Trauma: development of a sub-algorithm

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Background: Anaesthetists are regularly involved in the management of patients who have suffered trauma. Acute physiological derangements can occur at any time after the original injury, with life threatening sequelae. These problems may be complex in nature and evolve rapidly, often with an obscure aetiology, so a systematic approach to them is essential.

Objectives: To examine the role of a previously described core algorithm “COVER ABCD–A SWIFT CHECK” supplemented by a specific sub-algorithm for trauma, in the management of anaesthesia involving trauma cases.

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

Results: There were 38 relevant reports relating to trauma in the first 4000 reports to AIMS. In 39% of these there was “emergency corner cutting”, although in the majority the urgency was thought to have been more perceived than real. The previously described “core” crisis management algorithm (ABCD–A SWIFT CHECK) was not always promptly diagnosed or appropriately managed. It was decided that it would be useful, for these problems, to develop a set of specific sub-algorithms in an easy-to-use crisis management manual.

This study reports on the place of the COVER ABCD–A SWIFT CHECK algorithm in the diagnosis and initial management of trauma, provides an outline of a specific crisis management sub-algorithm for crises arising in patients under anaesthesia for these problems, and provides an indication of the potential value of using this structured approach.

METHODS

Of the first 4000 reports to AIMS, those which made reference to “trauma” were extracted and analysed for relevance, causes, diagnosis, management, and outcome. The COVER ABCD–A SWIFT CHECK algorithm, as presented 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 patients suffering from trauma are not dealt with by this algorithm, a specific sub-algorithm was developed for these problems based on EMST principles (see fig 1) and its putative effectiveness was tested against the reports.

The decision to develop a draft trauma algorithm before complete data analysis was taken because of the wide acceptance of EMST principles and was done in an attempt to validate the algorithm by the data analysis. EMST comprises four phases with the life threatening issues usually being addressed during the primary survey. This consists of five elements:

A - airway with cervical spine control;
B - breathing including ventilation and oxygenation;
ACUTE TRAUMA SUB-ALGORITHM
Early Management of Severe Trauma (EMST) protocol

As many incidents in trauma patients involve “corner cutting” such as failure to check due to perceived urgency, it is essential to recheck everything carefully. The best way to do this is to start again with COVER ABCD. If not successful consider possible missed diagnoses – follow EMST system – repeat primary survey, review results to date, and look for missed injuries.

A. Airway injury
look for failure to secure airway, failure to ventilate with tube in airway

manage failed intubation drill, consider surgical cricothyrotomy early with facial injury

cervical spine injury
look for priapism, areflexia, trauma above clavicles, history of neck pain or tenderness

manage immobilise neck, review cervical spine X-ray (radiologist if possible), further films as required

B. Tension pneumothorax
look for distended neck veins, decreased air entry on ipsilateral side, hyperresonance on ipsilateral side, mediastinal shift away

manage immediate needle thoracostomy, formal UWSD insertion

relevant algorithm: pneumothorax algorithm

massive haemothorax
look for distended or flat neck veins, decreased air entry on ipsilateral side, dullness to percussion on ipsilateral side, mediastinal shift away

manage volume load ++, formal UWSD insertion, beware increased bleeding on UWSD insertion, consider early involvement of thoracic surgeon

relevant algorithms: hypovolaemia/pneumothorax algorithms

bronghopleural fistula
look for continuous air leak via UWSD

manage consider UWSD piercing lung, consider inserting additional large UWSD, consider isolating lung with ETT down other bronchus or double lumen tube

relevant algorithm: desaturation algorithm

C. Unexplained blood loss/hypovolaemia
look for sites of concealed bleeding: chest/abdomen/pelvis, sites of visible bleeding

manage consider chest x-ray, consider pelvis x-ray, consider diagnostic peritoneal lavage or if severe urgent laparotomy, view operative site, examine known wounds if MAST suit in use: ensure correct inflation consider removal using standard method

relevant algorithm: hypotension algorithm

cardiac tamponade
look for distended neck veins, decreased heart sounds, unexplained hypotension, equalisation of cardiac pressures

manage consider pericardial tap/may need open drainage

relevant algorithm: hypotension algorithm

myocardial contusion
look for unexplained dysrhythmias, ST/T wave changes on ECG, hypotension with adequate filling

manage hypotension/hypothermic algorithms

hyperkalaemia after scoline
look for patient after head injury, spinal injury or burns, widened QRS, cardiac arrest

manage consider taking blood for K estimation, CPR as required, give glucose and insulin, consider giving calcium, consider giving NaHCO₃, do not discontinue CPR for at least 30 minutes

relevant algorithm: cardiac arrest/hyperkalaemia algorithm

D. Undiagnosed intracranial collection
look for dilating pupil under GA, unexplained bradycardia and hypotension in presence of known or suspected head injury, raised ICP if monitored, failure to waken

manage urgent CT scan if available, urgent neurosurgical consultation

E. Hyperthermia
look for temperature fall during long cases

manage cover as much of patient as possible, active heating methods, warm theatre

relevant algorithm: hypothermia algorithm

TRAUMA/BLEEDING

CONSIDER WITH
Any unexplained change in the patient’s condition

HIGH RISK SITUATIONS
After high velocity motor vehicle accidents
With any neck/head/chest/abdominal injury, no matter how trivial the external signs
With multiple injuries
Patients with pre-existing systemic disease
Elderly patients

PRECIPITATING FACTORS (1)*

Breathing:
Pneumothorax
Pulmonary contusion
Ruptured larynx/bronchus

Circulation:
Ongoing haemorrhage (evert or occult)
Intracranial hyperperfusion from any cause
Cardiac tamponade
Myocardial contusion

Hypothermia
Rapidly evolving clinical problems (2)
Especially before systematic assessment
Hyperkalaemia from suxamethonium

EMERGENCY MANAGEMENT (3)

Complete COVER–A SWIFT CHECK
Treat all cervical spines as untirable until cleared
Inform the surgeon about any concerns
If there is cardiovascular instability, consider:
Haemorrhage. Many blood volumes may disappear
Into a pelvis
Into the retroperitoneal space
Into extensive soft tissue damage
Myocardial contusion
Haemorrh/pneumothorax

If you suspect an intracranial problem:
Assess for focal signs
Inform a neurosurgeon immediately
Get a CT scan as soon as practicable
Check arterial line, measure filling pressures
Be prepared to completely expose and examine the patient, including top to toe, front and back.

Check haemoglobin, electrolytes and clotting regularly.

IF THE SITUATION IS STILL UNRESOLVED, RECHECK FOR:

Airway injury
Cervical spine injury
Pulmonary contusion
Bronghopleural fistula
Unexplained blood loss/hypovolaemia
Cardiac tamponade
Hyperkalaemia after suxamethonium
Undiagnosed intracranial collection
Hyperthermia

FURTHER CARE

Maintain vigilance
Continuously reassess the situation
Consider admission to ICU/HDU post operatively.

NOTES:

The COVER–ABCD algorithm detected (82%), diagnosed (68%) and corrected (66%) a high proportion of relevant incidents reported to AMS.

(1) Commonest modes of presentation were, hypoxia/desaturation – 8%, aspiration – 8%, cardiac arrest – 8%, air embolus – 6% and hypothermia – 3%.

(2) 39% of incidents were sequelae of “cutting corners” in an effort to save time. Retrospectively, in 73% of these incidents the urgency was judged to be perceived rather than real. Failure to check the machine resulted in up to 30 minutes.

(3) EMST – Early Management of Severe Trauma protocol (Australia).
USA/UK equivalent is ATLS – Acute Trauma Life Support protocol.


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

Figure 1  Acute trauma sub-algorithm. Early Management of Severe Trauma (EMST) protocol.
C - circulation with haemorrhage control;
D - disability and pupil status (a neurological assessment);
E - exposure and environmental control.

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, followed by the application of the sub-algorithm for management of trauma based on the EMST protocol) was assessed in the light of AIMS reports by comparing its potential effectiveness for each trauma incident with that of the actual management, as recorded in each report.

### RESULTS

There were 87 reports that contained the word “trauma”. Of these, 49 were either related to accidental trauma caused during anaesthesia to a non-trauma patient, most commonly damage to a tooth, or involved patients who had a past history of trauma mentioned in the report but which was unrelated to this episode. These unrelated cases were not used in the subsequent analysis and results. The remaining 38 reports related to patients with trauma where the trauma may have contributed to the incident or where the incident occurred in an acute trauma setting. Eight (21%) of these 38 cases involved children 14 years or younger. Incidents were evenly spread across the range of ASA status (table 1) with a surprisingly high proportion (29%) being ASA 1. Hypoxia/desaturation was the clinical situation occurring most commonly with 20 instances (53%). Fifteen incidents (39%) in apparently urgent cases had “corner cutting” as a factor (table 2). In 11 of these 15 cases, further analysis revealed that the urgency was perceived rather than real.

The COVER ABCD core algorithm was useful in discovering (82%), diagnosing (68%), and correcting (66%) of the trauma revealed that the urgency was perceived rather than real. In 11 of these 15 cases, further analysis (39%) in apparently urgent cases had “corner cutting” as a factor (table 2). For example, there seems to be a situation seems to engender a sense of urgency that may then lead to “corner cutting” in an attempt to save time; 39% of incidents seem to have occurred at least in part due to this situation leads to a failure of equipment. It is also crucial to note that on occasions staff must take the time to ensure that equipment is properly checked before use. The high percentage of emergency ASA E codes (95%) bears witness to this (table 1). The “emergency” situation seems to engender a sense of urgency that may then lead to “corner cutting” in an attempt to save time; 39% of incidents seem to have occurred at least in part due to this situation leads to a failure of equipment. It is also crucial to note that on further analysis 11 of the 15 “corner cutting” cases we identified had been amenable to prevention simply through better checking. These were a missed C1 fracture, a nerve block on the wrong side, and the giving of uncrossmatched blood. None of these incidents required any special corrective manoeuvres once they had been identified.

### DISCUSSION

It is clear that anaesthetising the acutely injured patient can be very stressful. The high percentage of emergency ASA E codes (95%) bears witness to this (table 1). The “emergency” situation seems to engender a sense of urgency that may then lead to “corner cutting” in an attempt to save time; 39% of incidents seem to have occurred at least in part due to this situation leads to a failure of equipment. It is also crucial to note that on further analysis 11 of the 15 “corner cutting” cases were not

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**Table 1** Classification according to the American Society of Anaesthesiologists (ASA) function/risk status

<table>
<thead>
<tr>
<th>ASA status</th>
<th>Definition</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Healthy patient</td>
<td>11</td>
<td>29</td>
</tr>
<tr>
<td>II</td>
<td>Mild systemic disease</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>III</td>
<td>Moderate systemic disease</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>IV</td>
<td>Severe systemic disease</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>V</td>
<td>Moribund patient</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>E</td>
<td>Emergency cases</td>
<td>38</td>
<td>100</td>
</tr>
</tbody>
</table>

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**Table 2** Incidents related to “corner cutting”

<table>
<thead>
<tr>
<th>Incident related to “corner cutting”</th>
<th>n ( = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilator/circuit failure due to no/poor checking</td>
<td>6</td>
</tr>
<tr>
<td>Temp set too high on humidifier</td>
<td>1</td>
</tr>
<tr>
<td>Partial extubation during movement</td>
<td>2</td>
</tr>
<tr>
<td>Throat pack left in</td>
<td>1</td>
</tr>
<tr>
<td>Missed oesophageal intubation</td>
<td>1</td>
</tr>
<tr>
<td>Uncrossmatched blood given</td>
<td>1</td>
</tr>
<tr>
<td>Nerve block wrong side</td>
<td>1</td>
</tr>
<tr>
<td>Suxamethonium given by mistake after intubation</td>
<td>1</td>
</tr>
<tr>
<td>C1 fracture missed pre-op—not viewed by radiologist</td>
<td>1</td>
</tr>
</tbody>
</table>

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**Table 3** Role of the various elements of COVER ABCD in discovering, diagnosing, and correcting incidents

<table>
<thead>
<tr>
<th>COVER ABCD Item</th>
<th>Discover</th>
<th>Diagnose</th>
<th>Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circulation (C1)</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Colour (C2)</td>
<td>9</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Oxygen (O1)</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Oxygen analyser (O2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ventilate (V1)</td>
<td>12</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Vaporizer (V2)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Endotracheal tube (E1)</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Elimination (E2)</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Review monitors (R1)</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Review equipment (R2)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Airway (A)</td>
<td>2</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Breathing (B)</td>
<td>1</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Circulation (C)</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Drugs (D)</td>
<td>0</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>No success</td>
<td>7</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Total number of cases</td>
<td>38</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

**Table 4** Classification of reports according to the algorithm or sub-algorithm that definitively addresses the presenting incident

<table>
<thead>
<tr>
<th>Algorithm/sub-algorithm</th>
<th>n ( = 38)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>COVER ABCD</td>
<td>25</td>
<td>66</td>
</tr>
<tr>
<td>Desaturation*</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Trauma</td>
<td>8</td>
<td>21</td>
</tr>
<tr>
<td>Bronchospasm</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Embolism</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Hyperthermia</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

*All desaturation cases would have been addressed by COVER ABCD.

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**Table 5** Breakdown of incidents addressed by trauma sub-algorithm

<table>
<thead>
<tr>
<th>Trauma sub-algorithm incident</th>
<th>n ( = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lacerated intrathoracic trachea</td>
<td>1</td>
</tr>
<tr>
<td>Broncho-pleural fistula</td>
<td>1</td>
</tr>
<tr>
<td>Hyperkalaemia after head injury</td>
<td>2</td>
</tr>
<tr>
<td>Uncrossmatched blood given*</td>
<td>1</td>
</tr>
<tr>
<td>C1 fracture missed pre-op</td>
<td>1</td>
</tr>
<tr>
<td>Nerve block wrong side*</td>
<td>1</td>
</tr>
<tr>
<td>Hypotension due to incorrectly used MAST suit</td>
<td>1</td>
</tr>
</tbody>
</table>

*Incident which can be addressed simply by being recognised.
Key messages

- There were 38 reports relating to trauma in the first 4000 incidents reported to AIMS. Eight (21%) of these involved children less than 14 years of age.
- These trauma cases related to incidents in which either the trauma may have contributed to the incident or the incident occurred in an acute trauma setting.
- Hypoxia/desaturation was the commonest occurring clinical incident (53%).
- Fifteen incidents (39%) involved unjustified “corner cutting”, where the level of urgency appeared to be more perceived than real. The commonest “corner cutting” incident was ventilation/circuit failure due to no/poor checking.
- ASA grades I to IV were almost equally represented among the 38 cases; 36 cases were emergencies, with three moribund cases.
- A specific trauma sub-algorithm was developed based on the widely accepted Early Management of Severe Trauma (EMST) course principles and its effectiveness was tested against the reports.
- The COVER ABCD core algorithm discovered 82%, diagnosed 68%, and corrected 66% of the trauma incidents.
- The application of several sub-algorithms from this series of papers, including the proposed trauma sub-algorithm, would have corrected the remaining incidents in this trauma series. The sub-algorithms that definitively addressed the presenting incident were: desaturation in nine cases, trauma in eight cases, embolism in two cases, and bronchospasm, hypothermia, and hyperthermia in one case each.
- The single largest contributor to the successful correction of the trauma incidents was “ventilate by hand” (V1) in COVER.
- Although consistency with current EMST principles is important, a larger series of trauma incident reports is needed for ongoing validation and revision of the protocol.

shown to be time critical. The use of the ASA E code causes the patient to be labelled as either “elective” or “emergency”. This “black and white” classification does not accord with reality, as there is clearly a spectrum of cases ranging from the true elective case to the true emergency. Thoughtful and careful attention to management may not be compatible with haste. A good example of this is acute trauma, where it is appropriate, even advantageous, to use a regional block for analgesia before surgical intervention. This again supports the view that trauma incidents have their own pattern and require the application of a specific trauma sub-algorithm. Given the small number of trauma cases, it is not possible to make much comment on the use of sub-algorithms in this 34% of the 38 trauma cases, other than to say that all cases would have been addressed if the trauma sub-algorithm had been used correctly (table 4).

EMST elements (fig 1, left panel) have been used to compose the acute trauma sub-algorithm by transposing them to the operating theatre environment. However a major issue in developing and testing the acute trauma sub-algorithm has been the infrequency of reported trauma incidents that relate specifically to the injuries. Disregarding the failures of checking, there were only four problems identified (table 5). Accordingly although the proposed trauma sub-algorithm identifies a number of major trauma problems, it has not been possible to validate it by this review. The number of relevant cases is still too small and clearly many possible problems which have been reported previously in the literature have not been reported in these 4000 incident reports. Equally, rewriting the algorithm to address only the trauma incidents found would leave major gaps when compared with well recognised and apparently uncommon problems. For example, the analysis of pneumothoraces in the first 4000 cases revealed that 24 were reported, with 17 associated with general anaesthesia, six with nerve blocks in the chest wall or clavicular regions, and one with an intercostal drain mishap, but although pneumothorax is a not uncommon trauma diagnosis, none were found among the trauma incidents reports. It is felt that it would be unwise to exclude pneumothorax from the trauma algorithm.

At this time, while the above data are insufficient to validate any trauma sub-algorithm, the sub-algorithm suggested (fig 1) is consistent with EMST principles currently used for management of acute trauma in the field and has successfully addressed the few trauma cases in the data. It will be appropriate to wait for further reports with a view to ongoing validation and revision as necessary.

Finally, it is important that a full explanation of what happened be given to the patient and that the problem be 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.

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REFERENCES