

# ARMoured FIGHTING VEHICLE CASUALTIES

Commentary: JP Garner

This paper from the Professor of Military Surgery was based on his presentation to the Director General's exercise the previous year and set very firmly in the era of the cold war and planning for mass casualties as the Red Army swept across the German Plain. It evaluates the levels and types of casualties that might be expected when armoured fighting vehicles are defeated by drawing on two sets of historical data with the specific aim of deciding how many casualties each Field Hospital should plan for.

It is an interesting and highly influential paper and merits re-evaluation in the current climate of high tempo operations on two fronts both of which represent a significant threat from improvised explosive devices (IEDs) and explosively formed penetrators (EFPs). As detailed elsewhere in this edition, there are many similarities between these IED-EFPs and the classical military shaped charge munition characterised by the High Energy Anti-Tank round (HEAT). Whilst an interesting read, any attempt to extrapolate from this 30-60 year old data to today's conflicts is troubled by many confounding issues, not least that the armours being defeated then were at best homogenous rolled armour - essentially solid steel- whereas the advent of complex reactive armours will clearly change the likely behind armour effects. Colonel Owen-Smith offers a clear description of the three predominant forms of antitank missile - of which the armour piercing round (AFDS) and the HEAT round are of current interest. A true HEAT round penetrates armour at 10-15, 000m/s whereas AFDS rounds penetrate at much lower velocity but with greater mass, a scenario identical

to that identified by Morrison et al (1) when describing the current IED-EFP weapons being used against allied forces- thus it may be argued that the explosively formed penetrators of the terrorist IEDs, and their injury profile, lies further towards the AFDS end of the spectrum than with the HEAT rounds. As no clear open source data are available to detail the injury patterns from the two current operations this remains supposition but the 'elephant gun' approach of the IED-EFP may generate spall/fragment, burns but less primary blast injury than might be expected by comparison against HEAT / SC rounds. Owen-Smith describes a two-fold increase in the incidence of burns following AFDS rather than a HEAT penetration in WWII.

In summary, Lt Col Owen-Smith's paper reviews many issues that are potentially relevant today. His aim was to predict casualty rates in the next Great War, in that context it is outdated as the numbers of injuries per defeated armoured fighting vehicle are small and therefore in the insurgent campaigns of Iraq and Afghanistan are unlikely to affect casualty flow to a significant degree. However burns, blast and fragmentation injuries should all be expected. Perhaps when data becomes available from these campaigns we will be able to confirm the existence of the "Anti-Tank Missile Syndrome".

## References

1. Morrison JJ, Mahoney PF, Hodgetts TJ. Shaped charges and explosively formed penetrators: background for clinicians. *J R Army Med Corps* 2007; 153(3): 184-187

## Armoured Fighting Vehicle Casualties

*J R Army Med Corps* 1977; 123: 65-76

Lt Col Owen-Smith MS FRCS, Professor of Surgery, Royal Army Medical College

### Introduction

The war between the Arabs and Israelis in October 1973 resulted in the most extensive tank battles since World War II. Indeed in one area involved they were claimed to be the most extensive in Military history, exceeding the 1600 tanks deployed at El Alamein. In association with these battles some 830 Israeli tanks and about 1400 Arab tanks were destroyed. The Israelis have recorded data on the wounded from this war in a number of articles and presentations. The most striking figure is that just under 10 per cent of all injured suffered burns. Virtually all these burns occurred in Armoured Fighting Vehicle (A.F.V.) crews.

### The problems I want to discuss are:

- a. Does the total incidence of burns from major tank battles create a definite departure from previous experiences and must we, therefore, include this figure in pre-planning for conflict in N.W. Europe?
- b. Does the present range of anti-tank weapons pose a greater

threat to tanks and crew than those of 30 years ago?

c. Is there such an entity as "The Anti-Tank Missile Burn Syndrome"?

d. What medical lessons can we learn from this war that would benefit the treatment of war wounded in general, and A.F.V. crew in particular.

To give some idea of the overall medical problem we are likely to have to cope with in British Army of the Rhine (B.A.O.R.), we must take some approximate figures of the numbers of A.F.V. involved. In round figures we might say that we have about 650 main battle tanks, and well over 1000 armoured vehicles of all sorts such as light tanks, Armoured Personnel Carriers, self-propelled guns and armoured reconnaissance vehicles. This makes nearly 2000 A.F.V. overall. The one thing all these vehicles have in common is that they are protected by armour and, therefore, the crew compartments are restricted in size and are very rigid. The tanks, of course, carry these to extreme lengths in that the interior is smaller, they have much thicker armour and are very solid in construction.

The Arab-Israeli war involved some 1700 tanks on the Israeli side and both the tanks used and the anti-tank weaponry involved

Correspondence to: Maj JP Garner, c/o Editorial Assistant, Journal of the Royal Army Medical Corps, FASC, Slim Road, Camberley Surrey.

were basically similar to those that exist in N.W. Europe. Given this similarity to B.A.O.R. in terms of A.F.V. deployed and likely anti-tank weapons in use we might logically be able to draw some useful conclusions that will be of help in planning the distribution of resources to receive and treat the probable casualties.

To start with we need two figures. The total number of A.F.V. casualties predicted in B.A.O.R. and the predicted number per Armoured Division. It is this latter number which, of necessity, will be evacuated to a Field Hospital and that is a Unit whose work load we all understand.

Overall figures may be estimated at 7-800 A.F.V. and 1500 personnel. Armoured Division estimates—say about 250 A.F.V. and 500 personnel. All within the first seven to ten days. For comparison we should remember that the Israelis lost over half their tanks and a lesser proportion of their other A.F.V. in under three weeks, mostly in the first week.

### Casualty estimates

We have two main sources of information. First from World War II:—

The situation up to 1945 was reviewed by Captain H. B. Wright, R.A.M.C. and Captain R. D. Harkness, R.A.M.C. in a paper entitled "A Survey of Casualties Amongst Armoured Units in North West Europe" 1946 (Body Protection Committee Report 46/455). The authors were well aware of all the previous work done and their conclusions may be taken as representative of a formed opinion at 1945. The report is comprehensive and is a model of its kind. It deals mainly with an analysis of data obtained on 333 A.F.V. and 769 personnel casualties sustained by 19 British Armoured Regiments equipped with cruiser tanks between the Rhine crossing in March 1945 and the end of hostilities in North West Europe. This sample comprised all the casualties in tanks and crews sustained by those regiments during this period (Table I).

**Table I**  
**Threat to A.F.V.—333 Tank casualties (1945)**

Anti-tank missiles	Anti-tank mines	others
Armour piercing 41 per cent		
Shaped charge 33 per cent	21 per cent	2 per cent
High explosive 3 per cent		

For both Armour Piercing (A.P.) and Shaped Charged (S.C.) weapons the proportion of all hits that actually penetrated the tank was 50-60 per cent. Over half the tanks were knocked out by a single penetration. It was very rare to find any tank that had been hit more than once by a S.C. weapon, this was probably because they were, at that time, fired by the infantry who were in exposed positions.

Table II shows the distribution of armoured regiment casualties.

**Table II**  
**Armoured regiment casualties. Total 769**

Killed	Wounded	Inside vehicle	Outside vehicle	Partial exposure (12.5 per cent were officers)
37 per cent	63 per cent	50 per cent	40 per cent	10 per cent

The partial exposure figure is important because this was usually the tank commander and, therefore, contained a relatively high proportion of young officers. The casualties inside tanks were analysed (Table III).

Penetration by A.P. was associated with a higher incidence of burns than by S.C. weapons (Table IV).

**Table III**  
**Casualties inside tanks**  
**Total of 371 in 333 tanks (1945)**

Cause	Casualty rates (A.P. and S.C.)
Armour piercing 51 per cent	Killed 0.58
Shaped charge 37.5 per cent	Wounded 0.66
Mines 8 per cent	Burned 0.28
Others 3.5 per cent	Total 1.52 Per tank penetrated

**Table IV**  
**Incidence of burns inside tanks**

Cause	Burns	Deaths	Cause	All burns
Armour piercing 88 mm	18 per cent	41 per cent	Armour piercing	66 per cent
75 mm	19 per cent	26 per cent	Shaped charge	25 per cent
Shaped charge	6 per cent	22 per cent	Mines	9 per cent

Secondly we have information from the Arab-Israeli war:—

We have no comparable figures of the details of damage to A.F.V. and the breakdown of casualties. We know that 830 Israeli tanks were destroyed, but we do not know exactly how. According to contemporary accounts it is likely that a far higher proportion of tanks were destroyed by shaped charge weapons both close and medium range. An unknown number of other armoured vehicles were destroyed.

The total number of wounded was 8135. We were told that 9.3 per cent of these were burns and that almost all came from A.F.V. If we take this number to be 750 from 830 tanks we get the ratio 0.9 burns from each tank penetrated. This compared with the figure of 0.3 from 1945. There is no reason to believe that the number of A.F.V. crew killed and wounded but not burned would be very much different from the 1945 figures. We might, therefore, express this in round figures per tank penetrated as follows (Table V).

**Table V**  
**Israel casualty estimates A.F.V. (1973)**  
**(Per tank penetrated)**

Casualty	Total number	Casualty	Total number
Killed 0.6	500	Burned 0.9	750
Wounded 0.6	500	Totals 2.1	1750

These figures must be high because the A.F.V. other than tanks are not included. You will appreciate these are estimates but even taking into account the different type of tank and the crew numbers, nevertheless there would appear to be a definite increase in the numbers of burns casualties and possibly of killed in action and wounded per tank penetrated.

The increased number of burns might be attributed to the increased proportion of S.C. weapons used. In 1945, S.C. weapons caused only a third of the tank destruction and of casualties. However they caused many less burns per tank

destroyed than did A.P. shot. We must remember that the amount of explosive in S.C. weapons in 1945 were only 20 per cent of those in 1973 and that the spall fragment damage, the pressure and temperature effects are all enhanced with the heavier charges.

Of the 750 burns some 30 per cent were 3rd degree of full thickness, and about 7.5 per cent (say 50-60) had pulmonary problems. As I interpret the papers about 40 burned patients required tracheostomy and 12 required I.P.P.V., but another paper stated that 8 per cent of burns had I.P.P.V.—that is about 60 (Nagan).

## Types of injury

These may be divided into those that occur inside the tank and those that occur to the crew outside the tank:—

- a. Outside tank. About 40 per cent of total casualties. The threat is that of the usual battlefield weapons. Namely small arms fire and fragments of H.E. devices. We were told that some 85 per cent of casualties resulted from fragment injury overall presumably as opposed to bullets.
- b. Inside tank. The threat may be divided into:—(i). Anti-tank missiles, (ii). Anti-tank mines, (iii). Anti-tank obstructions.

## Anti-tank missiles

Anti-tank missiles are essentially of three types:—

- a. Armour Piercing Shot (A.P.D.S.) (A.P.F.S.D.S.).
- b. Shaped Charge (S.C. or H.E.A.T.).
- c. Squash Head (H.E.S.H.).

All these types of missile were in use to some degree in 1945 but what has happened in the intervening period is that the means of delivering them has been made more efficient and more versatile. They can now be delivered by:—

Hand held. Soft skin vehicles. Light armoured vehicles. Tanks, Helicopter and Aircraft.

The missiles themselves can be powered by recoilless charges, rockets or shells, they can be sighted before firing or they can be guided in flight—a true guided missile. The armamentarium covers close, medium and long range weapons.

Now how do these different types of weapons cause injury?

## Armour piercing

Essentially this is very hard tungsten carbide shot which is fired at very high velocity. This has sufficient kinetic energy to penetrate the armour of the tank. When it hits, it causes spall fragments (Scab) to be driven off the inside face at high velocities to create injuries, and the missile may ricochet around inside the tank. There is a high pressure and high temperature effect on the crew with resultant burns and lesser changes of hearing and lung function. They are also likely to set off the ammunition causing further damage. Such missiles are usually delivered by shells from anti-tank guns and the guns of tanks such as the chieftain (Fig. 1).

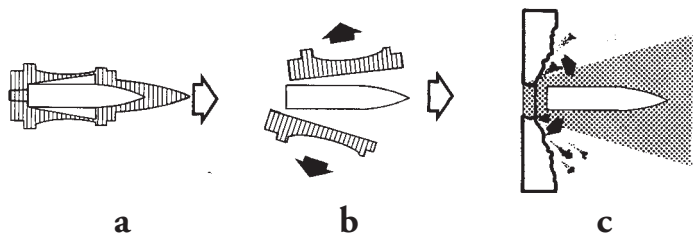


Fig. 1. Diagram of the mode of action of Armour Piercing Discarding shot (A.P.D.S.)

## APDS

### Shaped charges (S.C. or H.E.A.T.)

In August 1941 Zuckerman and Bernal carried out experiments



Fig. 2. Diagram showing the principles of the Shaped Charge Missile.

to determine whether shaping the explosive charges to give the “Munroe or Newman” effect could cause injury to the crew of tanks. The principle of the weapon is that the H.E. charge is shaped around a hollow conical metal liner usually made of copper (Fig. 2).

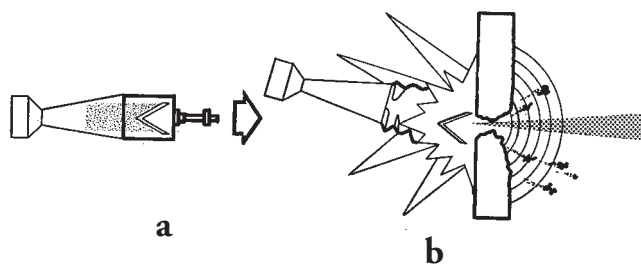


Fig. 3. Diagram of the High Explosive Anti-Tank (H.E.A.T.) Missile

When the front of the weapon touches the armour the charge is detonated at the “stand off” distance and the jet of hot gases and fine metal particles penetrates the armour (Fig. 3).

## HEAT

Spall fragments come off the inside of the armour, and as the jet enters the tank it expands rapidly causing a pressure pulse and a temperature pulse from the fireball effect (Figs. 4 and 5). In addition the explosive gases, smoke and combustion products form a pulmonary hazard.

These weapons have great penetration effects on armour, as it shown in the pictures of a direct hit on a tank (Figs. 6 and 7).

The shaped charge weapons come in various sizes from 50 mm (2 in) up to 150 mm (6 in). For example Law, Carl Gustav, R.P.G.7, Swingfire, Milan, anti-tank guns and guns on tanks.

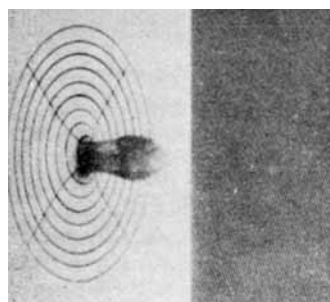


Fig. 4. High-speed photograph of the jet expanding into a steel chamber after penetrating armoured plate.

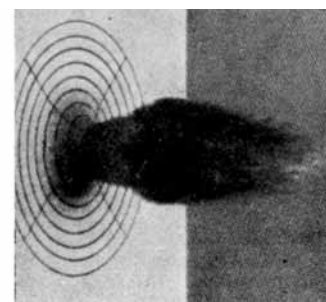
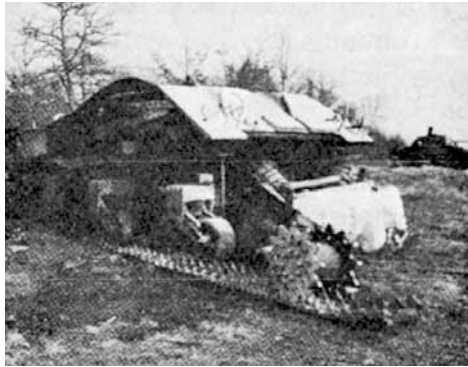


Fig. 5. The expansion of the penetrating jet at a later stage than in Fig. 4.

## Squash Head (H.E.S.H)

In this missile a charge of plastic type explosive squashes onto the outside of the armour and it is detonated. This results in a pressure wave causing spall fragments to come off the inside causing mainly high velocity fragment injuries, and the fragments cause burns and ignition of combustible materials (Fig. 8). Such a missile is used in the WOMBAT anti-tank gun and in the Chieftain tank.



Figs. 6 and 7. Tank before and after being hit by a H.E.A.T. missile.

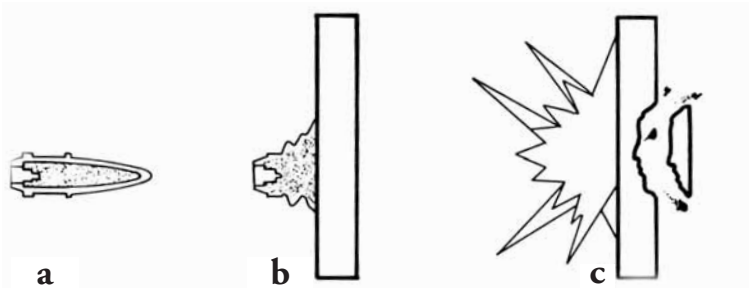


Fig. 8. Diagram of the mode of action of High Explosive Squash Head (H.E.S.H.) Missile.

### Anti-tank mines

By and large these only cause significant casualties if the charge is sufficient to breach the belly of the tank, or to accelerate it upwards to leave the ground. Many of the injuries are from crew being thrown around inside the tank.

### Methods of injury

The different ways in which various weapons cause damage are:—

- a. Blast—whole body, ears and lungs, b. Spall fragments, c. Flame—skin and lungs.
- d. Toxic gases—lungs, e. Light—eyes.

All must be considered when attempting to forecast the number of casualties, those killed, burned or with penetrating wounds, the type and distribution of the injuries.

### Experimental work

The physical effects of the different missiles on A.F.V. simulators has been investigated continuously since World War II. Recent emphasis has been on shaped charge missiles, perhaps because of the proliferation of small, easily carried and fired weapons. Such research from the medical point of view is designed to define the physical effects of the missiles upon men inside the A.F.V., to encourage methods of protection from such injurious effects and to establish the best methods of treatment to

alleviate suffering and promote healing and rehabilitation.

Research has been divided into several overlapping areas of missile effects:—

- a. The effects of blast in confined spaces, b. The effects of flash and flame, c. The effects of hot gases and vapours, d. The effects of penetrating and spall fragments.

### Blast

The damaging effects of blast are worse in confined space than in the open. The blast wave creates a blast wind of very high velocity and this may be sufficient to tear off parts of the body such as limbs. The positive pressure pulse has a direct effect on lungs causing contusion and haemorrhage to create the so called "Blast lung". It may cause closed abdominal injury such as visceral contusion or rupture at higher pressure levels. Mammals, including men, are very sensitive to the duration, magnitude, rate and character of the rise and fall of blast pressure. The animal's position, orientation and species difference all effect the tolerance to air blast. Although figures exist for tolerance to pressure—duration levels for air blast—little exists for penetrating anti-tank missiles. Work is being done on this at Porton and this graph shows a typical pressure/time curve, using 125 mm (5in) S.C. against 20 mm steel armour (Fig. 9).

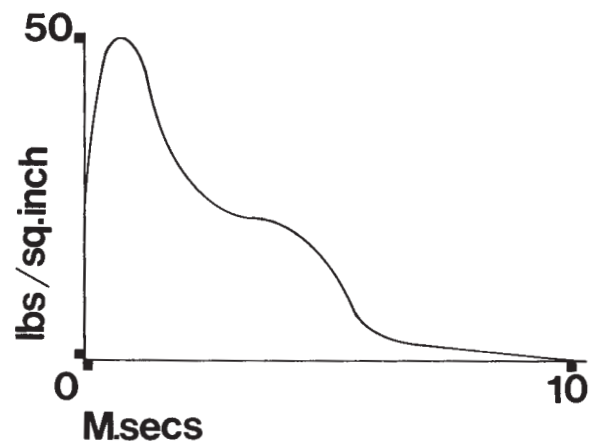


Fig. 9. Pressure—Time Curve inside a tank simulant after penetration of a Shaped Charge Missile

Calculations from air blast figures leads us to believe that 70 p.s.i. is the threshold for lung damage, and that 50 per cent fatality results from pressures of over 400 p.s.i. in the open. The figures for confined spaces would inevitably be lower than these.

The effects on ear drums and hearing are known, for ear drums start rupturing at 7 p.s.i. and even children's ear drums are ruptured by 30 p.s.i. In 1945 about 31 per cent of drums were ruptured or hearing impaired and in 1973 it was about 25 per cent.

### Spall fragments

The pattern of spall fragments for each weapon is known by the missile and fighting vehicle designers. The weight of the fragments and the pattern that occurs inside the vehicle may be defined in the spall 'cone' measurement to give some idea of the likely injuries to the crew (Fig. 10).

### Flame and heat

For unlimited exposure the threshold skin temperature is about 43°C. What matters is the temperature at the junctional layer of the dermis with the epidermis. An exposure time of 1 second to an ambient temperature of 45°C is sufficient to raise the junctional temperature to 43.3°C. This level is exceeded in this

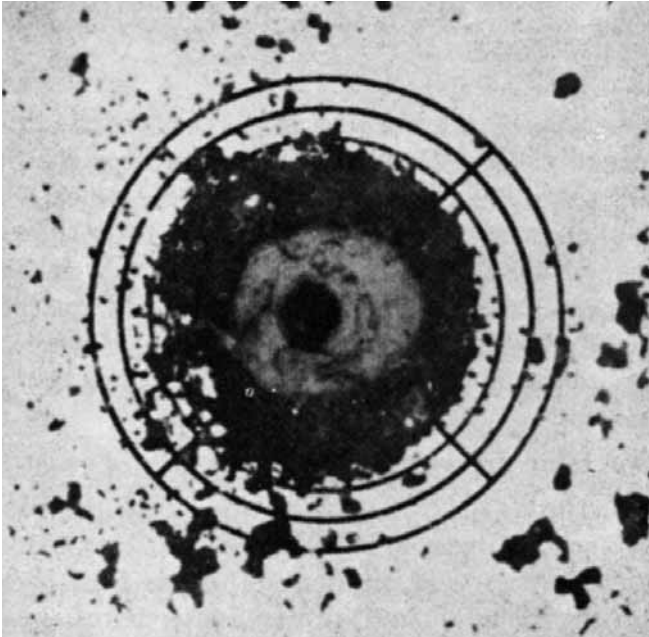


Fig. 10. The inside surface of a steel plate that has been penetrated by a Shaped Charge Missile. This shows the large amount of spall fragments that has come off the inside of the plate as a "scab" of metal.

Temp-Time curve of 125 mm S.C. attack on 20 mm steel armour, and burns would be likely to occur (Fig. 11).

### Hot gases

This heading covers the air in the tank heated by the missile effect, hot particles and vapours, and noxious gases both from the explosive penetration and from burning contents.

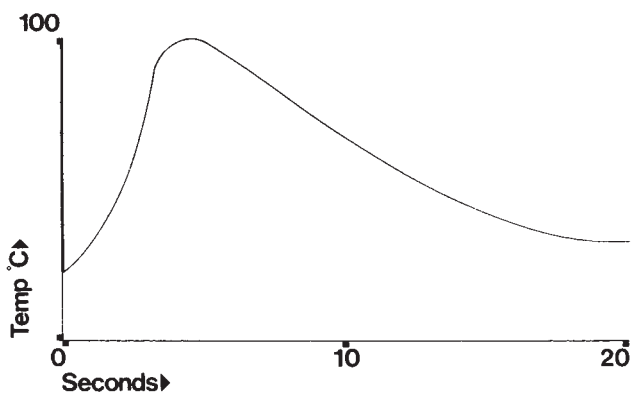


Fig. 11. Temperature-Time Curve inside a tank simulant after it has been penetrated by a Shaped Charged Missile

Thermal capacity of hot gas is low and most thermal effects will be experienced on the lips, mouth and pharynx. Experimentally it is difficult to induce pulmonary changes from hot gases unless the temperature is above 300°C. However, it is easy to induce lung damage with cold air and smoke. The respiratory syndrome reported in fire victims is usually from the inhalation of smoke, and identical syndromes with a typical delayed onset have been described in irritant gases such as ammonia, talc - particles and acid gastric contents. Similar pathology is described in all these cases of different aetiology namely, the trachea and bronchi show intense hyperaemia and oedema leading to progressive obstruction and pulmonary oedema.

These behind armour gases have been analysed in experiments at Porton to elucidate their toxic pulmonary effects.

Non-pulmonary thermal burns in general have a high incidence of respiratory insufficiency leading to pulmonary complications and, in addition, it has been found that there is an immediate reduction in the immunological response after burns.

One must always remember the reduction in oxygen content of the tank if the explosive, the metal fragments or combustible products utilise the ambient oxygen.

### Light

The brilliant incandescence inside the tank that is hit may well cause temporary blindness and therefore incapacitation. This would reduce mobility and greatly increase the chance of a further hit.

## Protection

### Personal

Overalls. Non-inflammable and flame retardant clothing can give effective protection to short duration exposure provided the applied heat is not too severe. The Israelis used 'Nomex' overalls which is a good non-inflammable compromise material in that it is practical to use. It gave good protection and certainly minimised burns as shown by the 50 per cent incidence of burns to hand and face. Body burns were much less than the 1967 Arab-Israeli war. Current development of protective clothing for A.F.V. crews is utilising similar materials.

### Helmets

These are required to give protection inside the tank simply as crash helmets, but the Israelis felt that there is a requirement for a helmet with Ballistic protection also. This was probably influenced by the injuries to the head of the tank commanders. A new A.F.V. helmet is being developed by S.C.R.D.E. Colchester.

### Gloves

These would certainly protect the hands and reduce the incidence of burns but there are big problems about making them acceptable to the crew. They are used, of course, by air-crew who face similar hazards from aircraft burns.

### Body armour

Current armour would give protection against low velocity fragments, and indeed is good protection when thrown around the vehicle. Suitable protection to thorax and abdomen against high velocity fragments could be given by ceramic plate inserts but at present these would be too heavy. The major problem would be the practical one of wearing cumbersome body armour within the confines of an A.F.V. Mention must also be made of the development of Chobham armour and the use of different tactics to combat the increasing effects of light anti-tank weapons, particularly guided missiles.

## Treatment of A.F.V. casualties

The main emphasis must be on the treatment of burns and of pulmonary complications, because the principles of penetrating wounds are well known to you all.

### Principles of burns treatment in the field

- Immediate resuscitation in the field using Hartmann's solution. Using this method the Israelis claimed no instances of hypovolaemic shock. About 70 per cent were superficial or deep partial thickness and 30 per cent full thickness or third degree. Half of the burns involved 20 per cent surface area or less.
- Evacuation to the Field Hospital with exposure of burns, the use of plastic bags for burns of the hands and feet and

attention to the airway.

At the hospital planned replacement of fluid loss using Dextran 110 as calculated. Assessment of pulmonary function followed by further evacuation to a burns unit. There the definitive treatment will be given both to the burned areas, and to the pulmonary problem after assessment with blood gases and pulmonary function.

- c. Burns—
  - i. Treatment by exposure.
  - ii. Closed dressings in certain areas.
  - iii. Skin grafting—meshing of graft—cadaver skin—lyophilised porcine xenografts.
  - iv. Silver sulphadiazine as topical agent.
  - v. Antibiotics and antifungal agents.
- d. Pulmonary problems. To be managed by an aggressive approach, repeated monitoring of arterial blood gases, early use of endo-tracheal tube and intermittent positive pressure ventilation with high oxygen concentrations, repeated endo-tracheal suction and the use of steroids.
- e. The management of severe burns pose great problems in the management of complications, reconstruction and

rehabilitation. The management of large numbers of burns pose equally important problems of first aid treatment and evacuation to major burns units.

## Conclusion

In conclusion then I might say in answer to the four questions I posed in my introduction:—

- a. There does appear to be evidence that a small but significant increase in burns from A.F.V. must be planned for. This should not exceed 1 per tank penetrated.
- b. The present range of anti-tank weapons does pose a greater threat to tanks and crew than in 1945. This threat is likely to increase.
- c. There is a combination of penetrating injuries, burns and pulmonary complications that warrants being called " The Anti-Tank Missile Syndrome ".
- d. The main lessons to be learned from the 1973 Arab-Israeli conflict involving A.F.V. casualties are those of early First Aid and resuscitation, attention to the airway, rapid evacuation to Specialist burns units, an aggressive approach to pulmonary insufficiency including I.P.P.V. and the concentration of medical expertise.