to be cardiogenic in five (14%), and to be due to neurogenic causes and anaphylaxis in one case each. Three (9%) had no obvious cause for the pulmonary oedema from examination of the report.

Seventeen (49%) of the incidents occurred outside the operating or procedure room. The COVER algorithm is not relevant to these incidents as it is designed for patients breathing gas from an anaesthetic machine. Twenty three of the patients (66%) were admitted to the intensive care unit and two (6%) died. Neither death could be directly attributed to the pulmonary oedema.

There were a number of symptoms or signs alerting the anaesthetist to the presence of pulmonary oedema as listed in fig 1. Hypoxia presenting as desaturation or cyanosis was the commonest sign (46%). Pink frothy sputum was noted in 23% and is diagnostic of pulmonary oedema. Increased airway pressure was observed in 14%, respiratory distress in
Pulmonary oedema often previously fit and well. The pathophysiological obstruction and its dramatic appearance in patients who its association with the reportable incident of airway and intensive care unit. It may be over reported here due to pulmonary oedema is a rare entity outside the operating suite coexist in a patient with ARDS.

mechanical ventilation. Similarly, cardiac compromise may not specific as normal filling pressures may be seen in threshold pressure differentiating the two. However, this is pressure of 18 mm Hg is regarded by convention as a venous pressure or invasively with a central venous or pulmonary oedema (ARDS) may be differentiated from normal permeability forms of pulmonary oedema requires the assessment of cardiac filling pressures. While the COVER ABCD core algorithm will serve to detect all presenting signs in pulmonary oedema, in none of the cases was it adequate alone to deal with the incident.

Once the diagnosis was made, the specific sub-algorithm was considered to be successful in the management of all but the one case referred to above.

CONCLUSION
Pulmonary oedema occurred in less than 1% of the 4000 perioperative incidents reported to AIMS. Initial management as suggested by the COVER ABCD algorithm and the pulmonary oedema sub-algorithm will sometimes be successful in treating the physiological abnormalities before a diagnosis is made. A sub-algorithm aimed at the management of perioperative pulmonary oedema was developed. This has been tested against the 35 incidents reported and appears to be appropriate.

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