MEDICAL SCENE RESPONSE
to the Entrapped Trauma Patient

"Good Evening, this is the 6pm news, I'm John Smith. Traffic on the M7 motorway remains blocked at this time while rescuers work to free a 23 year old man still trapped after a six car pile up nearly two hours ago. Meanwhile, in Canberra the Prime minister has announced . . ."

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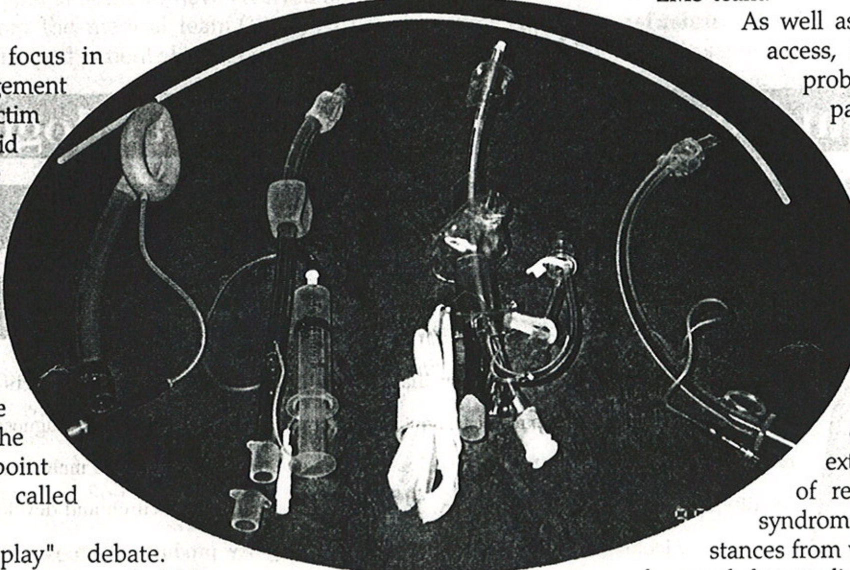
The predominant focus in prehospital management of the trauma victim has always been on rapid transport to definitive care usually with some degree of stabilisation and initial therapy at scene or enroute. Controversy still remains over the degree of stabilisation that should be attempted, and what the physiological endpoint should be - the so called "scoop & swoop" versus "stay and play" debate. However, the accident victim trapped within or beneath a vehicle or building cannot be immediately "scooped and swooped" to hospital, by the very definition of entrapment. Hence the emergency medical service team find their hands are forced. At least in the interim, they must adopt the stay and stabilise approach; whether or not this would otherwise be the ideal approach for this patient's injuries.

The entrapped patient also presents other special problems. Access, even visually, will almost certainly be incomplete. Hence a full assessment of injuries may be impossible and a treatment plan must be formulated with incomplete information, often by educated guesswork. Implementation of the treatment plan may also be limited by access, and interrupted at times by the conflicting priority of providing access for the extrication team. If the EMS team monopolises access, extrication may be prolonged almost indefinitely. Conversely if extrication proceeds with exclusion of EMS team access, life support priorities may not be met. Either way, the patient may die or deteriorate before completion of extrication. Access limitations include safety hazards well known to rescuers, such as electrical wires, fuel spills and other fire hazards, unstable vehicles, and broken glass or torn metal. As the victim cannot be removed from the hazard(s), these must be removed or neutralised to permit access by the EMS team.

As well as the practical problems of access, there are specific medical problems with the entrapped patient. Principal among these is the crush injury syndrome. This was initially recognised in people trapped during the London Blitz in World War II. It was noted that victims who had survived entrapment, often for prolonged periods, frequently died shortly after extrication. Others died later of renal failure. Crush injury syndrome is due to release of substances from within cells that are dead or damaged due to direct force and/or ischaemia.

The most significant and dangerous of these is potassium - present in high levels within cells, but normally only in much smaller concentrations in extracellular fluids. High serum levels of potassium or hyperkalaemia, particularly if the rise is sudden, will cause cardiac arrest. This rise is exacerbated by the acidosis which develops in ischaemic tissues. Also dangerous is the muscle protein myoglobin. Related to haemoglobin, myoglobin provides a reserve oxygen supply within muscle cells. When released into the circulation from damaged muscle, myoglobin, together with to a lesser extent haemoglobin from damaged red



Some of the airway devices that may be required in the entrapped patient: (top) flexible bougie; (then left to right) Laryngeal mask; Combitube and PTLA double lumen airways; and Endotrol nasaltracheal tube with 'ring pull' tip control and (orange) BAAM whistle airflow detector attached

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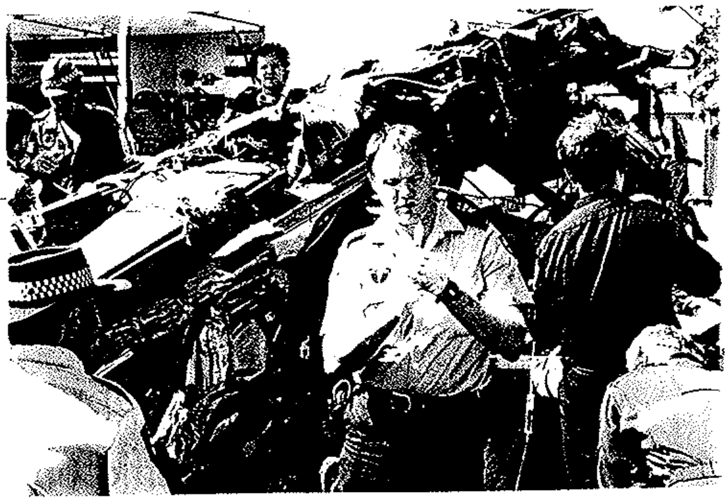
blood cells, is a potent cause of acute renal failure. This was formerly inevitably lethal. Since the advent of dialysis, it is recognised that acute renal failure can gradually resolve over a period of weeks; however mortality is still several times higher in trauma patients who develop it.

Other medical problems typical of entrapped patients relate mainly to the prolonged pre hospital times - meaning greater blood loss, more risk of hypothermia, more compromised tissue in wounds with consequent greater infection risk, and more chance of initially covert injuries becoming overt problems before arrival in hospital.



Spot the doctor! Barely visible to the left of the paramedic, as she works inside the vehicle to secure the patients airway;
(Far right) Helicopter transport enables a medical team to rapidly respond over a wide area

Are medical teams required for entrapment victims?

The entrapped patient is perhaps the paramount example of indications for a medically based critical care team at scene. The philosophy behind this is based on the observation that sometimes one cannot deliver the patient to the hospital as rapidly as one would wish - and therefore taking (many of the capabilities of) the hospital to the patient is the best option. There is little literature specifically on the subject of entrapment, although a recent position paper by the trauma committee of the Royal College of Surgeons in England mandates the use of a trained trauma doctor on scene for entrapments (1). In more general terms this is alluded to in the Australasian standards for transport of the critically ill (2). Disaster plans often call for medical teams, although some of these tend to focus overly on scene amputation as the principal on scene therapy in entrapment (3). A medical team incorporating both doctors and paramedics trained in confined space medical care is recommended as part of international standards for urban search and rescue (USAR) teams (4).

Other than in the disaster setting, a critical care team working prehospital is likely to come from an aeromedical transport service. Staffing of such helicopter services for critical care scene response has been controversial. In the USA, the primary patient attendants on most air medical helicopters are procedurally certified critical care nursing staff (5), often working under on line medical control from an emergency physician. By contrast, services in Europe almost universally utilise experienced emergency, critical care or trauma surgery trained doctors (6-8). Some Australasian medical rescue helicopter services utilise medical teams, others are staffed similarly to road ambulances.

Some studies from American air medical services show no

additional benefit (and no disadvantage either) conferred by a physician on scene (9,10); perhaps not surprising in a system which tends to emphasise rapid transport rather than field stabilisation, and where flight physicians tend to be junior residents, often restricted to the same protocols as the flight nurses. However, the only published controlled trial of staffing of air medical helicopters in trauma showed a 42% reduction in mortality with the use of a crew incorporating a senior physician (doctor) compared to nurse/paramedic crew on the same helicopters (11). More recently, comparison of scene response to trauma by two air medical helicopter programs, one American (nurse/paramedic staffed) and one German (doctor/ambulance officer staffed), showed reduced mortality in the latter (12). In both these studies the improved outcome was attributed to more aggressive management by the medical teams, and occurred despite longer scene times. The relevance of this to the entrapped patient scenario is obvious. A recent Australian study of paramedic helicopter scene response to trauma in Victoria, showed that 42% of unconscious patients were transported without definitive airway management - this having to be performed by the medical team, on arrival at the hospital (13). A study in NSW of medical team scene response to trauma showed over 80% of patients treated at scene to have received additional or revised treatment from the medical team.(14). Again, the implications for the entrapped patient should be noted.

The medical retrieval team approach to the entrapped patient

In the Greater Sydney region of Australia, medical support at the scene of trauma (entrapment or otherwise) is provided by the medical retrieval teams attached to the NRMA CareFlight and Westpac Lifesaver medical helicopter services. These teams are activated via the NSW Ambulance Service and can respond rapidly by either road (for short distances) or helicopter (for longer range responses, or when road access is impractical). Each team consists of a doctor who is a specialist or senior registrar in the critical care disciplines of anaesthesia, intensive care or emergency medicine, assisted by a senior NSW Ambulance Service paramedic from the Special Casualty Access Team. Additional medical or paramedical staff are sometimes also carried. The team is equipped with mobile intensive care monitoring and life support equipment and supplies, including Group O negative (universal donor) blood uplifted as required from the blood bank of the base hospital.

The principles of management of the entrapped trauma patient have been described (4). Over and above paramedic protocols, the medical team is capable of a wide range of treatment options which include:

- **Airway control and ventilation.** In contrast to cardiac arrest victims, many trauma patients suffer an intermediate level of coma that is profound enough to put their airway at risk but not deep enough to permit unmodified or "cold" intubation by paramedics. The medical team has the capability of using anaesthetic and muscle relaxant (paralysing) drugs to enable tracheal intubation and controlled ventilation. This is of particular benefit in head injury patients, where moderate hyperventilation may reduce the cerebral swelling and raised intracranial pressure that is the predominant problem in most such patients. Controlled ventilation may also be required in some chest injuries: such as flail chest, where the structural integrity of the chest wall is lost, impairing the patient's ability to draw breath adequately - a problem solved immediately by positive pressure ventilation; also pulmonary contusion and shock lung (ARDS), where positive pressure ventilation reduces the blood or fluid accumulation that impairs gas exchange across the lung, and hence oxygenation of blood. In all these cases there is positive patient benefit from instituting these measures sooner rather than later. In some entrapped patients, access may not permit conventional intubation. A range of other options is available to the medical team in these circumstances including: nasal intubation; the laryngeal mask airway; double lumen airway devices such as the Combitube and PTLA (Phryngo- tracheal lumen airway); and surgical airway by cricothyrotomy. (See photo). Each of these different techniques may be indicated in different situations, along with different drug regimes.

- **Tube thoracostomy or "chest drains".** Many lung injuries result in the leak of air or blood out between the lung and chest wall, hence partially collapsing the lung, and impairing adequate respiration. In extreme cases air under pressure completely collapses the lung and puts extreme pressure on the heart, resulting in effective cardiac arrest. This is called tension pneumothorax. The medical team approach is to insert large bore tubes into the chest for any suspected haemo- or pneumothorax (blood or air respectively) before a tension pneumothorax develops. These are connected to one way valves which drain the collection of air, blood, or both, and re expand the lung.

- **Blood transfusion.** While a certain amount of blood loss can be replaced by saline solutions or colloids (plasma substitutes), these replacement fluids contribute to neither oxygen transport nor coagulation (clotting). There comes a crisis point in ongoing haemorrhage where the oxygen carrying and clotting functions of the blood are diluted to the point of crisis. And while blood transfusion is itself not risk free, it is at this point that it may become literally life saving. (15). When blood is used, less overall volume may be needed. This may be valuable where intravenous access is limited, and also by avoiding massive saline infusions may reduce the risk of subsequent development of ARDS ("shock lung"). If near fresh blood is used it will also provide some platelets and clotting factors which may help prevent coagulation exhaustion.

- **Crush injury syndrome prophylaxis.** The pathology of crush injury syndrome has been described above. Various measures are available to the medical team to help prevent the (complete) development of the syndrome. Elective intubation, as described above, enables hyperventilation to reduce acidosis and hence potassium levels. Sodium bicarbonate is also effective in reducing acidosis, but only provided ventilation is adequate. An intravenous infusion of dextrose and insulin will help move potassium back into cells; while an infusion of calcium salts will partially protect the heart from the elevated potassium levels. The effects of myoglobin/haemoglobin on the kidney may be partially ablated by osmotic agents such as mannitol, and other diuretics, which increase urine flow and dilute the toxins.

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Blood transfusion is being administered as extrication proceeds

Administration of these requires careful judgement however, because mannitol itself in particular may be toxic if the kidney blood flow and urine output is already too low. Aggressive medical management at scene by Israeli medical teams according to these principles has been shown to significantly reduce the incidence of kidney failure (16).

- **Regional or general anaesthetic techniques.** Appropriate medical teams experienced in anaesthetic techniques can administer either general anaesthesia, or a regional (local anaesthetic nerve block) technique, to relieve pain and permit an extrication that might otherwise be impossibly painful for the patient. In our experience, effective anaesthesia often allows extrication without resorting to amputation. General anaesthesia will as a rule be combined with airway and ventilatory control, but where this is impossible "dissociative" anaesthesia with ketamine is an option. Ketamine provides sedation and analgesia while maintaining respiration and airway reflexes.

- **Surgical capability.** A limited surgical capability as provided by a medical team may be of value in several ways. While most external bleeding responds to direct pressure, bleeding from severed or torn major arteries may be almost impossible to control this way. Surgical haemostasis by identification, clipping and ligation of the offending vessels is the best option, especially as extrication and transport may interfere with maintaining pressure. Additional intravenous access may also be provided by either percutaneous central line or surgical cutdown techniques. These may be the only intravenous routes available if entrapment prevents access to other sites. Finally, but only as a last resort, amputation of a trapped limb may be required. As a rule this should never be performed unless skeletal and neurovascular integrity has been lost (i.e. all bones, nerves and vessels are already broken or severed, and only skin, muscle and tendon remain) - as such a limb is already only salvageable by microsurgical reattachment. The severed limb should accompany the patient, wrapped in a sterile saline moistened dressing and plastic bag, kept cold but not iced.

None of the above is unlimited - the medical, like the paramedical, team must work within the opportunities allowed by the particular rescue environment. However, the wider options and greater capabilities of the medical team also permit more aggressive management, especially with procedures such as airway control and chest drains. Such interventions can be performed semi-electively during a "window of opportunity" in the extrication process, rather than suddenly being required, at a potentially hazardous time in the extrication. The more advanced management also means patient stability is likely for longer periods of time. This may help take potentially hazardous haste out of the extrication. An effective medical team at scene may thus enhance the safety of all personnel and not just the patient.

The judgement capabilities of the medical team, and their familiarity with hospital capabilities and procedures may also enable the patient to be triaged to the most appropriate trauma hospital, on the basis of their particular condition, special interests and capabilities of different hospitals, and bed availability. The on scene medical team can also most effectively communicate the patient's diagnosis, status, and progress directly to the receiving medical team, thus expediting the preparation for the patient's management on admission.

One of the characteristics of an ideal prehospital trauma system is that it should provide seamless integration of care from accident site all the way to trauma hospital. The use of a medical retrieval team at scene can make a major contribution to this for entrapped patients.

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"An effective medical team at scene may thus enhance the safety of all personnel and not just the patient"

CASE STUDY I

A thirty four year old woman was the driver of a minivan which collided with a train at a level crossing. She was trapped upside down in her vehicle; her legs both crushed and partially impaled.

A medical retrieval team was responded by helicopter. Assessment by the medical retrieval team revealed a patient still trapped, with a slowly decreasing level of consciousness, and with compensated but progressive shock from ongoing blood loss, both internal and external.

After full cervical spine immobilisation, elective intubation was performed using sedative and paralytic agents. This provided airway protection, and allowed controlled hyperventilation for her head injury, and as an adjunct to crush injury management. Additional colloid infusion, plus blood transfusion were given during the completion of the extrication process, some forty minutes. After extrication, a clinically fractured femur was immobilised in a transport traction splint, before loading into the helicopter.

Treatment continued and additional monitoring was instituted during the 10 minute, 35 km flight to the regional trauma hospital. Development of changes in the electrocardiogram were noted consistent with hyperkalaemia from crush injuries; these normalised with infusion of sodium bicarbonate.

On arrival at hospital she had a head and cervical spine CT scan, which were normal, before proceeding to theatre for laparotomy and orthopaedic surgery. This patient made a protracted but complete recovery from head, abdominal, and limb injuries.

CASE STUDY II

A thirty nine year old male building site worker was trapped by a falling wall when a factory under construction collapsed. He was trapped across the upper thighs and pelvis and facing prolonged extrication from beneath the concrete slab.

A medical retrieval team was responded by helicopter. Assessment by the medical retrieval team revealed a patient still trapped, in extreme pain despite morphine from paramedics, with significant electrocardiogram changes from hyperkalaemia, despite bicarbonate therapy. He also had a degree of hypovolaemia, which was expected to worsen markedly on release.

Initial treatment was with calcium, which'normalised the ECG changes, plus volume infusion. Cervical spine protection was applied followed by induction of anaesthesia, and intubation, without use of the usual muscle relaxant suxamethonium, as this could have worsened his hyperkalaemia; then with controlled mild hyperventilation, throughout the extrication process which took over ninety minutes. Additional IV access was secured with a central venous line, and additional volume given, including blood.

On release from the slab, as expected the patient developed a major arrhythmia (ventricular tachycardia) presumably secondary to hyperkalaemia which responded to calcium and bicarbonate therapy; as well as severe hypotension which was treated with blood and colloid/crystalloid infusions as well as stabilisation of extremely severe leg and pelvic fractures in a pneumatic antishock garment (MAST suit).

A paramedic from the scene was taken as an additional medical team member during the 11 minute, 35 km flight to the nearest major trauma hospital. The patient remained unstable throughout the flight, and sustained a further cardiac arrest shortly after arrival in hospital, from which he was resuscitated with difficulty. He had an extremely stormy initial course in hospital, complicated by renal failure, and was ventilated for over two weeks, but eventually made a partial recovery. Although not expected to ever walk completely unaided again, he was able to be discharged to further rehabilitation after multiple operations and over four months in hospital.

CASE STUDY III

A 65 year old woman was the front seat passenger in a car which left the highway at high speed, striking the mounting pole of a large road sign. The car was torn in half with the woman remaining trapped in the left half, with her right arm torn off and multiple other injuries.

A medical retrieval team was dispatched by helicopter and arrived just as the woman was released. She was conscious, but grossly shocked, with no recordable blood pressure at all, bleeding profusely from the torn stump of her arm in spite of direct pressure. She also had a massive flail chest with severe respiratory distress.

Initial treatment was surgical control of her haemorrhage by the doctor, clipping and tying off the bleeding axillary artery and vein while the paramedic placed intravenous lines. Blood transfusion was commenced, including additional blood brought from the local country hospital by police car. Then, with stabilisation of the cervical spine, she was intubated to provide adequate ventilation with her flail chest. Chest drains were placed on both sides to drain associated haemo- and pneumothoraces. Only after some 45 minutes at scene was she considered stable enough to transport. The amputated arm was transported also, kept cool in the (now empty) "blood esky".

Ventilation, transfusion and monitoring were continued, and she slowly improved during the 29 minute, 95 km flight which bypassed the regional trauma centre in favour of another which had both cardiothoracic and microvascular surgical teams immediately available. This patient's progress was initially encouraging in spite of her massive injuries which also included a fractured neck and major facial bone fractures. It proved impossible to reattach her severed arm however. Unfortunately she developed renal failure and other late complications and died a week after her injury. **R**