Conjunctival oxygen monitoring in the initial assessment of trauma

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SUMMARY

The purpose of this study was to evaluate the use of the conjunctival oxygen tension ($P_{c, O_2}$) monitor during the early assessment of injured patients in the A&E Department of a large District General Hospital. The conjunctival oxygen sensor provides a non-invasive continuous monitor of tissue oxygenation in the palpebral conjunctiva and has been shown to detect early hypovolaemia in animal and human studies. For this preliminary report $P_{c, O_2}$ was recorded with initial clinical findings, standard cardiorespiratory parameters (pulse rate, blood pressure, respiratory rate, Glasgow Coma Score) and final diagnosis. Low $P_{c, O_2}$ (less than 45 mmHg) was associated with hypovolaemia, reduced cardiac output and chest injury. Normal $P_{c, O_2}$ in patients with severe head injury requiring transfer to the Regional Neurosurgical Centre or patients from multivictim road traffic accidents (RTAs) indicated no early occult cardiorespiratory compromise and this was subsequently confirmed. Monitoring $P_{c, O_2}$ seems to provide a valuable adjunct in the initial assessment of the injured patient.

INTRODUCTION

Outcome in the severely injured patient is improved if cardiorespiratory changes are detected early and corrected. The detection of early hypovolaemia is especially difficult as changes may be subtle and attributed to other factors, e.g. anxiety or alcohol, by inexperienced staff. Classic hypovolaemic shock with tachycardia and hypotension may be delayed by compensatory increased peripheral vascular resistance until more than 30% of blood volume is lost with resultant hypoperfusion injury to the kidneys, lungs and brain, which adversely influences outcome. Invasive

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monitoring which would allow accurate assessment of the cardiovascular system is not normally appropriate in the initial assessment of the injured patient in A&E.

The conjunctival oxygen sensor (To2M: Biomedical Sensors/Shiley, Slough, U.K.) is a Clark oxygen electrode mounted on an acrylic conformer. After simple calibration this is stored in normal saline and inserted beneath the eyelids to place the sensor adjacent to the lateral superior palpebral conjunctiva, less than 30μm from the capillary bed. Local anaesthetic eyedrops may be required in the conscious patient to prevent blepharospasm. Following insertion, the sensor stabilizes within 90s and reacts to changes in PCO2 within 45s, providing a continuous non-invasive monitor of peripheral oxygenation. The normal PCO2 is 50–60 mmHg (5–10 mmHg less than oxygen tension in capillary blood). Following haemorrhage, peripheral vasoconstriction occurs and cardiac output falls. Peripheral oxygen delivery is decreased with a subsequent fall in PCO2. In dogs, Smith & Abraham (1986) found an 18% loss of blood volume caused PCO2 to fall by 27% whilst mean arterial pressure CMAP was unchanged. PCO2 was the first non-invasive variable to alter and changed simultaneously with invasively monitored parameters. Abraham et al. (1984) identified a ratio of PCO2 to arterial oxygen tension (Pao2) greater than 0.6 in normovolaemia, but in normotensive patients following a loss of 15% or more of blood volume, this ratio fell to less than 0.5.

RESULTS

Ten patients are reported from a 3-month period. The conjunctival oxygen sensor was inserted as soon as possible after arrival in A&E and PCO2 monitored until the patient left the Department. Arterial blood gas tensions were not recorded in all patients and the PCO2/Pao2 ratio was, therefore, not considered in this retrospective study.

DISCUSSION

Monitoring PCO2 proved to be of value during the initial assessment of the injured patient in A&E. Typical problems in victims of blunt trauma, where the significance of subtle changes in standard cardiovascular parameters may not be appreciated, were illustrated by Patient 1 (see Table 1). Although blood pressure was maintained during the 50 min of assessment, pulse rate rose to 108 min⁻¹, a degree of tachycardia often not considered significant and attributed to other factors, in particular anxiety. PCO2, however, fell from 44 to 23 mmHg during this period. At laparotomy over 21 of blood were found in the abdomen from splenic injury. In Patient 2, PCO2 fell in response to hypovolaemia due to haemothorax, multiple rib fractures and pulmonary contusion. Again standard assessment of cardiorespiratory status remained satisfactory despite these injuries. The validity of a low or falling PCO2 was not always accepted by admitting specialty staff, however in Patient 3 this observation supported the equivocal abdominal signs on examination and prompted
<table>
<thead>
<tr>
<th>Patient number</th>
<th>Age</th>
<th>Mechanism of injury</th>
<th>Initial Diagnosis</th>
<th>Blood pressure (mmHg)</th>
<th>Pulse (per min)</th>
<th>Respiratory rate (per min)</th>
<th>Glasgow Coma Score</th>
<th>P&lt;sub&gt;C&lt;/sub&gt;O&lt;sub&gt;2&lt;/sub&gt; (mmHg)</th>
<th>Final Diagnosis</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>Moped rider vs. car</td>
<td>Chest ? abdomen</td>
<td>138/73</td>
<td>92</td>
<td></td>
<td>15</td>
<td>44</td>
<td>Fracture left 8th rib</td>
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<td>Ruptured spleen</td>
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<td>2</td>
<td>39</td>
<td>Motorcyclist vs. tree</td>
<td>Chest/back ? abdomen</td>
<td>132/70</td>
<td>56</td>
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<td>15</td>
<td>23</td>
<td>Fracture left 5–9 ribs</td>
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<td></td>
<td></td>
<td>140/80</td>
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<td>Left haemotorax</td>
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<td></td>
<td></td>
<td></td>
<td>130/70</td>
<td>66</td>
<td></td>
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<td>Left pulmonary contusion</td>
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<td>Left knee ligamentous injury.</td>
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<tr>
<td>3</td>
<td>25</td>
<td>Car passenger Multivictim RTA</td>
<td>Head/chest ? abdomen</td>
<td>130/70</td>
<td>80</td>
<td></td>
<td>12</td>
<td>32</td>
<td>Fracture right 2–8 ribs</td>
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<td>Fracture left 2–4 ribs</td>
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<td>Ruptured left diaphragm</td>
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<td></td>
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<td>Fracture pubic rami (3)</td>
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<tr>
<td>4</td>
<td>48</td>
<td>Motorcyclist vs. car</td>
<td>? chest</td>
<td>170/110</td>
<td>60</td>
<td></td>
<td>15</td>
<td>36–41</td>
<td>Fracture left 2–8 ribs</td>
</tr>
</tbody>
</table>

Table 1. Breakdown of patient information.
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| 5 | 26 | Fall through glass window | Penetrating anterior chest wound | 47/20 | 130
|   |   |   | Pericardiocentesis performed | 92 | 20
|   |   |   | Repeat pericardiocentesis | 90/60 | 15
|   |   |   |   | 130/90 | 15
|   |   |   |   | 80/50 | 15
|   |   |   |   | 100/60 | 15
|   |   |   |   | 125/65 | 15
|   |   |   |   | 120/65 |   |
| 6 | 25 | Car passenger vs. tree | ? head only | 100/60 | 50
|   |   | Pedestrian struck | ? head only | 125/65 | 12
|    |    | Cyclist | ? head only | 100/60 | 3
|   |   | RTA | Car driver-multivictim | 125/65 | 62
|   |   | RTA | Car passenger-multivictim | 125/65 | 55
|   |   |   | Head/ right femur | 120 | 50
| 7 | 89 | Primary head injury | Facial fractures | 130/70 | 50–55
| 8 | 55 | Primary head injury | Left intracerebral haemorrhage | 180/90 | 55
| 9 | 22 | Primary head injury | Fractured skull with cerebral oedema | 160/80 | 50
| 10 | 16 | Fracture right humerus | Fracture pubic ramus and acetabulum | 130/78 | 45–50
|   |   | Fracture right femur |   | 135 | 45–50

Myocardial laceration

Primary head injury

Facial fractures

Primary head injury

Left intracerebral haemorrhage

Primary head injury

Fractured skull with cerebral oedema

Fracture right humerus

Fracture pubic ramus and acetabulum

Fracture right femur
the surgical team to perform diagnostic peritoneal lavage, which was positive, and proceed to laparotomy.

The final diagnosis confirmed the combination of significant chest and abdominal injury.

In penetrating cardiac injury (Patient 5) $Pc_o_2$ reflected alterations in cardiac output, falling as tamponade developed and rising after pericardiocentesis.

Full assessment of the severely head injured patient is difficult and outcome adversely affected by undetected or inadequately treated hypoxia or hypovolaemia occurring in transit to a regional neurosurgical centre. Five seriously head injured patients in this study required transfer. In four patients, initial $Pc_o_2$ was normal but in Patient 10, with head and skeletal injuries, $Pc_o_2$ was marginally below normal values but remained stable. None later revealed previously undetected injury. Patient 8 was a cyclist found unconscious on the road beside her bicycle. The mechanism of injury was unknown, the implications for multiple system injury would have been greater had she been struck at speed rather than simply falling. $Pc_o_2$ was normal and the final diagnosis was of spontaneous intracerebral haemorrhage causing the fall (Table 1).

Rapid assessment of several seriously injured patients from multivictim RTAs increases the risk of significant injury being overlooked. Three such patients in this study demonstrated $Pc_o_2$ values which in Patient 9 were normal with isolated severe head injury, in Patient 10, were borderline but stable associated with head and skeletal injuries, and were low in Patient 3 described above.

There are disadvantages. There is, at present, no small sensor to monitor children under 12 years of age. Accurate assessment of the injured child is particularly difficult and this is a group prone to severe head injury. The aesthetics of inserting a sensor beneath the eyelids were initially problematic for some junior staff but rapidly overcome. Insertion of the sensor is contra-indicated in patients with pre-existing eye disease or injury, but does not interfere with observations of pupillary size and reaction.

The role of pulse oximetry to detect hypoxia due to airway or ventilatory problems remains, although the reliability of haemoglobin oxygen saturation measurement in hypovolaemia is not proved. The two modalities should be regarded as complementary, oximetry being ideal in the pre-hospital environment where $Pc_o_2$ monitoring is impractical, but both are appropriate during initial hospital assessment and inter-hospital transfer.

**CONCLUSION**

In this preliminary study monitoring $Pc_o_2$ proved to be a valuable adjunct in the early assessment of the injured patient in A&E. Low $Pc_o_2$ indicated the presence of hypovolaemia, reduced cardiac output or chest injury. Normal $Pc_o_2$ implied normal cardiorespiratory status but this observation should be carefully monitored and not regarded as an absolute exclusion of significant injury.

A further study is under way to establish: (1) the value of the $Pc_o_2/Pa_o_2$ ratio as a prospective index of injury severity; (2) the relationship between $Pc_o_2$ and
haemoglobin oxygen saturation in injured patients using pulse oximetry and; (3) how these observations correlate with the Advanced Trauma Life Support Course criteria for early hypovolaemia, i.e. tachycardia, delayed capillary refill, reduced pulse pressure, tachypnoea and altered sensorium.

REFERENCES
