# UNIVERSITY COLLEGE
# OF
# RHODESIA

**FACULTY OF MEDICINE**

**POST - GRADUATE MEDICAL**
**EDUCATION COMMITTEE**

# MISSILE INJURIES

SALISBURY
1968

*University College of Rhodesia*

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# SYMPOSIUM ON MISSILE INJURIES

*held at the University College of Rhodesia*
*on the 4th November, 1967.*

**UNIVERSITY COLLEGE OF RHODESIA**
**SALISBURY**
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## FOREWORD

At a symposium arranged by the Postgraduate Medical Education Committee of the Faculty of Medicine the discussion was devoted entirely to Missile Injuries. Although the basic principles of military surgery have remained largely unchanged since World War II, a new generation of Rhodesian surgeons, nurses, and medical auxiliaries have grown up since the end of the last major conflict in which we have been involved. In the interim there have been major advances in the care of the wounded especially in the methods of resuscitation, primary care and evacuation as the result of further experience in Korea, Viet Nam and Israel. These abstracts from the papers and demonstrations presented at the Symposium are not intended to replace but to supplement standard works on military surgery. Stress has been laid on the lessons learnt in other countries about the importance of good primary treatment in those wounded by small arms fire. It is to be hoped that these papers may assist in reducing the morbidity and mortality of missile injuries in Rhodesia.

J. A. M. WHITE,
Chairman,
Postgraduate Medical Education Committee,
Faculty of Medicine.

## ADMINISTRATION OF RHODESIAN CASUALTY SERVICES

**Dr. M. H. Webster, O.B.E.**
**Secretary for Health**

The civil and military medical services of Rhodesia are closely integrated. Military medical services are based on the existing civil facilities. There is no need to provide for medical services beyond our borders because of the purely defensive role of the security forces.

Casualty services are based on the defensive role of the security forces operating on internal lines of communication. Locating the casualty, providing first aid and removing casualties from the field may be extremely difficult in our terrain. Immediate supportive measures in the field should be followed by rapid evacuation to a medical centre for further resuscitation and early surgical treatment. Definitive surgical care, rehabilitation and re-employment are the responsibility of a major surgical centre. Sophisticated means of transport may allow the immediate transport of a casualty to a major centre.

During defensive operations the provision of early and adequate surgery is dependent on the tactical situation, the intensity of the action, the number and distribution of the casualties and the sophistication of the weapons used. The arrangements for Field Surgical Units (F.S.U.) must be related to the dispersal of small numbers of troops over a wide area. The location and security of such units is governed by the communications of the security forces and nature of the enemy facing these forces. Under Rhodesian conditions the sole indication for providing a fully equipped mobile surgical team is a "boxed" defensive position. F.S.U. teams will be deployed to an established government, mission or industrial hospital close to the forward areas on the normal axis of communications of security forces in the rural areas. Such a hospital would provide basic facilities such as water, power and communications. Its surgical facilities would be supplemented by a surgical team capable of treating a casualty by further resuscitation and such surgical procedures as are necessary to save life, render early evacuation safe and comfortable and hasten complete recovery. Many of these hospitals have landing facilities for light aircraft and helicopters. Early surgical treatment can be assured at such a centre with adequate provision for the security of the wounded and medical personnel. Rapid evacuation to a major centre after primary treatment is ensured. Primary treatment in the field and immediate transport to a surgical centre is the responsibility of the military medical service. Surgical care in the forward areas and in the main centres will remain a civil responsibility.

The equipment of an F.S.U. has received study and will be discussed at this symposium. Arrangements have been made to standardise equipment and we will rely on normal sources for intravenous fluid, plasma and blood. Steps have been taken to ensure supplies of Group O blood in standard plastic packs of good quality and laboratory technicians will form part of the surgical team at F.S.U. level to perform emergency cross-matching of blood.

The use of sophisticated means of air transport of casualties is governed by the tactical situation. With small numbers of casualties a "one-stop" policy of evacuation to a major centre after emergency treatment is possible along internal lines of communication with air superiority. A "two-stop" policy could be dictated by a tactical situation involving larger numbers of casualties at a greater distance from a main centre. The use of light planes operating from landing strips would conserve valuable and limited helicopter facilities for immediate evacuation flights of short duration.

# WEAPONS AND BULLETS

**Chief Inspector D. Hollingworth**
**British South Africa Police**

In 1248 the ingredients of gunpowder were first described by Roger Bacon, who did not exploit its explosive properties as an offensive weapon. Hand cannons, using gunpowder, made their appearance in the 1300s, and the use of gunpowder was further developed through the centuries in the Matchlocks, Wheel-locks and Flintlocks with increasing range, accuracy and destructive power. In 1807 the percussion cap utilising fulminate of mercury was discovered, which heralded a leap forward in firearms efficiency.

In 1846 nitro-glycerine was discovered, but for many years its only application was in medicine for the treatment of angina pectoris.

In 1859 Alfred Nobel, a Swedish engineer, discovered a means of detonating this extremely powerful explosive, but it was too powerful to be used in small arms. In the late 19th century nitro-glycerine was brought under control for use in small arms by mixing it with cotton and vaseline. This was known as cordite, and is still used today.

In 1862 Dr. Richard Gatling invented a machine gun which would fire more than one round for each operation of the trigger. In 1884 Sir Hiram Maxim invented the Maxim machine gun, which was the prototype of the Vickers machine gun and still used today.

Improved weapons developed from the late 19th century onwards, not only increased the fire power of small arms, but also increased muzzle velocities to well beyond the speed of sound.

From medieval times the projectile fired from small arms was made of lead. But with high muzzle velocities it became necessary to jacket the lead to keep it from melting from the intense heat of the powder gases under high pressure and the friction of passing through the barrel at high speed. In the late 19th century a cupro-nickel jacket (60% copper and 40% nickel) was introduced in England, but this has now been replaced by gilding metal (90% copper and 10% zinc). Communist bloc countries use a cheaper alternative jacket of steel with a light copper coating to prevent rusting.

The wounding power of any bullet is most closely related to its energy of movement on impact. expressed in ft.-lbs., which may be calculated from the formula:—

$$\frac{\text{weight x velocity}^2}{\text{2 x acceleration of gravity}}$$

Therefore the energy of a bullet varies **directly** as to the weight, but with the **square** of the velocity. Example: a bullet weighing 100 grains and travelling at 3,000 ft./sec. would be nine times harder to stop than the same bullet travelling at 1,000 ft./sec. In other words, the heavier the missile and the faster it moves the greater is its wounding power. However, military and ballistic considerations over the last hundred years have led to a reduction in the weight of the bullet from 650 grains to 144 grains (British) and 122 grains (Communist); this reduction in size, however, has been accompanied by a steady increase in muzzle velocity. For instance, the muzzle velocity of the .303 rifle is 2,440 ft./sec., whilst the 7.62mm. F.N. rifle is 2,755 ft./sec. The Communist equivalent varies from 2,330 ft./sec. to 2,410 ft./sec. depending on the length of barrel from which fired.

In the early part of this century, explosive wounds were first noted. But extensive destruction along the path of the bullet through the tissues is not due to an explosion of the missile in the tissues. Explosive effects were first noted when velocities reached 2,300 ft./sec. and it would seem that this is the critical velocity where bursting effects begin. It is my opinion that the "tissue quake" caused by the passage of a bullet through tissue is caused by the bow wave forming at the nose of the bullet and not by the in-rush of air into the track behind the bullet.

Communist weapons with lower muzzle velocities are less liable to produce the explosive type of wound in soft tissue; however, the copper-clad steel jacket of Communist bullets are more likely to break up and could cause multiple exit wounds from a single entry wound. Tracer bullets, incorporating, possibly, barium, peroxide and magnesium powders, are being used in the magazines of Communist rifles, machine guns and pistols—and it is possible that these may also cause burning in the tissues.

As stated earlier, the penetrating power of a bullet is related to the square of its velocity on impact. A 7.62mm. F.N. rifle bullet has, therefore, a much greater penetrating power than the .303 or the Communist equivalent. A 7.62mm. F.N. bullet will pierce a ¼ inch steel plate at a range of 200 yards, and although the velocity of all bullets decreases as the range increases, the destructive power of the F.N. bullet in tissue is still tremendous at 200 yards.

Shotguns are used by security forces in serious civil disturbances, and when fired at a distance of less than 20 feet it is possible that three of the four pieces of wadding from the cartridge could be forced into the tissues with the shot.

A demonstration of British and Communist small arms used in engagements in Rhodesia followed.

## GRENADES AND ALLIED DEVICES

**Dr. R. S. Thompson**
**British South Africa Police**

The grenade in its present form was first introduced in World War I. The cast-iron cylinder has a firing-pin, handle and striker. The pin is removed on throwing the grenade and there is a 4-second delay mechanism before the charge explodes. Cast-iron fragments are carried into the tissues from a fair range. There is a Russian equivalent to the British cast-iron grenade but some modern Russian grenades are made from thinner pressed steel. Damage from a similar American grenade is increased by the inclusion of small steel balls within the casing. There is a 3-second delay on throwing these grenades which produce wounds by virtue of the small metal fragments rather than from the explosive charge. The size of fragment varies from an inch down to very small particles with very little penetrating power.

Offensive grenades have been introduced into the country. They differ from those previously described in that they have a thin metal casing and are designed to explode on contact. Removal of the firing-pin ensures explosion of the charge on contact. The thin metal or plastic casing does not blow-back on the thrower and damage is inflicted by the explosive charge. These grenades are designed for use at close range.

Anti-tank grenades are hollow-charge weapons designed for use at close range against armoured vehicles. Russian weapons of this type can penetrate ½ inch steel plate at 20 feet from the point of impact. The explosive charge is thrown forward, carrying steel fragments into the vehicle.

A demonstration of the type of grenades in current use was given.

## PATHOLOGY OF MISSILE TRACKS

**Dr. C. M. D. Ross**
**Government Pathologist, Harare Hospital, Salisbury**

A bullet crushes and tears the skin at the point of impact and the tissues in its path. Abrasion of the skin at the margin of the entry wound occurs.

Secondly, compression of tissue in front of the bullet generates a **shock wave** of spherical form which passes extremely rapidly, usually preceding the missile, and compressing and disrupting tissue in its path. Viscera containing air, such as gut, are most susceptible to damage by this wave.

Thirdly, when a high velocity missile traverses body tissues, the latter will be accelerated forwards and sideways with such force that their own inertia will cause particles of tissue to move away from the path of the bullet to produce a cavity. In ideal circumstances such a cavity is cone-shaped with the base nearer the entry point. This is called **temporary cavitation** and generally forms and partially collapses in about 1/50 second. Collapse occurs in a pulsatile fashion, initially at the wider ends of the cone. The cavity is an area of reduced pressure, and bacteria from the air, contaminated clothing or skin fragments may be drawn in. (The bullet itself may carry bacteria, since sterilisation does not necessarily follow heat generation in the barrel of the firearm.) Tissue disruption extends beyond the margins of the residual permanent cavity and is more likely to affect smaller vessels and nerves than large vessels. The damaged area may show altered staining reactions.

Where a great deal of energy transfer has to take place very rapidly, e.g., with a very high velocity bullet, possibly yawing, temporary cavitation may expand so much that the elasticity of the surrounding tissue cannot accommodate it. The resultant damage is explosive in character, e.g., burst skull.

Apart from the missile mass, velocity and surface area, various factors modify the character of the injury. Yaw results in the bullet presenting a larger surface to the tissues with increased retardation rate and, therefore, increased energy transfer and greater damage.

Spin is relatively slow and unimportant.

Nutation is a fine wobble of the bullet and tends to be more marked and disruptive in denser tissues. Tumble and yaw can cause temporary cavitation to be of very irregular shape.

Exit wounds are generally larger than entry wounds because of yaw and deformation of the bullet, possibly associated with bone splinters.

With very close discharge, a large cruciate entry wound due to explosive gases may occur. Often, entry wounds are smaller than the diameter of the missile owing to skin stretching. Oval or irregular entry wounds may be due to a yawing or richocheting bullet.

## RENAL EFFECTS OF MASSIVE HAEMORRHAGE

**Dr. David Dukes**
**Lecturer in Medicine, University College of Rhodesia**

The immediate and delayed visceral effects of massive haemorrhage follow a sustained reduction in capillary perfusion and cellular anoxia. In those casualties reaching an F.S.U. alive during the Italian and Korean campaigns renal tubular necrosis secondary to a sustained reduction of renal blood flow was the commonest of these injuries. Renal biopsy of these cases shows that the essential lesion is tubular rather than glomerular. The severity and functional effects of the lesion are variable. In the majority of cases the lesion is reversible. Adequate treatment of the associated injuries, the cause of the tubular necrosis and the functional effects of renal failure ensure the survival of the majority of these patients.

An efficient F.S.U. will save 97% of those patients who reach it alive. The great majority of these patients have minor injuries. Of the more serious trunk injuries reaching an F.S.U. alive during the Italian campaign, 40% developed acute tubular necrosis. Uraemia was the cause of death in 58% of these cases. In Korea the mortality of acute renal failure in these cases was dramatically reduced by the use of an artificial kidney for the first time.

Acute renal failure may be diagnosed by a series of simple tests. The severity of the renal failure is proportionate to the severity of the wound, the amount of blood lost and the delay in replacing the blood volume deficit. **Rapid replacement of the blood volume deficit** markedly reduces the incidence of all degrees of renal failure in casualties reaching an F.S.U. Correct qualitative as well as quantitative replacement therapy is important. Volume replacement required in Korea, Viet Nam and Sinai was much greater than that used in World War II. Early and rapid electrolyte infusion should be the initial method of blood volume replacement. Difficulties of terrain may preclude early blood transfusion. Adequate blood transfusion should be given as soon as possible in the immediate resuscitation period.

In cases of acute renal failure secondary to missile injuries massive tissue breakdown leads to rapidly progressive metabolic acidosis and the accumulation of other products of tissue destruction. Metabolic acidosis and hyperkalaemia may be rapidly fatal. Using an external arterio-venous shunt and an artificial kidney it is possible to carry out several dialysis over a short period. The secondary effects of massive katabolism can be more readily corrected over a short period than by peritoneal dialysis. The latter method is unsuitable for many abdominal cases. Dialysis is a necessary adjunct to and may be co-ordinated with further surgical treatment of the primary missile injury.

Acute renal failure can be predicted in major missile injuries in which circumstances have caused a delay in adequate blood volume replacement. Early diagnosis and referal to a centre possessing an artificial kidney are life-saving measures for this group of serious missile injuries.

## RESUSCITATION IN HAEMORRHAGE

**Dr. R. A. Cahi**
**Senior Government Anaesthetist, Harare Hospital, Salisbury**

Body fluids are maintained by various forces in two compartments: The following figures apply to a 70 kg. adult male.

| | | |
|---|---|---|
| Intra-cellular Fluid | | 25-30 Litres |
| Extra-cellular Fluid | | 12-16 Litres |
| Interstitial Fluid | 12 Litres | |
| Plasma Volume | 3 Litres | |

The blood volume is 5 litres of which the red cell mass accounts for 2 litres and the plasma for 3 litres (venous haematocrit 42-45%). Internal or external haemorrhage will cause certain defensive reactions in the body. Some are beneficial in that the depleted blood volume is directed to vital structures. Beyond a certain point they are a liability and measures must be taken to restore homeostasis.

**Secretion of catechol amines,** noradrenaline and adrenaline, produces peripheral vasoconstriction in the skin and splanchnic area. The blood pressure is maintained despite hypovolaemia. Vasoconstriction is responsible for many of the classical features of oligaemia—cold extremities, pallor, sweating, collapsed peripheral veins, mental confusion, etc. Inadequate tissue perfusion leads to anaerobic metabolism, lactic acid accumulation and metabolic acidosis.

**Isotope studies** show that there is a functional loss of extra-cellular fluid during haemorrhage greater than the volume of blood lost. This loss follows within an hour of the onset of haemorrhage. A loss of 2.5 litres of blood (50% of blood volume) is **accompanied** by a loss of at least 25% of the extra-cellular fluid volume (4 litres in a 70 kg. male).

**Management** of patients following haemorrhage must be directed at the restoration of tissue perfusion. This is the first priority in the treatment of hypovolaemic shock. To ensure logical treatment the **maximum number of parameters of tissue perfusion** possible must be monitored in the individual patient.

a. **cerebration**—mental confusion is a serious sign of hypovolaemia. Adequate correction of the volume deficit should make the patient alert.

b. **venous pressure**—peripheral veins should fill following adequate correction. One of the most valuable parameters is the central venous pressure.

c. **temperature, pulse, respiratory rate and arterial blood pressure** are simple parameters.

d. **urinary output**—recorded as an index of renal perfusion.

e. **haematological investigation**—includes estimation of the haemoglobin, haematocrit, blood urea and lactic acid, serum electrolytes, acid-base balance and blood gas analysis (arterial $CO^2$ and $O^2$ tensions).

f. electrocardiograph.

g. cardiac output.

h. blood volume studies.

The maximum number of parameters possible should be recorded according to circumstances and the facilities available. In an emergency in the field few special facilities are available. Assessment must be clinical and rest on the basis of common sense. Past experience will dictate the urgency and need for volume replacement in relation to the nature and duration of the injury in relation to the signs of oligaemic shock. If signs of oligaemia are present, immediate measures must be taken to correct the fluid deficit lest irreversible changes ensue.

**Therapy** is based on the initial replacement of the fluid deficity by a balanced salt solution. The following measures are taken.

a. **ESTABLISH A CLEAR AIRWAY**—an obstructed airway must be cleared and kept clear as a first priority.

b. **Position of patient** with trunk flat (injuries permitting) ensures maximal venous return from the extremities.

c. **Arrest obvious external haemorrhage**—stop arterial bleeding.

d. **Set up an intravenous drip** and take a blood sample for **grouping and cross-matching** through the same needle.

e. **Administer a balanced salt solution** such as Ringer's lactate or a balanced salt solution containing bicarbonate (Plasmolyte B). If shock is severe give 50 mEq. of sodium bicarbonate (50 c.c. of 8.5% Na $HCO_3$) at once and add a further 150 mEq. to the first vacolitre of Ringer's lactate. Give 1-4 litres of lactate over the next 30-40 minutes (do not exceed a rate of 540 c.c. in 5 minutes) until the emergency cross-matching of blood is completed. Electrolyte solutions can be given more rapidly to a shocked patient than blood, dextran, etc.

f. **Relief of pain** should be by simple measures to make the patient comfortable — splinting limbs, etc. Severe pain will require the **intravenous** administration of morphine in dilute solution (15 mg. of morphine diluted in 5 ml. of lactate taken from the drip tubing). At about 3 minute intervals 1 ml. (3 mg.) is given slowly until the desired effect is obtained without undue depression of respiration. It is **dangerous** to administer morphine subcutaneously or intramuscularly to a shocked patient because absorption is irregular from such sites in the presence of oligaemia.

g. **Establish records** of pulse, respiration, blood pressure, etc., and record injuries detected with a note of treatment given.

Prior to transfer to the rear for further resuscitation all serious injuries should be treated by the above régime in forward areas. At this point, in serious cases, the following further measures will be needed:

h. **establish further parameters** by inserting a cannula into a large central vein to record the central venous pressure, a plastic catheter into the bladder to record hourly urine volume (aim is not less than 30 ml./hr.) and a heparinised nylon cannula in the radial artery with a two-way tap for acid-base and blood gas analysis.

i. **continue correction of fluid deficit** by further transfusion with a balanced salt solution and blood (ratio 2 : 1) using as a guide the central venous pressure, urinary output and clinical indices of tissue perfusion such as pulse volume and blood pressure. The arterial blood pressure may be normal in the presence of severe oligaemia in young persons. Restoration of a normal blood pressure is not an aim in itself. Assessment of the blood pressure must be taken in relation to other indices of tissue perfusion (skin colour, temperature, etc.). An adequate pulse volume, warm extremities, etc., even with a systolic blood pressure of 70 mmHg., is better than a normal systolic blood pressure associated with cold extremities, rapid pulse of poor volume, etc. The latter state is seen during administration of pressor agents. Pressor agents are rarely necessary in the treatment of hypovolaemic shock. Catechol amine production responsible for peripheral vasoconstriction is already maximal, and further administration is valueless. Many workers advocate the use of vasodilator drugs (rogitine, dibenzyline, etc.) as the treatment of choice in certain cases following adequate restoration of the blood volume.

**Central venous pressure monitoring** is a simple technique dependent on measuring the pressure in a large central vein via a cannula introduced percutaneously. To this cannula is attached a vacolitre of balanced salt solution, a water manometer calibrated in cms. $H_2O$ and a three-way tap (Fenwall set). A Rochester cannula is easily introduced into a large intra-thoracic vein via the external jugular vein. Correct placing of the cannula is shown by a free swing in the manometer on respiration. The manometer is calibrated from the level of the right atrium. A normal reading is 5-12 cms. $H_2O$. The central venous pressure is used as an index of **permissive infusion.** Fluid may be given safely and rapidly in oligaemia until a level of 12 cms. $H_2O$ is reached, without risk of pulmonary oedema. A high central venous pressure (over 15 cms. $H_2O$) indicates over-transfusion or a failing heart.

**Cardiac failure in oligaemia** is indicated by a rising central venous pressure without a corresponding improvement in the arterial blood pressure and peripheral circulation. In such cases the drug of choice to correct the cardiac deficit is isoprenaline (B-receptor stimulator with direct stimulant effect on the myocardium and peripheral vasodilatory effect). Rapid digitalisation may be needed. In severe cases cortisone in pharmacological dosage (25-50 mgs. per Kg. body weight every 4-6 hours) may produce improvement.

**Accurate measurement of acid/base disturbance** allows precise correction of a metabolic acidosis with sodium bicarbonate.

**Blood transfusion** (A.C.D.) lowers the ionised calcium level of the blood. After the administration of two pints of such blood, 5 ml. of a 10% solution of $CaCl_2$ or 10 ml. of a 10% solution of calcium gluconate should be given with each further pint of blood transfused. Calcium is given to maintain ionic balance and normal cardiac action and not to improve coagulation. Blood should never be given to a patient rapidly straight from the refrigerator (4°C). Cold may precipitate serious cardiac arrhythmias in the presence of a low serum calcium, a high serum potassium and metabolic acidosis.

**Colloid solutions** such as dextran are rarely used in correcting blood volume deficits provided blood is available within 1-2 hours. Dextran is retained longer in the circulation than a balanced salt solution and said to produce disaggregation of red cells in stagnant capillaries. The latter effect is readily produced by haemodilution and these colloids have the grave disadvantage of producing occasional antigenic reactions and haemorrhagic tendencies. Subsequent cross-matching of blood is made difficult because dextran induces rouleaux formation. Low molecular weight colloids (Rheomacrodex, etc.) are expensive and have no advantages over balanced salt solutions. Plasma is scarce, expensive and liable to induce homologous serum hepatitis.

**Osmotic diuretics** (mannitol) are indicated in cases in whch the renal output falls despite adequate volume replacement of the fluid deficit, crush injuries and incompatible blood transfusion.

**Antibiotics** are given routinely in cases with contaminated wounds.

## BALANCED SALT SOLUTIONS IN HAEMORRHAGE

**Dr. J. Bank**
**Medical Adviser, Baxter Division Keatings Ltd.**

A balanced salt solution is one containing the common electrolytes of the extra-cellular phase of the body fluids (E.C.F.) in similar proportion to these in extra-cellular fluid. The concentrations of sodium, potassium and chloride in Ringer's lactate closely resemble those in plasma. Lactate, however, is substituted for the bicarbonate ion. Under aerobic conditions lactate is converted in liver, muscle and other tissues into bicarbonate. Under anaerobic conditions in these tissues during oligaemic shock, lactate conversion is impaired and serum lactate levels may be markedly raised. Balanced salt solutions containing bicarbonate instead of lactate do not have the disadvantage of possibly raising serum lactate levels. Balanced salt solutions containing bicarbonate are now available (Plasmolyte B).

In oligaemic shock there are important changes in the microcirculation and the distribution of the body fluids. Changes in the E.C.F. are most marked. Major blood losses (more than 25% of blood volume) maximally stimulates the adrenal medulla and the sympathetic nervous system. Maximal catechol amine secretion causes contraction of the metarterioles, pre-capillary sphincters, post-capillary sphincters and venules. The residual blood volume is diverted from less essential tissues (skin, splanchnic area, etc.) to vital organs. The marked reduction of tissue perfusion in the presence of a persistent blood volume deficit causes tissue anoxia, metabolic acidosis and functional disorders.

Metabolic acidosis tends to cause dilatation of the pre-capillary sphincters, closed under the influence of the catechol amines, without a corresponding relaxation of the post-capillary sphincters. Pooling of blood follows in the stagnant capillaries with further reduction in the effective circulating blood volume. In severe metabolic acidosis and tissue anoxia there is a further loss of plasma into the interstitial fluid with haemoconcentration of the blood in the stagnant capillaries. Hypercoagulability and movement of potassium from the cells follows. The volume of fluid required to replace the normal volume of the E.C.F. is increased by delay in replacing a blood volume deficit. Litres of replacement fluid may be needed in losses exceeding 25% of the blood volume. The beneficial effects of drugs used in the treatment of shock may be lost in uncorrected metabolic acidosis. Isoprenaline and hydrocortisone may be ineffective. The action of calcium on myocardial conduction and contractility is impaired. Hyperkalaemia caused by cellular changes adversely affects the heart. Severe acidosis is followed by impaired conduction and contractility of the heart, a falling cardiac output, arrythmias and cardiac failure. Ventricular fibrillation may cause sudden death.

Isotope estimations permit studies to be made of each component of the body fluids. Red cell, plasma, interstitial and total extra-cellular fluid volumes may be separately estimated. In cases of blood loss isotope studies show that the total loss of functional extra-cellular fluid is greater than the volume of blood lost externally. Replacement of a measured blood volume deficit by blood alone or by blood and plasma is followed by a higher mortality than that following replacement of the same measured blood volume deficit by accurate replacement of lost red cells by blood and of the **total** extra-cellular fluid deficit by a balanced salt solution.

In a 70 kg. adult a loss of only 1,200 c.c. of blood may be accompanied by a 5 litre loss of **functional** extra-cellular fluid. The total extra-cellular fluid deficit is made up of external losses, movement of E.C.F. into traumatised areas (third space effect), movement of fluid into the intra-cellular fluid (I.C.F.) and incorporation of fluid into the collagen molecules of the connective tissue. The relative importance of these factors may vary. Losses of functioning E.C.F., **out of proportion to external losses,** in oligaemic shock are an established fact. Such losses are greater with delay in replacing the blood volume deficit.

Balanced salt solutions are used to correct blood volume deficits, metabolic acidosis and losses of functional extra-cellular fluid. Whole blood replacement is given to correct red cell deficits. Losses of 25% of the blood volume (1,200-1,500 c.c.) may be replaced solely by balanced salt solutions in the initial stages of treatment. If the response is transient or there are continuing losses it is imperative to give blood. Red cell replacement should be secondary to replacement of the volume deficit and confined to replacement of the estimated red cell deficit. Overtransfusion with red cells causes pulmonary oedema more readily than overtransfusion with balanced salt solutions which can be excreted by the kidneys. The initial use of balanced salt solutions in major haemorrhage causes haemodilution and increased capillary flow. This increase in capillary flow has the major advantage of correcting tissue anoxia and acidosis. A haematocrit reading of 30-35% is acceptable in the early stages of resuscitation. The use of bicarbonate in the balanced salt solution assists in the early correction of acidosis. It is impossible to assess accurately the required volume of balanced salt solution in the individual case. The volume given is indicated by **careful monitoring of the patient.** The central venous pressure is a most valuable parameter.

## MANAGEMENT OF THE AIRWAY

**Dr. David Carter**
**Government Specialist, Harare Hospital, Salisbury**

In the management of any injury the maintenance of a normal airway has first priority. If the airway is damaged, obstruction is relieved and definitive repair postponed until a later stage of management. The airway may be prejudiced in two groups of cases:

(a) **Distant injuries**—a head injury is the commonest cause of serious obstruction of the airway in civil practice.

(b) **Local injuries**—two types are encountered:

i. **immediate**—the lumen may be obstructed or distorted or the wall partially or completely severed at any level from the mouth to the bronchial tree.

ii. **delayed**—extrinsic compression from haemorrhage, oedema or infection may take some hours or even days to develop. The recognition of such a danger may have an important bearing on a decision to operate or evacuate a patient. NO PATIENT should be evacuated with an insecure airway.

The recognition of the type of injury commonly associated with airway obstruction will allow proper **preventive measures** to be taken in order to avoid adding the danger of anoxic anoxia to the hazards of major injury.

**Airway Obstruction**

(a) **Head injury** is the commonest cause in civil life. Depression of the cough reflex, loss of control of the tongue and jaw, the liability to inhale vomitus, the accumulation of blood and secretions and the inability to expel these make head injury the commonest indication for tracheostomy. Lesions of the respiratory tract are the commonest cause of death in head injury.

(b) **Facial, oral and mandibular injuries** in missile wounds may be very extensive. Obstruction follows distortion or destruction of the upper air passages, impaction of foreign bodies (dental plates) and the accumulation of blood and secretions. Subsequent swelling commonly causes serious obstruction in less severe cases.

(c) **Neck injuries** may cause immediate or delayed obstruction. The lumen may be blocked or distorted by foreign bodies and secretion from above, partial or complete severance of the larynx or trachea and extrinsic compression from haematomata, etc. An early feature of laryngeal obstruction is a change in the character of the voice. Burns and gas may damage any part of the upper respiratory tract.

(d) **Chest wall, tracheo-bronichial tree, lung and pleura** — see chest injury. The lower respiratory passages are most commonly blocked by secretions and blood from above or by retention of their own secretions below an obstructing lesion.

**Recognition of airway obstruction:**

(a) **General signs:**

i. **cyanosis**—frequently difficult to detect. Examine the mucous membranes.

ii. **cerebral signs**—restlessness and confusion precede loss of consciousness. This is a late and ominous sign.

iii. **circulatory signs**—sweating and hypertension are variable signs caused by carbon dioxide retention. Pulse rate is fast in early stages and later becomes slow as the anoxic myocardium fails.

(b) **Local signs:**

i. **noisy respiration**—retained secretions at all levels cause moist sounds (bubbling). **Stridor** on inspiration suggests laryngeal obstruction. Bronchial obstruction gives expiratory stridor. A to-and-fro stridor suggests tracheal obstruction.

ii. **forceful respiratory efforts** of the chest wall and accessory muscles cause intercostal and subcostal indrawing.

**Emergency Management:**

Recognition of the level of obstruction makes for rational emergency care. The airway, however, is commonly obstructed at **more than one level.**

(a) **Management of the upper airway**—keep the tongue forward by an oral airway (resuscitube), tongue forceps or by inserting a holding stitch in the tip of the tongue. Secretions should be removed from the mouth and pharynx by swabbing or catheter suction. The angle of the jaw is held forward and upwards by finger pressure. If the other injuries permit, the casualty is nursed and transported in the 45° semi-prone position. In more serious oral injuries the mouth may have to be by-passed by a naso-pharyngeal tube or even by a naso-tracheal tube; passing the latter requires experience.

(b) **Management of laryngeal obstruction**—an oro-tracheal tube can sometimes be passed by an experienced person using a battery-operated laryngoscope. Such a tube may be safely left in situ for 48 hours and used for tracheal toilet. In severe obstruction of the upper airway and larynx an artificial opening must be made into the airway below the larynx—**laryngotomy or tracheotomy.** Nursing orderlies in the field should carry for use in an emergency a small special trochar and cannula which is used to pierce the crico-thyroid membrane (laryngotomy). The cannula is left in to provide a temporary free airway. In an emergency an opening can be made either into the larynx or trachea with a pen-knife which is inserted in the mid-line, turned sideways to maintain the opening and allow a plastic tube, biro-pen cover or rolled cigarette box to be slipped into the airway. If the facilities are available formal tracheostomy is preferred. There is less risk of permanent damage. The airway provided is more secure and the lower air passages can be more easily cleared by intermittent suction. A catheter is inserted intermittently 15cm. down from the tracheostomy stoma and gentle suction applied by a foot-operated suction pump made from a motor car tyre pump with the valve reversed.

(c) **Management of the lower airway**—see chest injury. The lower air passages must be kept clear in lesions of the upper airway.

A demonstration of emergency equipment was given.

## PRIMARY TREATMENT IN THE FIELD

**Mr. Denis Thompson, O.B.E.**
**Consultant Surgeon, Bulawayo**

Field surgery markedly differs from civil practice. Operating conditions are far from ideal. Circumstances may require rapid evacuation of the casualty. The patient, unlike his civilian counterpart, is frequently exhausted by battle and climatic conditions. The missile injury is very different to civil injuries of the same region. Wounds contain more dead tissue, more foreign debris and tend to be heavily contaminated with anaerobic organisms. Contamination is commonly from the skin and clothing of the wounded man. The theory that a bullet is sterile has been finally disproved. Organisms and debris are sucked into the track via both entry and exit wounds.

The ratio of wounded to killed was 2 : 1 in World War II. It has increased from 3 : 1 in Korea to 8 : 1 in Viet Nam. A new type of casualty, frequently suffering from the effects of massive haemorrhage survives to reach a forward surgical unit (F.S.U.). Early resuscitation and speed of transport have been important factors in increasing survival rates. Recent campaigns have revealed a marked tendency to by-pass the first aid posts and regimental aid posts (R.A.P.) of previous wars. Sophisticated means of transport allow a casualty to be treated **within 6 hours** at a fully equipped surgical unit in a general hospital. Emergency treatment in the field by properly trained **medical orderlies** is essential to ensure survival from rapidly lethal conditions which can be controlled by simple measures such as the arrest of haemorrhage from wounds of the extremities, control of sucking wounds, etc. Medical orderlies are responsible for primary resuscitation in the field. In the absence of a medical officer he must be capable of recognising oligaemic shock and giving immediate intravenous therapy. His basic training must include periods of instruction in the casualty departments, theatres and intensive care units of our busy central hospitals. Under Rhodesian conditions a well-trained medical orderly, equipped with wireless, should accompany each patrol. **Every soldier** should, during his basic training, receive instruction in the first aid management of the obstructed airway, the application of field dressings, the modern principles of the use of tourniquets and the control of sucking wounds of the chest. Instruction in the **art of resuscitation** and **adequate first aid** are the two measures most likely to prevent a high initial mortality during limited operations.

In each forward area there must be a **regimental aid post** capable of treating and returning to duty minor injuries, continuing resuscitation and arranging for evacuation. Air supremacy is sine qua non for direct air evacuation. In a highly mobile campaign with air supremacy, the **F.S.U.** is sited in a general hospital. Direct evacuation to the F.S.U. makes really early primary surgery possible. An F.S.U. must have facilities to deal with wounds of all regions (Table 1). Laboratory facilities should include provision for blood transfusion, electrolyte estimations, blood pH estimations and blood gas analysis. Metabolic acidosis is a common complication of severe haemorrhage. Studies in Viet Nam, however, have shown that 20% of casualties have a respiratory alkalosis secondary to hyperventilation during battle and following wounding. Ideally blood gas analysis and pH estimations should precede the administration of bicarbonate solutions.

| **Site of Wound** | **% Total Casualties** |
|---|---|
| Extremities | 64 |
| Head and neck | 13 |
| Chest | 14 |
| Abdomen | 9 |

Table 1.—Regional distribution of wounds in 3rd General Hospital in Viet Nam (1966)

The figure for abdominal injuries is lower than that in the Normandy campaign of World War II (25%). Other figures are similar. A forward surgeon must be trained in the military surgery of all regions. In World War II the amputation rate following ligature of a major artery in wounds of the extremities was 49%. In Viet Nam this rate has been reduced to an **overall rate** of 7.9% for all wounds of the extremities. The marked reduction can be attributed to rapid evacuation of arterial injuries to centres with surgeons trained in the use of saphenous vein graft replacement of major arteries. In amputations folowing missile injuries, the rule should be to conserve length and never close flaps by primary suture. Once all danger of sepsis is past, a definitive amputation is carried out.

The new generation of surgeons has had to learn the lessons of World War II again. Primary closure is reserved for certain wounds of the hands and face. Serous cavities are closed with later closure of the skin wound. Wounds require adequate toilet with extension of the wound sometimes required to lay the depths widely open. Damaged muscle and fascia are ruthlessly excised. Viable skin is conserved. Adequate drainage is esential. Wounds are **lightly** packed and immobilised. Padded and completely-split plaster casts may be superseded by inflatable splints of transparent plastic through which the wound may be inspected. **Secondary suture of wounds remains the rule in missile injuries.** In missile injuries non-observance of the above basic rules, despite advances in antibiotic therapy, will be followed by a high sepsis rate.

## PRIMARY TREATMENT IN THE FIELD

Arrest of haemorrhage is the first priority. Resuscitation must be rapid. In Viet Nam rapid infusion through two cannulae inserted into the inferior cava via the femoral veins is monitored by a cannula in the superior cava introduced through the subclavian vein. Infusion pumps are used to give Group O blood, albumen and dextran. Once haemostasis is secured, further resuscitation is continued before the full extent of the injuries are dealt with by a more formal surgical procedure. Despite all efforts a number of cases cannot be resuscitated due to pump failure secondary to changes in the myocardium and increased pulmonary resistance secondary to changes in the pulmonary capillary bed, which may be associated with disseminated intra-vascular coagulation in the pulmonary tree.

## CASUALTY EVACUATION IN VIETNAM

**Dr. Leo Brown**
**Medical Superintendent, Driefontein Sanatorium, Umvuma**

The U.S. Navy is responsible for the medical services in the northernmost one quarter of Vietnam in the area for which the Marine Corps has responsibility. There is only one large permanent military hospital in this zone. The greater part of the surgery is carried out in **temporary field surgical units.**

Air transportation has revolutionised the treatment of casualties. A low morbidity and mortality is attributable to rapid transportation from the field to a well-equipped surgical unit. Casualties are picked up by helicopter 200-300 yards from the site of injury and transported directly to the F.S.U. for definitive surgery. Helicopters fly day and night. The smallest unit (14 men) is equipped with wireless and is accompanied by a corpsman carrying a limited amount of equipment in his pack. Such a squad is in direct contact with the helicopters. First aid received on the spot is limited. Helicopters transport casualties to helipads placed close to the surgical units. There is a significant attrition rate in these machines. The larger helicopters used for medical evacuation can take two stretchers or four ambulatory casualties without elaborate stacking. This permits rapid loading in the field. Newer machines have a cruising speed of 150 m.p.h. Turbine-powered machines, however, are susceptible to ground fire. The concept of direct transportation to a well-equipped surgical unit works well for the most part in the limited war in Vietnam.

Relatively small units (200-300 men) are the main combat forces. Even a 10-20% casualty rate does not pose a transportation problem. A small surgical unit can readily handle 50-60 patients at a time. There is one of these units to cover a radius of 50-60 miles. If greater distances are involved, a further unit is provided. If more than one battalion (1,000 Marines) is involved, the method of direct helicopter transportation of all casualties is inadequate in the face of abnormal casualty rate. Helicopters may be blocked by multiple shrapnel wounds to the exclusion of more serious casualties with active haemorrhage. One surgical unit can cope with a sudden influx of 300-400 casualties and there may be maldistribution of casualties between nearby surgical units. There are a certain number of casualties in whom delay cannot be tolerated and who will not withstand even a 20 minute helicopter ride. Every wounded man must be given the optimal chance of survival. In large operations, therefore, involving more than a battalion, a **resuscitation team** comprised of two doctors and fifteen corpsmen is sent forward to within 2 kilometres of the engagement. The team must contain a surgeon. It is sited at the immediate forward base. The purpose of this team is to carry out the first aid and immediate resuscitation which cannot be carried out by the forward corpsmen with his limited equipment in the heat of an engagement. Such a team is provided with tents and a total weight of equipment of about 5,000 lbs. Light and suction are provided. Blood is available. All the wounded can be delivered by a 3 minute helicopter ride to such a temporary centre for immediate resuscitation and sorting. Surgical equipment of the team is limited. Airways can be provided by endotracheal tubes. Lower extremity injuries are common. The external jugular vein was the site of choice for rapid infusions and transfusions with C.V.P. monitoring. Large amounts of fluids could be given and continued during subsequent evacuation to the surgical unit. Acute renal failure was a rarity. Large volumes of fluid (up to 12 litres) were given rapidly using plastic blood and electrolyte packs. Pressure could be applied by placing the packs under the buttocks or by the foot of the corpsmen. Good operating-room tourniquets were available in adequate number. Improvised tourniquets frequently fail to arrest haemorrhage in severe injuries of the lower limbs. The application of these tourniquets is difficult in the field. A resuscitation unit can require 500-600 litres of Ringer's Lactate per day. Such a resuscitation team is in wireless contact with neighbouring surgical units and hospitals. Casualties can be directed to surgical units with immediately available operating-room facilities or special surgical facilities. One casualty in four requires operating-room facilites. This provides the main bottle-neck in casualty management. Forward surgical units had four air-conditioned operating rooms. Skilled sorting is vital in mass casualty management.

A **base hospital** and **hospital ship** were available with comprehensive facilities as modern as any major centre. These facilities included banks of frozen cells which were non-antigenic, easily reconstituted and available for immediate use in recipients of all groups. All surgical specialties were represented at base. The facilities of such a base hospital were available to relieve forward surgical units of difficult cases in mass casualty crises and act as a staging post to major hospitals in the Phillipines and Japan. Large helicopters, unsuitable for use in forward areas, are used to transport patients from forward surgical units to base. Seriously wounded cases, in whom homeostasis has been achieved, stand such air transportation well. At the base hospital the case is retained until convalescent or transported overseas for further definitive care.

## MEDICAL ASPECTS OF THE THIRD ARAB-ISRAELI WAR

**Mr. Charles Malkin**
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Experience gained in other wars has been adapted by the Israeli medical services to the training of medical orderlies, medical officers and the ordinary soldier. Every effort has been directed to improve methods of casualty evacuation and management. Speed in evacuation was regarded as essential. Experience was gained at the Hadassah Hospital, Jerusalem, in the treatment of 900 casualties, of whom 200 were orthopaedic cases. The good condition of these casualties on admission was attributable to a high standard of resuscitation in the field. Every Israeli doctor receives special training in traumatology and resuscitation. Every Israeli medical graduate must do a period of military service followed by 5 months in a traumatology service. An annual refresher course in traumatology and resuscitation of one month's duration is given to every doctor in Israel, irrespective of speciality. All doctors have experience of intravenous therapy, management of the airway, etc.

A **five-stage line of communication** was used by the Israeli army but many of these services were by-passed by direct evacuation to a base hospital. **Every soldier** received a course in first aid and 20% of the wounded were first treated by the soldiers themselves. **Medical orderlies** were highly trained and sustained a high casualty rate in the front line. They were responsible for initial resuscitation, bandaging, splinting, documentation, etc. **Field casualty stations** were mobile casualty reception centres with medical officers which could move around the battle area and provide further resuscitation and immediate treatment. **Divisional field medical centres** acted as holding centres for longer periods. **Field hospitals** (surgical units) were sited in tents or temporary buildings and equipped to deal with all types of casualty. Each had a mobile team. In the early stages of the campaign the base hospitals received casualties directly within an hour of wounding. The more mobile services were left free to deal with the anticipated casualties of the later stages of the war. Speed of evacuation was deemed essential and 20% of all casualties were evacuated by helicopters with an accompanying doctor. The remainder of the casualties were evacuated by road.

A **disaster plan** is needed in any country which may require its civil hospitals for use as base hospitals and which is exposed to air attacks on the civilian population. In any country 80% of the patients can be rapidly discharged without immediate detriment. In Israel 15,000 beds in civil hospitals, requisitioned hotels, etc., were made available on this basis. In the course of the war 2,900 wounded were admitted to hospital. Admissions were centrally controlled by the D.G.M.S. who was in wireless contact with all medical units. If a hospital could not provide surgical facilities for the wounded in 6-8 hours, it was regarded as overtaxed and casualties were directed to another centre.

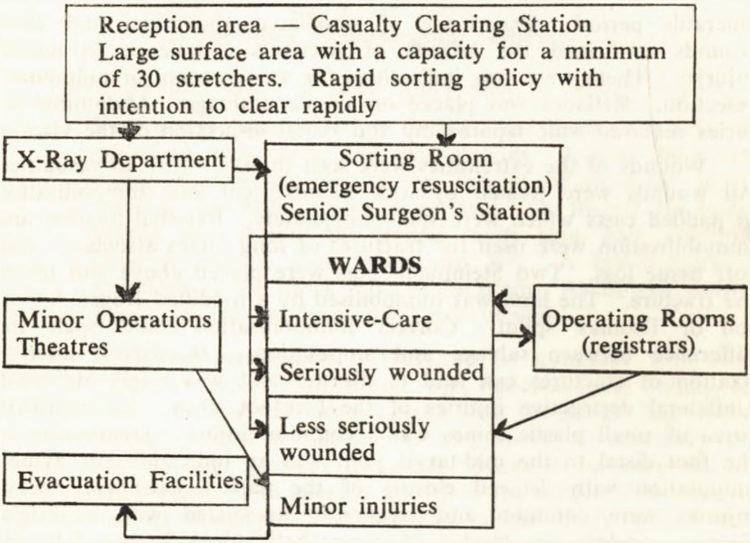


**Figure 1.—Plan of Emergency Treatment Centre**

The senior surgeon of the team is responsible for organisation, diagnosis, sorting, deciding on priorities and operating lists, supervising documentation and giving written instructions to registrars who carry out the actual operative procedures. Documentation is pinned to the casualty's clothing on admission to the reception area. The senior surgeon is never embroiled in the operating theatre. It was not necessary to adopt the system of triage (classification of casualties into minor injuries whose wounds permitted of delay, serious injuries with little chance of survival and serious injuries with a good chance of survival following immediate surgery).

Casualty management was based on principles defined in World War II and Viet Nam. Adequate debridement was followed by secondary wound closure after 4-10 days. Missile tracks were unroofed or saucerised from the entry and exit wounds dependent on the situation of important overlying structures such as major arteries and nerves. Small fragments of shrapnel in neck wounds were found to be common causes of oesophageal or pharyngeal perforation. Major arterial injuries were treated by early vein replacement with conservation of the limb in 80% of cases. The results of popliteal artery replacement were unsatisfactory due to a combination of venous insufficiency, lack of soft tissue cover and difficulties in immobilising adjacent fractures. Unless sharp spikes of bone compromised the arterial repair, internal fixation of fractures was avoided. Extensive fasciotomy was practised following arterial repairs and in any case in which a tourniquet had been employed for a considerable period. Experience of associated abdominal and chest wounds confirmed the lessons of previous experience in missile injuries. There were few indications for thoracotomy or pulmonary resection. Reliance was placed on simple drainage. Abdominal injuries required wide laparotomy and visual inspection of the viscera.

Wounds of the extremities were seen in 60-70% of all casualties. All wounds were treated by wide debridement and immobilisation in padded casts which were split immediately. External fixation and immobilisation were used for fractures of long bones associated with soft tissue loss. Two Steinmann pins were placed above and below the fracture. The limb was immobilised by a modified Roger Anderson or Thomas' splint. Correct immobilisation could spell the difference between salvage and amputation. Ill-advised internal fixation of fractures can lead to disaster and was rarely indicated. Unilateral destructive injuries of the forefoot from the explosive force of small plastic mines was a common injury. Destruction of the foot distal to the mid-tarsal joint was an indication for Syme's amputation with delayed closure of the flaps. Peripheral nerve injuries were common and frequently associated with causalgia. Severe causalgia was treated by sympathetic block instituted by inserting a catheter down to the sympathetic chain and instilling procaine solution. Some cases settled on this régime. The majority, however, required exploration, neurolysis from peripheral fibrosis and excision of lateral neuromata as a secondary procedure. Most nerve sections were treated by secondary suture. Some homologous nerve grafts were used in sciatic nerve injuries.

Tankmen formed the great majority of the 100 serious burns treated in special burns units. Common sites of severe burning were the dorsum of the hands, face and back. The drivers were most affected. The "open-turret" policy, however, allowed rapid evacuation of the crew. Burns were treated by the closed dressing technique of the American Army using sulphamylon cream as an agent against Ps. pyocyaneus. Ps. pyocyaneus septicaemia was treated by gentamycin with a 75% survival rate.

Lessons learnt from this war include the important points that the morale of the soldier is improved by the knowledge that he is backed by an efficient casualty service. Doctors require special training in military surgery. Massive fluid therapy is needed in a hot and dry climate. Infusion of 14 litres of fluid is not exceptional. Speedy evacuation to a surgical unit is a most important factor in reducing morbidity and mortality.

## REGIONAL SURGICAL MANAGEMENT OF MISSILE INJURIES — HEAD INJURIES

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There are four types of head injury seen in missile wounds.

(a) **Very severe injuries** follow through and through injuries of the skull with entry and exit wounds. Unless the bullet passes transversely across the frontal or occipital lobes, there is very little chance of survival. On impact the bullet carries with it into the cranial cavity skin, hair, clothing, bone fragments, dura mater and dirt. A broad track is produced by the shock wave in the brain. At the exit wound there may be an "explosive" exit wound.

(b) **Unilateral penetration** is produced by a missile with relatively low velocity on impact, e.g., ricochet, spent bullet, etc. Such a wound may be produced after the missile has passed through a steel helmet or may be primarily of relatively low velocity, e.g., grenade fragment. There is an entry but no exit wound. The effect is related to the nature of the missile and its velocity. The character of the entry wound and track is related not only to velocity but also the question of fragmentation of the missile on entry. In both categories of injury the patient is deeply unconscious.

(c) **Tangential injuries** are caused by glancing blows and are characterised by depressed fractures of the skull. Such a patient may become unconscious due to associated brain damage with localising signs or the brain may escape significant injury. Bone fragments are depressed. The skin is usually lacerated. The dura may or may not be torn and there is always some cerebral contusion.

(d) **Simple non-penetrating injuries** have an entry and exit wound. The latter may be situated some distance away. The bone is undamaged by the tangential injury. These injuries are deceptive.

**First Aid Management:**

(a) **Management of the airway** is vital in the unconscious patient. It has already been discussed. Obstruction of the airway grossly aggravates any cerebral injury.

(b) **Arrest external haemorrhage** from skin wounds by external compression.

(c) **Apply external dressing** and take preventive measures against secondary infection including anaerobic infection (tetanus, gas gangrene, etc.).

(d) **Sedate** as required with chlorpromazine or pethilorfan. Do not give morphine because of its depressant effect on respiration and its constrictive action on the pupils.

(e) **Transport** in the semi-prone position to keep the airway clear of secretions.

**Definitive Surgical Management:**

**Immediate exploration** of brain wounds, toilet and closure of external wounds was the initial policy during World War II. There has, however, been an increasing trend in neurosurgical practice to defer exploration for 24-48 hours in order to stabilise the patient's general condition. **Delayed exploration** follows primary suture of the skin wound, the intensive administration of antibiotics to prevent the onset of meningitis and intensive care of the unconscious patient. The onset of signs of cerebral compression makes immediate exploration essential. The results of the two methods show possible advantages for the latter.

Exploration of the first two categories of wound requires wide exposure. The path of the bullet is thoroughly cleansed of all debris and haemostasis secured. Desperate efforts to explore the depths of a track to extract a bullet are not advised. Retained bullets do not invariably give rise to cerebral abscess. It is more important to remove debris and foreign matter which are potent sources of infection. The dura mater cannot be closed. Drainage is not provided because it encourages cerebral herniation. Skin cover is provided and antibiotic therapy continued with penicillin and streptomycin.

Exploration of depressed fractures is deferred. The skin wound is closed. Elevation of the fracture is performed as an emergency in the presence of **increasing** signs of compression such as a deteriorating conscious level, increasing paresis, unequal pupils, etc. With non-penetrating injuries of this type a less elaborate procedure is indicated. Fragments are removed and **not** replaced because these wounds are more contaminated than those of civil practice. If the dura is torn. there is a risk of meningitis or cerebral abscess. Even if the dura is not torn, there is a risk of sequestration. The dura is repaired and all bleeding controlled. Non-penetrating wounds are treated like all other missile injuries of the skin.

**Special Problems:**

(a) **Cerebral swelling** is common in missile injuries. Haemorrhage requires evacuation. Oedema of the brain, however, either preceding or following surgery is frequently responsible for deterioration. Dexamethasone or betamethasone (8mg. IV and 4mg. every 4 hours) is most effective. It is commonly supplemented by the administration of urea (urovert) intravenously.

(b) **Tracheostomy** is a life-saving adjunct in serious cases.

(c) **Diagnostic measures** should include special skull projections to demonstrate all foreign bodies. Cerebral angiography is used less in penetrating than non-penetrating injuries for the demonstration of surface clots. Lumbar puncture is reserved for cases of suspected infection.

(d) **Cover** in the form of elaborate flaps is rarely needed in missile injuries. Foreign material, even absorbable cellulose, is not introduced as a dural substitute at the primary procedure because of the risk of infection.

## ABDOMINAL INJURIES

**Mr. B. Hammar**
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Penetrating injuries of the abdomen differ from similar injuries in civil practice. There is a greater risk of infection along the track of the bullet and at the entry and exit wounds. Foreign material is carried into the abdomen and the degree of tissue trauma is greater with increasing velocities of modern missiles. Laceration of tissue in solid viscera (kidney, liver, spleen, etc.) is much greater and the bowel may be injured at many points by direct trauma. Shock waves in high velocity injuries may damage intestine away from the path of the bullet due to the effect of these waves on the gas in the alimentary canal. The wall of distant parts of the canal (stomach, etc.) may be ruptured or devitalised by the sudden expansion of gas during a temporary reduction of abdominal pressure during the passage of the bullet through the peritoneal cavity. Similar waves may cause extensive damage to retro-peritoneal structures. A missile may fragment before or after entry. Very small fragments may cause as much damage as the larger parent missile. Secondary missiles such as splinters of glass and wood, clothing, etc., are carried through the entry wound. Many such entry wounds may be minute and the entry wound missed with serious consequence. The degree of internal damage is not necessarily related to the size or nature of the entry wound. Multiple perforations may complicate a tiny entry wound. Patients require routine careful inspection of both the posterior and anterior abdominal walls. Perineal and buttock wounds may be associated with abdominal penetration. The position of the patient at the time of wounding is important in trying to assess the path of the missile.

Close observation of the patient may be needed to determine the nature and extent of the injury. Signs of intestinal perforation or internal haemorrhage may not be immediately obvious. Associated injuries must be carefully assessed. The abdominal injury must be given a **high rate of priority for transfer to a surgical unit.** Once the diagnosis of perforation or haemorrhage is made or suspected, there is little that can be done in the field other than intensive resuscitation. Early laparotomy is mandatory. The mortality of abdominal wounds is closely related to the **time interval from wounding to exploration.** Once the diagnosis of a penetrating wound is made, oral fluids are withheld, an intravenous drip is set up and intensive resuscitation continued. Suitable sedation is given by intravenous morphine, as previously indicated, in the absence of serious head injury. A naso-gastric tube is inserted and the stomach kept empty. A sterile dressing is firmly applied to wounds of the abdominal wall and the casualty rapidly transferred to a surgical unit. Prolapsed bowel or omentum should not be replaced in the abdomen. Such patients should be transferred on their side with the knees and lumbar spine flexed. Helicopter evacuation is the method of choice. Adequate documentation is extremely important and should be carried out by the person responsible for primary treatment. The date, time and circumstances of injury should be stated. The nature of the type of missile, if known, should be stated. Details of drug therapy should be given.

**Definitive Management**

**Further resuscitation** is continued for one to two hours after admission to a surgical unit. If there is **continuing haemorrhage,** immediate laparotomy is indicated. Tangential wounds of the abdominal wall are associated with signs of local peritonism. Such cases show improvement on conservative management. Haemorrhage is the predominant cause of death after wounding. Bleeding comes from solid viscera, mesenteric vessels or retro-peritoneal arteries and veins. There may be considerable blood loss from the edges of perforated bowel. Venous haemorrhage may be profuse. Circulatory collapse from oligaemia may cause spontaneous arrest of bleeding. Resuscitation followed by release of intra-abdominal pressure may provoke reactionary bleeding.

**Radiological examination** may demonstrate opaque retained foreign bodies and assist in predicting the path of the missile. Free gas in the erect film will confirm penetration. Associated thoraco-abdominal injuries may be demonstrated by plain films of the chest.

**A urethral catheter** should be passed routinely to detect haemorrhage from the urinary tract and record the hourly urine volume during resuscitation.

**Exploratory Laparotomy**

Unless there is profuse haemorrhage within the peritoneum, posterior wounds should be treated in the first instance. Patients do not tolerate turning into the prone position after long and difficult operations for abdominal trauma.

**Long paramedian incisions** are the incisions of choice. All viscera must be **seen and palpated** in missile injuries. Good light and suction are essential adjuncts to adequate laparotomy. Haemorrhage is arrested. Blood and intestinal contents are completely aspirated from the peritoneal cavity. Immediate resection of an actively bleeding spleen or a severely bleeding segment of liver may be needed. Once haemorrhage is controlled, the whole alimentary canal is systematically inspected. Inspection of all surfaces and both borders of the canal is required. Small perforations of the intestine on the mesenteric border are easily missed. The duodenum and posterior surface of the stomach will require mobilisation. Until a complete exploration has been completed all devitalised areas and perforations are merely marked.

**Intestinal resection** is required in cases of extensive damage to the intestine and its mesentery, numerous perforations over a small area and localised severe examples of blast injury. The latter injury is particularly prone to break down 4-5 days after injury and give rise to faecal fistulae. End-to-end anastomosis is used to establish continuity in the small intestine. In missile injuries this technique should **not** be employed in similar injuries of the large intestine. Colon wounds should be treated by resection and exteriorisation. Rectal wounds are repaired and a proximal colostomy performed.

**Gastric wounds** are seen in 12% of abdominal injuries. These are commonly associated chest wounds and injuries of adjacent viscera. A posterior perforation may be the sole injury of the stomach. The lesser sac is opened routinely. Perforations are treated by simple suture.

**Small intestinal wounds** are the commonest visceral injury. Unless there is an indication for intestinal resection, these may be closed by simple suture.

**Large intestinal wounds** are less common but more dangerous than similar wounds of the small intestine. Contents are more infective and extravasate more easily. Segments are partly retro-peritoneal with a liability to the serious complication of retro-peritoneal cellulitis. If there is adjacent retro-peritoneal haemorrhage or emphysema, full mobilisation of a retro-peritoneal segment is indicated. The local management has been indicated. Methods used in the low velocity injuries of civil life and elective colon surgery should not be applied to the colon injuries of high velocity projectiles. The entry wound may be used to establish a colostomy or a separate incision made as required. Perforations distal to a colostomy may be closed. Drainage should be routine. Drains should be placed in the peritoneum and retro-peritoneal tissues.

**Hepatic wounds** are commonest in right thoraco-abdominal injuries. The liver is frequently shattered. Damage is so extensive that local suturing fails to control haemorrhage. Radical resection by hepatic lobectomy may be needed. Temporary portal compression may allow time for resection. Minor injuries may be controlled by haemostatic sprays. All hepatic injuries should be drained because of the risk of biliary leakage.

**Splenic wounds** are treated by splenectomy. **Pancreatic injuries** are rare and are treated by partial pancreatectomy and drainage.

**Urinary tract wounds** are less common. Renal injuries may require partial or total nephrectomy for the control of haemorrhage. Rupture of the bladder may be intra-peritoneal or extra-peritoneal.

**Thoraco-abdominal wounds** are common and best deal with by the thoracic route.

# MISSILE INJURIES OF THE CHEST EMERGENCY MANAGEMENT IN THE FIELD

**Mr. Douglas Thompson**
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The present paper is confined to the management of a missile injury of the chest in the field until the casualty reaches hospital.

## APPLIED PHYSIOLOGY

The lungs may be represented simply as two balloons connected to a common outlet within an airtight box consisting of two segments. The bottom of each segment is able to move up and down as a piston. Under normal circumstances both the balloons and the box are intact. Air passes in and out of the common outlet as the pistons (diaphragm) move down and up.

If there is a defect in the wall, air enters the cavity of the box (pleura) through the defect (wound). The effect will vary according to the size of the defect. Large defects will cause the balloons (lungs) to collapse because air enters until the pressures within and outside the thoracic cage are equal. Small defects vary in size according to the phase of respiration. Air enters the pleura as the defect widens in inspiration. The defect decreases in size on expiration and the gap may close. Air gradually accumulates and the lung collapses. Marked rise in pleural pressure does not occur.

If the defect is in the lung and not the chest wall, air is sucked in inspiration from the lung into the pleural space. The lung collapses. If the pressure in the lung is increased by coughing, air passes into the pleura under pressure. Pleural pressure rises (tension pneumothorax) and the lung collapses. The mediastinum (central septum) moves across to the opposite side and the other lung is compressed.

If the defect is in the lung and the chest wall, the effect varies according to the size of the defects in each. If both defects are large, the lung will collapse under atmospheric pressure. If the defect in the thoracic wall is small relative to the size of the lung defect, pressure will rise in the pleura and produce a tension pneumothorax.

## CLASSIFICATION

### A. Open Injuries

The effects vary according to the size of the defect and the degree of lung damage. Large defects mainly cause haemorrhage but small defects produce effects in proportion to lung damage (tension pneumothorax).

B. **Closed Injuries**

In missile injuries entry and exit wounds may be small and leave no communication with the atmosphere. Considerable lung damage, however, may be caused by shock waves and changes in the flight characteristics of the bullet as it crosses the pleura and lung. Leakage of air and blood into the pleura follows. If major blood vessels are damaged, the effects of haemorrhage predominate. Unless a major pulmonary vessel is damaged, bleeding from the low-pressure pulmonary system is rarely serious. Serious intra-pleural haemorrhage is usually associated with damage to a systemic vessel in the chest wall or mediastinum. Air leakage effects therefore predominate in pulmonary lesions.

Injuries to the heart and great vessels may be rapidly lethal but some are repairable. Accumulation of blood in the rigid pericardium **(cardiac tamponade),** interferes greatly with the pumping action of the heart.

**MAJOR CAUSES OF EARLY DEATH**

If quick action is taken by personnel in the field, lives may be saved by using simple measures in the following five conditions.

a. tension pneumothorax
b. haemothorax
c. respiratory obstruction
d. cardiac tamponade
e. blood vessel damage.

**CLINICAL RECOGNITION**

In the field the presence of certain symptoms and signs, taken in conjunction with the probable track of a missile, will direct attention to the chest cavity as a potential source of rapid deterioration in the condition of the casualty. The five major causes of death (listed above) are responsible for 90% of the deaths in the field from missile injuries of the chest. Table 1 lists the simple means of differentiating the three main clinical syndromes.

| | |
|---|---|
| | **Severe Chest Bleeding** |
| Appearance | Sweaty and clammy |
| Pulse | Rapid and thready |
| Neck Veins | Collapsed |
| Heart | Normal position |
| | **Tension Pneumothorax** |
| Appearance | Increasing difficulty with breathing |
| Pulse | Rapid but volume may be good |
| Neck Veins | May be slightly distended |
| Heart | PUSHED TO THE OTHER SIDE |
| | **Cardiac Tamponade** |
| Appearance | Severe distress with shock out of proportion to injury |
| Pulse | Rapid and weak |
| Neck Veins | GROSSLY DISTENDED |
| Heart | Normal position: beat neither felt nor heard. |

## MANAGEMENT

The aim of emergency care in the field is to keep the casualty alive until he can receive definitive care. This entails keeping his heart and breathing going. An adequate oxygen supply must be assured through an adequate airway to lungs which are expanding normally in order that the heart may be enabled to pump an adequate volume of blood to the tissues.

### Open Wounds of the Chest

Obvious bleeding points must be controlled, preferably by forceps and ligature, and the wound converted to a closed wound by the application of a gauze field dressing-pack covered with vaseline and kept in place by strapping. The soldier must be watched carefully. A tension pneumothorax with increasing respiratory distress may be created by closing the chest wall defect. In these circumstances a trochar and cannula (Viet Nam pattern) or a wide-bore needle must be inserted into the pleural space and a **"no-return" valve** fitted to prevent air entering the chest wall from the atmosphere during decompression of the tension. A simple valve is made by tying a finger stall over the butt end of the needle or cannula and making a slit in the finger stall. Such a simple device should be in the pack of every medical orderly in the field.

### Closed Wounds of the Chest

A tension pneumothorax is treated by the above method. A "stony-dull" chest on percussion will suggest an accumulation of blood (haemothorax). The effects of blood loss are treated. It is unusual for the volume of blood alone to cause respiratory distress. If, however, the casualty is dysnoeic the blood may be drained from the pleura by the above "no-return" valve method. The evacuation of some blood will relieve the distress. No attempt is made to drain the chest completely because this encourages further bleeding. An Ambu ventilator should be part of the equipment of an ambulance or helicopter used to evacuate casualties. It may be required to assist respiratory effort. It is vital to keep the airway clear.

### Cardiac Tamponade

If this is suspected, the trochar and cannula can be inserted very gently upward from the xiphi-costal angle. It may be possible to tap blood from the pericardium (pericardiocentesis) and relieve the pressure on the heart.

If the above simple measures fail to maintain the vital functions, there is little point in attempting cardiac massage in the field.

# MISSILE INJURIES OF THE CHEST DEFINITIVE MANAGEMENT

**Mr. A. J. P. Graham**
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On admission to a surgical unit, the adequacy of the airway and the respiratory effort must be checked. The patency of the airway may be assisted by endotracheal tube or tracheostomy and the respiratory effort assisted or supplanted by an Intermittent Positive Pressure Respirator (I.P.P.R.). The adequacy of previous treatment of shock must be checked. Assessment is completed by a thorough evaluation of the thoracic and other injuries sustained by the casualty. **Good radiological facilities** are essential for this purpose and must be provided in any surgical unit treating missile injuries of the chest. Cases can be classified into those acute cases which require early surgery, e.g., wounds of chest wall, heart, thoraco-abdominal, etc., and those non-acute cases in which there is no immediate need for surgery.

## CHEST WALL

Adequate debridement is vital but the pleural cavity must be closed by primary suture. The skin may be closed by secondary suture but wide excision of damaged muscle, etc., may require swinging in large flaps of undamaged muscle to close a gap in the chest wall. Fatal haemorrhage may follow the tearing of one intercostal artery. Bleeding points are ligated or undersewn. All debris, etc., is carefully removed from the wound. Late repair of residual defects is effected by plastic procedures or the insertion of prostheses.

## LUNG

Bruised and damaged lung has amazing powers of recovery and should not be subjected to the same ruthless debridement as muscle. Lobectomy is reserved for devitalised lung, e.g., major vessel injury. Bleeding and air-leaks are controlled by ligature and oversewing by atraumatic suture. Under Rhodesian conditions with good facilities, thoracotomy is advised in missile injuries in which a pneumothorax or haemothorax is demonstrated. All easily accessible foreign bodies can be removed but no attempt is made to extract deeply situated small particles embedded in the lung. Profuse haemorrhage may result. All haemothoraces should be drained by an under-water seal drain following thoracotomy.

## HEART

Major wounds are rapidly lethal. Smaller wounds causing cardiac tamponade over the anterior or lateral chest wall may be inconspicuous. Temporary relief by aspiration must be followed by **continuous personal observation** because recurrence of cardiac compression may be very rapid. A repeat aspiration may allow time to prepare for formal antero-lateral thoracotomy through the fifth intercostal space. The wound is extended upward by division of one or two costal cartilages. The pericardium is rapidly opened longitudinally parallel to the phrenic nerve. Clot is rapidly evacuated and the bleeding point in the heart controlled digitally. One finger is usually enough to control the source of the bleeding. At this point massive infusion is given to restore the blood volume. The heart wound is undersewn with an atraumatic silk suture. A bleeding coronary vessel is ligated. No heroic attempts are made to remove deep foreign bodies. The pericardium is closed loosely. The pleural cavity is drained.

### GREAT VESSELS

The best approach is through a sternal-splitting incision from the manubrium to the fourth intercostal space. Operative conditions are difficult. Vessels may have more than one hole in them. Bleeding is profuse and, if it cannot be safely controlled, it may be necessary to temporarily clamp the superior and inferior vena cava. This arrests the circulation. **No more than 3 minutes** are available to secure temporarily the actively bleeding points.

### OESOPHAGUS

Oesophageal perforation is commonest in wounds of the posterior mediastinum. Soiling of the mediastinum and pleura are revealed by radiographs showing gas in the mediastinum and neck or by finding food or saliva in the pleura at thoracotomy. No food or fluid should be given to a suspected case of perforation. Simple toilet, suture of the oesophagus and drainage following thoracotomy is combined with adequate antibiotic therapy.

### THORACO-ABDOMINAL WOUNDS

In missile injuries of the lower chest, perforation of the diaphragm is common. The position of the diaphragm may have been much higher at the time of wounding than it is at the time of examination. Injuries of the upper abdominal viscera, e.g., stomach, spleen, etc., should be suspected in all lower thoracic wounds. These viscera are easily approached through the diaphragmatic wound at thoracotomy. Formal thoraco-abdominal incisions are essential for proper exposure of the full extent of lower thoracic wounds. Blast injuries may rupture the diaphragm without producing an open wound of the chest or abdomen. The cause of the severe respiratory embarrassment is readily diagnosed on X-ray.

### RESPIRATORY EMBARRASSMENT

Any form of assisted respiration in cases of lung damage may cause a tension pneumothorax in cases in which an intercostal drain with under-water seal drainage is not provided. Bilateral tension pneumothoraces are rapidly fatal.

## LATE SEQULAE

**Haemothoraces** were treated in Korea by early evacuation at thoracotomy to prevent the late sequelae of organising haematomata preventing full expansion of lung and chest wall. Small haemothoraces can be treated by aspiration but demonstrable clot requires formal evacuation, as soon after injury as is convenient.

**Pneumothorax** persisting implies an alveolar or broncho-pleural fistula. It may clear on intercostal drainage with continuous suction, but if not, formal thoracotomy with lung suture or partial resection may be needed.

**Empyemata** are prevented by adequate primary surgery. Empyemata complicating haemothoraces are best treated by early decortication.

## ADDITIONAL MEASURES

**Bronchoscopy** is an invaluable method of keeping the lower air passages clear in missile injuries and allowing expansion of areas of atelectasis.

**Pethilorfan** given in small repeated doses is the drug of choice in relieving pain and permitting better coughing. **Pentazocine** is a good oral alternative.

**Physiotherapy** is an essential adjunct of all thoracic surgery.

**Antibiotics** are given routinely in all chest injuries. A combination of penicillin and streptomycin is preferred until the results of bacteriological examination are available.

In the treatment of missile injuries the indications for formal thoracotomy are severe or continued bleeding with large clotted haemothoraces and cardiac tamponade, severe pulmonary lacerations with uncontrollable pneumothoraces and penetrating wounds of the oesophagus and diaphragm.

## ARTERIAL INJURIES

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One per cent. of the wounds of warfare are arterial injuries. The minority resemble the open (glass fragments, etc.) and closed (fractures, dislocations, etc.) injuries of civil life. The majority complicate open wounds from missiles. Closed arteral injuries are rare in warfare.

### ARTERIAL WOUNDS

(a) **Incised wounds** may be lateral or terminal injuries. The wound is not associated with tissue damage in the arterial wall or adjacent tissues other than those tissues in the track of a sharp object. The wound is situated at the site of the skin wound. Severance of the artery permits the muscular wall to contract and retract with a marked tendency to spontaneous arrest of bleeding. Lateral injuries tend to continue bleeding.

(b) **Lacerated wounds** follow the closed injuries of civil life and missile injuries. The wall may be contused and lacerated. The intima may be torn without there being marked external damage. Associated damage in the arterial wall over a long segment is common. Adjacent soft tissue damage may be extensive.

(c) **Arterial contusion** with intimal lesions is commonly followed by **thrombosis of the segment** and arrest of the distal arterial circulation.

(d) **Arterial spasm** is a rare entity and can only be accepted as the cause of arterial arrest in a limb following exposure of the artery. Intimal lesions may cause thrombosis without marked damage to the other coats of the artery. Arterial spasm cannot be accepted as the diagnosis in cases where there is danger to the viability of the limb. It is notoriously resistant to relief by sympathetic blockade and vasodilator drugs given locally or systemically.

The local arterial injury follows direct damage to the artery, indirect damage following the explosive effect in an adjacent missile tract or secondary involvement from bone fragments of a comminuted fracture. Due to fragmentation of the missile or bone, the arterial injuries of warfare may be sited at a considerable distance from the entry wound.

**Aneurysms and arterio-venous aneurysms** of warfare do not pose an immediate threat to the viability of the limb. Small lateral wounds of arteries and veins are temporarily controlled by clot in the vessel wall and adjacent tissues. There is an adequate collateral circulation in the early stages.

**EFFECTS OF ARTERIAL INJURIES**

(a) **General effects**—wounds of major arteries such as the aorta or common iliacs are rapidly fatal from the effects of rapid loss of blood. In injuries of smaller arteries the external or internal (body cavities, tissue planes, etc.) loss of blood may overshadow the local effects of arterial arrest. The decreased tissue perfusion following marked reduction of the blood volume gravely affects the ability of the collateral circulation to maintain tissue viability distal to the arterial wound.

(b) **Local effects**—highly variable according to numerous factors such as:

i. **Site of injury**—in World War II gangrene followed 80% of femoral, 70% of popliteal and 60% of proximal brachial artery injuries due to inadequacy of the collateral circulation in these regions.

ii. **Nature of associated injury**—massive injuries of the adjacent soft tissues may damage the collateral channels and be associated with greater risk of secondary infection. Arterial repair requires good soft tissue cover to have a prospect of success.

iii. **Nature of arterial injury**—complete division of the artery is associated with a marked tendency to spontaneous arrest of haemorrhage and marked local ischaemia. Small lateral wounds may close with a tendency to aneurysm formation at a later stage. Larger lateral wounds do not readily close and there is a tendency to continued bleeding.

iv. **Inadequate tissue perfusion**—shown by signs resembling those of the acute arrest of arterial embolism.

v. **Age and general condition**—elderly patients have more severe local effects because there is a poorer collateral circulation and a lower tolerance to associate blood volume deficits.

vi. **Time interval since wounding**—irreversible changes may be anticipated **6-8 hours** after complete arterial arrest. The period may be extended in incomplete lesions, young persons and by good general and local management of blood volume deficits and the ischaemic limb. The period is decreased by adverse factors such as the application of a tourniquet, inadequate replacement of blood volume deficits, damage to collateral from soft tissue injury, local freezing, cold and damp conditions, etc. All the tissues in the limb do not have the same tolerance to ischaemia, nerve and muscle being the most sensitive.

**WOUNDS OF VEINS**

Injuries of large veins cause massive bleeding into body cavities. Larger peripheral veins (proximal femoral, popliteal and axillary) cause severe bleeding. Gangrene rarely results from interruption of these veins but there may be late evidence of venous insufficiency.

**RECOGNITION OF ARTERIAL INJURY**

Bleeding from a major artery is easily recognised. In closed injuries, however, the local signs of arterial arrest are more easily missed. In missile injuries these signs closely resemble those of arterial embolism in civil life. Absence of pulses, "glove and stocking" anaesthesia, paralysis, cooling of the part, etc., are readily detected on routine examination. All signs are **distal to the level** of arterial injury. Peripheral nerve injuries are present in 50% of the arterial injuries of warfare.

**TREATMENT**

The general care of the patient—corection of blood volume deficits, associated injuries, etc., is vital for the success of any local measures.

(a) **Emergency treatment**

Most of the common arterial injuries of the limbs can be controlled by **effective local compression.** The application of a tourniquet is a last resort and carries with it the responsibility of evacuating the casualty to a centre capable of repairing the arterial injury within 6 hours. Gangrene is otherwise inevitable. A tourniquet must be applied efficiently at a pressure adequate to exceed the arterial flow. There must be protection for the skin and peripheral nerves beneath the tourniquet and it must not be applied **unduly proximally.** The time of application and the reasons for applying the tourniquet must be attached to the patient.

Position the limb horizontally, keep the part cool and splint carefully any associated fracture to minimise the risk of further arterial or nerve trauma. Arrange for high priority evacuation, replace the blood volume deficit and start protective antibiotic therapy.

(b) **Definitive treatment**

It is rarely possible in missile injuries to repair a damaged artery by direct suture. The damaged adventitia must be radically excised and contused media resected. Direct suture is rarely possible without producing marked stenosis of the vessel. A lateral defect may be covered by a **venous**

**patch graft.** A long defect is repaired by a **reversed saphenous vein graft** placed end-to-end. In the case of smaller vessels, e.g., popliteal, it may be necessary to use an end-to-side technique. Care must be taken to meticulously ligate all small tributaries in the vein graft and identify the proximal and distal ends of the graft. The distal section of the artery is cleared of clot by irrigation prior to completion of the arterial repair. Distal heparinisation and lavage by distal arteriotomy may be used to clear the distal arterial tree. Systemic heparinisation is never used.

All arterial repairs must be covered by adequate antibiotic therapy. The site of the repair must be covered by adequate soft tissue cover. All adjacent fractures must be adequately immobilised. External fixation should be used as required. Internal fixation should be avoided.

Wounds of large central veins should be repaired. Packing and ligature are secondary alternatives.

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