PREHOSPITAL CARE

A brief overview of personal safety at incident sites

V Calland

Emerg Med J 2006;23:878–882. doi: 10.1136/emj.2004.022624

Safety at the scenes of trauma is not routinely taught to ambulance crews or medical teams. This article considers identification of the various hazards at an assortment of scenes by looking for unstable energy sources. While no substitute for practical training and experience, it provides a concept around which safety awareness can be developed.

Every book on giving care to the injured emphasises scene safety, but nevertheless, every year some people die trying to save the lives of others, many others are hurt, and almost all emergency personnel will be able to recall a lucky escape from some kind of injury. What goes wrong, and how do you prevent such incidents?

In theory, accidents can be prevented by ensuring a safe working place and a safe working practice.¹ If this truly were possible then personal protective equipment (PPE; helmet, goggles, etc) should be unnecessary, but unfortunately, at accident scenes both safe working place and safe working practice can be unavoidably compromised, so appropriate PPE is essential. In the UK, the employer is legally responsible for providing PPE that is both appropriate and fit for purpose, and to provide training in its use.² There is, however, no consistency between services as to what constitutes necessary PPE. Some ambulance services offer stab vests to their paramedics, but they are only worn when there is felt to be a risk.³ This attitude does not appreciate that the major cause of injuries is the failure to perceive the risk until it is too late.

Few, if any emergency personnel wish to injure or kill themselves. Rescuer injury does not occur because the individual knowingly sacrifices themselves, but because they do not recognise the danger they are in. While fire crew will try to protect those at an incident, they are not always in attendance when the first paramedic or doctor arrives, and even when they are there they can be distracted by problems that only they are equipped to tackle. Everyone in the emergency services must be able to recognise potential dangers for themselves, but, given the wide range of environments in which accidents can occur, the question is how to provide the appropriate training.

Injury occurs when there is an excessive application of energy to living tissue. This energy may be in any form, with kinetic, chemical, thermal and electrical being the most common. At the scene of an injury, there is the potential

for unstable energy sources. They may be clearly apparent as violent assailants, puddles of leaking corrosives, flames, or exposed electrical wires, or they may be more covert, such as an unstable wall, an undeployed vehicle air bag, or a high tension cable that can be re-energised without warning. The identification of these sources not only requires the discipline to look for them, but also sufficient general knowledge to be able to identify their existence. In this respect, the individual who is interested in how things work has an advantage. The rest of this article will look at three specific situations in which the ambulance and medical staff may arrive first at the scene, and will try to give an overview of some of the inherent dangers. It is impossible for this paper to be either exhaustive or unchanging; like safety at an incident scene, the subject as a whole is dynamic and ever evolving. No consideration will be given to the risks that are common to handling patients and sharps in ordinary clinical practice, as this should already be part of any responder's training.

EN ROUTE TO THE SCENE

The occasional responder is more at risk at this time than the emergency service worker who is on a regular shift, as excitement and anxiety tends to be greater; however, anyone can experience the "red mist" that creates a tunnel vision effect. The old adage of "Keep your tank full and your bladder empty" is sound, but understates the case. A moment or two of preparation, particularly a quick snack if the call will mean missing a meal, can make a considerable difference to performance at the scene. Unless you receive a call while actually driving, it is always advisable to put on your PPE before setting off, as the temptation to rush to help on arrival makes it unlikely you will put it on while you look at the carnage. Make certain you know where you are going. Satellite navigation is valuable, but will take you by what appears to be the shortest route on a map, not necessarily the fastest or safest one.

Driver training standards are now specified by the National Health Service, and all drivers who respond using blue lights should receive certified training to this standard.⁴ As you near the reported site, be cautious, as initial reports may have given the wrong location, and whatever road or weather conditions contributed to the accident will also have an effect on you. On arrival, think where you can park so that you will not cause an obstruction or put your vehicle in danger (fig 1), but you will still have ready access to the equipment it carries. Report your arrival to your control and to other personnel on site.

Correspondence to:
V Calland, 48 Broadgate,
Preston, Lancashire, PR1
8DU, UK; vic@
victorcalland.co.uk

Received
25 November 2004
Revised 25 October 2005
Accepted 25 October 2005

Figure 1 The driver of this rapid response vehicle parked close to have access to his equipment while treating the driver of the overturned fork lift. Unfortunately, he also parked in the path of the leaking battery acid, and found his vehicle had become part of a chemical incident.

MOTOR VEHICLE CRASHES

Over half of immediate care callouts are to motor vehicle crashes (MVCs). The commonest cause of traumatic death to rescuers attending road crashes is due to having their own crash while en route, but the commonest cause of injury, after muscle strain, is being cut by broken glass. A previous article concentrated on road crash extrication so this will not be considered here.

There is a mental discipline to be adopted when approaching any casualty at an incident: "Look from the outside inwards, and then from the inside outwards". The looking from the inside outwards relates to casualty disentanglement, extrication, and evacuation and was covered in the previous article. Scene safety relates to looking from the outside inwards.

Look for the energy sources

Kinetic energy

From outside the incident scene there is the possibility of kinetic energy—for example, a driver failing to see the accident and ploughing into it. Your car parked in the "fend off" position may reduce the risk of a car crashing in to you, but even a fire pump can be pushed a considerable distance by a 30 ton heavy goods vehicle. Your personal protection is best served by total road closure, but this may increase the risk to other road users and the police have to balance the risks.

Looking at the vehicles themselves reveals a profusion of energy sources:

Potential energy

Vehicles may be at rest, but their stability can be uncertain. Partially over parapets, over-riding each other, or on embankments, a vehicle's potential energy is easily converted to kinetic. Stabilisation by chocks, step blocks, ratchet straps, and cables may all be necessary before the vehicle can be entered and worked upon. Like all safety issues, vehicle stabilisation is a dynamic process – rescuers moving in the vehicle and the removal of parts of the bodywork, as well as external factors, can all change a stable environment.⁵ If first on scene, at least apply the handbrakes.

Potential energy is also within the structure of the vehicle. As the bodywork deforms on impact, energy is transferred to the metal, which bends until the elastic limit is exceeded, at which point the metal buckles and the process repeats until the applied force ceases. As fire crew start to dismantle the

vehicle, components under stress may suddenly spring free. While helmets and impact grade eye protection are inconvenient to wear within the confines of a vehicle, it is foolhardy to remove them.

In modern soft top cars, automatic rollover protection bars may also be present (fig 2). These are located behind the seats and are spring loaded. They are designed to deploy if the angle of the car exceeds preset limits.⁶ They have been known to deploy during rescue, and for this reason, stabilisation of the victim's cervical spine should be from the side in such circumstances.

The most common cause of rescuer injury at MVCs is broken glass. Procedures designed to reduce this are collectively known as glass management. At present, all passenger windows fitted to cars are made of toughened glass (which is treated to break into small pieces without sharp edges), and motor vehicle manufacturers are now fitting laminated glass (which is interlayered with plastic or resin and designed to hold the pieces in place even if the glass is shattered) to all windows. This reduces car theft from broken passenger windows, and reduces injuries should the occupant's arm, leg, or head fall out of the vehicle. It may also reduce the number of people being thrown from the vehicle. However, it poses new problems for the emergency services; while a spring-loaded metal punch or "life hammer" will break toughened glass, the only realistic device for medical personnel to use on laminated glass is the Glas-master® (Wehr Engineering; www.glasmaster.com).⁷

The most common hard protection for rescue personnel is a teardrop shaped perspex sheet that will deflect any projectile. Soft protection has traditionally been a salvage sheet, but these are also used to cover dead bodies, and the claustrophobia induced while underneath one is not helpful to the casualty, apart from the fact that the darkness does not permit casualty assessment. It is better to use the type of sheeting found on scaffolding, which is tough but translucent.

The use of hydraulic cutting equipment has revolutionised rescue techniques, but it introduces its own hazards and problems to the accident scene. Because of the tempo needed for the "Platinum Ten Minutes" (the time allotted for emergency assessment and intervention) to be achieved, non-fire fighters need to be aware of the actions of the tool operators to minimise risk of accidents.

There are three key phrases that ambulance and medical personnel may need to use during the rescue:

- Shut down. This means the sources of noise need to be turned off, usually to allow assessment of breathing with a stethoscope.

Figure 2 Undeployed "active roll over protection" bars behind the rear seats of a Volvo.

- Rest. This requires all rescue activity on the vehicle to cease in order to prevent any jarring movements that could foil a medical procedure such as cannulation.
- Stand clear. This is to provide space for a particular manoeuvre.

When using hydraulic cutting equipment at an incident, the fire service try to keep all unnecessary equipment and personnel 2 metres away from the incident.⁸ This should also apply to ambulance crew and medical kit, as the intention is to remove trip hazards and allow room for the casualty to be removed from the vehicle. The pumps for the equipment can create pressures up to 720 bar, and the load applied can be around 7 tons. Blade failure is rare, but I have seen it happen, and have learnt always to wear both safety glasses and a visor. As the tool operates, parts of the vehicle itself may become a projectile unless restrained, and objects such as doors will fall to the ground on an unsuspecting foot unless supported. The skilled operator will never place himself between the tool and the vehicle, as the tool can twist and trap him. The paramedic who realises this will have moved to allow the tool operator into the scene, and save time. The hydraulic hoses themselves should not be trodden on, but stepped over. They are very resilient, but the pressures they withstand merit respect. Fire fighters have suffered catastrophic oil injection injuries after previous misuse has damaged the hose. The tool should never be put down on the ground with the blades apart, and should never be picked up by the blades.

Chemical energy

Obviously most people immediately think of petrol and the risk of fire, although it is less common for cars to burst into flames on impact than film makers would have us believe. It is certainly rare for cars to catch fire after the rescue has begun.⁹ Nevertheless, all response vehicles should be equipped with a dry powder extinguisher of at least 2 kg capacity. Dry powder is good at putting out flames but does not cool the materials, and so re-ignition can occur. Several extinguishers may be required before the fire service arrives. Diesel fuel is less flammable, but like oil, turns the road in to a nightmare skating rink, particularly in the presence of rain.

Liquefied petroleum gas (LPG) is less frequently considered as a fuel. This heavier than air gas is increasingly used in dual fuel cars and occasionally as a sole fuel source. It evaporates as rapidly as ethyl chloride, causing similar freezing effects, and is also extremely flammable. The LPG tank is usually in the rear of the car, so the possibility of leaking LPG should be considered with collisions from the rear.

There is a range of corrosives in a motor vehicle, ranging from battery acid to the caustic brake fluid and so dripping fluids in overturned vehicles should always be treated cautiously. The greatest danger, however, probably comes from the loads that vehicles carry, as this encompasses the entire chemical and biohazard range. These products should be identified by appropriate warning signs, but this assumes compliance with the regulations (fig 3). Furthermore, it takes no account of what happens when chemicals mix as the result of the accident. When commercial vehicles are involved

Figure 3 An assortment of hazard signs. Test your knowledge (answers at the end of the article in appendix A).

in accidents, thought must be given to the nature of the load at an early stage.

A potent chemical introduced by ambulance personnel is often not considered at all. We all know that oxygen has the potential for turning a spark or smear of grease into a fire, but few rescuers think of the problems of oxygen in a confined space. At a flow rate of 15 l/min, we are putting effectively 3 gallon buckets of oxygen in to the car every minute, and a concentration of oxygen >23.5% is considered to increase the risk of fire. At present, a serious accident will almost certainly break the toughened glass in the side windows and ventilate the car, but as mentioned above, motor manufacturers are increasingly putting laminated glass in side windows, which, although it may crack, will not fall out. Thus, it is imperative always to ventilate confined spaces when oxygen is in use.¹⁰

Throughout modern cars, there are explosives. These deploy the air bags and seat belt pre-tensioners, and are designed to save lives. The design of the system, however, is such that not all airbags will necessarily deploy in an accident. If the system were undamaged, it is unlikely that further airbags would spontaneously deploy after the crash, but not only can the system be damaged and therefore be unstable, but the process of cutting the vehicle apart can short circuit live leads from other devices with the air bag wiring. There are devices that can protect rescuers from spontaneous steering wheel air bag deployment, but these only work for the airbag in the steering wheel and only if the wheel is intact. Disconnection of the battery does not immediately remove the risk as there is a residual electrical charge left in the device. Not only that, modern cars often have an auxiliary battery fitted, and indeed, disconnection of the battery could prevent the necessary movement of windows and seats during extrication.¹¹ American firefighters are taught the "5-10-20" rule: keep a minimum of 5 inches away from a door or seat airbag, 10 inches from a steering wheel airbag, and 20 inches from a passenger air bag (the distances are the same for European cars, but the numbers are not as memorable when converted to centimetres).

Thermal energy

While engine, brakes, and exhaust systems can be very hot to touch, the greatest risk is obviously from fire. This is usually started from the flammable fuels around the vehicle, and has already been discussed under the heading "Chemical energy".

Electrical energy

Until recently, cars had just two electrical power levels, the 12 V heavy duty power circuit and the high voltage leads that produce the spark at the spark plug. Dual fuel vehicles using battery power as the "around town" energy source have banks of battery cells that produce a direct current voltage double that of mains electricity. The manufacturers recommend the removal of the ignition key as the method of isolating the power, otherwise the internal combustion engine can start automatically.¹² Ignition keys are not always apparent, however (fig 4).

RAIL INCIDENTS

Network Rail (the body responsible for the maintenance of the UK rail network) have produced a CD with safety information for the emergency services. It is well worth obtaining access to a copy.¹³

Kinetic energy

The mass of a railway train is not to be argued with; from full speed, they can take over a mile to stop. Even when the power is cut, a train can coast for a long distance; possibly several miles if there are downhill sections. Do not go trackside unless your control has notified Network Rail.

Figure 4 A Renault Megane ignition key.

Ideally wait to liaise with the transport police or Network Rail personnel. If you really must go on to the railway, stay in the position of safety for as long as possible by walking in the “cess”; this is the area of wasteland beside the ballast (the chippings that lie beneath the sleepers). You should not regard the space between rails or the gap between pairs of rails as being safe. Be aware that bridges, tunnels, and cuttings may lack a position of safety on one or even both sides of the track. There is no absolute rule as to which direction a train may run on the tracks – look in both directions. If you do not have railway personnel with you, only leave the cess to save life, and only if no train or other hazards are present; do not work on the casualty in situ but immediately remove them back to the position of safety.

Potential energy

While walking in the cess, you will encounter many trip hazards and potholes. Concrete cable ducts are covered by small paving slabs, which are often unstable to walk on, and sleepers are often covered in oil and can be slippery. Most importantly of all, never put your foot between the blades of a set of points as these can be operated remotely and could trap you without warning.

In the event of a train accident, a major problem is that of access to the carriages, owing to their height. Carriage stability, ladders, and sloping walking surfaces all contribute to the hazards.

Chemical energy

One of the ways that trains are alerted to danger is by placing small explosive charges on the line, which are detonated when the front wheel of the train passes over them. These are carried in signal boxes and trains, and obviously can be a

serious hazard if there is a fire. When detonated by a train, shrapnel can be produced by these explosives, and you should stay at least 30m away from them.

A few carriages that have asbestos within the structure are still in service. This is only relevant in the event of a crash where cutting operations are necessary. Similarly, a few engines are still using chemicals in their motor units that can be very toxic in the event of fire. The range of chemicals that can be carried on goods trains further complicates the issue.

Thermal energy

The moving parts of trains get very hot indeed, but this only causes problems when it is necessary to get under a train to a casualty. Because of the speed, someone who stands front of a train usually ends up some distance behind it when it finally stops, although some body parts may be entangled into the train. On underground systems and trams, the slower speed at impact does mean the casualty may be under the carriages, and emergency personnel do need to crawl under the train. Minor burns are not uncommon when accidental contact is made with hot surfaces in such a confined space.

Electrical energy

The electrical power system of the railways is second only to train impacts in the number of deaths that occur. The vast majority of these people are unauthorised to be trackside and indeed many are deliberate suicides. Electrical power can be transferred to trains either by a conductor rail system or by an overhead system. Conductor rails can be identified as the third rail of a track (fig 5).

The rail is mounted on insulators and lies outside the running rails. The conductor rail carries 750 V direct current so you should not touch it or anything in contact with it, or step in any water in contact with it. You may step over it with care, but you should also step over the adjacent running rail at the same time. It is dangerous to put your foot between the rails. You should wait for the power to be switched off if it is a body recovery, but you may consider the use of an object made of non-conductive material to pull the person away from the rail if the life is salvageable. London Underground uses a fourth rail system, with the return rail being between the running rails. The live rail is usually furthest away from a platform, but this is not always the case.

The overhead line equipment is a power system in a completely different league (fig 6). This carries 25 000 volts and has to be treated with extreme respect. You should never come within 3 metres of the live cables as the power can and will arc across humid air. There is no alternative but to wait until it has been confirmed that the power has been switched off.

Figure 5 The third rail is clearly seen on the far side of the nearest set of running rails.

Figure 6 A web of overhead line equipment mounted on a gantry that can serve as a ladder for the suicidal.

Figure 7 Reproduced with permission from *Technical Rescue Magazine*,¹⁴ this scene is a tragedy in the making.

WATER INCIDENTS

Every year, the news bulletins contain the details of at least one tragedy where a rescuer has died trying to save someone who has drowned. A competent swimmer in a heated pool will find an entirely different scenario in open water.

Kinetic energy

The force of flowing water is frequently misunderstood. As the unwary rescuer enters a river, three processes are taking place that will begin to place them at risk. At the bank, the water flows more slowly, gaining speed towards the centre of the river, but as the rescuer moves deeper, more of their body weight is supported by the water and so the strength of their contact with the bottom diminishes. At 3 mph the water is applying a 7 kg lateral force on the rescuer, at 6 mph the force is 28 kg and at 9 mph it is 56 kg. In water more than knee deep, this force cannot be resisted and the rescuer will be swept off their feet.¹⁴

Potential energy

If the rescuer ties a rope around them, there is the danger it will snag on underwater obstacles and actually drag them below the surface. Under the water there can be both submerged obstacles that not only can cause injury but also become entangled. Submerged outflows can suck the person from the surface, weirs and waterfalls can have complex current patterns that trap a swimmer, and the person can also be trapped against obstructions to the current (fig 7).

Thermal energy

The sudden immersion in cold water causes 1–2 minutes of rapid respiration, cardiac arrhythmias, and poor muscle action even in strong swimmers, and during this time, they will be at the mercy of the water.¹⁵

There is absolutely no justification for emergency personnel who may work in close proximity to water not to be supplied with a personal flotation device. It is foolish to enter the water without proper training or equipment. The fire service, coastguard and Royal National Lifeboat Service all

have well developed water rescue protocols and it is now difficult to justify the risk of performing an unassisted swim rescue. The Royal Life Saving Society concept of “reach for a victim using a pole if necessary, throw a line if that is not possible, and then wade out no more than knee deep if appropriate to get extra distance to reach or throw the line” is as far as the unequipped and untrained rescuer should go.

CONCLUSION

This article merely touches on a subject that is relevant to everyone who works in the pre-hospital arena, but is rarely taught as a formal subject. Working safely relies on the right knowledge and some skills but above all the right attitude. Every situation is unique and changes with time. Formal policies can only go so far; rescuers need the training to perceive risks as they evolve and the skills to manage them.

Competing interests: there are no competing interests

REFERENCES

- 1 **HM Government.** Health and Safety at Work Act, 1974. London, HMSO, 1974.
- 2 **HM Government.** The Personal Protective Equipment at Work Regulations 1992. London, HMSO.
- 3 **Hull Daily Mail** 31 August 2004.
- 4 **Driving Standards Agency.** Blue light users working party expectations document. www.dsa.gov.uk/Documents/Blue_light/bluelight_users.pdf (accessed 17 August 2006).
- 5 **Watson L.** RTA. *Persons trapped. Vehicle accident rescue.* Halstead: Greenwave, 1990.
- 6 **Calland V.** *Safety at scene. A manual for paramedics and immediate care doctors.* London, Mosby, 2001.
- 7 **Advanced Automotive Glazing Manufacturers Group.** Laminated side glazing: essential information for emergency services. www.aagma.com.
- 8 **Watson L.** *Advanced vehicle entrapment rescue.* Halstead: Greenwave, 1994.
- 9 **Office of the Deputy Prime Minister, Department for Communities and Local Government.** *Fire statistics, United Kingdom 2001.*
- 10 **Royal Air Force.** Confined spaces training programme.
- 11 **Rescuers Guide to Vehicle Safety Systems 3rd edition Holmatro Inc.**
- 12 **Toyota Motor Corporation.** *Toyota Prius gasoline-electric hybrid. Emergency Response Guide (revised) 1991.*
- 13 **Network Rail.** *A clear case for safety, Training DVD.*
- 14 **Anonymous.** Firefighter dies attempting rescue during flood. *Technical Rescue Magazine* 2004;40:30.
- 15 **Institute of Naval Medicine.** *Cold water casualty, Video.* British Defence Film Library, 1990.

APPENDIX

Answers to the Hazard diamond question: (from left to right):

- A substance or article with a mass explosion hazard
- A flammable gas
- A poisonous gas
- A substance liable to spontaneous combustion under normal condition of transport, or when in contact with air, liable to spontaneous heating to the point where it ignites
- A corrosive substance that causes visible necrosis of the skin, or corrodes steel or non-clad aluminium.