CHAPTER XXX

# Reoperative Abdominal Surgery

Certain complications that arise after initial abdominal operation require abdominal reoperation. As the casualty progresses rearward along the medical evacuation chain, medical personnel must be ever vigilant in the early recognition of these complications. The U.S. Air Force, with its aeromedical evacuation responsibility, has a special interest and great experience in the recognition and treatment of these complications. During the Vietnam conflict, one of every six casualties with abdominal wounds removed from the air evacuation system at Clark Air Force Base required reoperation.

Because of the severity of their abdominal wounds and the high frequency of associated injuries, these patients frequently present confusing findings The indications for reoperation are often not well defined. To make matters even more difficult, these complications may not develop until the postoperative patient arrives at a higher echelon hospital and comes under the care of surgeons who were not involved in the primary operation. On occasion, the medical records accompanying these patients may lack sufficient detail regarding the injury and the details of the first operative procedure to be helpful in subsequent evaluation. Given these circumstances, the surgeon must rely heavily on past experience for guidelines in reoperation of abdominal war wounds. The inherent problems of making a preoperative diagnosis in the most difficult group of patients should not deter an aggressive approach. This philosophy will prove much more rewarding than procrastination. Practical points gained from such experience follow.

## TIME OF REOPERATION

The greatest number of reoperations for intra-abdominal complications are performed in the first three weeks, with a peak incidence from the fourth to the eighth day. This further serves to identify the timeframe during which the casualty should not be evacuated because frequent evaluation by experienced surgeons may not be available If transfers are essential during this period, the transit time should be measured in hours rather than days. When a heavy casualty load makes early evacuation necessary, the least seriously injured patients should be selected rather than those with extensive intra-abdominal injury. This philosophy will allow for earlier diagnosis and treatment of those complications that are most likely to arise. The ideal status for evacuation of the patient with a postoperative abdominal wound is after he has become afebrile and alimentation has begun.

## SPECIFIC REASONS FOR REOPERATIONS

### Dehiscence

In addition to wound infection, two factors contribute to dehiscence: the failure to place retention sutures in war wounds, and the air evacuation of patients with postoperative ileus. The lowest incidence of dehiscence is achieved when the abdomen is closed with retention sutures, 2-3 cm apart, through all layers, in combination with closure of individual layers. Of the 626 casualties with abdominal wounds seen at Clark AFB, there were 26 with dehiscence (4.1%). Retention sutures had not been used in any of the 26 cases. Ileus is a factor in dehiscence because of the pressure exerted by distended bowel on the abdominal wound. Bowel gas expands by 15-30% of sea level volume at the usual cabin pressure of evacuation aircraft. The avoidance, therefore, of evacuation when ileus exists is desirable. The use of reliable nasogastric decompression minimizes this problem.

### Retraction of Colostomy

Reoperation may become necessary in the early postoperative period because of retraction or necrosis of a colostomy or ileostomy. If the bowel has been exteriorized under tension, retraction may result. Tension becomes a problem when the bowel is not adequately mobilized by liberal incision in the lateral peritoneal reflections of the colon. The foregoing is especially applicable to fixed segments of the bowel, such as flexures and the descending colon. Failure to suture the mesenteric segment securely to the peritoneum also may contribute to retraction. Correction of this complication requires reoperation to perform the mobilization of the colon that should have been performed at initial operation. Construction of another stoma in more proximal bowel or within the retracted segment under no tension is then possible. If easy deliverance of the bowel to the abdominal wall is not possible even after such mobilization due to inflammatory shortening of the mesentery, performance of a more proximal colostomy in a mobile portion of bowel and resection of the bowel between the retracted colon and the new stoma must be carried out. In the case of ileostomy, immediate maturation of the stoma by eversion and mucosa-to-skin suture with fine absorbable suture prevents problems. In addition, mesentery-to-peritoneum suture is as necessary here as it is in the colon. If retraction of a ileostomy does occur, laparotomy is necessary to construct a new stoma in fresh bowel slightly more proximal to the original stoma.

## Missed Intra-Abdominal Injury

Three factors influence the failure to identify and treat significant intra-abdominal injury: the adequacy of the operative incision, the necessity for complete systematic exploration, and the failure to explore by dissection the hidden areas of the abdomen when indicated. The operative incision must be adequate in size as well as in position. A generous midline incision is best for exposure because of the facility with which it can be made and closed. Quadrant incisions are generally not as good unless the course of the wounding agent is known with absolute certainty, a situation that seldom prevails. Systematic exploration requires an adequate incision. An incision that admits only one of the surgeon's hands into the abdomen is inadequate for complete exploration. Changes in the location of certain intra-abdominal organs during changes in body position and respiration may be responsible for injuries distant from the external wounds and are an additional reason for systematic, complete examination of all organs. The most commonly overlooked injuries at celiotomy are those of the retroperitoneal structures, the fixed portions of the colon, and the viscera bordering the lesser sac. These areas can be inspected adequately only by intraoperative dissection, which should be done when there is any likelihood that injury to these organs has occurred.

Intra-abdominal injury can be overlooked when a missile penetrates the abdomen through an entrance site other than the anterior abdominal wall. When the patient, who has undergone operative treatment of thigh, buttock, chest, or flank wounds, develops signs of peritonitis, an intraperitoneal wound must be suspected. Abdominal roentgenography may be of help by identifying free air or a previously unrecognized intra-abdominal metallic fragment. This examination should be done in all such cases to assure early detection of these hidden wounds.

## Stress Ulcer Hemorrhage

Upper gastrointestinal hemorrhage in postoperative casualties is most often due to stress ulceration. The surgeon's most important priority in dealing with this problem is prevention, specifically with H2 antagonists and antacids. The mainstay and most readily available treatment uses antacids every 2 hours to titrate the gastric pH to greater than 5. Many burn and trauma units have found this condition a rarity since these aggressive preventive measures have been practiced.

Once developed, stress ulcers require vigorous evaluation and therapy. If endoscopy is available, it should be performed. Copious gastric lavage with iced saline, followed by maximum administra tion of Hz blockers and hourly antacids, may suffice Transfusions are frequently necessary. Operation is usually indicated for hemodynamic instability or if more than five units of blood must be transfused. These ulcerations are frequently multiple They may be gastric or duodenal, or both. The majority are gastric. Stress ulcers usually present in individuals with uncontrolled sepsis, in the intraperitoneal region or elsewhere. Generally, the nonoperative management of stress ulcers is not effective and lasting unless the sepsis is controlled. The choice of operative pro cedure for stress ulcer depends upon the experience of the surgeon. Generally, vagotomy, pyloroplasty, and oversewing of the bleeding ulcers suffice if the sepsis has been controlled. If the septic source has not been identified and addressed, then the surgeon should consider a major resectional procedure.

## Intestinal Obstruction

Postoperative mechanical intestinal obstruction, when present, usually develops within the first two weeks after injury. Early operative treatment has been employed with success; the use of long intestinal tubes having been less helpful. Adhesions and intraloop abscesses are the usual causes of obstruction in these cases. It should be stressed that this complication occurs relatively late and should not be confused with prolonged ileus in the earlier postinjury period. Water-soluble radiopaque iodine compounds such as Gastrografin can be employed to differentiate these two conditions. When administered orally, the contrast material fails to traverse the intestinal tract in mechanical obstruction. In the unobstructed case, the contrast material passes through the intestinal tract within a few hours, as evidenced by serial abdominal roentgenograms or by the initiation of bowel movements.

## Intra-Abdominal Hemorrhage

Late hemorrhage in abdominal wounds is seen when an infectious process erodes a blood vessel of significant size. This occurs most often in the retroperitoneum when a hematoma was not explored. When it results from a missile wound, the area is contaminated and cellulitis or abscess formation reactivates bleeding by clot resolution or vessel erosion. Undetected wounds in the fixed portion of the colon, duodenum, pancreas, and retroperitoneum (with eventual infection) and hemorrhage from the lumbar venous plexus are most troublesome and may be fatal. Since such hemorrhage is usually profuse, operation, although mandatory, may not be effective.

## Intra-Abdominal Abscesses

The drainage of abscesses accounts for the greatest number of reoperations in abdominal wounds. When this complication presents relatively early in the postinjury period, it is most often associated with other complications, such as stress bleeding fistula formation, and intestinal obstruction. Abscesses may also be chronic and present much later, with low-grade fever and inanition.

Treatment involves evacuation of the abscess, collapse of the cavity, and prevention of recurrence. Closed-suction drains help to achieve these objectives. If the cavity is not well formed, irrigation may disseminate organisms to other intraperitoneal sites.

Judgment, therefore, must be exercised regarding the use and volume of irrigating solutions. Drains should be dependently positioned to achieve the maximum effect of gravity.

## Large Abdominal Wall Defects

When a considerable portion of the abdominal wall has been lost as a result of a wound or necessary debridement, the surgeon must consider the effects of initial treatment on the subsequent course. If a primary closure is attempted, strangulation of tissue by undue tension may cause necrosis of wound edges. A too-tight closure can lead to limitation of diaphragmatic excursion and respiratory compromise. If small intestine is allowed to become the base of a granulating wound, fistula formation and intestinal obstruction may result. Both of these situations may require reoperation. The most successful form of treatment in these cases, at initial operation or reoperation, has been the insertion of a Marlex mesh prosthesis, sewn to the undersurface of the remaining viable abdominal wall. As it is becoming encased in granulation tissue, the mesh should be covered with a dressing soaked in saline. Once the base of the wound is covered by healthy granulation tissue, it can be covered by a split-thickness skin graft or a sliding pedicle graft. An occasional patient, without abdominal wall loss, may require this type of closure due to tension.

In the austere situation where Marlex or other stock prostheses are not available, the surgeon may have to improvise. Recent experimental studies have shown that these defects can be successfully covered with polyvinyl chloride (Via Flex). This is the material from which Ringer's lactate and blood bags are made. Experimental use of these bags in animals to close defects has been very encouraging.

## Fistulae

A well-formed fistula, regardless of source, may be treated by high-volume suction. This suction may be directed at the gut above the fistula, the fistula itself or both. Closure usually occurs when distal obstruction is not present. When it is associated with abscess or peritonitis, operative intervention is indicated. Closure with adequate drainage, resection, exteriorization, repair, and proximal diversion, singly or in combination, should be employed as the local situation dictates. Healing of fistulae always requires adequate nutrition. Nutritional support should be vigorously pursued, either enterally or parenterally.

CHAPTER XXXI

# Wounds and Injuries of the Genitourinary Tract

## INTRODUCTION

Genitourinary tract injuries in a combat zone constitute approximately 5% of the total injuries encountered. With the exception of the external genitalia, these wounds invariably will be associated with serious visceral injury and, as a result, are generally managed in areas where there are major surgical and roentgenographic capabilities. The treatment of urologic injuries does not vary from established surgical principles: hemostasis, debridement, and drainage. In contrast to intraperitoneal injuries, preoperative evaluation, utilizing appropriate urographic diagnostic procedures, is simpler and more expedient than an extensive retroperitoneal exploration at the time of laparotomy. Preoperative urologic contrast studies are particularly rewarding when an unsuspected injury, anomaly, or absence is discovered.

## WOUNDS OF THE KIDNEY

Renal injuries, except for renal pedicle injuries, are usually not life threatening, however, if not diagnosed or treated properly, they may cause significant morbidity. The diagnosis of renal injury should be suspected based upon the type of trauma sustained, the physical examination, and the urinalysis. Microscopic or gross hematuria is usually present; however, the absence of hematuria does not exclude renal trauma. Renal injury must be suspected in the presence of associated findings such as multiple rib fractures, vertebral body or transverse process fractures, crushing injuries of the chest of thorax, or any penetrating injury to the flank or upper abdomen.

The primary radiographic study used to diagnose renal trauma is the intravenous pyelogram (IVP). This study will usually define renal anatomy, showing injury to the affected kidney. Of equal importance, the IVP should also confirm the presence and functional status of the contralateral kidney and the presence or absence of congenital anomalies, such as horseshoe or congenital single kidney. Delayed films may be necessary to visualize contrast extravasation. If the functional status of the unaffected kidney is not ascertained prior to surgical exploration, an intravenous pyelogram must be performed on the operating table prior to any attempt at exploration of the injured kidney. It has been a generally accepted practice to perform preoperative IVPs on all individuals with abdominal wounds who require laparotomy.

Renal trauma, either blunt or penetrating, may be classified according to the degree or extent of anatomical damage to the kidney. Minor injuries consist of renal contusions or shallow cortical lacerations. Major injuries are comprised of deep cortical lacerations, shattered kidneys, renal vascular pedicle injuries, or total avulsion of the renal pelvis.

Some renal injuries will be minor and may be managed nonoperatively with hydration and bedrest. Major injuries usually require operative intervention with debridement of nonviable renal tissue (partial nephrectomy), closure of the collecting system, and drainage of the retroperitoneal area. In some instances, total nephrectomy may be required. Since there is an 80% incidence of associated visceral injuries with major renal trauma, most cases will require a laparotomy for evaluation and repair of intraperitoneal injuries. Hemodynamically significant injuries are addressed first. If control of hemorrhage requires exploration of the renal space, it is imperative to first gain vascular control of the renal pedicle prior to opening the perirenal fascia and releasing the relatively hemostatic tamponade Vascular control is obtained by using a periaortic approach to the renal vascular pedicle. The small intestine is retracted superiorly and the posterior peritoneum is incised over the aorta. Since the left renal vein crosses anterior to the aorta, over the origin of both the right and left renal arteries, it must be mobilized to gain control of the origin of either renal artery. After applying atraumatic vascular clamps to the appropriate renal artery and vein, the respective colon may then be mobilized and reflected medially. The perirenal fascia is then opened and the renal wound evaluated.

Operative treatment consists of hemostasis, local debridement and suture, total nephrectoniy, or rarely, partial nephrectomy. Urinary diversion in the form of tube nephrostomy or a ureteral stent is recommended in the presence of associated injuries of the duodenum, pancreas, or large bowel. If the tactical situation rules out immediate surgical treatment for major renal injury and the patient is hemodynamically stable, he should be supported with intravenous fluids until evacuation.

## WOUNDS OF THE URETER

Ureteral injuries are rare and are frequently overlooked. The diagnosis is made only if the possibility of such an injury is considered in all cases of retroperitoneal hematoma and injuries of the fixed portions of the colon, the duodenum, and the spleen. Ureteral injuries are diagnosed preoperatively by the IVP. Intraoperative location of the ureteral injury, if required, is facilitated by intravenous injection of indigocarmine.

Surgical repair is based upon three factors: the anatomical seg ment of the traumatized ureter, other associated injuries, and the clinical stability of the patient. Debridement, hemostasis, and drainage are key factors in any successful repair, especially with high-velocity missile injuries.

If a small segment of ureter in its upper or middle segment is damaged, the proximal and distal segments may be spatulated for 1 cm and a ureteroureterostomy performed using interrupted 4-O absorbable sutures. In the injury near the bladder, a ureteroneocystostomy should be performed. Upper and midureteral injuries in which a large ureteral segment has been damaged may require a temporizing cutaneous ureterostomy with stent placement or transureteroureterostomy. In the presence of duodenal, pancreatic, large bowel, or rectal injuries, proximal urinary diversion with a nephrostomy tube and internal ureteral stent management are required. When a distal ureteral injury is associated with a rectal injury, a ureteral reimplantation is not recommended, and a transureteroureterostomy should be performed. Adequate retroperitoneal drainage is always employed using soft rubber or silicone drains.

If the ureteral injury is not diagnosed initially and manifests itself at a later date, diversion with a nephrostomy tube is performed and ureteral repair should be delayed for 3-6 months.

## WOUNDS OF THE BLADDER

Bladder wounds are common and should always be considered in patients with lower abdominal wounds, gross hematuria, or an inability to void following abdominal or pelvic trauma. These tears may be intraperitoneal or extraperitoneal. After insuring urethral integrity in appropriate cases (see "Wounds of the Urethra" *infra*), the diagnosis is made radiographically. Cystography is performed by retrograde filling of the bladder via a urethral catheter with radiopaque contrast medium elevated 20-30 cm above the level of the abdomen. An X-ray of the full bladder is taken, and another X-ray is taken after draining the bladder by unclamping the urethral catheter. Small extraperitoneal areas of extravasation may be apparent only on the postevacuation film.

Penetrating injuries and blowout perforations of the bladder dome due to blunt lower abdominal trauma of a full bladder are most often intraperitoneal. Cystography reveals contrast medium interspersed between loops of bowel. Management consists of exploration, multilayer repair of the injury with absorbable sutures, suprapubic tube cystostomy, and drainage of the perivesical extraperitoneal space

Extraperitoneal injuries to the bladder are most often the result of laceration by bony fragments of a pelvic fracture. Cystography reveals a flame-like extravasation of contrast medium on the postevacuation film. Extraperitoneal injuries may be repaired primarily as above; however, they usually heal with 10–14 days of Foley catheter drainage without the need for primary repair.

## WOUNDS OF THE URETHRA

Injuries to the male urethra should always be suspect in patients with blood at the urethral meatus. Urethral catheterization is contraindicated until integrity has been established by retrograde urethrography. After sterile prepping of the penis, retrograde urethrography is performed by inserting the end of a cathetertip syringe into the urethral meatus with gentle retrograde instillation of 15–20cc of a water-soluble contrast medium. An X-ray is taken during injection. Urethral injury will be represented by extravasation of the contrast material. Contrast must be seen flowing into the bladder to ascertain urethral integrity proximal to the urogenital diaphragm.

The urethra is divided info anterior and posterior (prostatic) segments by the urogenital diaphragm. Posterior urethral disruption commonly occurs following pelvic fracture injuries. Rectal examination reveals the prostate to have been avulsed at the apex. Improved continence and potency rates are attained when suprapubic tube cystostomy is used as the initial management. No attempt at reapproximation of the urethral edges should be made, as such attempts increase the risk of impotency, release the tamponade of the pelvic hematoma, and too often result in an infected hematoma. With expectant observation virtually all these injuries will heal with an obliterative prostatomembranous urethral stricture, which can be repaired secondarily in 4-6 months after reabsorption of the pelvic hematoma. Initial exploration of the pelvic hematoma is strictly reserved for patients with concomitant transmural rectal injury.

Anterior urethral injuries may result from blunt trauma, such as results from falls astride an object (straddle), or from penetrating injuries. Blunt trauma resulting in minor nondisrup tive urethral injuries may be managed by gentle insertion of a 16 French foley catheter for 7-10 days. If any difficulty in passing the catheter is encountered, or if the blunt trauma has an associated perineal or penile hematoma indicating more than a minor mucosal injury, the urethra is not instrumented and suprapubic tube cystostomy is performed. Suprapubic urinary diversion is maintained for 10–14 days and urethral integrity is confirmed radiographically prior to removal of the suprapubic tube. Healing may occur without stricture formation. If a stricture develops, it is readily managed by direct vision urethrotomy or open urethroplasty at a later procedure.

Penetrating wounds of the anterior urethra should be managed by exploration and debridement. Small, clean lacerations of the urethra may be repaired primarily by reapproximation of the urethral edges using interrupted 4-O chromic catgut sutures. Most penetrating urethral injuries, however, will be associated with devitalized margins requiring debridement. One should refrain from the temptation to mobilize the entire urethra for a primary anastomosis, as the shortened urethral length in the pendulous urethra will invariably result in ventral chordee and an anastomosis under tension. Instead, the injured urethral segment should be marsupialized by suturing the skin edges to the cut edges of the urethra. Marsupialization should be performed until healthy urethra is encountered both proximally and distally. Closure of the marsupialized urethra is subsequently performed at six months to reestablish urethral continuity.

## WOUNDS OF THE EXTERNAL GENITALIA

The management of wounds of the penis, scrotum, testes, and spermatic cord consists of control of hemorrhage, debridement (which should always be as conservative as possible), and repair, as early as possible, to prevent deformity.

In injuries of the penis, tears of Buck's fascia should be sutured. When denudation has been extensive, the penis may be placed in a scrotal tunnel until plastic repair can be carried out in an appropriately equipped facility.

The scrotum has a good blood supply, and extensive debridement is therefore not necessary. In complete avulsion, the testes can be placed in protective pockets in the thighs.

It is essential, when dealing with testicular wounds, to conserve as much tissue as possible. Herniated parenchymal tissues should be replaced and the tunica albuginea closed by mattress sutures. The testicle is placed in the scrotum or in a protective pocket in some adjacent structure A testicle should never be resected unless it is hopelessly damaged and its blood supply destroyed.

CHAPTER XXX11

# Wounds and Injuries of the Hand

The hand is constantly subject to serious trauma. Even though minor injuries may be incapacitating, the hand has remarkable recuperative powers. It can be trained to compensate for much of its lost function. Hand injuries should never be taken lightly, even those that appear to be relatively minor. Appropriate early management will yield the maximum possible return of function.

Injuries of the hand, in themselves, seldom result in shock or fatality. The casualty with a hand wound who presents in shock should therefore be evaluated for other more significant wounds. Those life-threatening wounds should be given treatment priority prior to attending to the hand wound. When other priorities dictate delay in treatment of the hand injury, hemostasis and further injury to the hand are prevented by dressing and immobilizing the hand.

## CARE IN THE DIVISION AREA

Care of the wounded hand in the division area is limited to control of hemorrhage and immobilization by a compressive dressing (Figure 39). The immobilized extremity is elevated. Antibiotic therapy is initiated and the wounded soldier evacuated to a facility with roentgenographic and surgical capabilities.

Should the tactical situation preclude early evacuation, the following additional measures are recommended:

1. Wrist watches and rings are removed. The hand is thoroughly cleansed with soap and water. The combatant’s fingernails, which in combat are usually filthy, are clipped and cleaned.

2. Shreds of obviously dead tissue are excised. Amputation of digits is rarely indicated. If amputation appears necessary, it is done later, after the opportunity for more careful evaluation and planning.

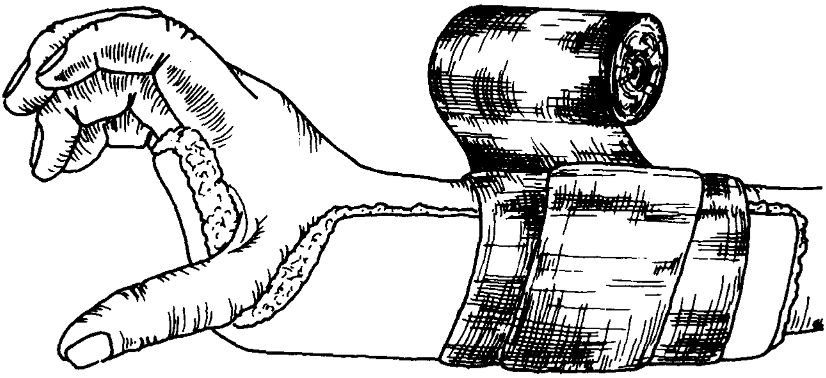


FIGURE 39.—Immobilization of injured hand and forearm in position of anatomical function.

3. Oozing is controlled by the application of a generous gauze dressing. Petrolatum-impregnated gauze and grease in any form should be avoided. The hand is immobilized in the position of function.

## INITIAL WOUND SURGERY

### Anesthesia

Both general anesthesia and conduction (nerve) blocks are satisfactory for surgical management of the wounds of the hand. Local anesthesia does not provide satisfactory anesthesia. Adrenalin is not injected into hands or fingers, since any additional perfusion compromise, coupled with already marginal perfusion, can result in irreversible ischemic changes.

### Debridement

Ideally, the surgeon works with an assistant, a good light, and adequate time. The surgeon. should operate while seated, with the draped extremity extended and the hand resting on a suitable sup port. Necessary instruments include fine tissue forceps, skin hooks, straight and curved ophthalmic scissors, small knife blades, and fine needles. Some sort of magnification is essential.

Cleansing of the surgical field prior to operation is of paramount importance. Since the combatant's hand is usually filthy, attention to detail at the time of the initial cleansing under anesthesia is invaluable in diminishing subsequent sepsis. The preparation extends from the distal edge of the tourniquet to the tips of the trimmed fingernails.

Hemostasis must be complete. It is accomplished with the aid of intermittent application of the tourniquet. The tourniquet should never be kept inflated for longer than two hours. It should be released prior to application of the dressing to allow identification and control of bleeding points. Injuries of the radial or the ulnar artery can usually be safely ligated, since both have rich terminal anastomoses. Both arteries should not be ligated.

Trimming of the wound edges should not be routinely carried out. The removal of even a few millimeters of normal skin may necessitate later skin grafting. Contused skin and dirt-tattooed skin is preserved for delayed closure. Only devitalized skin is excised.

The deep structures of the hand should be explored thoroughly to determine the full extent of the injury and to allow adequate debridement. Care must be exercised during wound exploration and debridement to prevent damage to previously undamaged structures. The carpal tunnel may be opened to locate and protect the median nerve and its branches during debridement. Incision of the transverse carpal ligament, in addition to decompressing the median nerve, will improve tendon function in the severely damaged hand. In certain injuries associated with massive swelling of the hand, decompression of the intrinsic muscles may be indicated. Incision of the intermetacarpal fascia through small dorsal incisions reduces the possibility of developing intrinsic contracture.

Dead muscle, tissue, bloodclot, readily accessible foreign bodies, and other debris are removed. Bone fragments that are not grossly contaminated are preserved. Severely damaged and useless tendons should be excised. Every bit of viable tissue should be preserved. During the procedure, the wound is copiously irrigated with physiologic salt solution.

Only digits which are irretrievably damaged are amputated. Amputation of the thumb is a last resort, and is performed only after repeated evaluation. It is sometimes possible to preserve a skin pedicle from a finger that must be amputated, to provide later coverage for the remainder of the hand. In digital amputations, the tendons should be removed with the bone, but the digital vessels and nerves should be retained. Tendon repair, including tendon grafts, should not be performed by the forward surgeon.

Nerves which are traumatically divided are usually disrupted over a considerable distance and should not be primarily repaired. However, nerves which can be approximated in relatively healthy tissue without any tension should be approximated with one or two sutures of nonabsorbable suture material. This will prevent retraction, thereby facilitating future neurorrhaphy. Digital nerves are an exception and when possible should be repaired primarily, with the expectation of avoiding a painful neuroma.

## WOUND CLOSURE

Delayed closure of the wound is performed several days after the initial debridement. In this way, one can be sure that the wound is free of sepsis and necrotic tissue prior to closure. Although it is possible to perform primary closure in certain wounds of the hand, the possibility of deep sepsis and wound breakdown does notjustify the risk of primary closure in the combat situation.

At the time of wound closure (i.e., within 3-5 days post-debridement), unstable fractures or dislocations may be stabilized with small Kirschner wires. Stability thus achieved results in a hand which can be actively moved in the post-wound period, lessening the development of later deformity. Internal fixation other than small Kirschner wires should not be used by the forward surgeon.

### Dressing

The dressing consists of well-fluffed gauze, applied evenly and snugly over a layer of fine-mesh gauze. Petrolatum-impregnated gauze impedes healing and should not be used. The deeper parts of the wound must not be plugged. The fingers are spread without tension, with the thumb in opposition. Padding is placed between the fingers. An attempt is made to align all fractures while apply ing the dressing.

The dressing should cover the entire wound, but should not constrict it. It is reinforced with layers of sterile absorbent cotton covered by a firm pressure bandage Only fractured fingers are splinted. Unaffected digits are left free to move. Whenever possible, the tips of all fingers are left exposed allowing periodic inspection to determine the adequacy of distal perfusion.

## Splinting

The hand is supported in the position of function on a molded volar plaster splint with the wrist dorsiflexed approximately 30°, the metacarpophalangeal joints at 70°, and the interphalangeal joints at 10° flexion. The slightly-flexed thumb should be placed in 45° of palmar abduction. This is the position of the hand holding a water glass.

## Postoperative Management

After operation, the hand and arm are elevated. Movement of all uninvolved joints is enforced.

CHAPTER XXX111

# Wounds and Injuries of the Spinal Column and Cord

## INTRODUCTION

Combat injuries of the spinal column, with or without associated spinal cord injury, differ from those generally encountered in civilian practice. Whereas the majority of civilian spinal column and cord trauma is closed, most combat injuries are open, contaminated, and usually associated with other organ injuries.

Management of the casualty with spinal column or cord injury is initially the same as for all casualties. Regardless of whether the wounds are single or multiple, open or closed, and involve one or multiple organ systems, medical intervention must be prioritized. The first priorities remain: A-airway, B-breathing, and C-circulation, followed by evaluation and management of less compelling problems. After the ABCs have been addressed, management of the spinal cord injury takes on a high priority.

From the prognostic standpoint, the greater the initial function retained, the better the neurological outcome. Data from both military and civilian spinal cord injury sources reveal that in those injuries presenting with immediate loss of motor and sensory function (complete injury), the likelihood of neurological recovery is minimal and will not be influenced by surgical intervention. On the other hand, operation may be neurologically beneficial in the incomplete injury in which there is evidence of neurological deterioration-and a potentially reversible cause of the deterioration. Even though the neurological outcome of the open, complete injury is not likely to be influenced by surgical intervention, operation is generally indicated to debride the wound so as to minimize the risk of CNS sepsis.

## CLASSIFICATION

Four discriminators must be considered in the classification of spinal cord injuries: (1) the *TYPE* of injury (open or closed); (2) the *EXTENT* of the injury (complete versus incomplete); (3) the ***LOCATION*** **of** the injury (cervical, thoracic, lumbar or sacral); and (4) the *DEGREE* of bony and ligamentous disruption (stable versus unstable).

To insure optimal preservation of neurological function during extrication and evacuation of the victim, several questions must be considered during the initial assessment. Might there be a spinal cord or column injury present? Does any neurological function persist below the level of the anatomical injury? What is the neurological level of the injury? Is it changing? Is the vertebral injury mechanically stable or unstable? If these questions cannot be answered and a spinal injury is suspected, the patient must be managed as if one existed.

## MECHANICAL INTEGRITY OF THE VERTEBRAL COLUMN

The vertebral column is composed of three structural columns (Table 15). Loss of integrity of two of the three columns results in instability of the spine Instability is common following closed mechanical injury of the vertebral column, but is not usually the case with gunshot or fragment wounds of the vertebral column. Instability of the vertebral column is documented on the lateral radiograph by demonstrating 3.5 mm or greater displacement or translation of one vertebral element on another, or by an interspinous, sagittal vertebral column angulation of 11° or more on the lateral view. Should questions exist regarding neck stability, lateral extension and flexion radiographs should be obtained under the direct supervision of a medical officer. Computerized tomography is effective in demonstrating spinal instability, but will not be available in forward hospitals.

TABLE 15.—*Support of the Spinal Column*

| Column | Bony Elements | Soft Tissue Elements |
|---|---|---|
| **ANTERIOR** | **Anterior two thirds of vertebral body** | **Anterior longitudinal ligament; Anterior annulus fibrosus** |
| **MIDDLE** | **Posterior one third of vertebral body; Pedicles** | **Posterior longitudinal ligament; Posterior annulus fibrosus** |
| **POSTERIOR** | **Lamina; Spinous processes; Facet joints** | **Ligamentum flavum; Interspinous ligaments** |

Because instability may not be immediately confirmed following trauma, any patient who complains of a sense of instability (holds his head with his hands), has unexplained vertebral column pain, has tenderness to percussion along the vertebral column, or has neurological injury without evidence of skeletal injury should be suspected of an injury to the spine Similarly, any trauma victim who is unconscious or confused, or has evidence of trauma above the clavicles, should be managed as though cervical spinal injury were present.

Injury of vertebral supporting structures (Table 15), with or without bony involvement, makes the spinal cord vulnerable to secondary injury. Proper emergency stabilization of the spine during extrication and transfer of the victim is crucial in order to prevent neurological complications in this group of patients. Ligamentous injuries, in contrast to bony injuries, frequently do not heal without surgical stabilization. Typically, bony injuries of the spine heal in I2 weeks, the recommended period for protecting spine fractures. After three months, flexion-extension X-rays should be obtained to assess stability. Evidence of instability or pro gressive loss of alignment are indications for operative stabilization.

## PATHOPHYSIOLOGY OF INJURY TO THE SPINAL CORD

Injury of the spinal cord results from the following mechanisms: (1) compression, (2) contusion, (3) edema, (4) ischemia and (5) physical transection. Usually an aggregate of two or more of these mechanisms is responsible. When the injury is complete and the cord is physically intact, the term physiological transection is used, as opposed to anatomical transaction where there is physical loss of continuity.

In physiological transections, the fundamental cause of irreversible damage to the spinal cord is loss of blood supply. The blood supply of the spinal cord is tenuous, especially in the thoracic region. Injury to the anterior spinal artery is the most common cause of spinal cord ischemia. Damage to the microcirculation, especially that of the central gray matter, is associated with compression-type injuries and edema formation. Closed trauma tends to cause vascular injuries. Axial loads are associated with displacement of bone elements or herniated disc material, with resultant compression injury. High-velocity missile wounds in the paravertebral area, even in the absence of direct contact, can cause neurological injury. The missile need not pass directly through neural tissue to induce injury. The pathological events which lead to injury at some distance from the actual projectile track are tissue contusion and/or hemorrhage produced by either radial stretching of the tissue around the missile's path during formation of the temporary cavity or fragmentation of the projectile and bone resulting in multiple secondary missiles. The destructive nature of high-velocity missiles explains the futility of decompressive laminectomy in the management of these wounds.

## ANATOMICAL CONSIDERATIONS

### Cervical Spine

Injury to the upper cervical spinal cord between C-l and C-4, the level from which the cervical plexus and the phrenic nerves are derived, can result in the loss of both voluntary and involuntary diaphragmatic motion, the loss of chest wall muscle function, and the loss of function of the cervical strap muscles, which serve as accessory muscles of ventilation. A complete injury at this level, in the absence of some method of immediate assist, results in cessation of ventilation and death. When the cervical cord is injured below this level, the level of the cord injury is determined by assessment of motor and sensory function (Figure 40 and Table 16). The presence of any neural function below the level of the bony injury, to include the-preservation of motor or sensory activity within the perianal (S-2, S-3) sacral dermatomes (sacral sparing), indicates an incomplete cord injury and is a favorable prog nostic sign.

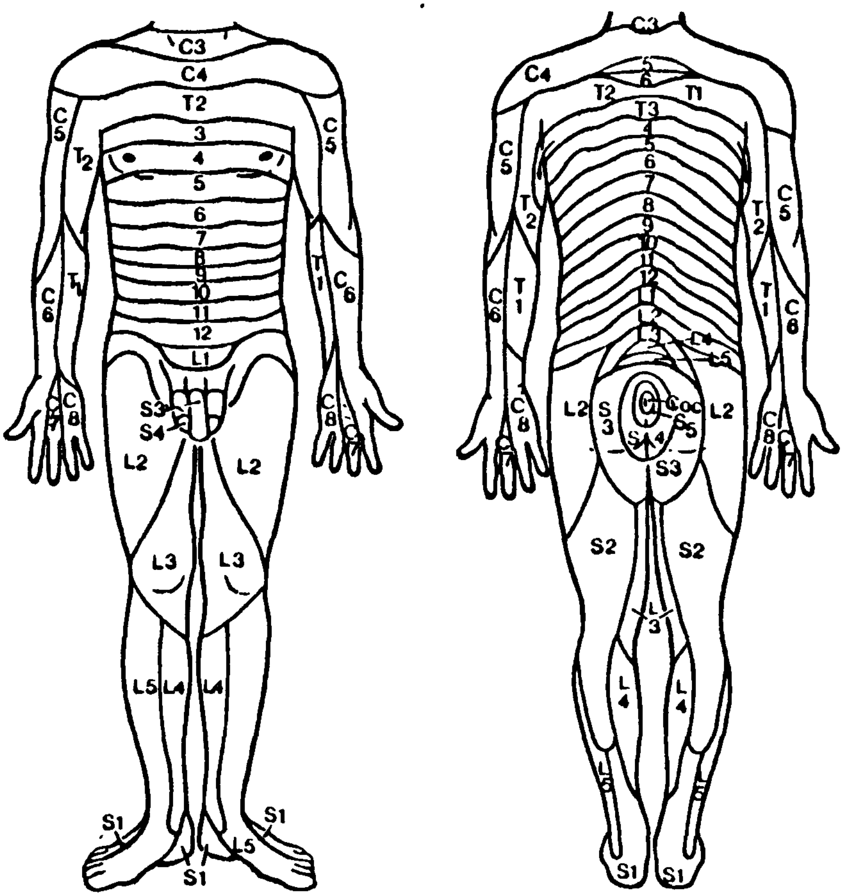



FIGURE 40.—Sensory Dermatomes

**Axial loading (compression) injuries of the upper cervical spine can cause disruption of the ring of C-l (Jefferson fracture). This fracture is rarely accompanied by cord damage because of the width of the neural canal at the C-l and C-2 levels? A C-l fracture is usually stable and can be managed nonoperatively in the absence of other fractures or signs of instability. An associated fracture of C-2 must always be ruled out when fractures of C-l are present. In this case, management depends on the type of injury present at C-2. Odontoid process (dens) fractures involving C-2**

***One-Third Rule: At this level one-third of the spinal canal is occupied by the spinal cord. one-third by the odontoid process, and one-third is free space.**

occur along the process in one of three locations. Type I fractures pass through the uppermost portion of the dens. Type II fractures of the odontoid pass through the base of the dens. Since the upper and lower segments are attached to opposing ligamentous and bony structures, there usually is separation and these fractures are unstable. Type III fractures occur at the junction of the dens and body of C-2. Type I and Type III fractures are normally stable and can be managed with immobilization only. Type II fractures are unstable and require surgical stabilization. These fractures must be stabilized during the assessment phase with Gardner Wells skeletal traction followed, in time, by either halo or other orthopedic apparatus, fixation or surgical stabilization with early internal wire, or plate and screw fixation.

Axial load forces applied to the head and upper cervical spine may disrupt the posterior elements of C-2 (Hangman's fracture). This is a relatively stable fracture and is usually managed nonoperatively. When fracture of the posterior elements of C-2 is accompanied by displacement, dislocation, or fracture of the body of C-2, surgical stabilization is indicated.

Fractures or dislocations of the cervical spine between C-3 and C-7 are caused by hyperflexion, axial load, rotation, or a combination of these forces. Typically these injuries result in instability. Hyperextension injuries to the cervical spine usually occur at the C-6, C-7 interspace, but produce complete neurological injuries less often than do flexion injuries. The extent of the injury depends on how much ligamentous and vertebral element integrity (two column integrity) is lost. The severity of the skeletal injury and the resulting neurological deficit do not always correlate.

Facetjoint fractures and dislocations are associated with flexion-rotation injuries. They are often difficult to demonstrate on the initial anterior-posterior and lateral radiographs. For this reason, tomographic studies may be necessary. Thirty percent displacement of one vertebra on another indicates unilateral facet dislocation, whereas 50 % displacement indicates bilateral facet disruption. Unilateral facet disruption is usually stable. In the absence of neurological findings, this injury can be managed nonoperatively. If it does not reduce with traction, this injury should be surgically reduced and stabilized. Bilateral facet dislocations are always unstable and require surgical stabilization. Complete neurological injury normally accompanies this injury.

TABLE 16.—*Assessment of Spinal Cord Injuries*

| Level | Sensory Deficit | Motor Deficit | Reflex |
|---|---|---|---|
| c-23 | Neck; back of head | Diaphragm; Accessory respiratory muscles. | — |
| c-4 | Shoulders | Diaphragm, Shoulder shrug | — |
| c-5 | Anterolateral side of arm | Elbow flexion | Biceps |
| C-6 | Radial side of forearm; thumb | Wrist extension | Branchioradialis |
| c-7 | Mid palm; long finger | Interior finger flexor; wrist flexion; elbow | triceps |
| C-8 | Ulnar side of hand; wrist | Interior finger flexors | — |
| T-1 | Ulnar side of forearm | Hand intrinsics | — |
| T-3 | Above nipples | — | — |
| T-4 | Nipple level | — | — |
| T-5 | Below nipples | — | — |
| T-9, 10 | Above umbilicus | Abdominal flexors | Umbilical |
| T-11, 12 | Below umbilicus | — | Umbilical |
| L-1 | Suprapubic | — | — |
| L-2 | Anterior thigh | — | — |
| L-3 | Around the knee | — | — |
| L-4 | Medial side of leg | Knee extension | Knee |
| L-5 | Laterial side of leg | Foot dorsiflexion | — |
| S-1 | Lateral foot, soles and heels | Ankle plantar flexion | Ankle |
| s-2, 3, 4 | Perianal; scrotum | Rectal sphincter | Bulbocavemosus; cremasteric |

## Thoracic and Lumbar Spine

The vascular supply of the spinal cord is most vulnerable between T-4 and T-6, where the neural canal is most narrow. Even minor degrees of vertebral column malalignment in this region result in neurological injury. Thoracic cord injury usually results from a combination of flexion, axial loading, and rotation forces. These stress forces are seen with parachute jumps and pilot ejections from high-performance aircraft. While the thoracic rib cage contributes to the rotary stability of the thoracic spine, wedge compression (flexion) fractures of the upper thoracic vertebral column are not uncommon. The most common site for a compression fracture is at L-l and L-2. When not accompanied by other elements of injury, anterior wedge compression fractures of 25-30% can be considered stable Greater degrees of compression and associated displacement require surgical stabilization.

Most axialloading burst fractures in the lumbar region occur between L-2 and L-4 and are unstable These fractures often cause extrusion of bone into the spinal canal and/or progressive angular deformity. Surgical stabilization and, occasionally, removal of bone fragments that compress the spinal cord constitute the definitive management of these injuries.

## MANAGEMENT CONSIDERATIONS IN THE COMBAT ENVIRONMENT

The medical officer must realize that there are certain fundamental differences between the civilian practice of medicine and the compelling realities of the battlefield. If this were not the case, handbooks such as this one, dealing with military surgery, would be redundant and unnecessary. One such difference is exemplified in the initial management of the casualty with a possible spinal column or cord injury where there is an ongoing and immediate threat to the life of both the casualty and combat medic who comes to his aid.*

Current Advanced Trauma Life Support (ATLS) guidelines concerning spinal column and cord injury or *potential* injury state that "any patient sustaining injury above the clavicles or a head injury resulting in an unconscious state should be suspected of having an associated cervical spinal column injury which should be immobilized with a properly applied spine board, and a semirigid cervical collar? US. Army field manuals present similar guidelines with regard to neck injuries and suspected fractures of the neck. Proper immobilization ofthe spine and movement of the casualty requires two or more people, a spine board and semirigid cervical collar. These guidelines are appropriate for the civilian

***The reader should bear in mind that the differences which follow apply only to the active battlefield where there is immediate and ongoing threat to the life of the casualty and those who come to his aid.**

sector, the peacetime military, 'and for secure military areas, but not for battlefields. The realities of war can make the ideal management of casualties unrealistic_ If ATLS guidelines were strictly adhered to, one could envision the first day of a NATO-Warsaw Pact conflict with thousands of casualties strapped to long boards and wearing cervical collars while waiting to have their spines "cleared." Simple logistics would preclude idealized management of this number of potential spinal injuries. Common sense must prevail.

On the active battlefield, during a fire fight or when one leaves his hole during an artillery or mortar barrage, the objective is to bring the casualty out of the line of fire, into a hole, or behind cover, where the basic fundamentals of casualty care (the ABCs) can be applied. The longer the casualty and the medic remain exposed, the greater the likelihood of additional wounds and additional casualties. Under conditions such as these, the prime consideration is preservation of the lives of both the wounded and the rescuers.

Additional insights regarding immediate battlefield management of the casualty with possible cervical injury is provided by the WDMET (Wound Data and Munitions Effectiveness Team) data from the Vietnam experience Only 1.4% of all casualties with penetrating wounds of the neck, who survived long enough to become candidates for cervical immobilization, might have benefitted from such treatment. These data do not support the use of cervical collars and spine boards for penetrating and perforating neck wounds on the battlefield. Also noteworthy in the WDMET data on cervical injuries is that 13 of those killed in action, and 7 of those wounded in action, were providing battlefield care for others when they were hit. The conclusion from the WDMET data is that battlefield splinting of the cervical spine was of very little value in preventing neurological injury, while it materially increased the risks to the casualty and the provider.

## INITIAL MANAGEMENT

Initial management of the individual with suspected injury of the cervical spine entails preservation of the airway, maintenance of ventilation, control of hemorrhage, and the preservation of residual neurological function. Movement of the head and neck must be minimized. When the injured individual presents in the prone position, he should be log-rolled into the supine position with the most experienced person present maintaining the neck in the neutral position. Once the victim is in the supine position, the airway should be maintained with the chin lift maneuver. The neck should never be hyperextended in these situations. If a surgical airway is required, cricothyroidotomy is the method of choice. Stabilization of the neck during transport is provided by a stiff cervical collar or sand bags. Then the head should be taped to whichever extraction device is utilized (Figures 41, 42).

When injury to the spine is suspected, spinal alignment must be maintained when the victim is moved. Table 17 summarizes extrication techniques for suspected spine injuries. This can be accomplished by log-rolling onto a stretcher or, where two-man assistance is available, the two-man arm carry is an appropriate method of initial transport to a rigid surface (Figure 43). This

TABLE 17.—*Extrication Techniques for Suspected Spinal Column Injuries**

| Technique | Cervical | Thoracic and Lumbar | Comment |
|---|---|---|---|
| Spine board with semi-rigid collar | YES | YES | Recommended technique; see figures 41, 42 |
| Two-Man Arm Carry | NO | YES | Conscious or unconscious victims; see figure 43. |
| Three-Man Arm Carry | YES | YES | Third man protects the cervical spine. |
| Pistol Belt Drag | NO | YES | Use these three on the battlefield if no other alternatives exist. |
| Shirt Drag | NO** | YES | " " |
| Neck Drag | NO | YES | " " |

*The following carries are not recommended for extricating casualties with suspected spine injuries.
1. Pack-strap carry
2. Fireman's carry
3. One-man arm carry
4. Cradle drop drag
5. Two-man fore & aft carry
6. Two-hand seat carry

**Extenuating circumstances where victim and rescuer must maintain low profile.

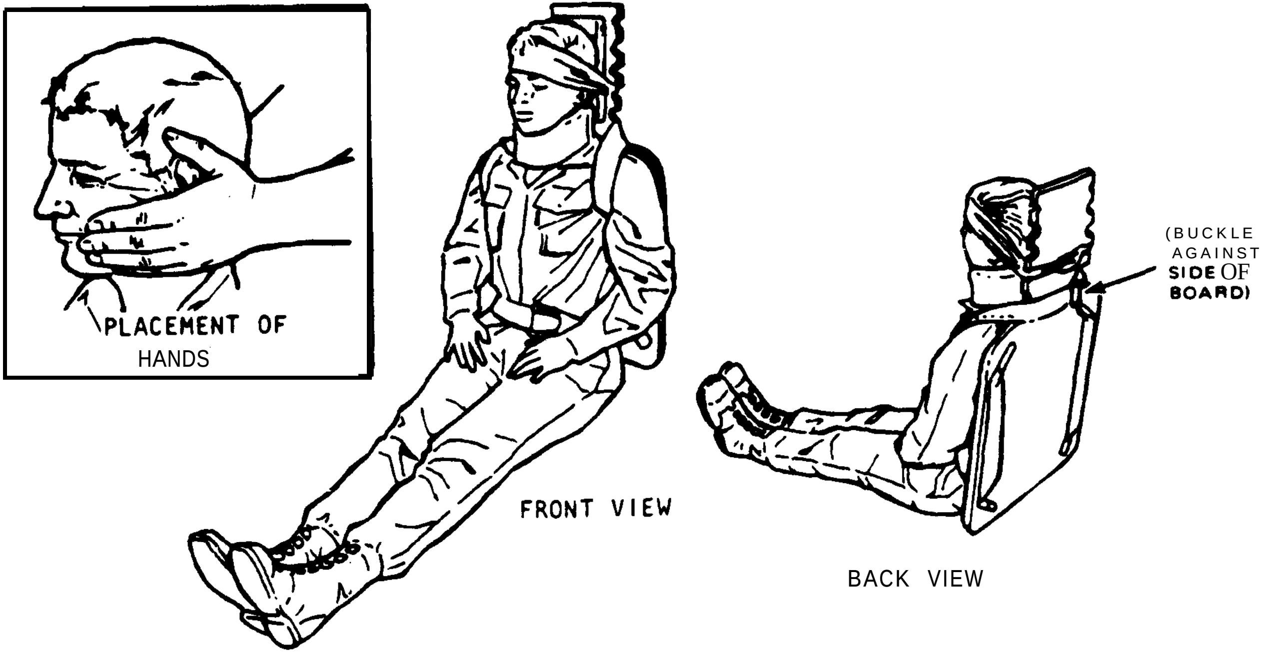



FIGURE **41.—Fractures** of the cervical spine can be immobilized by either a "short" or "long" spine board. Fractures of **thoracic-lumbar** spine are best immobilized on a long board. One person always maintains control of the head and neck, while others rotate and properly position the patient on the spine board.

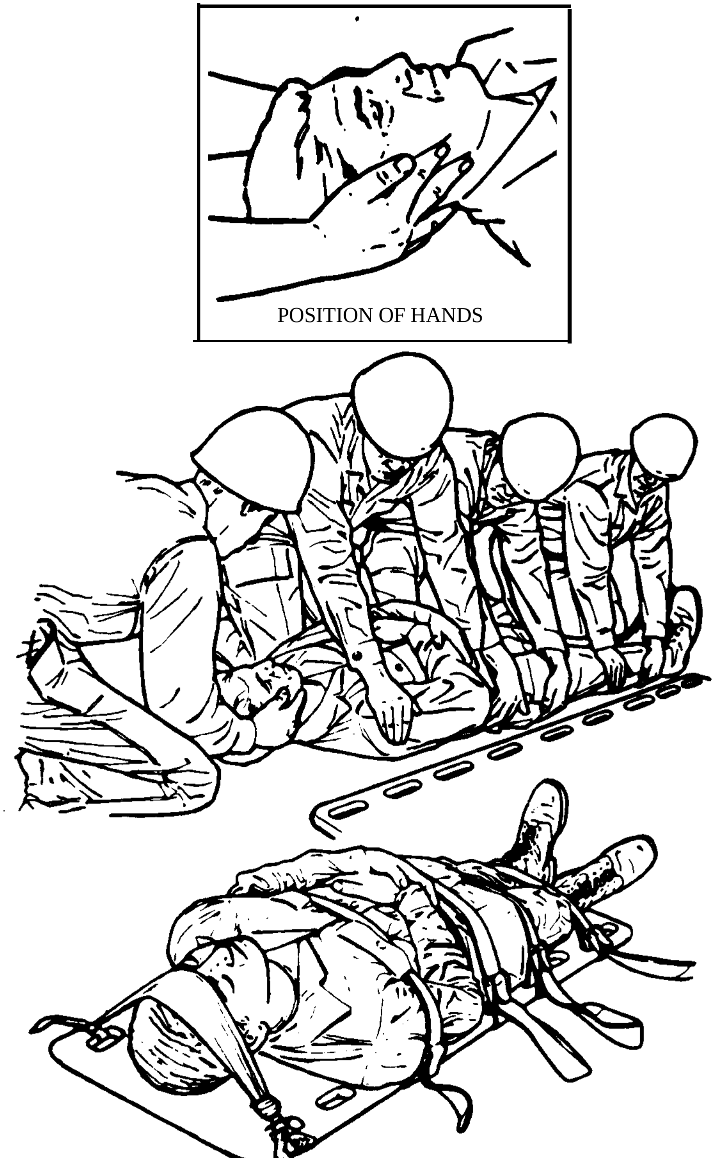



FIGURE 42.—Spinal immobilization using a long board. The bearers should assemble the required items: long spine board, four G-foot patient securing straps, cravat, and four pieces of padding. If an it&n is not available. the bearers should improvise it from available materials.

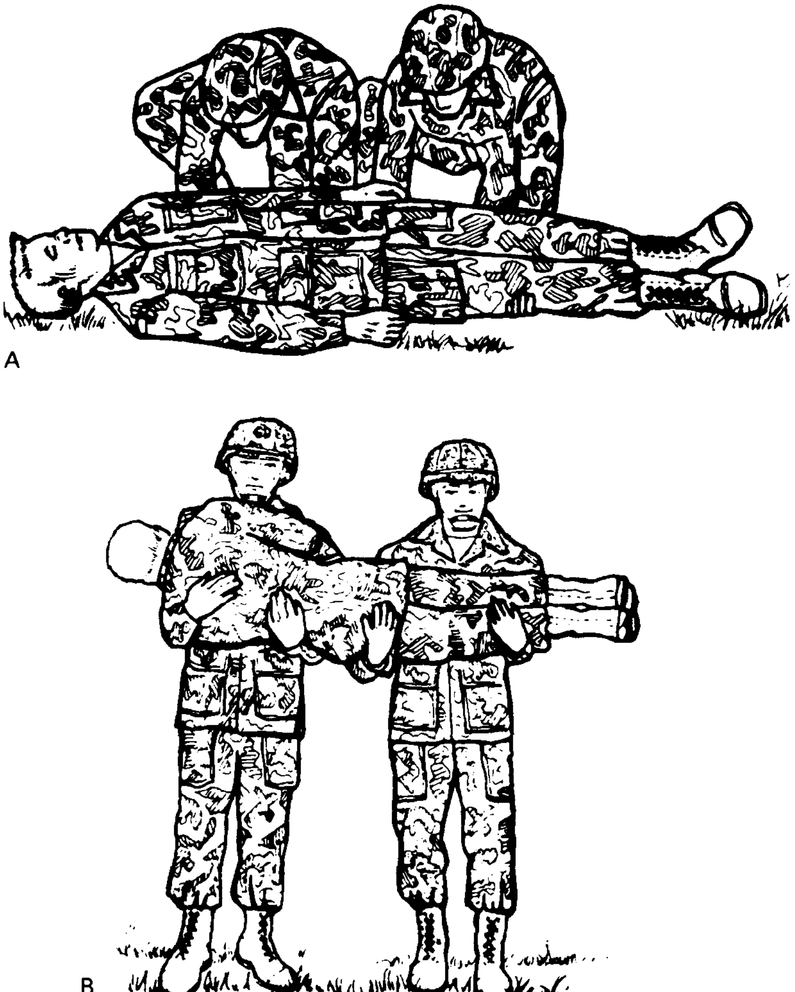
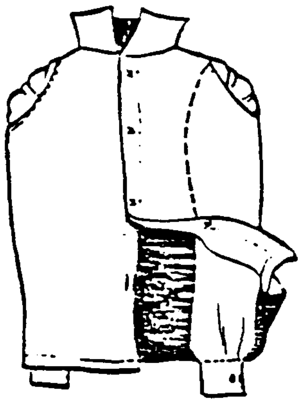


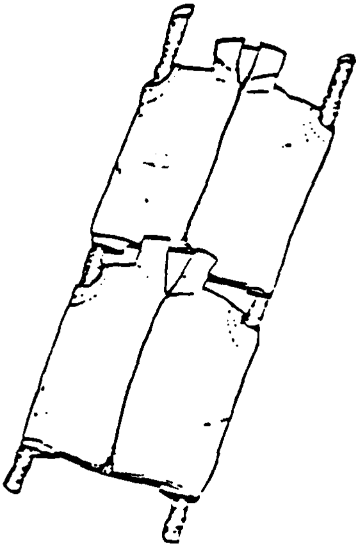

**FIGURE** 43.-Under more stable battlefield conditions, where assistance of another individual is available, in the absence of other alternative methods of stable spine support, the two-man arm carry is appropriate for suspected thoracic-lumbar spine injuries.

**technique does not protect the cervical spine; therefore, if *cervical* spine injury is also suspected, the victim should not be moved until a semirigid collar and spine board are available. In the absence**

**of back boards and stretchers, makeshift litters can be fashioned from doors, lumber, or poles and clothing. (Figure 44).**

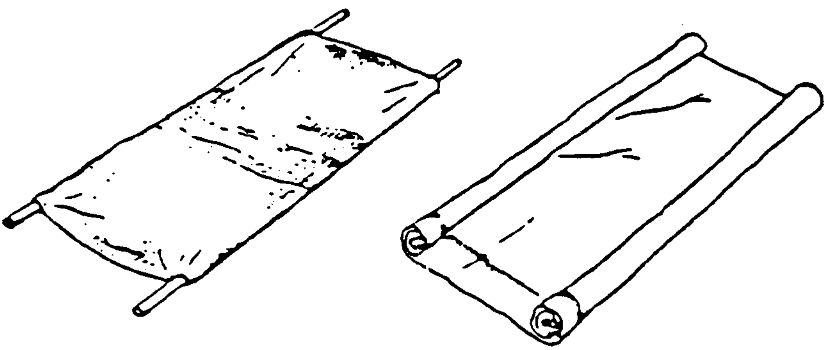


**A** **Button two or three shirts or jackets and turn them inside out, leaving the sleeves inside.**



**B** **Pass poles through the sleeves.**

*Litter made with pales and jackets (Illustrated A and B).*



*Litters made by inserting poles through socks and by rolling blanket.*

FIGURE **44.-Field-expedient litters.**

## RECEIVING AREA

Protection of the cervical spine must continue until that area is radiographically cleared. The first X-ray to be obtained is a lateral view of the cervical spine. The entire cervical spine, C-l to the C-7, T-1 junction, must be visualized. If the C-7 vertebra cannot be visualized, either the arms can be pulled towards the feet by an assistant standing at the foot of the stretcher, or a "swimmers view" (lateral X-ray of the cervical spine with one arm at the side and other elevated alongside the head) can be taken. If questions remain about interpretation of the cervical spine films and if the techniques to improve visualization are unsuccessful, protection of the neck must continue throughout the stabilization phase and the casualty must be transferred to a facility where either tomography or computerized tomography capabilities are available Immobilization can be discontinued only after all seven cervical vertebrae, including the ring of C-l, the odontoid, and the soft tissues anterior to the cervical spine are visualized and cleared. After the cervical spine has been evaluated, the remainder of the spine can be examined physically and radiographically. The medical officer should palpate the spinous processes in order to disclose areas of tenderness or malalignment. The search for malalignment is particularly important in the evaluation of the unresponsive patient.

When complex wounds involving the head, thorax, abdomen, or extremities coexist with vertebral column injuries, lifesaving measures take precedence over the definitive diagnosis and management of spinal column and cord problems. During these interventions, secondary injury to the unstable spine must be prevented by appropriate protective measures.

## INITIAL CLOSED REDUCTION AND STABILIZATION OF CERVICAL INJURIES

Skeletal traction using Gardner-Wells skull tongs is the treatment of choice for the reduction and stabilization of cervical spine injuries (Figure 45, Table 18). While a halter or chin strap may be temporarily utilized during the initial evacuation, they are not satisfactory for long-term use.

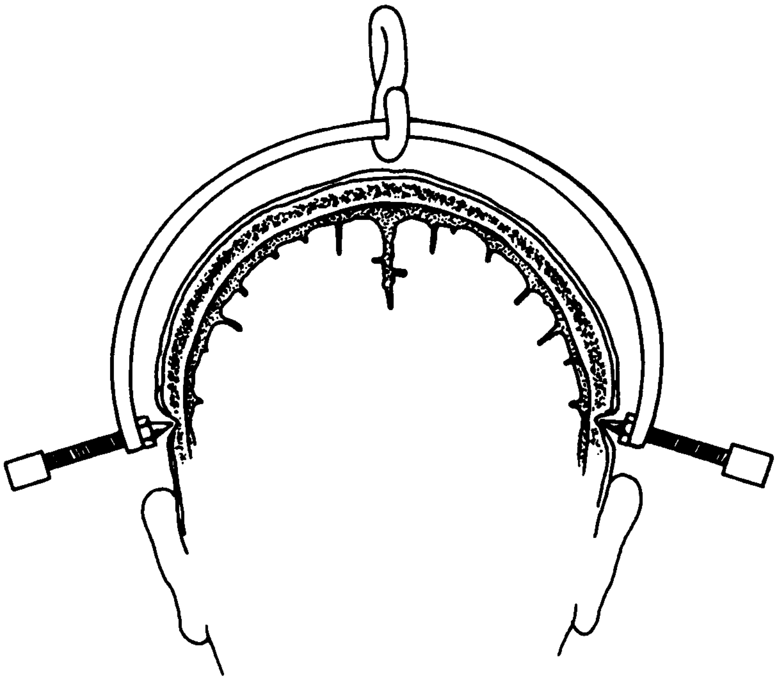


FIGURE 45.—Gardner-Wells tongs. See Table 18 for application.

When cranial tongs are used for traction, the rule of thumb for determining the amount of weight to be applied to the tongs for fracture reduction is 5 lbs. per level of injury. For example, to reduce a C-5 fracture, you would begin with 25 lbs. of weight. If this is insufficient weight to achieve reduction, appropriate additional increments of weight can be successively applied every 20-30 minutes under radiological control until reduction is attained. The maximal amount of weight that can be safely applied to properly placed Gardner-Wells tongs is 80-90 lbs.

TABLE 18.—*Application of Gardner- Wells Cranial Tong*

| Step | Procedure | Comment |
|---|---|---|
| 1 | INSPECT INSERTION SITE: Select a point just above apex of each ear. | Rule out depressed skull fracture in this area. |
| 2 | SHAVE & PREP PIN INSERTION SITE | |
| 3 | INJECT LOCAL ANESTHETIC: Inject 2-3 cc of 1% xylocaine or equivalent agent one centimenter above each ear in line with the external auditory meatus. | May omit if patient is unconscious. |
| 4 | ADVANCE GARDNER-WELLS TONG PINS: Insert pins into skull by symmetrically tightening the knobs. | A spring loaded device in one or the two pins will protrude when the pins are appropriately seated. (A data plate on the tongs provides additional information.) |
| 5 | APPLY SKELETAL TRACTION: Use a pulley fixed to the head of the litter or frame to direct horizontal traction to the tongs. | Use 5 Ibs. rule (i.e. 5 Ibs. of weight for each level of injury, (see text). High cervical fractures usually require minimal traction to reduce. Monitor with series X-rays. The tong-pin site requires anterior or posterior positioning to adjust for cervical spine flexing or extension as indicated. |
| 6 | ELEVATE HEAD OF LITTER: Use blocks in order to provide body-weight counter traction. | The knot in the cord should not be permitted to drift up against the pulley. Should this occur, traction is no longer being applied. |
| 7 | DECREASE TRACTION WEIGHT When X-rays confirm that reduction is adequate, decrease traction to 5-15 lbs. | Unreducibile or unstable fractures should be maintained in moderate traction until surgical intervention. If neurological deterioration occurs, immediate surgical intervention must be considered. |

TABLE 18.—*Application of Gardner-Wells Cranial Tongs (continued)*

| Step | Procedure | Comment |
|---|---|---|
| 8 | DAILY PIN CARE | Cleanse tracts with saline and apply antibiotic ointment to the pin sites. Maintain pin force (see Step 4) by tightening as necessary to keep spring-loaded device in the protruded position. |
| 9 | TURN PATIENT APPROPRIATELY: Use Stryker, Foster, or similar frame and turn patient every four hours. | When initially proned, obtain X-rays to ensure that the reduction is maintained. If reduction is not maintained when the patient is proned, rotate the patient only between the 30° right and left quarter positions. The use of a circle electric bed is contraindicated with injuries of the spinal cord or column. |
| 10 | IF SATISFACTORY ALIGNMENT CANNOT BE OBTAINED, FURTHER WORKUP IS NECESSARY. | Consider myelogram, CT scan, tomograms, and neurosurgical/orthopedic consultations. |

## INITIAL MANAGEMENT OF THE THORACIC-LUMBAR REGIONS

**Casualties with thoracic-lumbar spine injuries should always be transported on long spine boards and evacuated to a center capable of managing spine injuries. The thoracic-lumbar junction is notoriously unstable following injury. Short spine boards are unsatisfactory for evacuation because they provide insufficient thoracic-lumbar spine protection. Closed reduction of thoracic-lumbar spinal injuries above L-2 in the neurologically intact should not be attempted.**

## MYELOGRAPHY

The use of metrizamide myelography is indicated in the follow ing situations:

1. Patients with incomplete injuries who demonstrate neurologic deterioration upon serial reassessment.
2. Patients with an incomplete neurological injury who require surgery for spine stabilization or other procedures.
3. Patients with incomplete injuries who fail to improve following closed reduction.
4. Patients with progressive neurological improvement followed by the sudden appearance of a neurological plateau.
5. Patients with neurological injury without evidence of vertebral column injury.

Myelography is not advisable in neurologically complete injuries. If performed, and found abnormal in the patient with absent neurological function below the level of injury, a tendency exists for the obstruction to be surgically "relieved." Neurological improvement seldom follows operation and may contribute to mechanical instability of the spine Thus, knowledge of an obstruction to the flow of contrast material serves no beneficial function.

## EMERGENCY SURGERY IN CLOSED INJURIES OF THE CORD AND COLUMN

Emergency surgery is indicated in the following closed injuries of the spinal cord: 1) the spinal-cord-injured patient with an incomplete lesion who deteriorates neurologically, and 2) the neurologically intact or incomplete patient with an unreducible dislocation of the vertebral column. Where vertebral body fracture results in neural canal compromise, an anterior decompression is the indicated route in order to minimize anterior spinal artery compromise However, consideration must be given to the mechanics of the spinal column injury so that a stable column is not rendered unstable by the decompression. The operative approach is directed to the site of neurological compromise and to the level of spine instability. Consideration should be given to stabilizing the spine at the time of decompression. Rarely in the presence of a complete neurological injury, when subdura! or extradural hematomas or extrinsic masses resulting from fracture or soft-tissue fragments are decompressed, will neurological improvement occur. Individual nerve roots, in contrast to the spinal cord, frequently demonstrate recovery, with or without surgery. Some recovery of function can also be anticipated from injuries to the cauda equina, since this structure is also made up of peripheral nerves.

## EMERGENCY OPERATIONS IN PENETRATING INJURIES OF THE CORD AND COLUMN

High-velocity missile wounds of the spine, especially those with dural disruption, require immediate debridement. Low-velocity missile injuries of the spinal cord require less extensive debridement. The operative approach to the management of open wounds of the spine includes exploration of the path of the missile, assessment of the nature and extent of the anatomical disruption, and management of other concurrent surgical problems. Missiles that pass through the esophagus or colon, before striking the vertebral column, can cause osteomyelitis of the spine or disc-space infection. Consequently, when the colon or esophagus and the vertebral column are sequentially injured by a missile, both structures must be managed surgically. Intravenous antibiotic administration (a combination of first-generation cephalosporin and an aminoglycoside is recommended) and tetanus prophylaxsis should be started immediately. Where cerebral spinal fluid (CSF) leakage from the wound is identified following debridement, the wound can be closed loosely and a compression dressing applied. Continued subcutaneous spinal fluid collection or persistent leakage is an indication for wound exploration and dural repair.

In the presence of extensive open wounds of the spine, every attempt should be made to repair muscle and skin, and to perform a watertight closure of the dura within the first 6-12 hours post-injury. If logistics make it impossible to manage an open spine wound during the first 48 hours, it is preferable to debride and loosely pack the open wound. If there is no CSF leakage, the wound may be left open for 3-5 days followed by delayed closure, or allowed to heal by second intention. In those injuries with complete anatomical disruption of the spinal cord, the dural sack can be ligated to prevent CSF leak. Although not optimal, tissue deficits may require dural repairs or "patch" grafts to be left uncovered. Instrumentation for spinal stabilization and fusion (i.e., rods, etc) is contraindicated in the presence of an open wound.

## PHARMACOLOGIC TREATMENT

The value of pharmacological agents in the management of spinal cord injuries remains questionable. Attempts to prevent the deleterious effects of trauma on the nervous system or to restore lost neurological function have led some to use steroids (50 mg of Decadron initially, followed by 10 mg qid on a reducing scale over a four or five day period), and 20% mannitol (500 cc by rapid IV infusion). Benefit from either drug, employed singularly or in combination, has not been demonstrated. Hyperbaric oxygen therapy, which can reduce edema and hyperoxygenate tissues, may be of value in the incomplete injury if initiated within a few hours of injury.

## GENERAL MANAGEMENT

Traumatically-induced sympathectomy seen with injuries to the vertebral column above T-6 produce bradycardia, hypotension, and hypothermia. Ringer's lactate may be required to maintain adequate vascular volume and maintain a reasonable blood pressure. Atropine (0.4–0.6 mg every four hours) may improve blood pressure levels by maintaining the cardiac rate above 40/min. Hypotension in the complete spinal cord injury is to be anticipated, due to marked decrease in peripheral vascular resistance.

The use of a nasogastric tube is always indicated in the acute spine-injured patient. Its use reduces the chance of emesis, and allows earlier diagnosis of stress ulcer hemorrhage. Cimetidine (300 gm by IV infusion every six hours) is utilized during the first 7–10 days post injury, along with the installation of aluminum hydroxide gel (Amphogel, 30 cc) and a magnesium hydroxide (Mylanta II, 15 cc) into the nasogastric tube every two hours to prevent stress ulceration. The use of this combination tends to counteract the diarrhea caused by one and the constipation brought on by the other. The use of a nasogastric tube, connected to low suction, also reduces the effects of paralytic ileus, which often follows injury of the thoracic and lumbar spine.

A major concern following spine and spinal cord injury is the occurrence of deep venous thrombosis. The most appropriate prophylactic measures include: (a) awareness, (b) adequate fluid hydration, (c) thigh-length compression hose (changed two to three times daily to evaluate the skin and check for edema), and (d) subcutaneous heparin (5,000 units twice a day). This dose of subcutaneous heparin during the immediate post-trauma period is not likely to cause intraspinal bleeding.

The bladder is emptied by intermittent catherization. Frequently, for the female patient, this is not possible and an indwelling catheter is required. In the combat situation, for logistics reasons, it may be necessary to leave an indwelling catheter in place. Failure to decompress the bladder can lead to a hypertensive crisis severe enough to cause bleeding into the brain (autonomic hyperreflexia). The use of prophylactic urinary antibiotics is not advised. Liberal fluid intake (2,000 cc daily) and the use of an acidifying agent (e.g., cranberry juice) to reduce the occurrence of urinary calculi is recommended. Bowel training includes the use of suppositories.

Decubitus ulcers must be prevented. Patients are instructed in prevention techniques. Where self care is not appropriate, patient care and turning must be provided by attendants. For the recumbent patient, all pressure points are carefully padded and frequently observed. The skin is kept dry and powered. All bony prominences are inspected daily. Physical therapy is started immediately to minimize contracture and disuse atrophy. All joints incapable of being actively mobilized by the patient require daily ranging through their full arc of motion. Foot supports prevent contractures of the ankle and pressure decubiti of the heel.

# APPENDIX A

# Glossary of Drugs With National Nomenclatures

## ANTIBIOTICS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Ampicillin U.S.P. | Amblosin | Ampicilline | Ampicilline. |
| Bacitracin U.S.P. | Bacitracin | Bacitracine | Bacitracine |
| Cefazolin | Cefazolin | Cefazolin | Cefazolin |
| Cefoxitin | Cefoxitin-Natrium | Cefoxitine-Natrium | Cefoxitine |
| Ceftazidime | Ceftazidim | Ceftazidime | Ceftazidime |
| Cefuroxime | Cefuroxim | Cefuroxime | Cefuroxime |
| Cephapirin | Cefapirin-Natrium | Cefapirine-Natrium | Cefapirine |
| Chloramphenicol U.S.P. | Chloramphenicol DAB 7 | Chooramfenicol | Cloramphenicol |
| Clindamycin | Clindamycin | Clindamycine | Clindamycine |
| Erythromycin U.S.P. | Erythromycinum Ph. Int. | Erythromycine | Erythromycine |
| Gentamicin sulfate U.S.P. | Gentamicine | Gentamicine sulfaat | Gentamycine |
| Kanamycin U.S.P. | Kanamycin | Kanamycine | Kanamycine |
| Methicillin U.S.P. | Methicillin-Natrium | Methicilline | Methicilline |
| Metronidazole | Metronidazol | Metronidazol | Metronidazole |
| Mezlocillin | Mezlocillin | Mezlocilline | Mezlocilline |
| Nafcillin | Nafcillin-Natrium | Nafcilline-Natrium | Nafcilline |
| Neomycin sulfate U.S.P. | Neomycin | Neomycine sulfaat | Neomycine |
| Polymyxin B sulfate U.S.P. | Polymyxini B-sulfas Ph. Int. | Polymyxine B Sulfaat | Polymyxine B |
| Potassium penicillin G, U.S.P. | Penicillin G-Kalium DAB 7 | Kalium penicilline B | Penicilline |
| Potassium phenoxymethyl penicillin U.S.P. | Potassium phenoxymethyl penicillin | Kalium fenoxymethyl penicilline | Phenoxymethylpenicilline |

## ANTIBIOTICS (continued)

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Streptomycin sulfate U.S.P. | Streptomycinsulfat DAB 7 | Streptomycine sulfaat | Streptomycine sulfate |
| Sulfisoxazole | Sulfisoxazol | Sulfisoxazol | Sulfafurazol |
| Tetracycline U.S.P. | Tetracyclinum Ph. Int. | Tetracycline | Tetracycline |
| Ticarcillin | Ticarcillin | Ticarcilline | Ticarcilline |
| Tobramycin | Tobramycin | Tobramycine | Tobramycine |
| Trimethoprim/ sulfamethoxazole | Trimethoprim mit sulfa-methoxazol | Trimethoprime met sulfa-methoxazol | Trimethoprime + sulfamide |
| Vancomycin | Vancomycin | Vancomycine | Vancomycine |

## ELECTROLYTIC AND WATER BALANCE

| | | | |
|---|---|---|---|
| Calcium chloride injection U.S.P. | Kalziumchlorid-Losung | Calciumchlorideoplossing | Chlorure de calcium injectable |
| Calcium gluconate injection U.S.P. | Calcium gluconicum 10% | Calcium gluconaat injectie | Calcium levulinate |
| Dextrose injection U.S.P. | Traubenzuckerlosung 10% | Glucose injectie | Solution injectable de glucose, isotonique |
| Ethacrynic acid U.S.P. | Etacrynsaure | Ethacryne zuur | Acide etacrynique |
| Furosemide U.S.P. | Furosemid | Furosemide | Furosemide |
| Lactated Ringer's injection U.S.P. | Ringer-Lactat-Losung | Ringer lactaat injectie | Lactate de calcium |
| Mannitol U.S.P. | Mannit | Mannitol | Mannitol |
| Potassium acetate injection U.S.P. | Kaliumazetat-Losung | Kaliumacetaatoplossing voor injecties | Injection d'acetate de potassium |
| Potassium chloride injection U.S.P. | Kaliumchlorid-Losung | Kaliumchlorideoplossing voor injecties | Chlourue de potassium injectable |

## ELECTROLYTIC AND WATER BALANCE (continued)

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Probenecid U.S.P. | Probenecid | Probenecide | Probenecide |
| Ringer's injection U.S.P. | Ringer-Losung | Ringer injectie | Solution de Ringer |
| Sodium chloride injection U.S.P. | Natriumchloridlosung, isotonisch, pyrogenfrei steril (DAB 7) | Natrium chloride injectie | Solution injectable de chlorure de sodium, isotonique |
| Sodium polystyrene sulfonate | Kationen-Austauscherharz | Natrium polystyreen sulfonaat | Sulfonate de sodium polystyrenique |

## MISCELLANEOUS DRUGS

| | | | |
|---|---|---|---|
| Acetazolamide Injection | Acetazolamid-natrium | Acetazolamide | Acetazolamide |
| Acetylcysteine | Acetylcystein | Acetylcysteine | Acetylcysteine |
| Acetylsalicylic acid U.S.P. | Acetylsalicylsaure DAB 7 | Acetylsalicyl zuur | Acetylsalicylique acide |
| Amitriptyline | Amitriptylin | Amitriptyline | Amitriptyline |
| Amyl nitrite N.F. | Amylnitrit | Amyl nitriet | Nitrite d'amyle |
| BAL, Dimercaprol | Dimercaprol | Dimercaprol | Dimercaprol |
| Carbamazepine | Carbamazepin | Carbamazepine | Carbamazepine |
| Chlorpromazine U.S.P. | Chlorpromazini hydrochlorridum Ph. Int. | Chloorpromazine | Chlorpromazine |
| Dexamethasone sodium phosphate | Dexamethasonnatrium-phosphat | Dexamethason Natrium fosfaat | Phosphate de sodium dexamethasone |
| Digoxin U.S.P. | Digoxinum Ph. Int. | Digoxine | Digoxine |
| Diphenhydramine | Dipphenhyddramin | Difeenhydramine-hydrochloride | Diphenhydramine |
| Droperidol | Dehydrobenzperidol | Droperidol | Droperidol |

## MISCELLANEOUS DRUGS (continued)

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Fluoresceine | Fluorescein | Fluoresceine | Fluoresceine |
| Heparin | Heparin | Heparine | Heparine |
| Hydralazine | Hydralazin | Hydralazine | Hydralazine |
| Hypertonic glucose | Hypertonische glukose | Hypertonische glucose | Glucose hypertonique |
| Hydrocortisone acetate | Hydrocortisonacetat | Hydrocortison Acetaat | Acetate d'hydrocortisone |
| Hydrocortisone sodium succinate injection U.S.P. | Hydrocortisonnatrium-succinat | Hydrocortison natrium succinaat injectie | Hydrocortisone succinate de sodium |
| Indigocarmine injection | 5,5'-Indigodisulfonsaure dinatriumsalz ampullen iv | Indigokarmijnoplossing voor injecties | Injection de carmin d'indigo |
| Methylprednisolone sodium succinate | Methylprednisolonnatrium-succinat | Methylprednisolon natrium succinaat | Succinate de sodium methylprednisolone |
| Naloxone | Naloxon | Naloxon | Naloxone |
| Oxygen U.S.P. | Sauerstoff | Zuurstof | Oxygene |
| Regular Insulin | Altinsulin | Normale insuline | Insuline ordinaire |
| Sodium nitrite U.S.P. | Natriumnitrit DAB 7 | Natrium nitriet | Nitrite de sodium |
| Sodium thiosulfate U.S.P. | Natriumthiosulfat DAB 7 | Natrium thiosulfaat | Hyposulfite de sodium |

## DRUGS AFFECTING SYMPATHETIC NERVOUS SYSTEM AND NERVE ENDINGS

| | | | |
|---|---|---|---|
| Albuterol | Salbutamol | Salbutamol | Salbutamol |
| Atenolol | Atenolol | Atenolol | Atenolol |
| Atropine sulfate U.S.P. | Atropinsulfat DAB 7 | Atropine sulfaat | Atropine sulfate |
| Cyclopentolate hydrochloride U.S.P. | Cyclopentolathydrochlorid | Cyclopentolaat hydrochloride | Cyclopentolate |
| Dobutamine | Dobutamin | Dobutamine | Dobutamine |
| Dopamine | Dopamin | Dopamine | Dopamine |

## DRUGS AFFECTING SYMPATHETIC NERVOUS SYSTEM AND NERVE ENDINGS (continued)

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Ephedrine | Ephedrine | Efedrine | Ephedrine |
| Epinephrine U.S.P. | Adrenalin DAB 7 | Adrenaline | Adrenaline |
| Homatropine hydrobromide U.S.P. | Homatropinhydrobromid DAB 7 | Homatropine hydrobromide | Homatropine bromhydrate |
| Isoproterenol U.S.P. | Isoprenalini hydrochloridum Ph. Int. | Isoprenaline | Isoprenaline |
| Levarterenol bitartrate U.S.P. | Noradrenalinhydrogentartrat DAB 7 | Levarterenol bitartraat | Noradrenaline |
| Mephentermine | Mephentermin | Mefentermine | Mephentermine |
| Metaproterenol | Orciprenalin | | Orciprenaline |
| Metaraminol | Metaraminol | Metaraminol | Metaraminol |
| Methoxamine | Methoxamin | Methoxamine | Methoxamine |
| Phenylephrine | Phenylephrin | Fenylefrinehydrochloride | Phenylephrine |
| Physostigmine salicylate U.S.P. | Physostigminsalicylat DAB 7 | Fysostigmine salicyclaat | Physostigmine |
| Pralidoxime chloride U.S.P. | Pralidoximi methiodidum Ph. Int. | Pralidoxime chloride | Pralidoxime |
| Propranolol | Propranolol | Propranololhydrochloride | Propranolol |
| Scopolamine U.S.P. | Scopolaminhydrobromid DAB 7 | Scopolamine U.S.P. | Scopolamine |

## GENERAL ANESTHETICS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Cyclopropane U.S.P. | Cyclopropan | Cyclopropane | Cyclopropane |
| Enflurane | Enfluran | Enfluraan | Enflurane |
| Etomidate | Etomidat | Etomidaat | Etomidate |
| Fentanyl | Fentanyl | Fentanyl | Fentanyl |
| Halothane U.S.P. | Halothan | Halothaan | Halothane |
| Isoflurane | Isofluran | Isofluraan | Isoflurane |
| Ketamine | Ketamin | Ketamine | Ketamine |
| Midazolam | Midazolam | | Midazolam |
| Nitrous oxide U.S.P. | Distickstoffoxide, Lachgas | Lachgas, distikstofoxide | Protoxyde d'azote |
| Thiopental sodium U.S.P. | Thiopental-natrium | Thiopental-natrium | Penthiobarbital injectable |

## LOCAL ANESTHETICS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Bupivacaine | Bupivicain | Bupivicainehydrochloride | Bupivicaine |
| Chloroprocaine N.F. | Chloroprocain | Chloroprocaine | Chloroprocaine |
| Cocaine hydrochloride U.S.P. | Cocainhydrochlorid DAB 7 | Cocaine hydrochloride | Cocaine chlorhydrate |
| Dyclonine | Dycloninhydrochlorid | Dycloninhydrochloride | Dyclonine |
| Lidocaine hydrochloride | Lidocainii hydrochloridum | Lidocaine hydrochloride | Lidocaine |
| Mepivacaine hydrochloride N.F. | Mepivacainhydrochloride | Mepivacainehydrochloride | Mepivacaine |
| Prilocaine hydrochloride N.F. | Prilocainhydrochlorid | Prilocainehydrochloride | Prilocaine |
| Procaine hydrochloride | Procainhydrochlorid DAB 7 | Procaine hydrochloride | Procaine |
| Proparacaine hydrochloride U.S.P. | Proxymetacainhydrochlorid | Proparacaine hydrochloride | Proxymetacaine |
| Tetracaine hydrochloride U.S.P. | Tetracainhydrochlorid DAB 7 | Tetracaine hydrochloride | Tetracaine |

## MUSCLE RELAXANTS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Atracurium | | | besilate d'Atracurium |
| Curare | Dimethyltubocurarinium-chlorid | Curare | D-Tubocurarine |
| Pancuronium bromide | Pancuroniumbromid | Pancuronium bromide | Bomure de Pancuronium |
| Succinylcholine U.S.P. | Succinylcholin | Succinylcholine | Succinylcholine |
| Tubocurarine chloride U.S.P. | D-Tubocurarini chloridum Ph. Int. | Tubocurarine chloride | Tubocurarine |

## ANALGESICS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Alfentanil | Alfentanil | Alfentanil | Alfentanil |
| Butorphanol | Butorphanol | Butorphanol | Butorphanol |
| Codeine phosphate U.S.P. | Codeinephosphate DAB 7 | Codeine fosfaat | Codeine |
| Meperidine hydrochloride U.S.P. | Pethidini hydrochloridum Ph. Int. | Pethidine hydrochloride | Pethidine chlorhydrate |
| Methadone hydrochloride U.S.P. | Methadoni hydrochloridum Ph. Int. | Methadon hydrochloride | Methadone |
| Morphine sulfate U.S.P. | Morphini sulfas Ph. Int. | Morfine sulfaat | Morphine |
| Nalbuphine | Nalbuphinhydrochlorid | Nalbuphinhydrochloride | Nalbuphine |
| Sufentanil | Sufentanil | Sufentanil | Sufentanil |

## TOPICAL AGENTS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Copper Sulfate | Kupfer-sulfat | Kopersulfaat | Sulfate de cuivre |
| Mefinide | Mafenid | Mafenide | Mafenide |
| Petrolatum U.S.P. | Petrolatum | Petrolatum | Petroleine |
| Silver nitrate U.S.P. | Silbernitrat DAB 7 | Zilvernitraat | Nitrate d'argent |
| Silver sulfadiazine | Sulfadiazin-silber | Zilversulfadiazine | |

## CHOLINERGIC MUSCLE STIMULANTS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Edrophonium | Edrophoniumchlorid | Edrophoniumchloride | Edrophonium |
| Neostigmine | Neostigmin | Neostigminebromide | Neostigmine |

## GASTROINTESTINAL DRUGS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Bisacodyl | Bisacodyl | Bisacodyl | Bisacodyl |
| Cimetidine | Cimetidin | Cimetidine | Cimetidine |
| Glycerine | Glycerol | Glycerol | Glycerol |
| Metoclopramide | Metoclopramid | Metoclopramide | Metoclopramide |
| Ranitidine | Ranitidin | Ranitidine | Ranitidine |
| Sorbitol | Sorbit | Sorbitol | Sorbitol |

## SEDATIVES, HYPNOTICS AND ANXIOLYTICS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Amobarbital U.S.P. | Amobarbitalum Ph. Int | Amobartital | Amobarbital |
| Diazepam | Diazepam | Diazepam | Diazepam |
| Paraldehyde U.S.P. | Paraldehyd DAB 7 | Paraldehyde | Paraldehyde |
| Pentobarbital U.S.P. | Pentobarbital | Pentobarbital | Pentobarbital |
| Secobarbital U.S.P. | Quinalbarbitone | Secobarbital | Secobarbital |

## PLASMA EXPANDERS

| United States | Germany | Netherlands | France |
|---|---|---|---|
| Dextran | Dextran | Dextran | Dextran |
| Fresh Frozen Plasma | Gefrierfrischplasma | Vers ingevroren plasma | Plasma frais congele |
| Normal human serum albumin U.S.P. | Humanalbumin 20% | Norman humaan albumine uit serum | Albumine humaine |
| Plasma protein fraction U.S.P. | PPL, Humanalbumin 5% | Protein fractie uit plasma | Plasma |

## VACCINES AND ANTITOXINS

| | | | |
|---|---|---|---|
| Gas gangrene antitoxin, pentavalent | Gasodem-Antitoxin, polyvalent | Gas gangreen-antitoxine pentavalent | Serum antigangreneux polyvalent |
| Tetanus immune globulin (human) U.S.P., Hyper-immune human antitetanus | Tetanum-immunglobulin, Hyperimmunglobulin gegen tetanus | Tetanum-immuno globuline Serum tegen tetanus | Serum antitetanique (menselijk) |
| Tetanus toxoid U.S.P. | Tetatoxoid | Tetanus vaccin | Vaccin antitetanique |

## ANTISEPTICS

| | | | |
|---|---|---|---|
| Alcohol U.S.P. | Aethanol DAB 7 | Alcohol | Alcool ethylique |
| Hexachlorophene U.S.P. | Hexachlorophen WHO | Hexachlorophene | Exophene |
| Povidone Iodine Solution | Polyvidon-Iod | Povidon-ioodoplossing | Polyvidone iodee |