

## Wounds and Injuries of Peripheral Nerves

The majority of war wounds affecting the nerves do not require immediate operation. While soft tissue, bony, and vascular injuries associated with the neural lesion require emergency exploration, neural repair, if indicated, can be carried out electively. There are, however, important exceptions to this rule.

High-velocity missile injuries to nerves in combat are generally not neat and sharp. The nerve, if not directly transected by the projectile, is stretched by cavitation forces but remains grossly intact. Early on, there is no way to determine intraoperatively whether to resect such a lesion. Early repair of nerves transected by penetrating missiles is not satisfactory because of the difficulty associated with deciding how far back to trim the injured nerve before reaching potentially healthy fascicular tissue. As a result, acute repair under these circumstances runs the risk of anastomosing contused tissue of questionable viability. With time, however, the damage to the nerve stump will be delineated so that the amount of proximal neuroma or distal glioma requiring resection will become obvious. Ideal timing for such repairs is 2-3 weeks after injury. If a transected nerve is found during the course of debridement and/or repair of other nonneural injuries, it is best to "tack" stumps down with non-resorbable monofilament suture, to adjacent tissue planes and to place each stump at a different level. This maintains length, an important consideration since most nerves will retract after transection. By placing the stumps in different planes and, wherever possible, away from acutely repaired or traumatized vessels, tendons, bone, or muscle, neuroma formation is prevented. Sling sutures, holding the stumps together until an elective repair can be performed at a later date, are to be discouraged, since they tend to produce neuromas. These neuromas, when they occur, will require resection that often produces a larger gap than if the stumps had been

left to retract. Placing the nerve stumps in a setting free of other traumatized or recently-repaired tissues minimizes the development of scar around the stumps and tends to reduce the subsequent length of required resection.

It is important to obtain a baseline **neurologic** assessment of the limb. The following questions must be answered: What nerve(s) is involved? What is the distribution of motor, sensory, and autonomic loss? Is the loss complete or incomplete distal to the level of the lesion? Partial losses which represent incomplete lesions tend to recover spontaneously with time, whereas complete losses probably will not, and will usually require surgical intervention. Electromyography (EMG) and conduction studies will not be of help in the first few weeks after injury since the Wallerian degenerative process takes time to produce deinnervational changes, at least for major nerves.

The suspected in-continuity lesion should be observed over time to see whether clinical or electrophysiological improvement is demonstrable prior to exploration and intraoperative evaluation by stimulation and recording of nerve action potentials (NAP). During this follow-up period, it is important to maintain motion in the injured extremity to prevent joint stiffness, tendon shortening, and pain. It is especially important to close soft-tissue wounds associated with neural damage as soon as practical so that physical therapy can be initiated early. There is no indication for putting the paralyzed or partially paralyzed limb, or the **non-repaired** nerve., to continuous rest. If devices such as cock-up wrist splints are used to keep the limb in a position of function, they should be dynamic and, whenever possible, removed several times a day for range of motion (ROM) exercises to the limb. If a splint or cast is necessary because of concomitant fracture(s) or acute vascular or tendon repair, then the joints both proximal and distal to the immobilized portion of the limb must be put through a full ROM at least three or four times per day. This is especially **important** for joints that have lost their innervation, for these tend to freeze or stiffen much more readily than normally innervated joints. ROM is also necessary for the limb with a bluntly transected nerve, since disabling joint stiffness can occur as early as two weeks after injury.

---

### MISSILE WOUNDS LEADING TO ANEURYSM OR ARTERIOVENOUS FISTULA COMPLICATING NERVE INJURY

An expanding mass in the shoulder and arm, the presence of a **thrill** and/or a bruit, and progressive loss of function with severe pain should alert the clinician to this possibility. The pain is almost like true causalgia with burning paresthesia and electric shocks, but usually presents without automatic manifestations. The patient, unlike the individual with true causalgia, usually permits manipulation of the distal extremity. To be accurate, traumatic aneurysms are usually pseudoaneurysms arising from dissection of blood into and around the vessel wall. Thus, angiography may not demonstrate extravasation of contrast or filling of the aneurysm. When this diagnosis is suspected, immediate exploration is indicated. At exploration, an aneurysmal mass or, in a few cases, a **fistula** will be found compressing and stretching neural elements. This situation is especially common when axillary or posterior popliteal vessels are involved.

### BLOOD CLOT OR SIGNIFICANT SOFT TISSUE CONTUSION

Occasionally missile wounds are associated with significant clot. If the clot is confined to a closed space incorporating neural elements, progressive loss of function can occur. Such closed spaces include the popliteal and knee spaces, the anterior compartment of the lower legs, and the buttocks, especially in the subgluteal space. Similar closed spaces in the upper extremity include the elbow and forearm, either beneath the lacertus fibrosis and pronator musculature, or the more distal forearm muscles. Immediate decompression and drainage are indicated for clots in these areas, while fasciotomy is indicated for extensive contusions which have resulted in a swollen, tight extremity. Nerve damage, muscle necrosis, fibrosis, and limb contracture can occur. A Volkmann's contracture, for example, can result in loss of median, radial, and sometimes ulnar function.

### **SHELL FRAGMENTS OR-OTHER FOREIGN BODIES IMBEDDED IN NERVE AND ASSOCIATED WITH SEVERE PAIN**

Shell fragments or other foreign bodies imbedded in nerve are associated with severe pain. An occasional patient will have a shell fragment come to rest within a neural element causing severe pain and paresthesia. Relatively immediate surgical removal of such an intraneural foreign body may ameliorate the pain or, failing this, may permit better control with analgesics or by a combination of Tegretol (Carbainazepine) and Elavil (Amitriptyline HCL).

### **TRUE CAUSALGIA**

Causalgia is a severe burning pain, often associated with autonomic changes and typically relieved by sympathetic block. Aggressive management is usually required. While **vasoconstriction** and dryness with **trophic** changes of skin and nails are more common later on, vasodilation of skin vessels and hyperhydrosis predominate initially. The pain is all consuming and the patient does not tolerate the least bit of manipulation of the affected extremity. In the combat situation, close to 50% of true causalgia presents within hours to several days after wounding. This pain pattern is invariably associated with incomplete injury to a nerve, typically the median or posterior tibial. Analgesics and even narcotics provide only minimal relief. Early sympathetic blocks with a local anesthetic are preferred. If the pain pattern is relieved but then recurs despite repetitive blocks, surgical sympathectomy is indicated. Other lesser pain patterns can be treated fairly successfully with pharmacological agents, at least in the early stages.

### **SHARPLY TRANSECTED NEURAL ELEMENTS**

Historically, close to 40% of nerve injuries cared for by the military during war have not been directly related to combat. These represent clean-cut transections of nerves by glass or sharp metal edges. These should be definitively repaired at an early date. Soft-tissue wounds due to sharp injuries and associated with complete paralysis of one or more nerves need to be closed in any case.

---

If, during such closure, the sharply transected and noncontused nerve stumps with neatly divided epineurium are located, there may be some advantage to acute (primary) repair. Stumps will not have had time to retract, anatomy is straightforward, and a repair under minimal tension can be readily carried out. The surgeon must have had some experience with nerve repair. The necessary instruments include magnification Loupes, a bipolar coagulator, and 6-0 suture. The surgeon should be willing **and** able to take the time to do a careful repair. Acute repair of transected elements is of special value for sharp transections of brachial plexus elements and the sciatic nerve where delay and secondary repair oftentimes require the use of nerve grafts because of stump retraction and scar formation.

# Amputations

The prime indication for amputation is the preservation of life, i.e., the sacrifice of the part in order to preserve the whole. Three factors influence the decision to attempt salvage of a severely traumatized limb: the extent of the extremity injury, the general condition of the patient, and the experience of the surgeon. Every effort should always be made to save a limb. However, experience has shown that a severely disrupted extremity provides the potential for sepsis and causes a far greater drain on the patient's limited resources than does amputation. The foregoing notwithstanding, conservative surgical management of an injured extremity should always be the rule. Such management includes prompt institution of antibiotic therapy, early repair of vascular injuries, prompt debridement, and postoperative immobilization. Even under unfavorable tactical situations, every effort should be made to control hemorrhage and minimize the likelihood of infection prior to resorting to amputation. The judgmental decision to amputate should compare the risk to life associated with attempts to preserve a limb as compared to the realistic likelihood of ultimate reconstruction of a functional extremity. It is always desirable to secure the opinion of a second surgeon before amputating.

Amputations for trauma are of two types: elective and emergent. Near the front, essentially all amputations are of the emergency type. In the great majority of these emergent amputations, the surgeons simply complete a traumatic amputation by achieving hemostasis and debriding the stump. They are indicated to save life and are performed at the lowest level of viable tissues to preserve limb length. After one has performed adequate **debride-**ment of skin, muscle, and other devitalized tissues, thereby converting the injury to a clean surgical wound, the decision to amputate or attempt to retain a viable limb frequently becomes **self-**evident. In upper extremity injuries, especially those involving the hand, as much viable tissue as possible should be retained for subsequent reconstruction. Reasonable attempts should also be

made to preserve the knee and elbow joints, even when their preservation results in extremely short stumps. Emergency amputation is rarely the definitive surgical procedure, as subsequent stump revision is usually required prior to prosthetic fitting. It should be kept in mind that long bone fractures and joint dislocations can cause elevated compartment pressures that, if allowed to progress unnoticed, can result in limb necrosis and subsequent limb loss.

## INDICATIONS

The following are clear indications for emergency amputations:

1. Massive injuries in which the components of an extremity are so badly mangled that the extremity is obviously nonviable.
2. Extremities with severe involvement of skin, muscles, and bone with an anesthetic terminus and irreparable nerve damage.
3. Overwhelming local infection, which, despite adequate surgical measures and antibiotic therapy, endangers life.
4. Established death of a limb (vascular gangrene), where vascular repair has failed or has proved to be impractical.
5. Massive septic gangrene (clostridial myositis) is a most compelling indication for amputation. Anaerobic cellulitis or myositis confined to a single muscle group can be managed by resection and is not an indication for amputation.
6. Secondary hemorrhage in the presence of severe infection, even though initial wound surgery apparently may have been adequate. Included in this group are patients in whom the tactical situation precluded adequate early surgical intervention.

## TECHNIQUE

In all amputations, the limb should be prepped and draped such that circumferential operative access is provided. When practical, the limb is kept elevated while prepping and draping to salvage as much of the distal venous blood as possible. A tourniquet is indicated, when practical, to prevent additional blood loss.

## LEVEL OF AMPUTATION

The level of amputation is determined by the nature and extent

---

of the injury. Amputations should be performed at the lowest possible level of viable tissues. All viable skin and soft tissues distal to the indicated level of bone amputations should be preserved for use in subsequent closure of the amputation stump. This is especially true for amputations below the knee, in which short tibial stumps can be saved with posteriorly-based flaps. Surgical principles concerning the construction and dimensions of viable flaps should be tailored to the specific need for each patient. To save length, any shape or form of a viable flap should be used.

### OPEN CIRCULAR TECHNIQUES

The open circular amputation, as described below, is the most acceptable type for combat conditions:

1. A circumferential incision is made through the skin and deep fascia at the lowest viable level. This layer is allowed to retract without further dissection (Figure 27A).

2. The muscle bundles exposed are then divided **circumferentially** at the new proximal level of retracted skin edge. The incised muscle bundles will promptly retract, proximally exposing the bone beneath (Figure 27B).

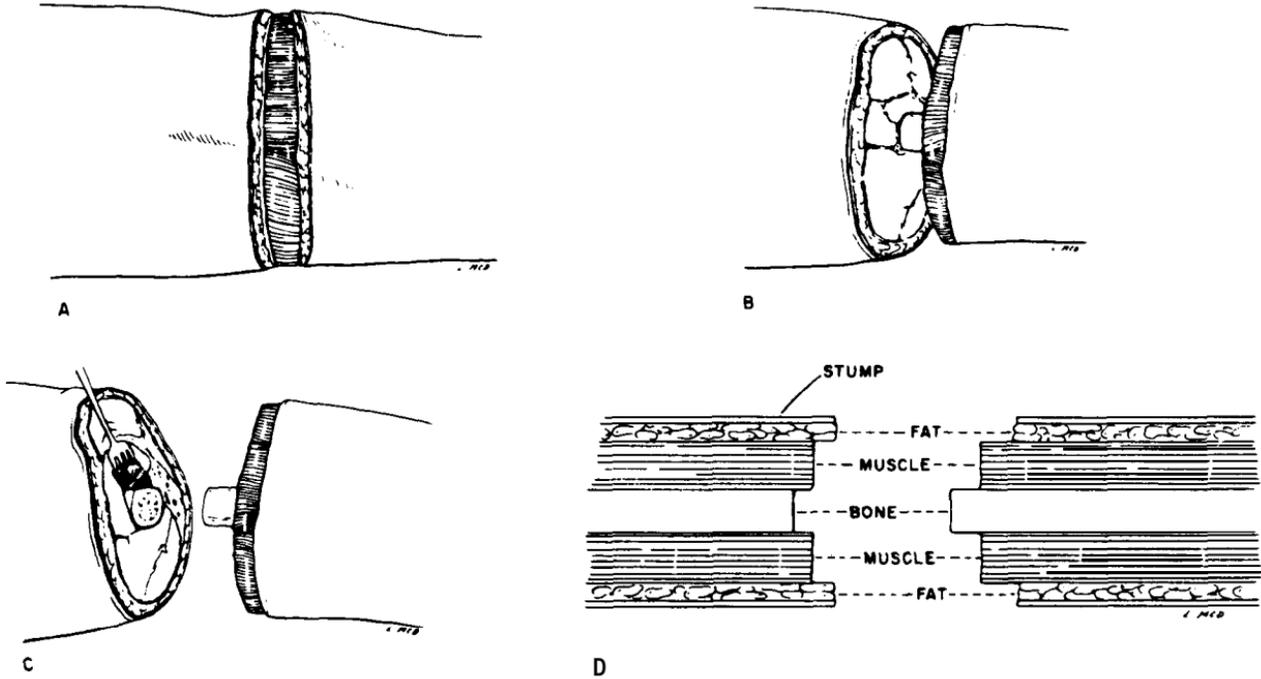
3. The soft tissues are then manually retracted proximally to facilitate bone transection at a still higher level (Figure 27C). Periosteum should not be stripped. This technique has the appearance of a cone with the apex directed proximally.

4. The blood vessels are divided between clamps and are ligated as they are encountered. In addition, a transfixing suture is added to the cuff of large arteries. The artery supplying the sciatic nerve may require separate ligation. Temporary pressure, bone wax or thromboplastin is applied to the open medullary cavities of large bones to control oozing when necessary.

5. Major nerves are transected 2-3 inches above the amputation at the highest possible level *without resorting to traction*. Nerve stumps are neither ligated nor injected with alcohol or other chemical agents, but may be injected with a long-acting local **anesthetic** agent to reduce pain during the postoperative recovery period.

6. Since the amputation has been performed because of irreparable damage to a contaminated, if not grossly septic, extremity, the stump is never closed primarily.

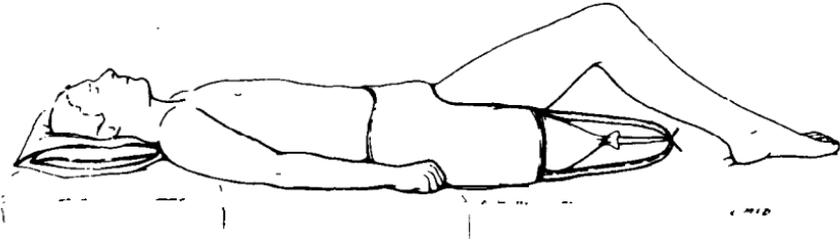
---



**FIGURE 27.-Technique of open circular amputation. A. Circular incision of skin. B. Section of the muscles at the level of retracted skin. C. Section of the bone at the level of retracted muscles. D. The resultant surgical wound has the appearance of an inverted cone**

## DRESSINGS

A layer of sterile fine-mesh gauze soaked with **betadine** is placed over the wound, and the recess of the stump is dressed loosely with fluffed gauze or other suitable material. A stockinette for skin traction is then applied to the skin above the open stump. A liquid adhesive (benzoin tincture) to prevent slippage of the stockinette is used. The stump is wrapped with gentle compression, decreasing proximally, and 5-6 pounds of traction are applied with weights and pulleys or with a self-contained traction device (Figure 28). Constrictive wrapping at or above joints must be avoided. Traction should be reapplied after dressing changes and maintained continuously.



**FIGURE P&--Self-contained traction device incorporated into a plaster cast facilitates evacuation.**

The amputation with preserved flaps requires individualized dressing consideration. The flaps should be held in their intended position by the dressing, although the major area of the amputation should be left widely open. No element of the flap should be suspended loosely within the dressing. No tacking sutures should be used. If possible, traction should be applied on the remaining skin elements and not on the flap.

## POSTOPERATIVE MANAGEMENT

To prevent **flexion** contracture of the hip following transfemoral amputations, the patient should be kept in the prone position as much as possible until he has become familiar with active range of motion exercises. When he lies supine, sandbags should be used

to hold the stump in position. A tourniquet should be readily available for emergency use during the first 5-7 postoperative days. It should be loosely attached to the bed or to the litter during evacuation.

Prior to amputation, or as soon as the patient becomes conscious postoperatively, the patient should be counseled that he will experience both normal and painful sensations in the phantom limb. This counseling is critical to allay apprehension and prevent fear which can drain the postoperative patient's energy for recovery. There is frequently severe causalgia-like pain in the end of the residual limb which subsides with healing. The patient should be told that this is normal and will subside soon. Adequate pain medication should be provided as required for stump pain.

### STUMP WOUND CLOSURE

The timing and the method of wound closure require as great a measure of surgical judgment as did the original decision to amputate. Delayed primary closure is not indicated in open circular amputations. Continued traction will often result in the skin eventually closing over the end of the stump. If it does not, small split-thickness skin grafts can be used. A definitive revision may be necessary later, but it can be performed at higher echelons which permit immediate fitting techniques, thereby allowing more rapid prosthetic application. Delayed primary closure too often results in a chronically inflamed, edematous, indurated, and sometimes draining stump that is unreceptive to prosthetic application.

### TRANSPORTATION

Traction ideally should be continuous throughout the evacuation chain. A customized traction device may be fashioned by incorporating a wire ladder splint into a cast. Rubber tubing between the wire ladder splint and the stockinette provides the traction.

---

**GENERAL' PRINCIPLES**

**Certain principles in the management of amputations in the forward area merit additional emphasis:**

- 1. Amputations are performed to save lives.**
  - 2. Amputations are performed at the lowest possible level of viable tissue.**
  - 3. An obviously useless extremity should be amputated as early as possible.**
  - 4. There is no ideal or standardized level of amputation in the forward area.**
  - 5. All amputations should be left open.**
  - 6. Cold injury, per se, is not an indication for emergency amputation.**
  - 7. During evacuation, continuous traction should be provided to the amputation stump to prevent skin retraction.**
  - 8. Patients should be counseled regarding stump and phantom pain. Adequate medications for stump pain should be provided.**
-

**PART IV**

***Regional Wounds and Injuries***

---

## CHAPTER XXII

# Craniocerebral Injury

### CLASSIFICATION

Craniocerebral injuries are classified according to the type and extent of injury sustained by the scalp, the skull, and the brain and whether the injury is open or closed.

TABLE 1 1.—*Classification of craniocerebral injuries*

Scalp	Skull	Brain
<i>Open:</i> puncture laceration <b>avulsion</b>	depressed fracture cornminuted fracture linear fracture	<i>Open:</i> penetrating injury
<i>Closed:</i> contusion		<i>Closed:</i> diffuse parenchymal injury focal intracranial hematomas: <b>extradural</b> subdural intracerebral

In open injuries, the scalp may be punctured, lacerated, or avulsed. In closed injuries, the scalp is not penetrated but is almost always contused.

Skull fractures are classified as linear, cornminuted, and depressed. If open, they are termed compound. It is rare to have cornminuted or depressed skull fractures without an overlying scalp laceration. It is important to determine whether fractures cross the meningeal vascular markings or the dural venous sinuses of the skull and whether they involve the paranasal sinuses or mastoid air cells. The depth of fracture depression should be measured on tangential X-ray views.

Brain injuries are classified as open (with penetration of the

brain) or closed. The category of closed injury encompasses focal intracranial hematomas (extradural, subdural, and intracerebral) and diffuse parenchymal injury. Various combinations of scalp, skull, and brain injuries often coexist.

### MECHANISMS OF INJURY

An understanding of the mechanisms and pathophysiology of injury is necessary for successful treatment. The mechanisms of injury can be divided into the primary events occurring at the time of impact, and the secondary events that develop over subsequent hours to days (Table 12).

TABLE 12.-Mechanisms and *pathophysiology*

---

**Primary:**

*Open:* transection, disruption

*Closed:* diffuse parenchymal injury:  
shearing of axons  
disruption of capillaries

**Secondary:**

*intracranial:* hematomas, edema, seizures, loss of cerebrovascular autoregulation, waves of increased intracranial pressure.

*systemic:* hypoxia, hypotension, hypercarbia, electrolyte imbalance

**Primary open** injuries disrupt neurons, **glia**, and blood vessels. **Primary closed** injuries produce parenchymal damage through the shearing of axons and capillaries, particularly in the white matter, and through small pectechial hemorrhages. These may coalesce over the first week after injury into delayed focal hematomas.

Secondary brain injuries occur as a result of systemic and intracranial processes following the primary brain injury. The brain can be protected from secondary injury by prompt recognition of such systemic events as hypoxia, hypotension, hypercarbia, hyponatremia, and other forms of electrolyte imbalance. Secondary injury of intracranial origin can be reduced by the prompt detection and treatment of hematomas and of waves of

---

intracranial pressure elevation 'that accompany loss of cerebrovascular autoregulation, cerebral edema, seizures, and infection.

The causes of death after head injury can be divided into those occurring in the acute phase within a few hours of injury and those occurring in the subacute phase within a few days of injury. In the acute phase, massive sympathetic and parasympathetic discharges give rise to cardiac arrhythmias, low cardiac output, and respiratory difficulties due to ventilation/perfusion mismatches.

Patients who survive the immediate effects of coma-producing injury develop a hyperdynamic cardiovascular and metabolic condition caused by a preponderance of sympathetic overactivity. Cardiac output is often elevated to twice normal by a combination of arterial hypertension, a reduction in systemic vascular resistance, and tachycardia. The metabolic rate of the body is increased to 1.5 times normal. This state lasts 5-10 days. Dehydration therapy for the purpose of preventing cerebral edema may lead to cardiovascular collapse and should be avoided.

Death in the subacute phase is usually due to the enlargement of an intracranial mass in the form of a hematoma or parenchymal swelling. In response to increasing intracranial pressure, the temporal lobe(s) herniate through the tentorial notch, or the cerebellar tonsils herniate through the foramen magnum, causing damage to the cardiovascular and respiratory centers. The time required for casualty evacuation and triage results in the majority of neurosurgical care being delivered in the subacute phase of injury. Initial care is directed toward the prompt recognition, treatment, and prevention of secondary injuries, particularly those due to hypoxia and to focal intracranial hematomas. Definitive neurosurgical treatment is best carried out by specialist teams in fully-equipped hospital facilities.

## HISTORY AND NEUROLOGICAL EVALUATION

The history should record the time of injury, the type of missile or cause of injury, and the state of consciousness immediately after injury. It is very important to make permanent records of all observations for physicians elsewhere in the evacuation chain to review. The examination should begin with evaluation of consciousness. Consciousness can be described qualitatively with the terms

conscious, (awake, aware); lethargic, (conscious, but with slowed reactions); stuporous (arousable only by painful stimuli); and comatose (unarousable).

1. The neurological condition may be expressed quantitatively with the Glasgow Coma Scale (GCS), in which numerical scores quantitate to the best level of motor, verbal, and eye-opening response to standardized verbal and tactile stimuli (Table 13). Coma in the GCS is defined as absence of verbal response ( $V = 1$ ) and eye-opening ( $E = 1$ ), with a motor response that can vary from none to localizing ( $M = 5$ ). A summed GCS of 7 or less, six hours after injury, in a patient with adequate blood pressure and ventilation, indicates severe brain injury. Survival and neurological outcome are accurately predicted by the GCS score.

2. The pupillary size and response to light should be recorded. Progressive dilation of a pupil indicates an expanding intracranial mass and transtentorial herniation that in 85% of cases occurs on the side of the dilated pupil. The oculocephalic reflex, or eye movement in response to head rotation (doll's eyes reflex), should be recorded. Loss of this reflex indicates brainstem injury. Unilateral pontine injury will produce fixed deviation of the eyes to the contralateral side; frontal lobe injury will produce eye deviation to the side of the injury.

3. Motor responses should be tested in each limb. Asymmetries between right and left and between upper and lower limb strength should be noted. Abnormal (extensor) plantar responses should be sought.

4. Blood pressure, pulse rate and rhythm, respiratory pattern (waxing and waning or Cheyne-Stokes, irregular or gasping), and body temperatures should be recorded. Frequent recording of neurological status and vital signs on a time-oriented flow chart is very helpful in revealing neurological deterioration, particularly when patients are transferred from one echelon to another with suboptimal continuity of care along the evacuation route. Although the GCS correlates well with eventual outcome, it is only a shorthand for certain aspects of the neurological examination and does not substitute for detailed notes regarding the patient's condition.

TABLE 13.—*Glasgow Coma Scale*

<i>BEST MOTOR RESPONSE</i>	<i>EYE OPENING</i>	<i>BEST VERBAL RESPONSE</i>
Obeys	6	
Localizes Pain	5	Oriented, Conversing 5
Withdraws	4 Spontaneous	4 Disoriented, Conversing 4
Abnormal Flexion	3 To Verbal Command	3 Inappropriate Words 3
Extension	2 To Pain	2 Incomprehensible Sounds 2
None	1 No Response	1 No Response 1

Add the scores for each category.

A total score of 7 or less indicates a severe injury.

The most common patterns for comatose patients are M = 5 or less, V = 1, E = 1.

## X-RAY AND LABORATORY EVALUATION

Skull films should be obtained in the AP, right and left lateral views in order to localize fractures and fragments. The presence of an irregular area of increased or overlapped bone density suggests a depressed fracture, and a tangential X-ray should be obtained. Stereoscopic films can help localize intracranial fragments. Lateral shift of the pineal gland if calcified (rare in young individuals) can indicate the presence of an intracranial hematoma. Cervical spine fractures may occur in association with head injury, and cervical spine films should be obtained. The presence of an intracranial hematoma can be visualized by CT scanning, which should be available where definitive neurosurgical treatment is carried out.

Lumbar puncture with a 20 or 22 gauge needle, with 3-5 cc of spinal fluid removed for glucose cells and culture, should be performed if meningitis is suspected after a penetrating wound or after basal fracture with cerebrospinal fluid (CSF) leakage or pneumocephalus.

Frequent measurement of arterial blood gases, serum electrolytes, and osmolality are of great importance in management.

## MANAGEMENT

## Triage

Subtle changes in neurological condition or state of consciousness can be the first or even the only sign of impending intracranial disaster. On the other hand, apparent neurological deterioration can be the first sign of systemic problems, such as hypoxia or shock.

As a first step, the airway must be cleared and maintained, even if this necessitates intubation or **tracheostomy**. Unconscious patients must not be transferred or evacuated without airway protection. Where there is hemorrhage into the upper airway, a cuffed endotracheal tube is imperative. The use of low-pressure cuffs obviates many problems.

Definitive neurosurgical management will rarely, if ever, be carried out at the front lines. Patients in extremis at the front line will not usually survive, regardless of what treatment is given. Many considerations will enter into the priorities of triage. As a rule, thoracic, vascular, and abdominal injuries take precedence over head wounds. Multiply-injured patients will require evaluation and treatment by several surgical teams simultaneously. When faced with a number of evacuated but untreated head-injured patients, the neurological surgeon will be required to make initial triage decisions on clinical grounds. Even the decision to send a patient to CT scan implies a commitment to a certain level of treatment. Deteriorating casualties who are not moribund are treated first. Alert patients with the potential to deteriorate are taken next. Among the stable patients, those with obtundation are evaluated before those who are awake. As a rule, head injuries are more urgent than spinal injuries.

## EMERGENCY MANAGEMENT

After the airway is protected, shock is treated or prevented by placing two large-bore venous catheters and infusing plasma, normal saline, or lactated Ringer's solution. The stomach should be emptied and the bladder catheterized.  $\text{NaHCO}_3$ , 1meq/kg is given for metabolic acidosis, and should be administered empirically when respiration has been compromised.

In the face of neurological deterioration, some time can be gained to prepare for operation upon an expanding intracranial mass by administering furosemide, 40mg IV, followed by mannitol 1gm/kg. This will result in dehydration and must be carefully watched. The osmolarity should not be permitted to rise above 305 mOsm/l. Since the value of steroids is unproven, steroids need not be administered.

Anticonvulsant prophylaxis is begun with phenytoin, 1 gm IV push over 15-20 minutes. Cardiac arrhythmias may result from too rapid administration. If given as an IV solution, phenytoin must only be diluted in 50cc normal saline, and dripped in over 20 minutes. Any other solution of phenytoin will precipitate. A maintenance dose of 400 mg/day is required.

The use of narcotics or sedation in the spontaneously breathing patient is contraindicated.

Intravenous antibiotics are administered in meningeal doses for one week. Although the efficacy of prophylactic antibiotics has not been proven, the use of antibiotics in this setting is considered therapeutic and represents a full course of treatment for contamination of injured tissue and CSF by a foreign body. Which antibiotics to use will depend on local conditions and the types of organisms that are encountered in any given situation.

## OPERATIVE MANAGEMENT

### Operative Management of Open and Penetrating Wounds

Treatment is carried out in the following order:

(1) The head is shaved and the wound inspected. X-rays are examined to determine the distribution of bone and metallic fragments.

(2) Endotracheal intubation and general anesthesia are preferable in most cases. Adequate blood is made available for wounds near major dural venous sinuses.

(3) The scalp is scrubbed with an antiseptic solution, preferably an iodophor. The wound is copiously irrigated with 1-2 liters of sterile saline.

(4) The patient is positioned and draped so that entry and exit wounds are accessible and a contralateral burr hole can be made if needed. The head should be elevated slightly above heart level,

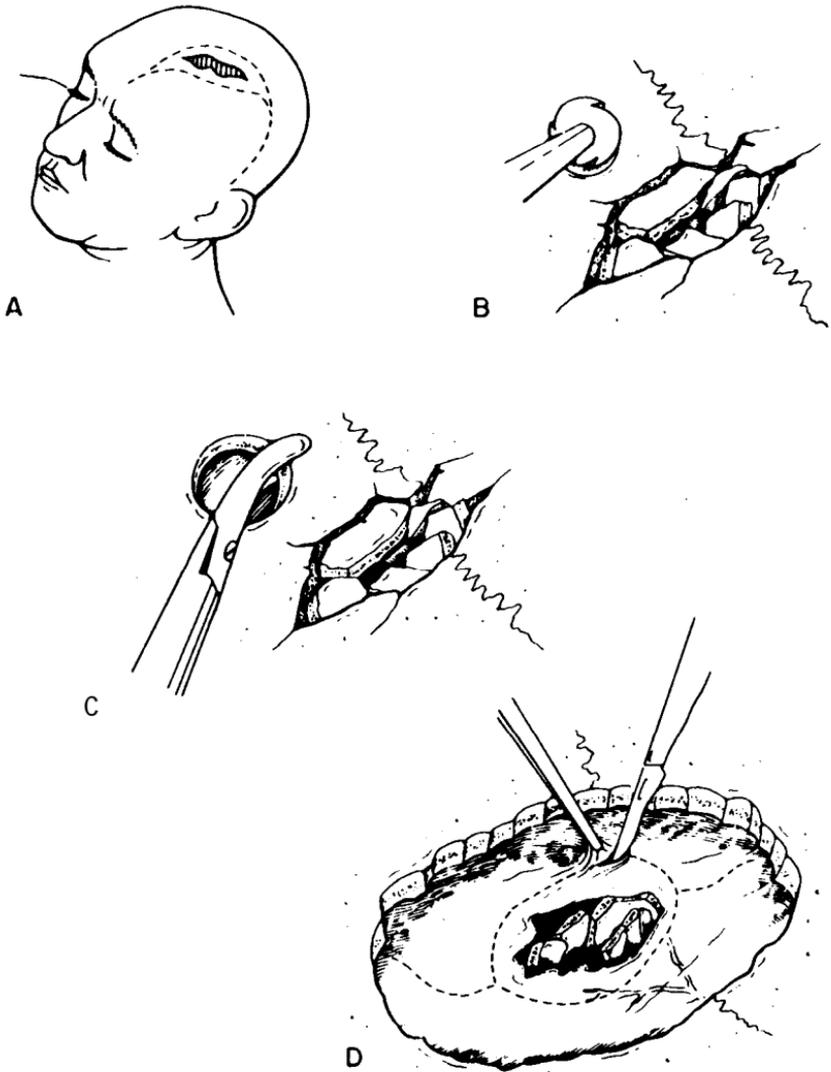


FIGURE 29.—Technique for debridement of head wounds. A. Conservative excision of devitalized skin and galea. B. Burr holes should be placed in intact bone adjacent to the area of damage. C. Bone is then removed by rongeur towards the area of contamination. D. Only minimal trimming of the dural edges is required.

to encourage venous return, but not so high as to risk air embolism.

(5) Devitalized scalp and foreign bodies are removed. Incisions

are made along lines that can be utilized to rotate the scalp, should it become necessary to perform plastic repair of the scalp. As much scalp as possible is preserved (Figure 29A).

(6) Contaminated pericranium is removed. Burr holes are made in intact bone adjacent to the area of damage. A margin of normal dura is exposed. Bone is removed with rongeurs toward the area of contamination (Figure 29 B, C).

(7) Contaminated dura is removed, preserving as much as possible for closure (Figure 29 D).

(8) Damaged brain, blood clots, and foreign bodies are removed with gentle saline irrigation and suction. Removal of all bone fragments is of greater importance than removal of all metal fragments. The use of intraoperative ultrasound facilitates localization of fragments. The debrided track should remain open after debridement. Closure of the track suggests the presence of deeper or adjacent clot or necrotic brain tissue exerting pressure on the track (Figure 29 E).

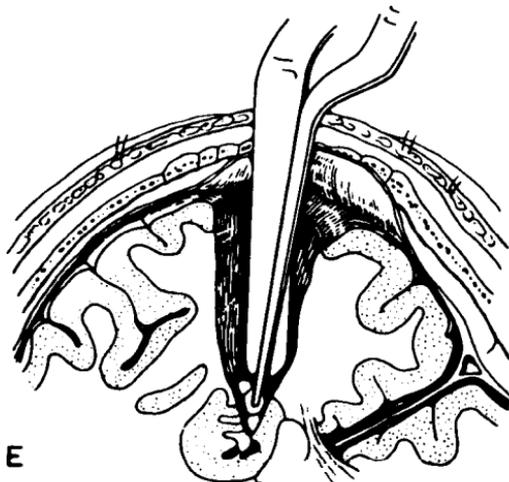


FIGURE 29.-Continued. E. All blood clots, devitalized brain tissue, indriven bone fragments, and visible foreign bodies are removed.

With high velocity injuries, there is more destruction at the wound of exit than the wound of entry, and debridement of the exit wound initially may provide the most rapid decompression. Complete hemostasis is accomplished before closure.

The brain is copiously irrigated with normal saline solution

containing 1000u/l bacitracin at body temperature. A concentrated bacitracin solution (500u/cc) should be used to irrigate the track.

(9) Massive swelling of the brain is an uncommon but serious occurrence during operation that may represent the development of an intracerebral hematoma or a contralateral subdural hematoma. It may also represent an anesthetic complication or loss of autoregulation of the cerebral vasculature. After determining that there is no technical difficulty with anesthesia, swelling is treated in a **stepwise** fashion by increasing the ventilatory rate to obtain a  $\text{PaCO}_2$  of about 25mm Hg, by tapping the ventricle and draining CSF, and by administering barbiturates. Pentobarbital sodium, 100-300 mg, is given intravenously. Additional doses of 100 mg may be required hourly. If the brain is swollen at the time of closure, an intracranial pressure monitoring catheter is placed, preferably intraventricularly, and the intracranial pressure is monitored in the post-operative period.

(10) The dura is closed without tension. Dural grafts may be harvested from pericranium, temporalis fascia, or fascia lata.

(11) The scalp is closed primarily without tension. Rotation of scalp flaps with closure of the secondary defect with split-thickness skin grafts or a myocutaneous pedicle flap may be necessary.

(12) Post-operative X-rays or CT scans are obtained to check for the presence of retained fragments.

(13) The need for reoperation for retained fragments is a difficult judgment call that requires much experience. It need not be done routinely if optimal follow-up neurosurgical and CT scan capability is anticipated.

### Operative Management of Closed Injuries

A critical step in the management of closed injuries is the recognition of which patients require operation for evacuation of intracerebral hematomas that can cause, or are likely to cause, neurological deterioration. Recognition of the presence of hematomas may have to be made solely on the basis of deteriorating neurological status if intracranial pressure (ICP) monitoring and CT scanning are unavailable. The presence of fractures across venous channels or sinuses, the site of intracranial fragments, or a tangential wound of the skull may indicate the

presence and location of an intracranial hematoma. Tangential wounds produced by high-velocity missiles should be evaluated carefully, as there is often extensive brain injury under the site of skull impact. If a compound depressed fracture has been produced by a tangential wound, a craniectomy should be performed and the dura opened to inspect for subdural or intracerebral hematoma.

If the presence of a hematoma is suspected, radiographic confirmation can be obtained by CT, cerebral arteriography, or ventriculography. Useful information can be provided by even the most simple form of arteriography, obtained by puncture of the common carotid artery with a 18 or 20 gauge needle, injection of 10 cc of low concentration radiopaque contrast over 1-2 seconds, and exposure of a single AP X-ray film of the head. Ventricular puncture and injection of 5 cc of air can also be used to demonstrate shift of the midline of the brain.

Intracranial hematomas that produce more than a 5 mm shift of the midline or similar depression of the cortical or cerebellar surface should be evacuated, as such hematomas are capable of producing neurological deterioration. Evacuation of acute subdural and epidural hematomas will require a craniotomy. A large fronto-temporal-parietal flap can be elevated quickly and provides good exposure of the cerebral convexity. If exploratory twist-drill holes or burr holes are made prior to a craniotomy, aligning the skin incisions should be done so that they can be extended into a craniotomy incision. The frontal burr hole is placed at the mid-pupillary line and 1 cm anterior to the coronal suture; the temporal hole is made at the pterion (junction of the frontal, parietal, temporal squamosal, and sphenoidal bones).

### **Non-operative, Intensive Care Unit Management of Closed Injuries and Post-operative Patients**

The goal of management is the prevention of secondary brain injury due to systemic and intracranial causes. Good pulmonary care is essential. How long intubated patients can be maintained before performing tracheostomy will depend on the respiratory care facilities available. In some cases, intubation can be maintained for one or two weeks without tracheal damage.

Feeding should be started via nasogastric tube as soon as bowel

sounds are present. As high **a**caloric intake as can be accomplished without producing fluid overload is desirable. Arterial hypertension should be controlled with hydralazine and **beta**-blocking antihypertensive drugs if blood pressure becomes greater than 160 mm Hg systolic. Arterial blood gases, serum osmolality, electrolytes, and hemoglobin should be monitored daily, or more frequently as needed.

Prevention of secondary damage due to intracranial swelling and herniation can be accomplished most easily when the intracranial pressure is monitored. This may not be practical in the combat environment. A rising intracranial pressure indicates either (1) the expansion of a hematoma, (2) the late development of a hematoma, typically intracerebral, or (3) the presence of brain swelling. Expanding hematomas should be localized and evacuated. Brain swelling should be treated with a series of steps listed here in order of increasing complexity:

(1) Repositioning the patient to avoid neck vein compression. In general, a flat position or slight head elevation will minimize the intracranial pressure.

(2) Correction of hypoxia and hypercarbia; hyperventilation to achieve a **PaCO<sub>2</sub>** of about 25 mm Hg.

(3) CSF drainage via ventriculostomy.

(4) Administration of mannitol 1 **gm/kg**, IV.

(5) Other pharmacological measures to reduce intracranial pressure, such as lidocaine infusions or the induction of barbiturate coma, may be of benefit but should only be considered if optimal neurosurgical ICU support is available.

## PROGNOSIS

The prognosis of craniocerebral injuries is good in patients who are not deeply unconscious, who respond to simple commands, and who do not deteriorate. In any head-injured patient who shows signs of deterioration, it must be determined whether or not this deterioration is due to a problem requiring surgical intervention. The prognosis is grave in patients who are rendered immediately comatose and who remain in a state of unconsciousness for a long period of time. Any improvement in the neurological condition of the acutely injured patient is significant. Restlessness and return of voluntary activity are phases which many head-injured patients go through as they recover.

# Maxillofacial Wounds and Injuries

The management of maxillofacial injuries is divided into immediate, primary, and reconstructive phases.

1. In the immediate phase the establishment and maintenance of the airway and control of hemorrhage have the highest priority. Appropriate protective dressings are applied and hydration is maintained. The institution of antimicrobial therapy in this phase contributes to minimizing the incidence of subsequent infection.

Penicillin is the drug of choice. If there is a question of penicillin allergy, clindamycin is an excellent alternative.

2. The primary phase consists of early definitive surgical repair of the wound and is accomplished at the first primary care facility to which the casualty is evacuated. Treatment performed during this phase of management significantly influences the subsequent requirement for or the magnitude of bony as well as soft tissue reconstruction and, therefore, the ultimate long-term functional and cosmetic outcome. Generally, both hard and soft tissues are conservatively debrided. Repair begins with reapproximation and fixation immobilization of fractured bones, application of intraoral devices, reestablishment of dental occlusion or **intermaxillary** ridge relationships, and finally, primary closure of intraoral mucosa and overlying soft tissues wherever possible.

3. In the third or reconstructive phase, the tertiary care center attempts to correct deformities, such as malocclusion, and to obliterate defects with grafts or prosthetic devices. Ideally, treatment is carried out in specialized units staffed by dental, oral, and plastic surgeons who work in close cooperation with specialists in otolaryngology, ophthalmology, and neurosurgery. At least 25% of casualties with maxillofacial injuries also have injuries of the head and neck. In addition, dental laboratories should be available for the fabrication of dental appliances.

## DIAGNOSIS

To be certain that wounds which are not obvious are not overlooked, patients with maxillofacial injuries require careful roentgenologic and local examination, including inspection and palpation. Cervical spine fracture must be ruled out by X-rays.

Both the injured and intact sides of the head and face are examined comparatively to detect contusion, swelling, emphysema, tenderness, areas of analgesia, and distortion of bony landmarks. The surgeon should examine particularly for asymmetry of the level of the eyeballs and the presence of diplopia, periorbital hematoma, and edema, all of which are indicative of orbital floor fracture. Otorrhea and rhinorrhea of cerebrospinal fluid origin indicate fractures involving the **sphenoidal** and ethmoidal bones of the tegmen. Temporomandibular joint function is noted, as is the integrity of the palate and buccal sulci and the alignment of the upper and lower teeth.

Wounds within the oral cavity suggest segmental dental alveolar fractures or damage to the body of the mandible. The open-mouth or so-called gagging **facies** usually is caused by fractures of the mandibular **ramus** or by condylar dislocation, but it may also result from a horizontal fracture of the maxilla, higher level **mid**-face fractures, displaced teeth, or hematoma formation around a posterior fragment of the mandible.

## INITIAL MANAGEMENT

The problems associated with maxillofacial injuries are similar to those of other injuries; that is, maintenance of the airway, control of hemorrhage, reduction of fractures, prevention of infection, and maintenance of fluid balance. Special problems arise because of mechanical interference with breathing and swallowing. A patent airway and an adequate fluid and nutritional intake are difficult to achieve in many maxillofacial injuries because of the partial or complete obstruction of the respiratory or alimentary orifices.

If patients with maxillofacial injuries require sedation, narcotics must not be used until it is certain that there is neither associated intracranial injury nor a marginal airway. **Tracheostomy** may be required.

## RESPIRATORY OBSTRUCTION

Respiratory obstruction in a patient with maxillofacial injuries may be due to several causes, as follows:

1. Blockage of the airway by accumulated blood and secretions or by loose objects, such as broken teeth or dentures.
2. Prolapse of the tongue, which occurs frequently with injuries, especially when acute avulsion of the mandibular symphysis has occurred.
3. Injuries of the hyoid bone and its attached muscles, with resulting loss of control of the tongue-hyoid complex.
4. Swelling of the tongue and soft palate.
5. Laryngeal spasm, which may be caused by anesthetic agents.

No time should be lost in reversing hypoxia, which can rapidly progress to death. The patient is positioned to permit drainage by gravity, and the airway is rapidly cleared of blood, secretions, foreign bodies, or whatever else may be blocking it. Direct vision and strong suction are necessary. In the event that these **non-invasive** maneuvers fail to immediately relieve obstruction, there must be no hesitancy to perform endotracheal intubation or cricothyroidotomy. In certain laryngotracheal crush injuries and other wounds which transect the trachea, it may be necessary to perform emergency **tracheostomy**. Cervical spine in-line control must be maintained during these maneuvers.

## SHOCK AND HEMORRHAGE

Hemorrhage is temporarily controlled by digital pressure until permanent control can be achieved by clamping and ligation. Clamping must be done under full vision, not blindly, because there are numerous important anatomical structures in this area, the damage of which could be extremely serious. Ligation of the external carotid for regional control of hemorrhage is seldom necessary.

## PREVENTION OF INFECTION

Because of the contiguity of the **naso-oral** passages and the perforating nature of these wounds, maxillofacial wounds are doubly exposed to bacterial contamination. The mouth, pharynx, and

nose are heavily populated by a variety of pathogens. All fractures in this region, except for fractures of the ascending ramus of the mandible, usually communicate with the internal mucus membrane wound and the external skin wound.

Antibiotic therapy must begin early and be maintained if serious infection is to be prevented or controlled. Oral hygiene, with particular attention to the teeth, is also necessary. Placement of a nasogastric tube for feeding in the immediate postoperative period in the presence of extensive intraoral wounds may be desirable.

### INITIAL WOUND SURGERY

The surgical field is prepared as usual, ingrained dirt being removed by gentle scrubbing with a soft brush. The eyebrows are not shaved.

**Debridement.** Tissues should be handled very gently, with fine instruments. The blood supply of the facial tissues is so adequate and resistance to infection so high that only the most minimal excision of skin is necessary. From 1-2 mm of the wound edges are trimmed to be certain that noncontaminated, nonbeveled edges can be accurately approximated. The trimming is done with ophthalmic scissors or a sharp No. 15 blade. The remainder of the procedure is carried out with conservation of as much tissue as possible. No bone with retained periosteal or musculovascular attachment should be removed from the wound. Only that bone which washes freely away with copious irrigation should be removed.

**Primary wound closure.** Maxillofacial injuries furnish one of the very few exceptions to the general rule that soft-tissue wounds should not be closed at the time of initial wound surgery. Whereas primary wound closure of facial injuries is preferred to delayed primary wound closure, this policy does not pertain to associated wounds of the neck.

Ideally, treatment of these multisystem wounds is carried out by multidisciplinary teams that include otolaryngologists, ophthalmologists, neurosurgeons, oral surgeons, dentists or plastic surgeons. This sort of coordinated team approach allows surgeons of several different specialties to make diagnostic, prog-

nostic, or therapeutic contributions during a single general anesthetic

Closure, which must be accomplished without tension, is begun intraorally and proceeds outwardly. When the parotid duct is found severed, primary repair should be considered. If primary repair is not deemed practical, both the distal and proximal portions of the duct should be cannulated with a plastic catheter which is securely sutured to the buccal mucosa and retained in place for 5-7 days. When the proximal portion of the duct cannot be located or is missing, the cannula should still be placed into the depth of the wound prior to closure and brought out through the distal segment of the duct intraorally. If the distal segment of the duct is missing the catheter should be brought out into the mouth through the mucosal wound repair in order to prevent or reduce the incidence of cutaneous salivary fistulae. The foregoing guidance is more difficult to apply with injuries of the submandibular gland because of its dependent position in the floor of the mouth and the likelihood that an injured duct will become stenotic. Extensive injury to the submandibular gland duct is often best managed by removal of the gland.

The repair of severed branches of the facial nerve, identified during wound repair, should be accomplished utilizing fine suture material and magnification. All branches proximal to a vertical line extending downward from the lateral canthus should be repaired primarily. When there is bone destruction as well as extensive soft-tissue damage, it may be necessary to suture the buccal mucosa to the margins of the skin to cover the fracture site. Watertight closure over a fracture is always desirable. The oral mucosa is closed with fine chromic catgut; otherwise, the finest nylon or silk, mounted on swaged needles, should be used. Skin sutures are introduced close to the cut edge and are placed not more than 3 mm apart. Temporary application of a pressure dressing may help to prevent edema and hematoma formation.

In rare cases, when a defect is so large that closure is impossible without tension or distortion, a flap may be used. All skin flaps must be carefully approximated and held in position by suturing without tension.

## FRACTURE-MANAGEMENT

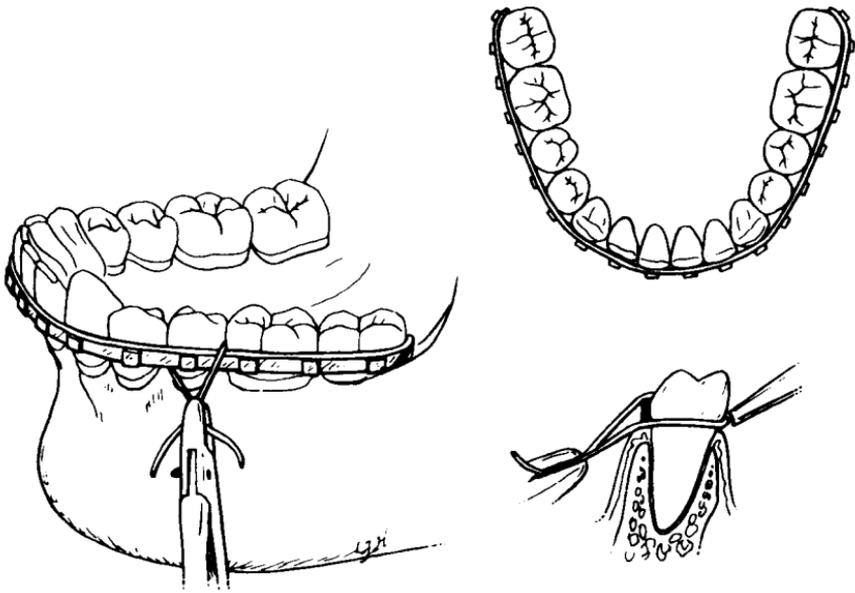
After conservative debridement of bone fragments has been completed, any remaining exposed bone must be covered by soft tissue. A mandibular stump can be covered by suturing mucous membrane to the skin edge. If the oral cavity has not been excluded by watertight closure, the fracture site must be drained to the exterior for 2-5 days.

Only teeth which are completely loose or fractured teeth with exposed pulp should be removed. Firmly embedded teeth are left in situ, even if they are near fracture lines. Damaged teeth are useful for immobilization of fractures. Residual molar teeth in otherwise edentulous jaws are especially valuable for fixation. Although dead, **carious**, or loose teeth may cause infection, they should not be disturbed at this time.

Immobilization of the jaws is necessary for accurate reestablishment of occlusion as well as early union of fractures. It also facilitates the healing of soft-tissue wounds, limits the spread of infection, and prevents deformity.

Several methods of immobilization of the jaws are practical, as follows:

1. Application of commercially-produced **archbars** to the labial and buccal aspect of the maxillary and mandibular teeth with simple **circum dental** wires (Figure 30). Fixation is then achieved either with intermaxillary wires or elastics or both.
2. Any one of several other commonly described techniques; i.e., eyelet loops, continuous loops, and Risdon wiring.
3. In the edentulous situation, the patient's dentures may be fixed by circumferential wires in the mandible and by peralveolar pins or wires in the maxilla. The dentures may then be used as anchorage for intermaxillary fixation. **If** dentures are not available, other options, depending upon the situation and preferences of the surgeon, include open reduction and rigid **fixation** with a bone plate or similar device, or the application of an external biphasic splint. Construction of individualized dental splints is seldom possible or indicated in a combat zone hospital.
4. When portions of the mandible have been avulsed, the external biphasic splint is an excellent and expedient technique by which the mandibular segments may be retained in good position and alignment during healing. Other types of preformed or adaptable plating and bridging devices may be used, but they require



**FIGURE 30.—Technique of archbar application to maxillary and mandibular teeth.**

larger wound exposure and entail a greater risk of infection and therefore are not recommended for use in the combat zone.

5. Multiple and grossly comminuted fractures are most often best managed by closed reduction techniques.

### POSTOPERATIVE MANAGEMENT

Patients without intermaxillary fixation may be given all ordinary fluids and soft foods which require little or no chewing. If intermaxillary fixation has been used, the diet, which must be thin enough to suck through a tube, should consist of such nourishing items as milk and milk products, any of several commercially available dietary supplements in liquid form, thin custards, and thick soups. Feedings should be at frequent intervals and in adequate amounts.

If it is necessary to protect the lips from the wires used in intermaxillary fixation, pieces of soft wax are useful. Lubrication of the lips and nostrils will help to prevent fissures and ulcers.

After repair of **maxillofacial** wounds, a pressure dressing is applied whenever possible and left in place for at least 48 hours. Sutures are removed on the fourth or fifth day.

## REGIONAL FRACTURES

### Fractures of the Mandible

Next to the nasal bone, the mandible is the most commonly fractured facial bone. Its weakest and most frequently fractured area is the neck of the **condyle**. Forces delivered to one side of the mandible often produce fractures of the opposite side, either at the condylar neck or at the angle, and forces directed to the chin often produce fractures at the condylar neck and parasymphyseal regions. Such fractures may, in fact, occur bilaterally and it should be remembered that nearly half of all mandibular fractures resulting from blunt trauma are multiple in nature.

Examination will reveal one or more of the following findings: restriction of the normal movements of the jaws, abnormal mobility of the jaws, crepitation upon manipulation, an open injury extending into the mouth, irregularities in alignment of the teeth, and abnormal occlusion. Swelling and bruises of the soft palate, **fauces**, and lateral wall of the pharynx are occasionally seen in severe fractures of the ascending **ramus**.

Primary treatment of mandibular fractures is dictated by a number of considerations, among which are the nature, location, and severity of the fracture and the condition of the existing **dentition**. Some of these fractures may be managed by dietary control only, others by closed techniques utilizing simple **intermaxillary** fixation, and some by open reduction and internal fixation. There is no indication for immediate bone grafting in the primary repair of mandibular fractures in the combat hospital.

## FRACTURES OF THE FACIAL BONES

Zygomaticomaxillary compound fractures. Fracture dislocations involving the zygomatic bone are the third most common fractures of the facial skeleton. The zygoma forms the major portion of the lateral and inferior rims of orbit, as well as a portion of the orbital floor. Because of its complex articulation and the

---

importance of the soft tissue' structures attached to it as well as those which it supports, early reduction of these fractures is highly desirable.

Fractures of the zygoma will usually displace the lateral palpebral ligament inferiorly, and are often accompanied by an orbital floor fracture which produces enophthalmos and diplopia. Diplopia may also be caused by entrapment of the inferior **extraocular** muscles which restrict upward and lateral motility of the eye. Additional signs of this injury may include loss of cheek bone prominence, limitation of mandibular excursion due to impingement upon the coronoid process of the mandible by the depressed zygoma or fractured and depressed zygomatic arch, **subconjunctival** hematoma, sensory disturbance over the distribution of the infraorbital nerve, and a palpable bony step-off at the inferior and lateral rims of the orbit and at the lateral wall of the maxilla **intraorally**. Bleeding from the nostril on the injured side is frequently seen. Nose blowing should be avoided.

Special attention should be given to the eye examination. Direct ocular injury is occasionally observed, particularly hyphema, dislocated lens, retinal detachment, and rupture of the globe, which are all ophthalmologic emergencies. Occasionally many of the findings associated with this and other **midface** fractures are obscured by swelling, edema, and ecchymosis. Thus, a knowledge of the fracture combined with a careful clinical examination and a well-directed radiographic survey are all essential to an appropriate diagnosis.

Definitive treatment of this injury depends upon the nature and severity of the fracture. In a straight-forward and non-comminuted type of fracture, an incision over the zygomaticomaxillary region at the lateral brow is made. An appropriate elevator is passed behind and beneath the zygoma and the fracture is elevated and reduced. If stable, no interosseous wiring is necessary. An unstable fracture may require wiring both the frontozygomatic and rim fracture. Orbital floor exploration frees muscle or fat entrapped inferiorly after realignment of the fractures. Intermittent release of pressure to intraorbital tissue is mandatory. **Methylmethacrylate** globe protectors are preferred. Large floor defects are repaired with an implant of suitable material. Except in grossly complicated cases, the use of packing or an antral balloon in the maxillary sinus is seldom required.

**Midface** Fractures. Fractures of the middle third of the face most

frequently are described as **Le Fort I** (horizontal), **Le Fort II** (pyramidal), and **Le Fort III** (craniofacial **dysjunction**). All result in disturbances of the dental occlusion and share certain similarities upon clinical examination. The distinction between and complexity of these injuries lie principally with the level within the **midface** at which fracture dislocation has occurred.

**Le Fort I** level fractures course through the lateral walls of the maxillary sinus, nasal **fossa** (including the nasal septum usually immediately superior to the floor of the nose), and the pterygoid process of the sphenoid bone posteriorly. The entire alveolar process of the maxilla containing the teeth, palate, floor of the maxillary sinuses and nose are mobilized. Upon clinical manipulation, all of these structures are mobile and, depending upon the magnitude of displacement, there will be varying degrees of malocclusion of the teeth. The fracture fragment is most often one mobilized segment, but occasionally may be fractured sagittally or into several segments. When this occurs, the ideal method of treatment is with an individualized palatal splint, application of maxillary and mandibular archbars, and **intermaxillary** fixation in centric dental occlusion. Sagittal and segmental fractures of the maxilla can be treated with **intermaxillary** fixation without palatal splints, and indeed on occasion must be so managed, but bony union and healing in **malposition** with significant malocclusion is a frequent sequella. Treatment for the **Le Fort I** level component rarely requires anything other than simple intermaxillary fixation. Blood accumulated in the maxillary sinus is ordinarily absorbed without incident. On rare occasions, additional suspension from a point above the level of the fracture may be required. A final inspection of the nasal septum is done and, if repositioning is required, it should be done at the time of primary repair.

The **Le Fort II** level fracture presents a more complex problem. Posteriorly, the fracture resembles that of the **Le Fort I** injury. Anteriorly it courses superiorly through the inferior rims of the orbits, often involving the orbital floors, then across the nasal bones separating them from the nasal process of the frontal bone. Frequently there is compounding into the anterior cranial **fossa** in the region of the cribriform process and **crista galli** of the ethmoid bone, with cerebrospinal rhinorrhea presenting as a part of the clinical findings. Clinical manipulation reveals mobility of the dentition and maxilla, which is **trans-**

mitted to the infraorbital rims' and to the junction of the nasal bones with the frontal bone. Periorbital ecchymosis and edema are usually more profound and the face may appear to be elongated. The latter finding results when the pyramidal midface fracture fragment is displaced superiorly in its anterior portion and inferiorly in its posterior portion. This type of anteroposterior rotational displacement in a counterclockwise direction, when viewed from the patient's right side, results in premature posterior occlusion, anterior open bite, and the appearance of increased vertical facial height.

Treatment of the Le Fort II fracture consists of repositioning the midface fragment and stabilizing it to the intact mandible by intermaxillary fixation. Depending upon the nature of the fracture, open reduction and internal wire or bone plate fixation at the infraorbital rims, implantation of the orbital floors, and appropriate suspension from a stable point above the level of the fracture may be required. If it is necessary to pack the nose for hemostasis in the presence of cerebrospinal rhinorrhea, the packing should be removed as soon as possible as it is a significant promulgator of infection, placing the patient at increased risk of developing meningitis. When cerebrospinal rhinorrhea is not at issue, nasal packing for support of fractures may be done if desired. In any case, the combination of intermaxillary fixation and nasal packing is ordinarily a clear indication for tracheostomy.

The Le Fort III fracture separates the nasal bones from the frontal bone, courses downward and backward through the medial wall and floor of the orbit, across the lateral wall and rim of the orbit, and posteriorly through the maxilla, zygomatic arches, nasal septal-ethmoid region, and pterygoid process of the sphenoid bone, thus producing a dysjunction of the facial skeleton from that of the cranium. Many of the findings and treatment considerations previously described for the Le Fort II fracture are shared by this injury, except that manipulation of the maxilla results in mobility of the midface which is transmitted to the junction of the nasal and frontal bones and at the lateral rims of the orbits.

**Nasal-Orbital Ethmoid Fracture.** Direct blunt trauma to the nasal region may produce fracturing and dislocation of the nasal bones and septum of varying degrees of severity. With increasing force of trauma, the resulting injury is often much more

extensive In the nasal-orbital-ethmoid fracture, the nasal skeleton is separated from the frontal bone and driven posteriorly into the interorbital region occupied normally by the ethmoid air cells. The medial walls of the orbits become laterally splayed into the medial portion of the orbits. With lateral splaying of the medial wall, the medial **canthal** ligament is likewise displaced or on occasion severed free.

Some commonly associated clinical signs of this injury are widening of the nasal bridge, increased intercanthal distance (normally about 34 mm in the adult white male), and an alteration in configuration of the medial palpebral fissure which has been described as "almond shaped." The injury is frequently accompanied by significant and sometimes massive edema and **ec**-chymosis. Recognition and appreciation of the extent of the injury is therefore sometimes difficult. Evaluation by plain film radiography is often inadequate and more sophisticated studies are helpful, especially computerized axial and coronal tomography. In the final analysis, in most cases involving appreciable disruptions and displacements, accurate assessment and optimal repair are most often achieved by open exploration. The goals of treatment are:

1. Reattachment of the nasal skeleton, which is not infrequently cornminuted, to the nasal process of the frontal bone.
2. Recontouring of the medial orbital walls (medial **canthal** ligaments are repositioned and fixed by transnasal wiring).
3. Stenting of nasolacrimal duct injuries with silicone tubing.

Superior-Orbital-Fissure Syndrome. Although uncommon in injuries of the face, direct trauma and fracturing into the orbit may produce hemorrhaging and encystation of blood or an extension of the fracture into the superior orbital fissure, impairing or directly traumatizing the III, IV, and VI cranial nerves which course through this fissure, resulting in ophthalmoplegia, ptosis of the lid, proptosis, and a fixed and dilated pupil. Sensory disturbances over the distribution of the ophthalmic division of the V cranial nerve, supratrochlear and supraorbital, complete the superior-orbital-fissure syndrome. In most instances, the treatment of choice is conservative. Ophthalmological consultation is indicated, and occasionally decompression is performed. Extension of the superior-orbital-fissure syndrome to include optic nerve involvement has been called the orbital-apex syndrome.

FRACTURES OF THE' **PARANASAL** SINUSES

## Frontal Sinuses

Simple nondisplaced fractures of the anterior and posterior walls of the frontal sinus require no specific therapy. If the anterior wall is depressed, open reduction and direct wire fixation are indicated. When the anterior wall is comminuted, it can be supported with packing material, such as medicated gauze or Penrose drains. The frontal sinus may be approached through the open wound or via a brow incision.

If the nasofrontal duct is destroyed, it will be necessary to remove the mucosal lining of the frontal sinus and obliterate the sinus, preferably with fat harvested from the abdomen. When the posterior wall of the frontal sinus is depressed and the dura is torn, resulting in CSF leak or spinal fluid rhinorrhoea, neurosurgical consultation should be sought.

## Ethmoidal Sinuses

Partial ethmoidectomy may be required in the debridement of some wounds. If there is evidence of CSF rhinorrhoea, neurosurgical consultation is indicated.

## Maxillary Sinuses

Simple effusion of blood into the maxillary sinuses is best left alone, as it usually is absorbed. If infection develops, nasal **an-**trostomy and lavage is performed. Missile wounds of the **max-**illary sinuses are debrided through a Caldwell-Luc approach if foreign body removal is necessary.

Occasionally, it may be necessary to pack the maxillary sinuses for hemostasis or support of comminuted fractures; however, it should be borne in mind that such packing of the sinus is a source of infection that should be avoided whenever possible. All wounds and injuries of the paranasal sinuses should receive antimicrobial coverage. Empirically, penicillin is the antibiotic of choice.

---

## EVACUATION

As previously discussed, the immediate priorities in the management of the maxillofacial casualty are airway, hemorrhage, and circulating fluid volume. Once the patient has arrived at the primary treatment facility and early definitive surgical repair of the injury has been accomplished, the considerations for movement of the maxillofacial casualty consist of the following:

1. The patient should be afebrile, without evidence of active infection, comfortable, and taking adequate nourishment by mouth.

2. If intermaxillary fixation is in place and there is not sufficient space (i.e., missing teeth) to permit autoevacuation of regurgitated gastric contents, a means of rapid removal of the fixation must be provided. At the minimum, the patient must wear scissors or wire cutters around the neck.

3. Antral and nasal packings and other drains, along with date of placement, must be clearly identified.

4. Indwelling IV catheters should be of a flexible polyethylene type, well secured, and labeled with the size and date of placement.

5. Tracheostomy tubes and cannulas:

a. must be of proper size, and

b. must be well secured in place with the faceplate of the outer tube sutured to skin.

c. Instructions for humidification must be clearly written. Aircraft have notoriously low cabin humidity, and this and other instructions concerning tracheostomy care are critical.

6. If it becomes necessary to evacuate a patient who has required nasogastric suction at ground level, it will certainly have to continue to be observed during flight.

7. Cerebrospinal fluid leaks, not uncommon in maxillofacial war wounds, do not contraindicate evacuation, but increases in such drainages may occur at altitudes and it must not be impeded.

8. Clear, concise, legible orders must accompany the patient with special attention to:

a. IV fluids

b. antibiotics

c. analgesics

d. antiemetics

- f. remaining packings, dannulae, drains, and tubes**
  - g. diet**
-