NOTES ON MILITARY SURGERY

By Dr. George W. Crile

Introductory Note

This volume was hastily compiled in the autumn of 1917 in the midst of the Great War at the request of the Medical Section of the Council of National Defense and was approved for publication by the Surgeon-General. Its purpose was to extend to our medical officers impressions gained from service with the French at the American Ambulance in 1915 and from a later service with the British, especially during the campaign of Sir Douglas Haig in Flanders in 1917, for it was a rare privilege and an illuminating experience to be intimately associated with our British and French colleagues during these periods of great military activity.

Although these notes were intended for publication in 1917 as one of the stop-gap war series, in the confusion of government activities the volume had reached only the page-proof stage at the time of the Armistice. It seemed to me then that any purpose it might have served had also passed, and I requested that it be not published. On rereading the proof sheets recently, however, with the perspective gained by five years of active practice since the war, it has seemed that it might be of value to publish this at this time as a permanent record of the debt still owed by civilian surgeons to the enormous experience accumulated in the war. It will serve also as a permanent expression of my own appreciation of the great privilege of intimate association with the great surgeons of the Allied Armies.

George W. Crile,
Cleveland, Ohio.

Armistice Day, 1924.

TO

THE BRITISH AND FRENCH SURGEONS
OF THE GREAT WAR

WITH ADMIRATION FOR THEIR WORK
WITH GRATITUDE FOR THEIR TEACHING
WITH APPRECIATION OF THEIR SPLENDID COMRADESHIP

Notes *on* Military Surgery

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Table of Contents

INTRODUCTION

PART I
General Principles

CHAPTER

PART II

PRACTICAL POINTS

PART III

A Suggested Plan of Clinical Organization of the Medical Service

Notes on Military Surgery*

INTRODUCTION

I. *The supreme duty of the medical service is to preserve by every means the fighting strength of the army.* Therefore the medical man, especially the regimental medical officer, must regard it as his highest duty to maintain the moral forces of the men at the same level as their physical forces. Every medical officer, in particular the eye, nose, and throat specialists, the specialist in nervous diseases and the dentist, must bear in mind that he can easily weaken the line and fill special hospitals by unintentionally educating soldiers in disease. It is absolutely essential that medical officers discourage introspection and encourage endurance and duty. The scientific man must foreswear his pleasure in purely academic research; in field service he must put this aside, and in its place must attack the present problems of the soldier, he must be guided in these problems by the clinicians. The laboratory worker must be willing to work with simple apparatus under simple surroundings; he must be ready to do routine work for the benefit of the soldier. The impatient medical officer who becomes bored when the inevitable lull comes must bear in mind that in war there is an alternation of feast and famine of work. Now he works furiously night and day — now he has no work at all. Occasionally the medical officer comments that he would be of more use to his country were he at home — in his hospital, in his laboratory, in his practice, with his family and friends; he must be reminded that this is equally true of every officer and every soldier in the army; and moreover that the medical officer is perhaps the only officer from civil life whose military activities not only keep him in touch with his

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profession, but also give him the opportunity to increase his professional knowledge. But idle hours are self-imposed. What an opportunity is presented at these quiet periods for reading, for study, for compiling notes, for research! Above all the medical officer should remember that his own want of occupation is due to the good fortune of the men in the fighting line. Who would wish the enemy more success so that the medical officer need not be bored by having too little of the soldier's misfortune to keep him busy!

II. These notes, based on observations of the military surgery of our Allies are presented in the hope that they may be of service to the U. S. Army which should profit by the great work of the British and French surgeons — work that challenges the highest admiration.

In the form of presentation it has seemed well (1) merely to mention briefly in this introduction those points which appear to be satisfactorily settled at the present time, and those points whose status at the present time appears to be unsatisfactory or in the process of evolution; (2) to discuss in some detail certain general underlying principles; and (3) to present brief outlines of the surgical procedures which at the present time seem best adapted to the successful treatment of the injuries most commonly met at the front.

POINTS SETTLED AND SATISFACTORY

1. Organization of the service so that the administrative and the clinical work are differentiated.

2. Wooden huts for hospitals with crisis expansion capacity of canvas.

3. Need of crisis expansion capacity everywhere.

4. Shell-proof field stations.

5. Retention near the front of the lightly wounded and lightly sick.

6. Least possible transportation of all wounded.

7. Postponed transportation of chest wounds.

8. Thomas splint for legs and arms, and its application at the Regimental Aid Post or the next station.

9. In the area in front of the Casualty Clearing Station (Evacuation Hospital), no surgery beyond the arrest of serious hemorrhage or the amputation of a dangling limb.

10. Immediate surgical revision of all wounds.

11. Immediate operation for all abdominal penetrations.

12. Closure of most knee injuries without drainage after revision by a good surgeon.

13. Performance of all surgery during the period of contamination if possible, *i. e.*, within the first twelve hours.

14. Harm done by superficial work. A wound should be either completely revised or passed on.

15. Establishment of a splint and apparatus factory at a good field distribution point.

16. Use of morphin in the field *only when patients are not cyanosed*.

17. Efficiency of tetanus antitoxin.

18. Prompt treatment of phosgene gas poisoning by bleeding at the Advanced Dressing Station.

19. Official diagnosis and treatment of so-called "shell-shock" and neurasthenia by specialists only.

20. Transfusion of blood the best remedy for shock and hemorrhage; use of slightly wounded as donors; in exigencies and before infection, blood need not be tested.

21. Nitrous oxid-oxygen alone or supplemented with ether the best routine anesthetic; special training in its administration absolutely essential.

22. Resistance to infection lowered by exhaustion.

23. Restorative power of sleep, warmth, rest, food, drink and comfort.

24. *Sound surgical principles, in war as in peace, constitute the only safe foundation on which good practice can be built.*

POINTS NOT SETTLED BUT UNDER DEVELOPMENT

1. Prevention and treatment of infection.

2. Treatment of peritonitis.

3. Utility of the tourniquet and the probe — should they be discarded?

4. Employment of nurse anesthetists.

5. Method of providing for crisis expansion in the operating rooms at the front.

6. Establishment of Field Training Schools for the medical department.

7. Consolidation of the entire hospital system into Sectors, each consisting of Regimental Aid Posts, Field Hospitals, Evacuation Hospitals and a Base Hospital, the Evacuation Hospitals located eight or more miles behind the lines.

PART I

General Principles

CHAPTER I

WOUNDS AND INFECTIONS

Outstanding Facts.—At present, in spite of faithful trials of various methods, about 95 per cent of all wounds are infected when they arrive at the Base Hospitals. No such high percentage of wound infections occurs in civil casualty practice nor in at least two specially featured military hospitals. What determines this difference? What factors are common in civil practice, at these special military hospitals and in British and French war surgery? What are the variable factors?

Common Factors.—1. The surgeons are of approximately equal skill, judgment and experience.

2. The distance from the point of injury is approximately the same at the military hospitals referred to above and at the British and French Casualty Clearing Stations, *i. e.*, the primary surgical treatment is given about eight miles behind the lines.

3. In general the methods are similar, or if dissimilar, they are not as dissimilar as the results.

4. The wounds are all inflicted by the same enemy; with similar weapons; on like soil.

Variable factors.—There is but one important variant:

In civil practice, and at the military hospitals but a few miles behind the lines, patients *are not moved after the first surgical treatment* and the first surgical treatment is early.

Discussion.— We may then infer that in transportation there is somewhere a basic adverse factor. Is it the fatigue of the journey? Is it loss of sleep? Does transport injure the wound, disturb the dressing, or add new infection? In transport are the dressings left on too long? Do they become too dry? Are they too moist? Do open wounds progress better than closed wounds? In answer to these questions, we find that dressings are but little disturbed in travel. The journey to the Base Hospita from the Casualty Clearing Station takes but from twelve to eighteen hours. As a rule even in a hospital the wounds are not dressed every twelve hours. The Carrel treatments are done on the train, perhaps not as well as one would desire, but they are done. Therefore the adverse factor is not want of dressing nor disturbance of dressing. With few exceptions, open wounds and antiseptically dressed wounds, small wounds and large wounds — nearly all arrive at the Base Hospital infected. Therefore for the adverse factors we must look not only at the wound, but we must look also beyond the wound.

As for the wound itself, the frequent handling, the jiggling train, the incidents of travel cause numerous mechanical and muscle pull injuries — direct violations of a fundamental surgical principle, viz., *physiologic rest*. Interference with physiologic rest is interference with resistance — with repair. Because the wounded man complains little during transport and his wounds are not disturbed it is fallacious to assume that he is not further injured. He complains little because by exhaustion and by morphin he is deprived in part of the protective warning of pain.

It is admitted that all open wounds are contaminated; that no wound is made bacteria-free by the best surgical revision; that no antiseptic destroys all the contaminating bacteria in every wound; that the critical point is from the twelfth hour on, *i. e.*, the period during which contamination becomes infection. It is admitted that soldiers exposed to cold and to fatigue, and tissues partially devitalized by injury or by anemia more readily become infected; that the wounded fresh soldier does better than the wounded exhausted soldier; that the wounds of victorious troops do better than the wounds of defeated troops; that the incidence of medical as well as of surgical infections is increased among exhausted troops.

What causes the exhaustion? First of all, there is the strain of waiting. The soldier is in consuming expectation in advance of the attack. During the long and furious bombardment, he awaits tensely the order to "go over;" deliriously he goes over, and passes along to his struggle with bomb and bayonet in shell holes and dugouts and trenches; his is a raging metabolism; all his organs are speeded up — his brain, his adrenals, his thyroid and his muscles. The great increase in metabolism correspondingly increases the waste products and heavily taxes the organs of elimination, especially the liver. The margin of physiologic safety rapidly diminishes. In the midst of this struggle he falls. After further uncertainty, he finds himself in the Regimental Aid Post, then in the Advanced Dressing Station. From thence he is taken to the Main Dressing Station, thence to the Casualty Clearing Station. In a state of exhaustion he has been dressed and redressed and man-handled several times. At the Casualty Clearing Station, if his wound is light, it is promptly dressed; if serious, he must wait his turn for operation. For his operation, as a rule, he is given a lipoid solvent anesthetic—ether or chloroform. There is evidence that these lipoid solvents depress or suspend the action of the phagocytes, his principal defense mechanism. This suspension of his best defense lasts approximately twelve hours, extending through the critical period during which contamination becomes infection. This effect of ether and chloroform may be compared to that of an attack upon the first line troops while they were helpless under anesthesia. These anesthetics add seriously to the battle exhaustion. After several hours in bed, and before the wounded man has been restored he is put aboard a train for a jiggling twelve hours' journey, and on arrival at the Base Hospital, usually at night, he is man-handled again into bed. After a few days at the Base, he is sent on an interrupted journey to England. In point of time the following may serve as a homely illustration of what the exigencies of war have compelled the British to do: — In a field a hunter, dirty and exhausted by the chase and by loss of sleep, sustains a compound gunshot fracture of the tibia and fibula. He is taken to Racine, Wisconsin, and dressed, then in a motor ambulance to an aid station in Milwaukee where his wounds are dressed by an experienced surgeon; he is then sent to Chicago where he is taken to a hospital, anesthetized and the wound revised and good splints applied. After a few hours he is taken out of the hospital on a good stretcher, placed on a good bunk in a baggage car and taken to Cleveland. Here he is taken to a hospital for a few days' rest and restoration and interim treatment; then again he is taken on his stretcher in a baggage car to New York where he remains permanently under the charge of a surgeon until he is well. Up to this time he has had fragmented sleep — fragmented rest — fragmented treatment.

As to the wounded soldier, the net result is that, as a rule, he gets his first physiologic rest on the second or third day. Meanwhile, the wound has become infected; the man is sallow, weak and dejected. If left alone after his arrival at the Base Hospital he sleeps for one or two days, the depth and the length of this sleep being a correct index of the degree of his exhaustion and the corresponding loss of resistance. This sleep is his first restoration since he went into battle. We may say he has continued in battle ever since the receipt of his injury — the effects of this latter battle being in many instances perhaps no less damaging than the wound inflicted by the enemy. These individuals reach a degree of acute exhaustion equal to the chronic exhaustion of the hard-pressed troops in the 1914 period of the war. In a heavy engagement the exhaustion is not limited to the wounded. The unwounded soldiers in the same engagement may be in such a state of exhaustion that they must be withdrawn for rest and restoration. When for want of reserves this cannot be done, then a larger sick call appears. It is in this period of deep *exhaustion* from the combined effects of loss of sleep, of worry, of exertion, of injury, of pain, of anesthesia, of operation, of depressed phagocytosis, when the *local resistance* of the wound has been lowered by the grinding of handling and transport during the critical period when contamination becomes infection, that the difference between the results of civil surgery and the results of French and British battle surgery is established. The soldier is fresh and keen when the German attacks him — he is depressed when the bacteria attack him. The battle against bacteria is as important as the battle against the human foe. Vigor in a wound is as necessary for the defeat of its bacterial enemy as vigor in the soldier for the defeat of his human enemy.

Then if the patient cannot go safely to the hospital, why not take the hospital to the patient? Why not modify the Casualty Clearing Stations so that they may become *Advance Hospitals for Restoration and Primary Treatment* — specialized general hospitals? These hospitals, enlarged and better equipped than the Casualty Clearing Stations, could keep patients a longer time and until the restoration of the wound and of the man is established and the period of infection has passed. In accordance with this conception, also, the Base Hospitals should be brought near the Advance

Hospitals in order that in time of stress they might receive the overflow from the Advance Hospitals in order to provide sufficient free beds for new casualties. In emergencies many patients could be carried from the field directly to the Base Hospital — say from sixteen to twenty-four miles. The Base Hospitals would be of the same character as the Advance Hospitals — they would, in fact, be supporting hospitals.

CHAPTER II

ADVANCE HOSPITAL FOR RESTORATION AND PRIMARY SURGICAL TREATMENT — EVACUATION HOSPITAL

General Consideration.— The hospitals for Restoration and Primary Surgical Treatment should if possible be located from eight to twelve miles back from the front — the Base Hospitals from eight to twelve miles farther back, and if possible along the same railway lines, or still better they should have their own light railway. Evacuation then would be rapid, the duration of transportation short and correspondingly less harmful and transport could be made by train, by ambulance or by both. The following special advantages of this plan may be mentioned:

(*a*) The *wound* and the *patient* would profit by the all-important immediate physiologic rest.

(*b*) Sleep, rest and hospital care would accomplish the restoration of the wound as well as of the lowered general resistance, before the period of contamination ends and the period of infection begins.

(*c*) If possible, no patient should be evacuated after operation until restoration has been secured and the period of acute infection is past; and as far as possible he should be kept in the same hospital and under the care of the same surgeon until his wound is healed.

(*d*) Even with small wounds, if there is exhaustion, restoration should be secured before evacuation.

(*e*) Concentration, instead of dispersion of hospitals, through elimination of duplication, will permit a more liberal personnel per patient, and will correspondingly improve results.

(*f*) The dispersion plan was unavoidable in the early and uncertain period of the war before it was appreciated that modern warfare is essentially stationary; before it was appreciated to what extent motor transport and light railways annihilate distance. According to present-day conditions a new organization should be made which is not based on the traditions of horse ambulances and the swinging tides of battle of former conflicts.

(*g*) As to battle danger and the risk of capture, if our lines are flung back ten miles on a wide front, before evacuation of hospitals can be made, the war is over! The chance of occasional battle disturbance is but slightly more behind the lines than in London or on the Channel.

(*h*) In order that the wounded may be cared for at the front, there must be a complete revision of the hospitals at the front — new features must be introduced, new provisions must be made.

GENERAL PLAN.— The general plan of the Advance Hospital (Evacuation) should include the following features:

(*a*) It should have a large capacity, say for 2,000 beds with canvas provision for crisis expansion.

(*b*) It must be compact.

(*c*) It should be planned for the transport of patients within the hospital on wheeled stretchers.

(*d*) Factory efficiency must be provided.

(*e*) Facilities for operations must be made on a wholesale scale so that the number of operations performed in twenty-four hours may equal half the bed capacity.

OPERATIVE AREA.— Facilities for operations should be made on a wholly different scale than for civil practice. Operations must be planned for on a wholesale, not a retail basis. The same personnel should be able to perform several times as many good operations as now. This end may be secured by providing adequate capacity, and by dilution of work, as follows:

(*a*) In a 2000-bed hospital sufficient capacity should be provided to permit one thousand operations each twenty-four hours.

(*b*) The operating area for a 2,000-bed hospital should be no less than 60x100 feet.

(*c*) Each wheeled stretcher should be an operating table.

Thus in the operating area many patients would be simultaneously in the process of preparation; of operation; of post-operative dressing. The proposed plan is approximately as follows: To establish in the center of a rectangular operating area a serve-self counter in which will be kept stocks of instruments; basin and instrument sterilizers; quantities of supplies, many trays, etc. Trays of soiled instruments will be turned in at either end of this central counter, and trays of sterile instruments and supplies issued. The standardized trays will be designated by number, *e. g.*, No. 1 tray for amputation; No. 2 tray for skull operation; No. 3 tray for excision of foreign body; No. 4 tray for compound fracture of the thigh; No. 5 tray, abdominal; No. 6, chest tray, etc. The operating tables will be placed about the outer side of the operating area (Fig. 1).

There will be a managing surgeon, or surgeons. In a general way, he or they will decide in each case what operation is to be done and will designate by number the standard instrument trays and apparatus and the operator for each case. The managing surgeon will see all operations and will inspect the final splints and dressings. The orderly will prepare the field for the surgeon and will bring the designated tray from the central counter. The operating teams will take cases as selected by the manager. There should be two anesthetists, two scrub-up nurses and two orderlies — and in abdominal cases an additional surgical assistant for each operating surgeon. In this manner the patient will be wheeled along to the designated location in the operating area; will be prepared for operation there; dressed there; and then wheeled off to his bed in the ward. By this plan

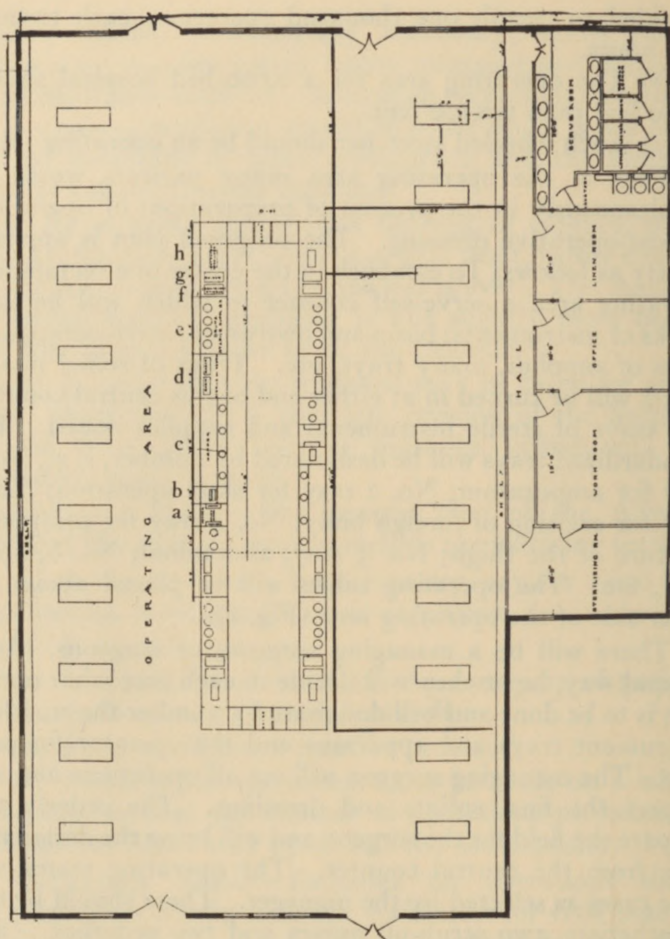


FIG. 1.—Floor plan of operative area planned for the performance of 1000 operations per day

a. Hoppers for soiled gloves.
b. Glove sterilizer
c. Hopper
d. Basins
e. Drums for sterile supplies
f. Sterile instruments
g. Basins
h. Instrument sterilizer

the surgeon of greater experience and riper judgment will be engaged in making decisions — in giving advice — not in routine operating. The skilled operator will be engaged in operating — not in disrobing the patient or clearing the operating table.

During the battle the intake of the hospital should be simultaneous and continuous. By admission in periods, patients frequently are obliged to wait unnecessarily long for their turn for operation. With the proposed plan, there will be far less fatigue for the personnel; the relays of teams will be easily managed; and there will be less delay for patients. By this plan we have not an operating room, not an operating theatre, but an *operating area*.

RESUSCITATION WARD.— Patients too exhausted for operation and seriously ill post-operative cases should be collected in a highly organized ward, especially arranged and equipped for this purpose. It should be in charge of an officer of the highest judgment and skill with a personnel of willing and resistant "never-say-die" workers possessing infinite optimism. This main ward should be divided into smaller wards, one of which is for the stage of final dissolution. There should also be subdivisions for noisy patients, and for cases with objectionable features. Just as soon as a patient has turned on the road to recovery, then he should join a normal ward, where sleep and rest are most easily secured.

The arrangement of the resuscitation ward should include:

(*a*) Officers, nurses and orderlies shod for noiseless steps.

(*b*) Every bed on wheels or with apparatus for putting it on wheels, so that it may be shifted from one place to another.

(*c*) Every bed provided with a mechanism whereby the nurses may with simple effort put the patient in a lying, sitting or head-down posture.

(*d*) Every bed provided with the following equipment:

1. Electric-light heating for part or all of the body.
2. Subcutaneous saline infusion apparatus.
3. Rectal tap apparatus.
4. Complete intravenous infusion apparatus.
5. Oxygen tank and tube and mask.
6. Humane restraint appliance.
7. Morphin in ready syringes.

(*e*) The ward provided with:

1. Apparatus for transfusion of blood.
2. Tracheotomy set.
3. An artificial respiration apparatus.
4. Minor operating set, sufficient to tie bleeding vessels.
5. Gas and oxygen apparatus, with small cylinders.
6. Extension apparatus.
7. Four overhead frames (Balkan).
8. Alcohol.
9. Antiseptic dressings.
10. Catheters.
11. Suprapubic trocar-catheter (Lower).
12. Stomach tube.

(*f*) A wooden timber or a piece of piping running along overhead the beds for suspension of some of the foregoing appliances.

METHOD OF PROVIDING CRISIS EXPANSION.— (*a*) *Tentage.*— Good tentage capacity should be provided for light cases, and for crisis expansion for all kinds of patients. Crisis expansion can be secured by what may be termed:

(*b*) *Stock-room storage of patients* in a tent, or better, in a hut having free ventilation. By such a plan, which is in operation in one of the British Main Dressing Stations, patients on stretchers can be stacked up in tiers of three, as lumber is stacked, leaving just enough space between the tiers for handling the patients — in effect, a huge filing case. In these positions men are fed quite readily and are accessible for withdrawal or rearrangement, etc. Though closely assembled, yet they are comfortable on good litters with blankets. In this manner, an enormous crisis expansion may be provided for in relatively small space. Each military unit has, as a rule, but one supreme test — everything is prepared for the peak of the load on the great day.

The plan described above provides facilities for taking care of battle injuries equal to the facilities for caring for civil injuries. The location of the hospital orientates the wounded soldier into the favorable surgical position of the wounded civilian. It puts civil and military surgery on the same level. It puts within the reach of military surgery a success equal to that of civil surgery. All good surgeons could thus achieve good results by the application of sound, well-established surgical practice. We may conclude that the much-sought-for specific for infection is not a chemical agent, but orientation of the injured man and good everyday surgery — *aided by good antiseptics.*

CHAPTER III

THE RESTORATION AND REPAIR OF THE WOUND AND COMBATING CONTAMINATION AND INFECTION

The restoration and repair of the wound may be divided into four stages, each presenting its own problems.

A. The stage of depressed local resistance and contamination, *i. e.*, the first twelve hours.

B. The stage of infection.

C. The stage of granulation and healing.

D. Superficial healing — end-defects, sinuses, deformities, etc.

Obviously, each of these stages presents a specific set of problems each so different from the rest, that no one set of procedures will answer for all.

A. Stage of Depressed Local Resistance and Contamination.— In this stage the indications are:

(*a*) Restoration of depressed local resistance.

(*b*) Destruction of the contaminating bacteria.

(*a*) *Restoration of Depressed Local Resistance*

1. Excision revision.

2. Physiologic rest.

1. *Excision Revision.*— The depressed resistance of a contused wound may be most quickly raised by immediate excision of its partially devitalized tissue. This must be done lightly and sharply; for if there be rough handling or needless moving of compound fractures; if piercing hooked retractors tear the flesh; and if intermittent muscular contractions grind tissues between the ends of ragged bone fragments, then the net result of excision revision is the substitution of surgically devitalized tissue for the devitalized tissues of battle casualty. With the aid of damaging inhalation anesthesia the rough surgeon does slowly and

awkwardly what shrapnel does painlessly and quickly — the shrapnel injury is to be preferred!

Next in importance to *excision revision* is the application of the great physiologic principle so clearly set forth in an earlier day by Hilton, appreciated by the civil surgeon everywhere, reaffirmed in war surgery by Sir Anthony Bowlby, Sir G. H. Makins, indeed, by British surgeons generally, and no less by Sir Almroth Wright, viz., *physiologic rest.* In the last analysis the resources of the patient are the only means of restoration and repair.

2. *Physiologic Rest.*— Physiologic rest includes more than mere muscular and psychic rest; it implies equally *cellular rest.* Living cells are disturbed by air; by dessiccation; by physical contact of dressings; by many chemical antiseptics; by bacterial toxins. These points have been strongly emphasized by Sir Almroth Wright whose teaching has given the impetus which has emphasized the importance of the *cellular* protection of wounds, to ensure cellular physiologic rest.

To secure physiologic rest in the case of a fracture, an even adequate continuous extension must be made — an extension sufficient to prevent the goading of soft tissues by sharp bone, and to prevent bony fragments from grinding each other. Physiologic rest of the soft parts means mass quiet by means of supports — such as splints, slings, swings, and extension suspensions; it means for compound fractures and for injuries of the soft parts no tight bandages, no tight stitches, no accumulation of wound secretions — blood, serum, etc. For open wounds it means that antiseptics must not be damaging; that dressings must be painless; it means elevation for comfort and the prevention of swelling. For visceral injuries it means absolute rest, low diet, freedom from excitation, anociated environment. Physiologic rest implies no transport, no painful dressings, no alarms. It means noiseless steps and quiet neighbors.

(*b*) *Destruction of Contaminating Bacteria.*— The first and most dependable agency for the destruction of contaminating bacteria is the bactericidal power of tissues. This normal defense of tissue against bacteria is present only in living tissues; and the ability of living tissue to overcome infection depends on its vitality. Normal living tissue has strong bactericidal power. As vitality is impaired down to the death point, so is the bactericidal power impaired to the zero point. Moreover, when infection begins, the infecting agent itself has the power of diminishing the vitality in advance of the infection through chemical injury, tension and swelling. Thus as Kenneth Taylor, Cuthbert Wallace, Bashford, and others have shown, many anaërobes cannot live at all in normal tissue, but only in damaged tissue. The anaërobic invasion is made possible only by injury through chemical action, through shell injury, through swelling or anemia whereby the resistance of the tissue is lowered. Pyogenic infections attack most successfully in the wake of a creeping, damaging barrage. Therefore in a compound fracture that is settling down, one goading by a ragged bone will devitalize a small area, and in consequence an area of infection with its advancing barrage will be established. Therefore we may say that the whole wound is defensively only as strong as its weakest point. If the defense line is broken at one point, the entire line may give way.

As for antiseptics, no chemical antiseptic can command good results with bad surgery; good surgery commands good results without chemical antiseptics, but the best results are the sum of good surgery and the good use of good chemical antiseptics. In the period of contamination the state of depressed vitality of the wound is overcome by exquisite excision of devitalized tissue; by general and local physiologic rest; by assisting the re-invigorated wound to overcome the contamination through the use of antiseptics that do not interfere with the defense of the wound; by leaving the wound temporarily open. If this plan be carried out, the incidence of acute infections will be minimized, and the wound may be closed early by loose stitches or by adhesive plaster.

This is why excellent surgeons may quite disregard antiseptics — for the same reason that Lawson Tait required no antiseptics. It is because the work of Sinclair and Tait produces rifle wounds, while the rest of us produce shell-torn wounds. If it is a military necessity that a patient be rushed down the lines of communication, and if the attention of the surgeon is focussed away from the principles of surgery and only toward the antiseptic — to the degree that good surgery is out of the reach of both the patient and the surgeon, to that extent must antiseptics be depended upon; *e. g.*, when the wounded are being received in wholesale numbers; when isolated from surgical ways and means; when evacuation is urgent and continuous travel compelled; when inexperienced surgeons and internists must take the place of good surgeons; when the shelter of a cave must needs become a hospital — then antiseptics are a boon. Again, if a wound has become infected in the midst of good surgical opportunity, antiseptics *may* be required. If antiseptics are required, then the choice at present would lie among Carrel-Dakin, B. I. P.,[1] eusol, the recently proposed dichloramin-T and flavine.

If the opportunity exists, *i. e.*, if there is sufficient assistance, if the wounds are deep and extensive, Carrel-Dakin is probably the choice. If through the rush of large numbers of cases or through want of help, Carrel-Dakin cannot be *well* administered, then B. I. P. is indicated. B. I. P. is an excellent dressing for travel, as the wound requires no care for several days. If the wound be deep or superficial, if there is a rush, a good B. I. P. dressing is better than a *defective* Carrel-Dakin. Many wounds do well with eusol, and many cases travel well with a Wright

[1]B. I. P.—bismuth, 25 parts; iodoform, 50 parts; paraffin, 25 parts.

pack. The ideal antiseptic would be a form of energy such as the ultra-violet ray, Coolidge tube, or electrolysis, whereby the entire wound and the surrounding tissue could be sterilized at a single seance of short duration. Solar energy and electric-light energy are excellent antiseptics, but are not available for war surgery in the area of the advance. Conditions are variable — methods must be variable. Relative values may be summed up as follows: About 80 per cent of a good result is due to a good surgeon and good surgical opportunity; 10 per cent to chemical antiseptics, and the remaining 10 per cent to after-care.

B. STAGE OF INFECTION.— The treatment of the period of infection demands physiologic rest in the broadest sense; and in addition, if there is sufficient pain, redness and swelling to indicate the actual presence of an invading infection many and free incisions should be made into the area of infection — throughout the area of infection — until redness and the damaging tension disappear. The reason for the good effect of free incisions is that they remove an interference with the normal vital defense. In addition to free incisions, heat — preferably moist heat, physiologic rest of the man as well as of the wound, and elevation of the wounded member is indicated. Not only free but dependent drainage is always indicated. If, however, the Carrel-Dakin method is used then pool and do not drain. If the numbers of wounded make the Carrel-Dakin treatment impossible, and this is the rule during active warfare, then use B. I. P. Good surgery contributes about 80 per cent of the treatment. Of the remaining 20 per cent, about 10 per cent may be contributed by antiseptics; about 10 per cent by after-care.

During the period of acute infection, the following should be avoided — pain, lipoid solvent anesthetics, rough handling. Rough handling of infected compound fractures under ether or chloroform anesthesia not only spreads local infection, but promotes septicemia. If one were endeavoring to produce septicemia experimentally, one of the best methods would be to first "gas" the phagocyte with chloroform or ether; and then "bonejab" through the established line of defense.

The acute infection period is usually past in four days, leaving a granulating surface protected by a strong line of defense — the wound is now well "dug in." The wound that has cleared contamination before infection and the wound that has gone through the stage of acute infection next enter the stage of granulation and healing.

C. STAGE OF GRANULATION AND HEALING.— In the stage of healing we have to deal with:

(*a*) Contaminated wounds that have become relatively sterile and may be closed.

(*b*) Infected wounds that have become relatively sterile and may be closed.

(*c*) Wounds with too much loss of tissue; wounds too deep and too extensive for closure.

The closed wounds require no further discussion. The deep wounds, such as compound fractures, present one fundamental problem, viz., the prevention of the pocketing of pus. The pocketing of pus should be met by real dependent drainage; by correct suspension extension. The accumulation of pus is prevented by what Sir G. H. Makins has aptly termed "curtain drainage." Curtain drainage with simultaneous antiseptics under war conditions is at present best achieved by B. I. P. or the Carrel-Dakin method. Dichloramin-T holds out much promise.

D. SUPERFICIAL HEALING OF WOUNDS.— The ideal method by which to secure superficial healing is by immediately covering the surface by skin graft; otherwise, hot packs of eusol or normal saline, alternating with electric lights or sunlight give the best results. When superficial healing has been accomplished, the patient has been brought to the final stage — the stage of sinuses, of osteomyelitis, of deformities, of defects, of aneurysms, of nerve injuries, of scar contractures — none of which will be considered here.

E. SUMMARY OF POINTS GOVERNING THE RESTORATION AND REPAIR OF THE WOUND.— (*a*) *Recapitulation of Points Governing the Choice of Antiseptic Methods in the Period of Contamination.*— With adequate wound revision; physiologic rest for the wound and for the man; and good hospital care, what is the method of choice in:

1. Fresh, superficial open wounds.
2. Fresh deep wounds — such as compound fractures of the thigh.
3. In the midst of a deluge of patients during heavy engagements.
4. When there is a shortage of surgeons.

An open, fairly superficial wound without inaccessible areas does admirably with normal saline, Carrel-Dakin, B. I. P., eusol or electric light — perhaps best of all with the last named. A wound with deep injured areas will do well with Carrel-Dakin or B. I. P. In a great rush B. I. P. is indicated.

(*b*) *Recapitulation of Points Governing the Choice of Methods in the Period of Acute Infection.*— With free *incisions*, the best *posture* and *physiologic rest* what further treatment is indicated for:

1. Accessible areas.
2. Inaccessible areas.
3. In stress of work.
4. When nursing and professional staff are inadequate.

If conditions permit, the best single treatment undoubtedly is hot packs; in time of stress, B. I. P.; for deep wounds, dependent drainage; in quiet times, Carrel-Dakin. When the wounded come in waves, and surgeons and nurses are swamped, incision and B. I. P. give the best results to the greatest number per surgeon. But B. I. P.

must be spread on thinly, not applied in masses and the *wound should not be sutured* but should be lightly packed.

(*c*) *Recapitulation of Points Governing the Choice of Antiseptic Methods in the Stage of Healing.*— For accessible wounds the best treatment consists of sunlight or electric light, with eusol or Wright's hypertonic solution, and hot packs applied for an hour night and morning. In the absence of sunlight or electric light, however, use a protective dressing. In deep inaccessible areas — granting always dependent drainage and physiologic rest, use B. I. P., or instead of drainage, pooling with Carrel-Dakin. It must be remembered that owing to the lack of dependent drainage, if Carrel-Dakin goes wrong it goes badly wrong.

(*d*) *Recapitulation of Meaning of Physiologic Rest.*— Physiologic rest implies:

1. No irritating dressings.
2. Comfortable position.
3. No compressing bandages.
4. No painful handling.
5. Even and balanced muscular pull.
6. No accumulation of wound discharges.
7. Apparatus that will permit necessary moving about in bed without breaking physiologic rest.

CHAPTER IV

EXHAUSTION AND RESTORATION

INTRODUCTION — GENERAL CONSIDERATIONS RELATING TO THE TREATMENT OF EXHAUSTION IN THE FRONT AREA.— Our obligation to the wounded soldier is discharged only when every wounded man who is anatomically operable can be physiologically prepared for an early and safe operation. Thus only can the hazards of infection and hemorrhage be overcome. Not only this, but in rush periods the larger technic of restoration must not block the operating room, as this would be unfair to the *waiting wounded.* This may now be achieved fairly well by an adequate organization and certain restorative measures. These restorative measures may be carried out without blocking the operating room by establishing in rush periods a night and day *restoration team* which is charged with the preparation of the exhausted patient for operation, and with his care after operation. This restoration team would perform the work of infusion and transfusion in the restoration ward, and the patient would not be transferred to the operating room until he is safe for operation. In case of a progressive internal hemorrhage, only a partial restoration should be made, just enough to produce a sufficient rise in blood-pressure to assure a safe anesthesia. As soon as the abdomen has been opened and the bleeding points secured, then the transfusion of blood should be completed during the operation by the resuscitation team in collaboration with the operating team.

Thus by organization, by applying restorative and operative measures in proper sequence, and by team work, outstanding problems may be largely met. In other words, every patient anatomically operable should be rendered in the briefest time physiologically operable. We should recognize as inevitable only anatomical deaths.

A. BASIC PHENOMENA OF EXHAUSTION

1. Loss of muscular power.
2. Loss of mental power.
3. Diminished arterial blood-pressure.
4. Increased respiratory rate.
5. Cold and moist skin.
6. Pale or yellow tinted color.
7. Collapsed facies.
8. Cyanosed nails.
9. Increased H-ion concentration of the blood; diminished reserve alkalinity.
10. Cytologic changes in the brain, the liver, and the adrenals (Figs. 2 and 3).

These symptoms indicate the presence of an intra-cellular acidosis with interference with intracellular metabolism — especially oxidation.

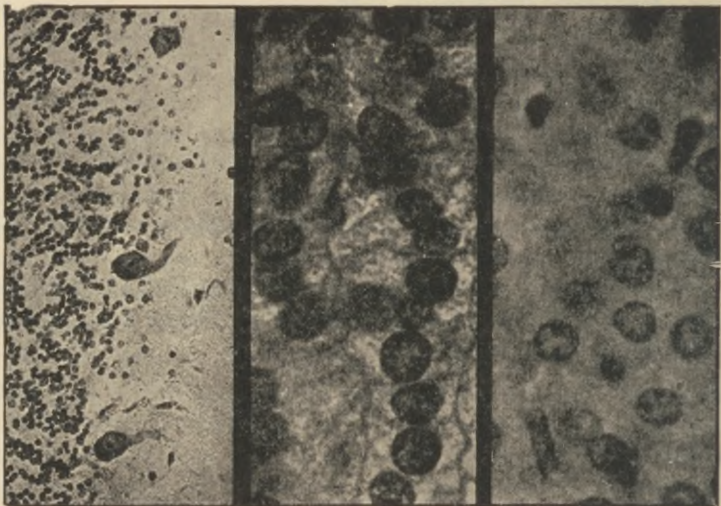
B. CAUSES OF EXHAUSTION

(*a*) *Clinically observed:*

1. Loss of sleep.
2. Hunger and thirst.
3. Cold and wet.
4. Worry and fear.
5. Physical exertion.
6. Injury.
7. Infection.
8. Hemorrhage.
9. Asphyxia, as in phosgene poisoning.
10. Inhalation anesthetics, especially ether and chloroform.
11. Trauma of operation.

(*b*) *Experimentally observed:*

1. Intravenous injection of acids.
2. Excessive alcohol.
3. Excessive drug stimulants, such as strychnin, adrenalin, iodin, iodoform.
4. Excision of the adrenals; excision of the liver.



A B C

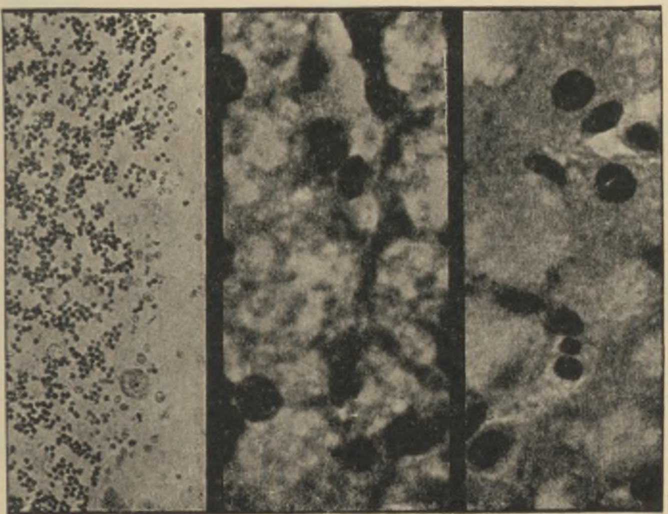
FIG. 2.—Normal cerebellum (*A*), adrena' (*B*), and liver (*C*). (From photomicrographs. Cerebellum × 310, liver and adrenals × 1640.)

Any one of the above-mentioned causes by itself alone may produce fatal exhaustion, but in war, exhaustion is rarely due to a single cause, rather to a combination of several causes; and it is conceivable that in a given case all of the causes in group (*a*) may play a part. Whatever the cause or the causes of exhaustion, the leading symptoms are identical and the principles of treatment are the same.

C. RESTORATION

Experimental research has shown:

1. That from six to eight hours after the application of the cause of the exhaustion, the cytologic lesions of the brain, the liver, and the adrenals, and the clinical phenomena are always associated.



A B C

FIG. 3.—Effects of extreme exhaustion on the brain, liver and adrenals. Section of the cerebellum (*A*), adrenal (*B*), and liver (*C*) of a soldier who died from the effects of *extreme exhaustion.* (Compare with Fig. 2, normal cerebellum (*A*), adrenal (*B*), and liver (*C*).

2. That whatever the cause of the exhaustion, the restoration of the cells takes place largely or wholly during sleep.

3. That rest alone, alkalies alone, hypertonic solutions alone, cannot restore the normal.

4. That whatever the cause of exhaustion and the re-

sultant cytologic lesions, sleep is the final restorer. The fact that sleep is a negative state gives a cue to the treatment.

The indicated treatment then consists in:

I. *Combating existing causes of exhaustion.*

II. *Establishing a state of negativity, through natural sleep, and through agencies that accomplish in part what is accomplished by sleep.*

I. COMBATING EXISTING CAUSES OF EXHAUSTION.—

1. *Acute anemia from low blood-pressure.* The outstanding damaging factor in exhaustion is the low blood-pressure. Therefore, whether or not there has been hemorrhage, if the exhaustion is so profound that life is threatened, the transfusion of blood is indicated. The principles and the technic of transfusion will be taken up later. Excepting in chest and in head cases, the foot of the bed of an exhausted patient should be elevated.

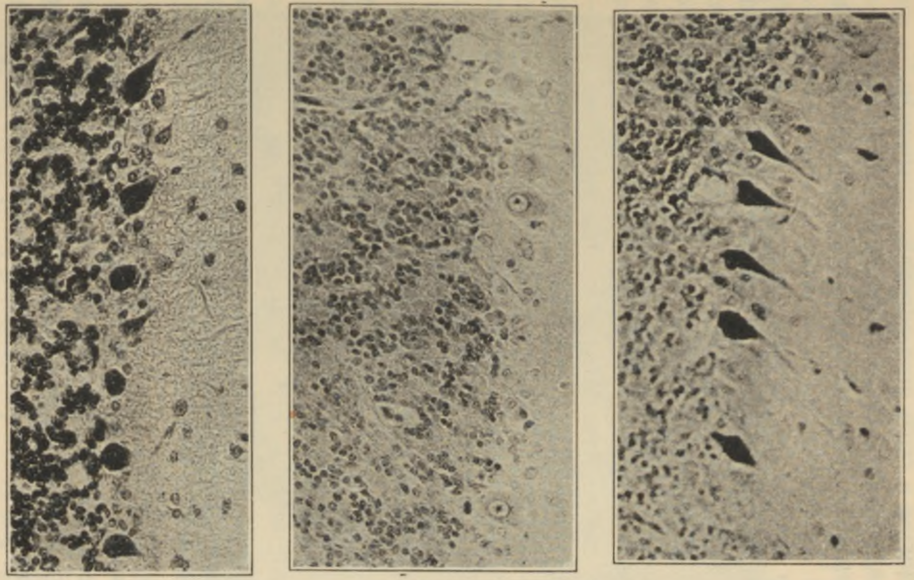
2. *Cold.*— Most exhausted patients are cold and clammy. Cold and clammy patients should obviously be warmed by (*a*) blankets; (*b*) hot air; (*c*) electric-light bath. The last-named treatment is preferred.

3. *Pain.*— Relieve pain by attending to the position of injured parts; by adjusting splints and bandages; by securing comfortable positions of limbs and body; if these methods do not afford relief, and *cyanosis is not present*, give morphin.

4. *Psychic Drive.*— Overcome worry and anxiety by reassurance and attention.

5. *Hunger and Thirst.*— Give hot drinks and if it is not contra-indicated give hot liquid food such as cocoa. A teaspoonful of whisky in a pint of saline or of glucose and soda bicarbonate solution may be given per rectum, although nourishment and fluid per rectum, though highly desirable, are in most cases impracticable in military surgery.

6. *Acidosis.*— Give oxygen; secure a good exchange of



A *B* *C*

FIG. 4.—Restorative effects of sleep on brain cells of rabbit in presence of acidosis. (From photomicrographs. × 310.) *A*, section of normal cerebellum of rabbit; *B*, section of cerebellum of rabbit after intravenous injection of an acid; compare with *A* and *C*; section of cerebellum of rabbit which had been allowed to sleep as desired for twenty-four hours after intravenous injection of an acid.

fresh air; push fluids; give intravenously a 5 per cent solution of sodium bicarbonate with 5 per cent glucose. In grave cases during a crisis give adrenalin cautiously.

II. ESTABLISHMENT OF THE STATE OF NEGATIVITY.— The most complete state of negativity, and therefore the most potent reparative agent is sleep — *deep, untroubled sleep.* Sleep should be broken only for some strongly urgent reason, certainly not to substitute a less potent aid, but only to avoid a danger, such as operation to prevent gas gangrene, or to secure bleeding vessels. Comfort and quiet and assurance are lesser, but strongly beneficial states, principally because they lead to sleep. The value of sleep is attested by its insistence in the intense phases of war — soldiers sleep in trenches; in mud; on stones; in rain; under bombardment; on horseback; on the march; in shell holes; on No Man's Land. They sleep with compound fractures or abdominal perforations; they sleep despite pain and hunger and thirst; sleep though they may be captured; sleep on stretchers awaiting operation. In the hospital, oblivious of time, without wants, and unconditionally somnolent, the sleep-wearied soldier presents the collapsed facies that characterizes exhaustion from other causes; when at last in a comfortable bed, he often sleeps for two days. When the heavy desire for sleep has been satisfied, the soldier has wants, appreciates pain, experiences hunger and thirst; the shrunken face is filled; exhaustion is relieved; normal life is restored.

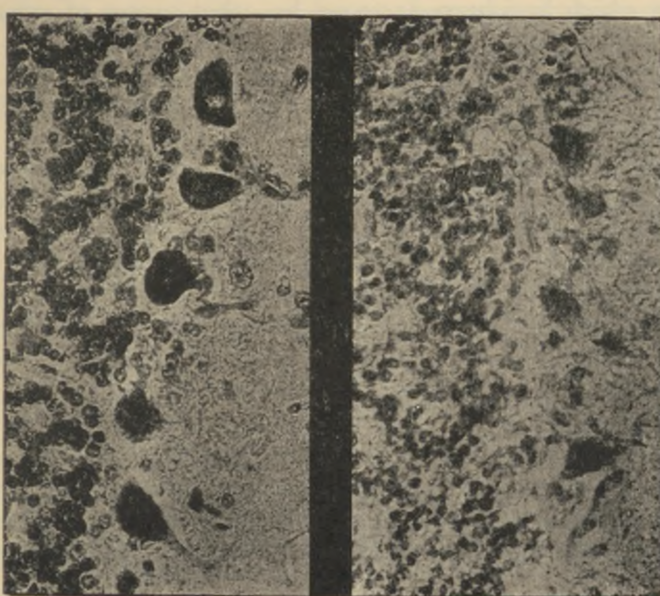
What damage is done by prolonged consciousness unbroken by sleep, and what repair is effected by sleep is seen by the following summary of a research in my laboratory to establish these points:

1. Animals become exhausted and inevitably die if kept awake continuously for from five to eight days.

2. Histologic studies of every organ and tissue of the body show constant intracellular changes in only the

brain, the liver and the adrenals. These changes are identical with the histologic changes seen in exhaustion from other causes (see Fig. 3).

3. The cellular changes in these organs are restored to the normal during one period of sleep, excepting those brain



A *B*

FIG. 5.—*A*, section of normal cerebellum of a dog; *B*, section of cerebellum of an infected dog

cells whose nuclear membrane and cell membrane have ruptured — these brain cells are not restored, but die, and are never replaced; brain cells damaged to a degree just short of dissolution recover slowly; the remainder recover in one seance of sleep (Fig. 4).

4. Substitutes for sleep.

(*a*) Nitrous oxid-oxygen anesthesia is a partial substitute for sleep. Given one hour in six in an experiment continued for one hundred hours, it partially protected the brain from cytologic changes, but did not accomplish as much for the liver and the adrenals. In other experiments, nitrous oxid-oxygen, like sleep, partially restored the brain cells, which had been damaged by other causes of exhaustion (Figs. 5 and 6).

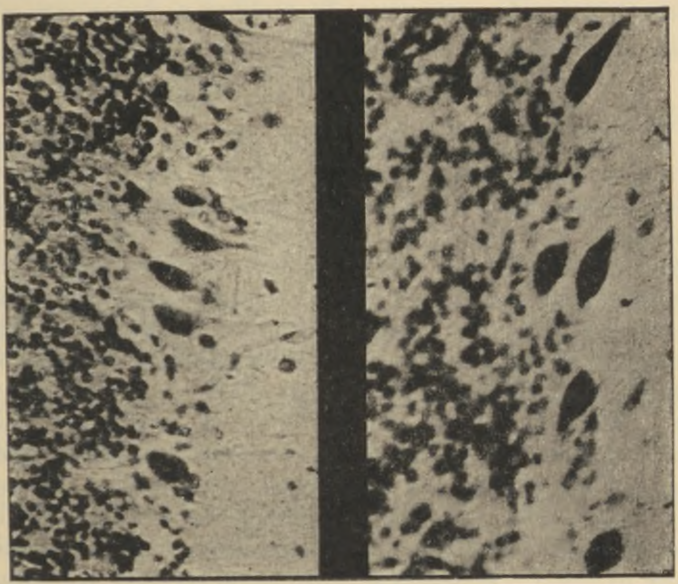
(*b*) Opium and its derivatives are partial substitutes for sleep, its protective effect being extended to all organs (see Figs. 5 and 6).

(*c*) The protective effect of magnesium salts is the same as that of opium, especially upon the liver. In larger doses, magnesium salts produce a sleep resembling normal sleep. Magnesium in large doses is a cardiac depressant. Its practical value remains to be determined.

From these facts we conclude that two sets of factors enter into the result of the treatment of exhaustion — one set to be avoided, and the other to be employed.

Avoid.— Factors to be avoided in the treatment of exhaustion are excitement; worry; anxiety; pain; rough handling; wet; cold; stimulants, such as strychnin, camphor, mustard and alcohol; chloroform and ether anesthesia; rough operating; *avoid large doses of morphin in the stage of deep acidosis.*

Employ.— Factors to be employed in the treatment of exhaustion are comfort; solace; drink; food; warmth; elevation of the foot of the bed; hot drinks — tea, cocoa; opium compounds, *except in the stage of deep acidosis;* blood transfusion; feather-edge, quick, gentle operating under nitrous oxid-oxygen. If a beginning of restoration is not secured, and the patient grows worse, then, if the case is not of long standing and the color is not sallow, and the nails are not blue, give liberal injections of morphin followed by blood transfusion, and if indicated, operate immediately. If the patient has been long in deep exhaustion, and presents a yellow-tinted color and is in a deep mental stupor, indicating impending final cellular dissolution, then give an intravenous infusion of 500 c.c. of a 5 per cent solution of glucose in a hypertonic solution to which have been added



A *B*

FIG. 6.—*A*, section of cerebellum of an infected dog after the injection of morphin; *B*, section of cerebellum of an infected dog after the continuous administration of nitrous oxid-oxygen for four hours. Figs. 5 and 6 show protective effect of morphin and of nitrous oxid on the brain cells of dogs in the presence of infection. (From photomicrographs. × 310.) Compare the Purkinje cells in Fig 6, *A* and *B*, with the disintegrated hypochromatic cells in Fig 5, *B*.

ten drops of adrenalin, follow by blood transfusion; and if indicated, operate immediately under nitrous oxid-oxygen or local anesthesia, if possible — otherwise under short ether or spinal anesthesia; but whatever the anesthetic, the operation should be done *deftly* and *quickly*, and with a *minimum* of *blood loss*.

D. CHOICE OF ANESTHETIC

The choice of anesthetic lies among the lipoid solvents, ether and chloroform; nitrous oxid-oxygen; and spinal, regional or local anesthesia. In making a choice, we must know (*a*) what damage, if any, is caused by the anesthetic *per se;* and (*b*) what protection, if any, is offered by the anesthetic *per se*.

(*a*) ETHER AND CHLOROFORM.— In normal animals and normal men, as shown by experiments in my laboratory in collaboration with Dr. Menten, inhalation anesthetics — chloroform and ether more markedly than nitrous oxid — cause increased H-ion concentration of the blood — acidosis — during and roughly for about one hour after anesthesia. Protracted ether or chloroform anesthesia causes cytologic changes in the cells of the brain, the liver and the adrenals identical with those resulting from other causes of exhaustion. After from four to six hours of continuous ether anesthesia, many animals die; some never regain consciousness, but die within the first twenty-four hours. Nitrous oxid-oxygen does no injury to the brain but measurably protects against shock, and possesses some of the restorative power of sleep. Ether and chloroform actively contribute to shock and exhaustion. They should therefore be given evenly and lightly as by the excellent Shipway apparatus. Captain Gregory Marshall has shown that patients may apparently do well during ether anesthesia but do badly afterward; but that they do well both during and after nitrous oxid-oxygen anesthesia. From the patient's viewpoint, nitrous oxid-oxygen is the choice (Fig. 7).

(*b*) NITROUS OXID-OXYGEN ANESTHESIA.— Nitrous oxid-oxygen anesthesia is light and gives less muscular relaxation than ether or chloroform. *Special training in its administra-*

tion is absolutely required, for it is technically the most difficult of all anesthetics to administer safely, although its administration is facilitated by recent improvements in the apparatus. These disadvantages, however, are far outweighed by its advantages as compared with ether or chloroform. It is quick in its action; is pleasant to take;

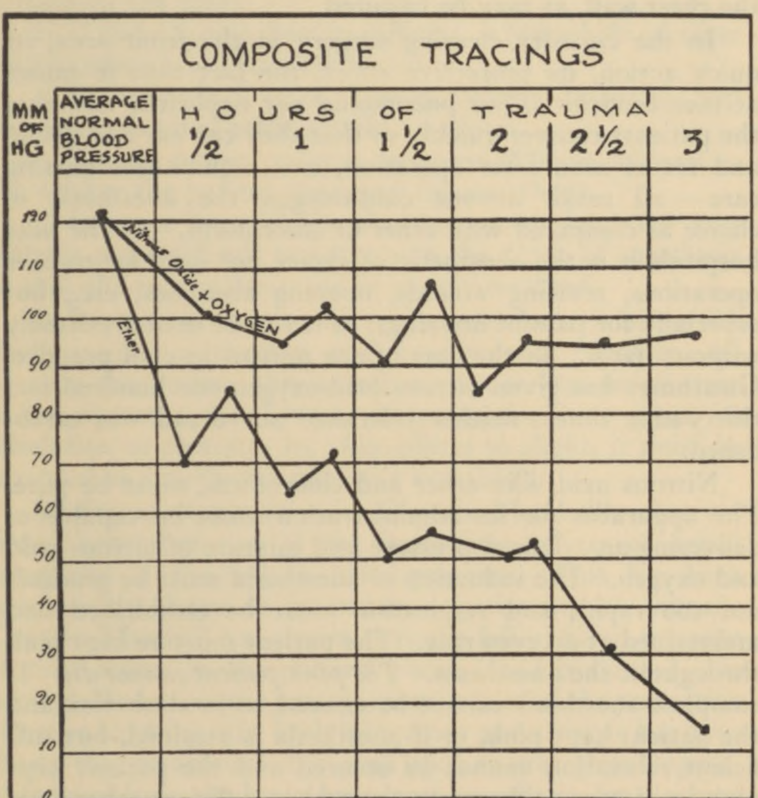


FIG. 7.—Chart compiled from laboratory experiments illustrating the protective effect of nitrous oxid-oxygen anesthesia in cases of shock, as evidenced by the maintenance of the blood-pressure.

recovery is immediate; it produces no nausea; it is protective — strongly protective against the shock of operation; for many minor operations it produces a pleasant analgesia in which pain is abolished while consciousness is retained; it can be given under positive pressure when desired, as in chest operations, maintaining the lung flabbily in the chest, against the chest wall, or protruding out of the opening in the chest wall, as may be required.

In the casualty clearing surgery at the front area, its quick action, its protective effect, the fact that it causes neither bronchitis, nor pneumonia nor nephritis, and that the patients recover quickly so that they can eat and drink, and travel soon after operation, and require less nursing care — all make nitrous oxid-oxygen the anesthetic of choice as compared with ether or chloroform. At the base hospitals it is the anesthetic of choice not only for routine operations, revising wounds, opening abscesses, etc., but especially for painful dressings, as it can be used repeatedly without harm. In the case of one patient in civil practice, Gwathmey has given nitrous oxid-oxygen one hundred and thirty-nine times; neither tolerance nor dread was established.

Nitrous oxid, like ether and chloroform, must be pure. The apparatus for its administration must be capable of delivering any desired pressure and mixture of nitrous oxid and oxygen. The induction of anesthesia must be gradual, not too rapid; and respiration must be established and maintained at an even rate. The patient must be kept pink throughout the anesthesia. *The pink patient cannot die.* If complete anesthesia cannot be secured, as in alcoholics, and the patient kept pink, or if anesthesia is attained, but sufficient relaxation cannot be secured and the patient kept pink by nitrous oxid-oxygen alone, then sufficient ether must be added. The safety of nitrous oxid-oxygen anesthesia is indicated by the fact that in my clinic at Lakeside Hospital, it has been administered by the chief anesthetist, Miss Hodgins, and her pupils over 22,000 times without an anesthetic death.

As for the technic of its administration, the following points may be noted:

1. In long operations, the fixation of the anesthetic mask with a towel fastened with forceps relieves the fatigue of holding the mask.

2. If induction is slow or difficult, a few whiffs of ether help to smooth out the respiration.

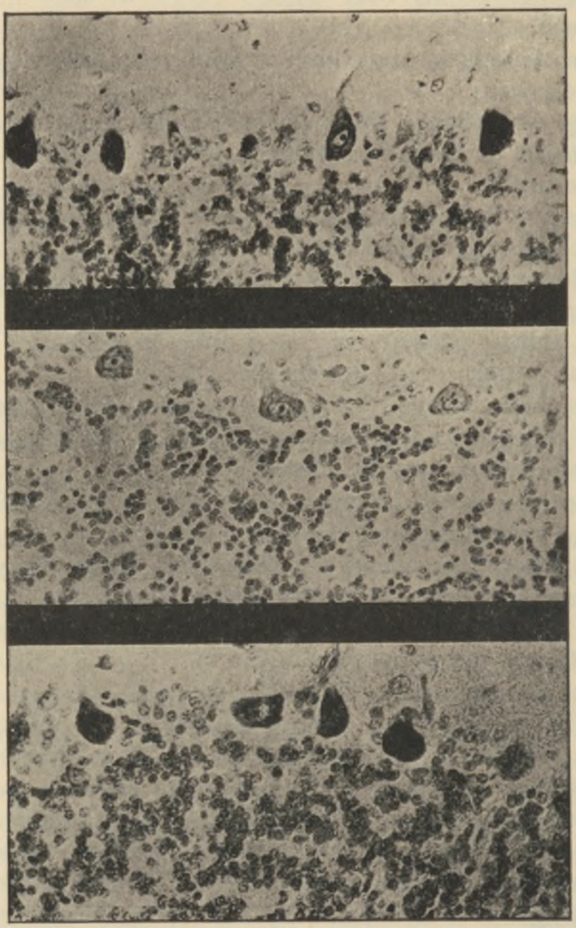
3. In abdominal cases local anesthesia is useful, and during exploration ether should be added.

4. Young, robust patients are most difficult subjects — the weaker the patient the easier the anesthesia.

5. In acute hemorrhage, the absence of pink color may make it more difficult to appreciate the depth of anesthesia so that the respiration must be closely watched.

6. Because nitrous oxid-oxygen anesthesia is more difficult to give, costs more, and requires more expensive apparatus than ether, this anesthetic seems less satisfactory to the operator; but because its protection is so great, its inhalation so pleasant, its after-effects so slight, it must be regarded as strictly the patient's anesthetic.

(*c*) SPINAL ANESTHESIA.— Captain Marshall's observations show that one of the immediate effects of spinal anesthesia is the fall in blood-pressure. This has been conclusively shown in laboratory experiments on animals. Captain Marshall has shown that the fall in blood-pressure is most severe in the patient whose blood is dilute — his hemoglobin low — the patient most in need of the protection of nerve blocking. In both laboratory and clinic it has been shown that no amount of trauma upon an area physiologically severed from the brain by a local anesthetic, by blocking the spinal cord or the nerve trunks, or by local infiltration can cause shock (Fig. 8). In this manner, as far at least as



A *B* *C*

FIG. 8.—Comparison between the effects of surgical trauma on a normal dog and on a dog whose cord had been severed. (From photomicrographs. × 310.) *A*, section of normal cerebellum of a dog; *B*, section of cerebellum of dog which had received severe surgical trauma; *C*, section of cerebellum of a dog which had received severe surgical trauma after the spinal cord had been severed.

trauma is concerned, a shockless operation may be performed, but the sights and the sounds of the operating room; the patient's knowledge that his flesh is being divided by a knife; that his bloodvessels are being divided and tied; the sound of the saw that severs his bones; all these contribute to psychic shock. Moreover, in a rush period the delay of spinal anesthesia does injustice to patients waiting for operation when anaërobic contamination so promptly becomes gas gangrene. Spinal anesthesia is therefore of value in all but rush periods, provided that the consequent great fall in blood-pressure may be prevented and that the psychic factor may be eliminated. As has been shown in the laboratory and confirmed in the clinic, the transfusion of blood stabilizes the circulation to the following extent: in animals that are over-transfused so that the blood-pressure rises higher than the normal blood-pressure, the elasticity in the bloodvessels provides a substitute for the peripheral resistance produced by the action of the vasomotor center and in consequence the blood-pressure is independent of the nervous system and behaves as if it were controlled by a system of rubber tubes. After over-transfusion, therefore, spinal anesthesia, the destruction of the medulla and the cord, or even decapitation, causes no fall in the blood-pressure, because the entire vascular system is not only filled, but elastically distended with blood. This over-distention lasts for one or two days. Therefore in a case of profound exhaustion, if an ordinary transfusion of blood be given first, then spinal anesthesia may cause no serious fall in blood-pressure. The other damaging factor, the psychic factor, may be largely overcome by morphin, but still better by nitrous oxid analgesia, by very light nitrous oxid-oxygen anesthesia, or by light partial ether anesthesia — just enough anesthesia to cut out psychic appreciation of the operating room and the operation itself. Equally shockless operations may be performed under regional anesthesia, by blocking the nerve trunks, or, if time permits, by local infiltration.

E. TRANSFUSION OF BLOOD

The special points of interest and importance in relation to the transfusion of blood are:

1. The technic of transfusion.
2. The fate of transfused blood.
3. Blood reactions.
4. The physiologic effect of transfusion.
5. Dangers of transfusion.

1. THE TECHNIC OF TRANSFUSION.— *Methods.*— (*a*) *Direct.*— The safest but the most difficult method of transfusion is by vessel-to-vessel — artery-to-vein, or vein-to-vein — anastomosis.

(*b*) *Indirect.*— There are now excellent indirect methods of transfusion, such as the collection of blood from the donor directly from the vein into paraffined glass receptacles, from which it is introduced into a vein of the recipient. Good models of these receptacles are the Vincent, the French, the Kimpton-Brown, and the adaptation of Colonel Cabot and Captain Dennis W. Crile. Through the aid of the staff of a Casualty Clearing Station and the utilization of the good points of other apparatus a very useful tube has been evolved. This tube, which is known as No. 17, has a capacity of 450 c.c. and is made by Gentile, Paris. The syringe methods of transfusion are also quick and useful, *e. g.*, the Lindeman and the Unger. Anastomosis and the citrate methods are also useful — the simplest of all being the citrate method. Whatever method is employed, the two special dangers to be avoided are (*a*) clotting, and (*b*) fragmentation of the red corpuscles. Clotting is prevented (*a*) by keeping intact the intima of the bloodvessels in contact with the blood stream; (*b*) by washing away all thromboplastin in the tissue wound and the bloodvessel wound with saline or citrate solution; (*c*) by carefully paraffining the receptacles and tubes employed.

2. The Fate of Transfused Blood.— The whole blood of a normal animal transferred to another animal of the same species functions normally, excepting in rare instances of reaction.

3. Blood Reactions.— The transferred blood of normal individuals of the same species may cause reactions — occasionally serious reactions. This can be obviated by agglutination tests. If this has not been done and at the beginning of a transfusion there is precordial pain, restlessness, respiratory distress, urticaria, flushed face, sweating, it would be well to stop the transfusion. If the condition is urgent, then in the face of these symptoms, a large dose of morphin is given and the transfusion cautiously continued. If time permits, however, the compatibility of the blood of the donor and recipient should always be established by the method of Brehm, as reported in the Johns Hopkins Bulletin. This is especially required at the Base Hospital. Prolonged infection causes changes in the blood — changes dangerous for transfusion — in some patients. Such changes are infrequent in Casualty Clearing Stations. In rush periods no test need be made.

4. Physiologic Effect of Transfusion.— In normal as in exhausted animals, transfusion causes a rise in the blood-pressure even to double the normal, the increased pressure being wholly or in part sustained for at least two days. At the high level thus mechanically established the nervous system exerts no control. As we have already stated in another section of this chapter, after over-transfusion the spinal cord may be anesthetized or destroyed, the medulla divided, or the animal beheaded without causing any change in the blood-pressure. This fact suggests the question: Can an animal be killed by traumatic shock in the presence of a high blood-pressure stabilized by over-trans-

fusion? It can be killed, but the amount of trauma required is greatly in excess of that required to kill a normal animal not so transfused.

5. DANGERS OF TRANSFUSION.— The one outstanding danger of transfusion is an acute dilatation of the heart. Minor dangers are serum reaction, hemolysis and embolism. If there is time, all these are readily avoided. When the blood-pressure has been low for some time as a result of hemorrhage or shock, the myocardium, like other tissue, is impaired and weak. If blood is transfused rapidly, acute dilatation and immediate death may follow. In this connection it is recalled that when the volume of blood in the heart is increased, the work of the heart is augmented in geometric ratio, *i. e.*, if the volume of blood in the heart is trebled, the work of the heart is increased nine times. The symptoms of acute dilatation may be most misleading. The pulse becomes more feeble, the respiratory distress increases, and in the urgency of the moment these phenomena may be interpreted as due to a failing circulation from want of blood — failure just as help is coming. If acute cardiac dilatation should be mistaken for a failing circulation, then disaster is quite sure to follow, for the patient's head will be lowered still more, the infusion of blood accelerated and death from acute dilatation assured. Whereas, if acute dilatation is promptly recognized, then relief is easily secured:— the patient is propped upright; pressure is rhythmically exerted with open hands upon the chest, thus emptying the overdistended heart; the patient is then laid down and by rhythmic pressure upon the chest the heart is assisted to do its work. Just as soon as a rising pulse is secured, it is well to pause, since the renewed and stronger circulation of blood in the coronary artery will rapidly restore the power of the myocardium. As an aid in this crisis — which is rare — an intravenous injection of digitalone is extremely useful.

How can the correct differentiation be made between acute dilatation of the heart and further collapse from anemia? By percussing the right heart. Before transfusion is begun the margin of the right heart should be outlined by percussion, and in the first period until the pulse comes up, the position of the right heart should be noted. In this way the status of the heart may be established with certainty. In doubt one should pause, and without changing the position of the patient, make rhythmic compression over the heart — should there be no dilatation, no harm will be done; if dilatation exists, benefit will result.

The behavior of the heart in these conditions has been experimentally studied with the chest open to direct inspection, while the carotid blood-pressure tracings were recorded on a drum.

How does blood transfusion minimize shock? By overcoming anemia — and perhaps by the presence in the blood of fresh buffer substance which tends to counteract the acidosis factor.

F. INTRAVENOUS INFUSIONS AND MEDICATION

1. Digitalone.—Digitalone or digitalin intravenously is a quick and lasting myocardial stimulant.

2. Adrenalin.— Adrenalin is the most potent of all stimulants to the circulation; it actively stimulates the heart and the bloodvessels and the respiration. On the other hand, the large and sudden volume of blood thus thrown into the heart may cause acute dilatation despite the stimulation of the heart muscle by the adrenalin. Adrenalin may defeat itself.

Experiments have shown conclusively that either too much or too little adrenalin causes exhaustion, in the one case by excessive oxidation, in the other by absence of oxidation. In the normal state, there is continued well-balanced inflow of adrenalin; and it is known that the output of adrenalin is increased by worry, anxiety, exertion, injury, pain, and hemorrhage. It might be concluded, therefore, that the organism of the soldier exhausted by any or all of these factors is in need of adrenalin. With this in mind, adrenalin in small doses has been given to resuscitation cases for the purpose of increasing intracellular oxidation. Its value is not with certainty established.

3. THE ADVANTAGES AND THE LIMITATIONS OF ISOTONIC AND HYPERTONIC INTRAVENOUS SALINE INFUSIONS.— (*a*) *Normal Saline*.— Intravenous or subcutaneous saline infusions are useful in cases of exhaustion of moderate severity. Their limitation is seen in the action of intravenous infusion, for if normal saline infusion be given to an animal at a slow or at a rapid rate in an indefinite amount until death — two outstanding facts are noted:

(1) The normal blood-pressure is not raised.

(2) The animal dies by asphyxia which is due to a mechanical fixation of the abdominal muscles, the lower ribs and the diaphragm. This fixation is due to a vast accumulation of saline solution in the walls and the lumina of the stomach and the intestine; *i. e.*, water runs out of the circulation through the areas through which water is normally absorbed and as rapidly as it enters. The blood cannot be more than momentarily diluted by normal saline. The value of normal saline, therefore, is hopelessly limited. Water is of great value — of most value when given by mouth.

(*b*) *Hypertonic Solution of Sodium Bicarbonate or of Sodium Carbonate*.— If intracellular acidosis exists in exhaustion, then will sodium bicarbonate or sodium carbonate overcome the acidosis? Attempts to find the answer to this question, both in the laboratory and in the clinic have yielded the following results:

In exhaustion sodium carbonate or sodium bicarbonate is more potent than normal saline, the blood-pressure picks up better and is better sustained, and the exhaustion is more relieved than by normal saline, but it accomplishes far less than blood transfusion. Even in straight hydrochloric acid intracellular acidosis, hypertonic sodium salts cause only a temporary change in the intracellular lesion — it is only during sleep that the intracellular lesion is overcome. Hypertonic sodium carbonate given prior to or during shock-producing trauma delays, but does not prevent the production of shock.

(*c*) *Magnesium Salts.*— In the laboratory it has been found that to a limited extent the intravenous administration of magnesium salts is apparently a strong agent in promoting intracellular restoration. Intravenous infusions of magnesium salts lower the respiratory rate, and induce a state resembling sleep. This magnesium "sleep" lasts approximately two hours. The good effects of the infusion are well sustained. Not only are the clinical results apparently good, but a study of the effect upon the cytologic changes in the liver cells in exhaustion show a diminution of the edema, not as marked but similar to that resulting from normal sleep. It is possible, therefore, that in the magnesium salts we have an agency that partially exerts the effect of sleep in aiding cellular repair; but the magnesium salts alone, in good dosage, are cardiac depressants. Their use is under observation, their value not established.

G. MORPHIN

Morphin has possibilities for good and for evil which are not yet fully appreciated. Laboratory researches have confirmed what clinicians have experienced, viz., that morphin diminishes shock, protects against the pyogenic infections, prolongs life in precarious situations — such as deep hemorrhage, shock, infection; that under morphin, patients require less food and the temperature and pulse in infections are materially controlled; that under such circumstances the morphin habit is not formed. Clinical experience shows further that morphin *does harm when patients are cyanosed.* Researches have shown that when large doses of morphin are given to animals under deep anesthesia, or in acute cyanosed exhaustion from intense exertion, they are deprived of the power to overcome their cyanosis, *i. e.*, their acute acidosis. Therefore cyanosed patients should never have morphin. *During the acute cyanosed stage of shock — no morphin.*

While morphin never causes a habit when given in these extremely critical states, it easily establishes a habit when given in cases of psychic distress, in worry, insomnia, etc. There is opportunity for wide discrimination in its use — in one case, none should be given; in another case, light doses may be beneficial; in other cases massive doses are most useful. When the way is clear so that massive doses of morphin may be given safely — it is a most potent agent.

H. RECAPITULATION OF THE TREATMENT OF SHOCK

1. Physiologic rest.
2. Warmth.
3. Fluids.
   (*a*) Water.
   (*b*) Sodium bicarbonate and glucose.
4. Elevation of the foot of bed.
5. *In absence of cyanosis*, large doses of morphin.
6. Transfusion of blood.
7. Nitrous oxid-oxygen anesthesia combined when possible, with local or regional anesthesia.
8. Quick, deft, light operation.

I. PHOSGENE POISONING IN RELATION TO ANESTHETICS AND OPERATIONS

Phosgene poisons by reason of its interference with the passage of oxygen through the walls of the air vesicles, thus producing *anoxyemia*. These cases of phosgene poisoning, as is indicated by rapid respiration, increased pulse-rate, cyanosis, loss of mental and muscular power, sweating, etc., are in a state of acute acidosis — the same end-effect as is produced by anesthesia, exertion, fever, emotion, shock and exhaustion, etc. Therefore, since inhalation anesthetics themselves cause acidosis, their administration adds one acidosis to another — the acidosis of anesthesia intensifies the acidosis of phosgene asphyxia. Surgical shock also produces a state of acidosis. The acidosis of the surgical shock of operation, therefore, if added to the acidosis of the phosgene and the acidosis of the anesthetic combined may finish the patient.

When operation is required in a case of phosgene poisoning, it should if possible be performed under local, or regional, or spinal anesthesia; the patient meanwhile being kept pink by oxygen under pressure with the positive pressure mask of a nitrous oxid apparatus or a Haldane apparatus. If there is a phase of operation that cannot be controlled by local or regional or spinal anesthesia, then one should give oxygen under pressure for a time, causing a pink color, then switch to nitrous oxid for the briefest time required for the operative move, then switch back again to oxygen under pressure.

CHAPTER V

PATHOLOGICAL PHYSIOLOGY OF EXHAUSTION

I. VARIOUS CONCEPTIONS AS TO THE CAUSE OF EXHAUSTION

1. It has been supposed that exhaustion (shock) is due to a physiologic breakdown of the vasomotor mechanism. This conception is inadequate, because death from trauma can be produced in animals whose blood-pressure is maintained by blood transfusion at or above the normal level up to the time of death. After exhaustion reaches a certain state, the restoration of a normal blood-pressure by blood transfusion may not prevent death. Therefore, low blood-pressure is an end-effect of other causes.

2. The conception that exhaustion is the result of a bodywide inhibition of function fails to harmonize with the known facts. If this were true, then narcotics and anesthetics, local and general, would be expected to overcome inhibition. This does not follow, and one cannot conceive cytologic lesions to be produced by inhibition. There is no analogy that suggests that men and animals suffer death through universal inhibition.

3. Myocardial exhaustion has been suggested as the cause of shock — but in animals in shock the blood-pressure has been raised to the normal by transfusion of blood and the heart has performed its work normally. Therefore, the myocardium is not at fault. It is true that the myocardial tissue, like other tissue, is damaged by anemia in shock, but this damage is an end effect, not a cause.

4. Another theory is that shock is the result of acapnia — diminished CO_2 tension from excessive respiration. If this theory were true, then the prevention and the cure of shock would be accomplished by supplying CO_2 to the

blood. In neither the laboratory nor the clinic has this result been realized.

5. Because emotion, pain, exertion, are attended by increased output of adrenalin, it has been suggested that exhaustion of the adrenals might be the cause of shock — but the continuous intravenous administration of adrenalin does not cure exhaustion. If the increased output of adrenalin exists constantly, it is only coincident, or at most, a partial rather than an entire cause.

6. Because of the failing circulation; because of the dilatation of the large venous trunks, because only a relatively small part of the blood plasma has left the blood vessels — as indicated by the degree of concentration of the blood — therefore, it has been thought that the cause of shock might be the accumulation of the blood in the venous trunks. This has been proved to be a secondary, not a primary cause of shock, because (*a*) such an accumulation of blood occurs in death from any other cause; and (*b*) death from exhaustion (shock) may occur after blood transfusion has supplied enough blood to entirely overcome the effect of the accumulation of blood in the splanchnic and other vessels. This conception again apparently gives causal values to end-effects.

7. Acute blood acidosis and diminished reserve alkalinity have been proposed as a cause of shock. This proposal needs to be examined more closely. Were the cause of exhaustion limited to changes in the blood, and those changes were those of acidosis, then alkalinization of the blood would be expected to cure; but alkalinization of the blood does not cure exhaustion, either in the clinic or in the laboratory.

(*a*) Positive Laboratory Findings.— In my laboratory in experiments conducted in 1912, 1913 and 1914, in collaboration with Dr. M. L. Menten, who had worked a year with Prof. Michaelis and used his apparatus and gas chain method, we found that the H-ion concentration (or acidosis) of the blood was increased:

1. During inhalation anesthesia.
2. During intense fear in rabbits.
3. During intense rage in cats.
4. During intense exertion in various animals.
5. In surgical shock.
6. In alcoholic intoxication.
7. In hemorrhage.
8. In asphyxia.
9. Several hours after excision of the liver.
10. Near the death-point after excision of the adrenals.
11. Near the point of dissolution, whatever the cause of death.

In brief, we found increased H-ion concentration in overwhelming excessive energy-transforming activities. Apparently, the corrective mechanism could not dispose of the increased acid by-products as fast as they were produced. We found increased H-ion concentration, also, as a result of *interference* with the corrective mechanism, as in hemorrhage, asphyxia, anesthesia and after excision of the liver and the adrenals.

(*b*) NEGATIVE LABORATORY FINDINGS.— We found further, that H-ion concentration was not increased in:

1. Narcosis — by opium and its derivatives.
2. During sleep.
3. During protracted consciousness unbroken by sleep, until near the death-point.
4. After decapitation in animals which were over-transfused, artificial respiration being maintained.
5. In serious, even fatal diseases, such as infection, exophthalmic goiter, cardiovascular disease, typhoid fever, iodoform poisoning.

II. ACIDOSIS

1. Morphin in Relation to Increased H-ion Concentration.— *Acute Acidosis.*— We found that if morphin in large doses was given during increased H-ion concentration of the blood (acute acidosis), such as is present in intense rage, intense muscular exertion, or under inhalation anesthesia, the correction of the state of acidosis was interfered with, even prevented. For example, a vigorous male cat, in which induced rage and struggle brought on a maıkedly increased H-ion concentration of the blood, was given heavy doses of morphin; the animal remained in acute acidosis for three and one-half hours and died in acidosis. In other experiments equally large doses of morphin interfered with the overcoming of the acidosis of inhalation anesthesia. The ill effects of morphin in certain types of cyanosed patients is well known to clinicians. *The soldier exhausted and cyanosed should therefore not have morphin. After cyanosis disappears* morphin is most useful. Disappointed in the value of observations on H-ion concentration we tested the value of observations on reserve alkalinity.

2. Reserve Alkalinity and Acid Excretion in the Urine.— When the Van Slyke method for determining the reserve alkalinity of the blood was published, it occurred to me that this at last would give a true indication of the reserve vitality of the patient. Through the collaboration of Dr. W. J. Crozier and Dr. W. B. Rogers, this method was investigated as to its availability in the clinic to determine the surgical risk. Crozier and Rogers in 1915, and until April, 1917, Rogers alone, made numerous observations on the reserve alkalinity of the blood (Van Slyke method) and in the laboratory and the clinic repeated the work of Prof. Lawrence Henderson on the acid excretion in the urine. This work may be summarized as follows: Laboratory animals in shock, under anesthesia, in infection, in as-

phyxia, in strychnin poisoning, in hemorrhage, in iodoform poisoning, in exertion, in emotion, showed varying degrees of reduction in reserve alkalinity, and alterations in the acid excretion in the urine. *The method played more true when an acute overwhelming drive with which the corrective mechanism could not keep pace was made, than in other instances.* When time for compensation had elapsed, the reserve alkalinity afforded less accurate information.

It was in the clinic that our best estimation of the value of reserve alkalinity and acid excretion determinations were obtained. Here, in acute infections; in late cancers; in desperate cases of exophthalmic goiter; in good and in bad risks of all kinds, we found great and unexpected irregularity in the results. In cases of impending death, not in the stage of dissolution, but inoperable, and in cases of infection with grave prognosis that died later, the reserve alkalinity sometimes was found to be as high as in the observer, and the quantity of acid excretion in the urine was not materially disturbed.

Therefore, after five years of observations in the laboratory and in the clinic on the various phases of acidosis, we have reached the reluctant conclusion that these methods, despite their scientific interest, as yet offer meager clinical value.

3. INTRACELLULAR ACIDOSIS.— During the past nine years, cytologic studies have been made in the laboratory and in the clinic on over 2500 animals and on many human autopsies by my associates, especially Dr. J. B. Austin and Dr. F. W. Hitchings. In these studies we found that the only constant criteria that could be consistently related to the clinical evidence of exhaustion, are the following:

(*a*) In all cases of exhaustion, whatever the cause, provided the animal lived from four to eight hours after an adequate degree of exhaustion had been established there were fairly constant cytologic changes in three vital organs

— the brain, the liver and the adrenals. No other changes were found to be as constant. Among these organs the changes in the liver and the brain were more marked than in the adrenals.

(*b*) Animals in which less than a fatal stage of exhaustion had been induced, showed cytologic changes in these organs in a less degree.

(*c*) In our research were included studies of exhaustion from electric stimuli, physical trauma (surgical shock), the emotions of fear and rage, muscular exertion, infection, hemorrhage, asphyxia, acute alcoholism, ether anesthesia, anaphylaxis; of exhaustion resulting from the injection of foreign proteins, of feces extract, of thyroid extract, of adrenalin, of iodoform, of strychnin, of chlorotone; of exhaustion from insomnia, eclampsia, acute acidosis; of the exhaustion of salmon at the headwaters of the Columbia River in the spawning season; of the exhaustion of electric fish and eels after electric discharge; of exhaustion in rats caused by prolonged swimming; of exhaustion produced by burns; by starvation; by excision of the liver, of the adrenals and of the thyroid; by the intravenous injection of acids, particularly of hydrochloric acid. Parallel observations were made on normal animals and on hibernating animals. These observations may be summarized as follows:

(*a*) The cytologic changes roughly parallel the clinical phenomena.

(*b*) In exhaustion produced by insomnia, by acid injections, by emotions, by exertion, by anesthesia, by asphyxia, etc., the cytologic lesions are repaired only during sleep. These results led us to institute a research on sleep and its substitutes.

(*c*) If intracellular oxidation be excessive, as in excessive muscular exertion, emotion, injury, infection — after the injection of iodoform, strychnin, thyroid extract, iodin, etc., then an excessive amount of acid by-products will be accumulated in the cell, and as Loeb, Clowes, and others have shown, when the *cell becomes acid it will accumulate water and swell and will take normal stain less well.* If the other conditions are normal, and there is lack of oxygen, as in asphyxia, in hemorrhage and after adrenalectomy, the physiologic balance will be disturbed, and similar swelling will occur. If an acid be injected, or an acid state be established, as by chlorotone, alcohol or anesthesia, the cells swell as before. Finally when sleep is abolished then repair cannot take place and the cells remain acid and death follows. Any one or all of the causes of exhaustion may produce the same end-effect — intracellular acidosis with a suspension of function according to the degree of exhaustion produced.

4. INTRACELLULAR PROBLEMS.— Since the balanced state of the cell is attained only during the normal supply of water and food, the rhythmic alteration of consciousness and sleep, and normal oxidation, it is obvious that the problem is not as simple as that of correcting the acidity of a fluid in a test-tube by putting in alkalies; but there must be supplied to the cell, not only the means of ridding itself of its excessive acids, but also the means whereby it can maintain a normally balanced oxidation. We must, therefore, get rid of the acid and establish the conditions required for continued oxidation within limits consistent with the life of the cell. The success of the restorative measures which we have described lend support to these conceptions of the fundamental condition present in exhaustion, but do not explain the ultimate cause.

III. COMPARISON OF LABORATORY WITH CLINICAL OBSERVATIONS

A. LABORATORY OBSERVATIONS.— As a result of our studies, I am at last forced to admit that no laboratory conclusion should be considered valid until it has been tested in the crucible of the clinic. For example, our laboratory studies of the H-ion concentration of the blood, the CO_2 tension, the reserve alkalinity, the acid excretion of the urine, furnished no criteria *always* reliable as an indication of the patient's condition.

Why should laboratory methods be less accurate than the clinical signs? Let us view this phase of the problem from a biologic stand-point:

1. *Alkalinity and Acidity in Relation to Animal Life.* The origin of life was probably in the sea; the sea is alkaline; animal life is continued only in an alkaline medium; when the blood becomes acid, life ends. As transformers of energy, animals are constantly producing acid by-products. The acid by-products are increased in proportion to the rate of energy transformation, *e. g.*, they are increased in muscular exertion, emotion, fever, etc. Therefore, the organism is in constant danger of killing itself; and many animals and men have killed themselves by the excessive production of acid by-products in great muscular struggles, which overcame the factors of safety, or the corrective mechanism,— namely, the lungs, the liver and the buffer substances — the reserve alkalies immediately available. It would be expected that during the vast selective struggle of animals, there would have developed wide factors of safety in these corrective mechanisms against the acute acidosis of muscular, emotional, and fever crises, not only wide margins of safety for immediate protection, but also large reserves of bases and alkalies in the fluids and tissues of the body, that are not available for a quick emergency, but are more gradually drawn out in the prolonged crises; prolonged struggles; prolonged defenses; prolonged want of food and water; prolonged exertion; prolonged fever, etc.

Our experiments on the H-ion concentration of the blood supported this biologic conception, because we were able to overcome the factor of safety only by an immense drive, by intense muscular struggle, by intense emotion; and on withdrawing the intensive drive, the normal H-ion concentration was quickly re-established, although the animal clinically was fatigued. Therefore, the H-ion concentration of the blood showed only the extent to which the corrective mechanism failed, and gave no information to what extent the reserves had been called out, nor how wide was the remaining margin of safety.

2. *The Reserve Alkalinity of the Blood.*— The estimation of the reserve alkalinity told us what the reserves in the blood were at that particular time. It gave no intimation as to the amount of reserves lying in store beyond the blood, in the body fluids, in the cells, in the bones. This was left to conjecture.

The information which these methods give is comparable to estimating the wealth of a man by holding him up in the street and counting the ready money in his pockets (H-ion concentration), and from this count, attempting to estimate his readily available cash reserve in the bank (reserve alkalinity in blood); or to estimating his ultimate financial resources by examining his bank account, without knowing what securities he held in his strong box (ultimate reserves). A man may be financially embarrassed if his immediate cash is exhausted; he is not bankrupt until his ultimate reserves are exhausted.

The scientific methods so far devised tell us what factors of safety are impaired in the blood at the moment the observations are made, but do not inform us of the extent of the reserves. Our present laboratory methods do not tell the whole truth as to the actual state of the patient.

B. CLINICAL OBSERVATIONS.— What of the clinical phenomena? Here we have a method of greater accuracy for estimating the reserves. The respiratory center is governed by the H-ion concentration of the blood; the respiratory center has been evolved to respond with infinite accuracy to acidosis. The respiratory center consists of nerve cells and fibers, and these cells, like other cells of the body, are modified by every passing phase of chemical change in the blood. In the respiratory center we have a mechanism of surpassing fineness and accuracy which not only reacts to intracellular acidosis, but has been evolved through eons to fulfill that purpose so correctly as to preserve life and health. But this delicate living mechanism is placed in the seat of life itself, while the man-made laboratory mechanisms are not only clumsy, but are outsiders.

This center responds to every phase of acidosis — the acidosis of asphyxia, of hemorrhage, of emotion, of exertion, of acid injections, of anesthetics, of injury, of starvation — the entire gamut; not only responds accurately, but its response is dramatically staged so that not only the trained professional eye, but the bystander, even the patient himself, cannot escape its obtrusive evidence.

The nerve cells of the respiratory center, however, are not the only nerve cells that are modified by acidosis; the cells that fabricate muscular and mental action are modified also; their power to do work is diminished. If their activity were increased to the same extent as the activity of the nerve cells in the respiratory center is increased, then the amount of muscular work done and the consequent amount of acid by-products would be increased, resulting in certain disaster; but the nerve cells that drive the muscles and express the emotions, are impaired. Hence, we have *increased* respiratory action and *diminished* muscular action — *a corrective antithesis.*

Why does the heart beat fast? The biologic interpretation would be that the circulatory mechanism was evolved so that the heart would beat fast in order that the blood might circulate more rapidly, and the more efficiently serve the cells of the body whose activity constitutes life. The low blood-pressure, on the other hand, indicates not an adaptation, but the failure of the circulatory mechanism, adding the resultant damaging anemia to the vicious circle of approaching disaster.

Why does the patient sweat? Sweating is not only a corrective mechanism for the elimination of the heat incident to the increased energy transformation of exertion, emotion, etc., but also a vehicle for the elimination of the acid by-products, assisting the overtaxed mechanism, the liver.

Why is there thirst? An adaptation to increase one of the most efficient means of correcting acidity, water.

Why is there pallor? Because the circulation is failing; blood is no longer sent in excessive amounts to the skin, as in the driving phase of excessive energy transformation in emotion, in exertion, etc.

Why are the nails blue? Because the circulation is failing, and the blood is not oxidized.

Why the collapsed facies? Because of the loss of power of the muscles of expression, as in sleep, in anesthesia, in death.

By granting the foregoing interpretation of exhaustion — what is the outstanding defect? With what mechanism has the intracellular acidosis interfered?

CHAPTER VI

SPLINTS AND APPARATUS

In this war there has come to pass a remarkable evolution in the treatment of fractures — methods and appliances and apparatus have been standardized as never before. Who would have believed that in the rush of war compound fractures of the femur would be repaired without shortening, with no appreciable deformity, and with relative freedom from pain and infection. Who would have expected that patients with compound fractures would be able to move themselves about in bed freely, to help themselves in nursing care, to keep up a good muscular tone and good morale. Such results are now common. There are many names associated with this progress among which those of Robert Jones, Blake and Sinclair are pre-eminent.

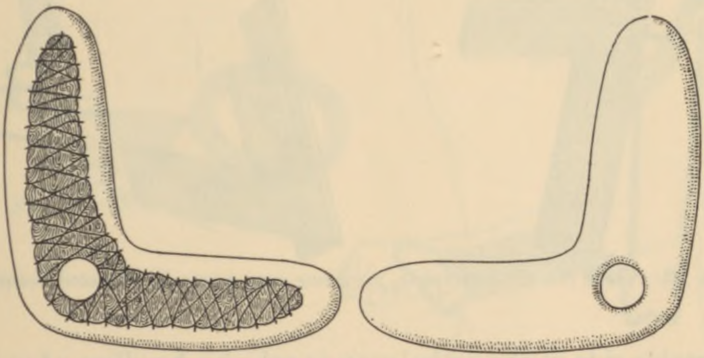


FIG. 9.—Angular splint for elbow. Wood covered with muslin.

(*a*) *The Thomas Splint.*— The Thomas splint alone can achieve better results than all previous splints combined. If to the Thomas splint the principle of suspension-extension, as elaborated by Blake or Sinclair, be added — by this alone extraordinary results can be achieved (Figs. 11 to 15). The Thomas splint is a versatile splint — an informal splint. It meets the patient as he is — in the field — anywhere. It can be applied in a few minutes without removing shoes or clothing. It gives the wearer a com-

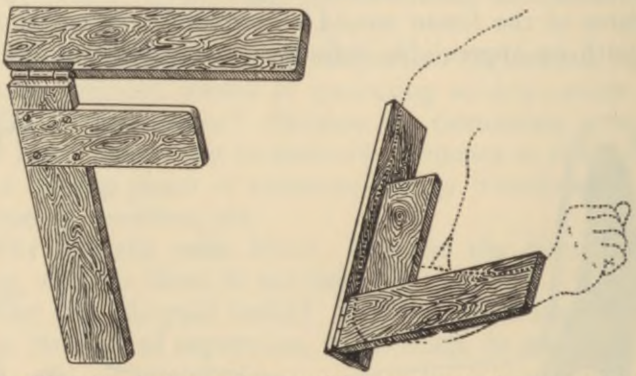


FIG. 10.—Clark No. 2 elbow splint, providing easy access for repeated dressing.

fortable ride in the ambulance; it robs his handling of most of its pain; it minimizes the shock of fracture transport. Its beneficence follows him when he is undressed at the Casualty Clearing Station and throughout his treatment there; it takes him comfortably to the train and to the Base Hospital where it serves its host well, even without any other aid; it smoothly rides aboard boat to the home stationary hospital; it is cheap and simple and cannot be worn out. The Thomas splint deserves to be canonized.

(*b*) *Suspension-extension* (Blake).— What does the suspension extension apparatus do? It abolishes the pressing splint, the compressing bandages; it liberates muscles from bondage; it gives opportunity for muscular exertion without breaking physiologic rest — without interfering with the position of fragments; it minimizes the boredom of fracture positions; it gives good opportunity for inspection and for the dressing of wounds; it permits such an adjustable dis-

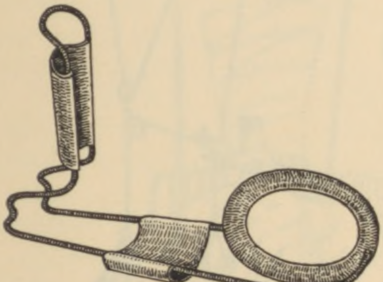


FIG. 11.—Thomas elbow splint.

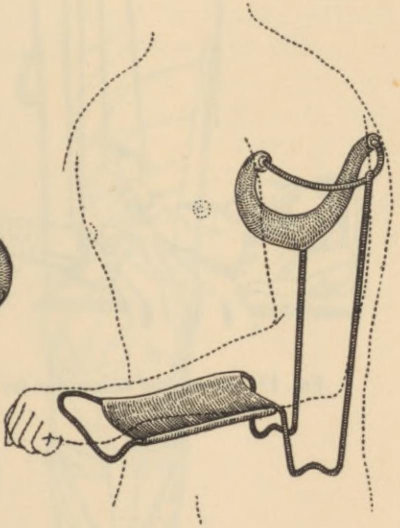


FIG. 12.—Modified Thomas elbow splint.

tribution of pressure on the bed that bed-sores do not occur, or if they are already present, they may be readily cured; it gives versatility and flexibility to meet many indications — it comes as a benediction to broken bones.

(*c*) *Splint and Apparatus Shop.*— A well organized splint, appliance, apparatus and special instrument factory

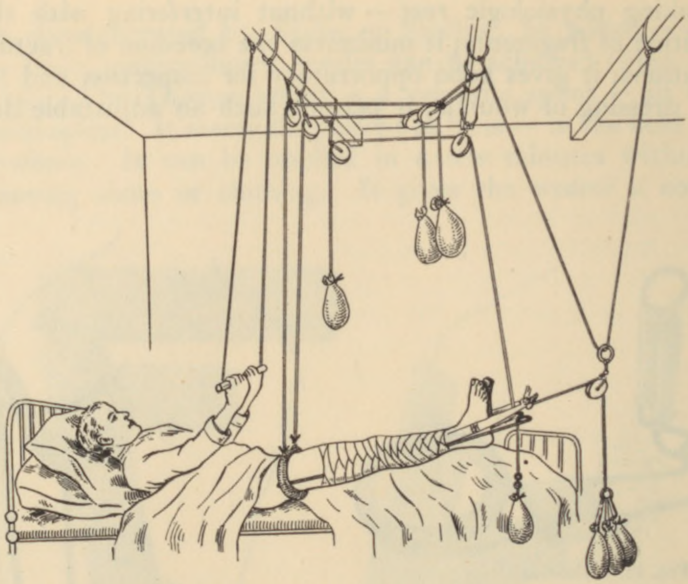


FIG. 13.—Improved suspension for Thomas splint with extension.

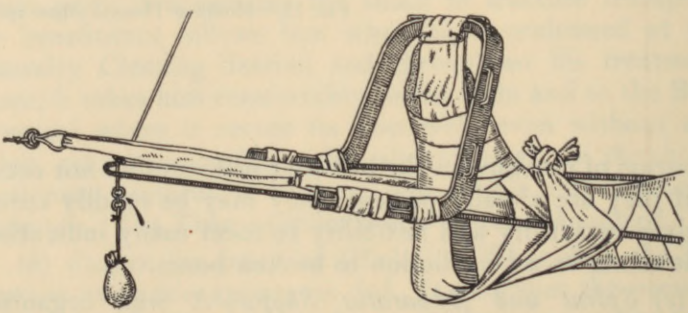


FIG. 14.—Detachable foot suspension on Thomas splint.

would be a boon to the surgical division. Sir George Makins speaks highly of the value of such a factory which for more than a year has been in operation in the British service. Were this shop near the training area, it would give a special opportunity for new surgeons to become familiar with the construction of splints and appliances.

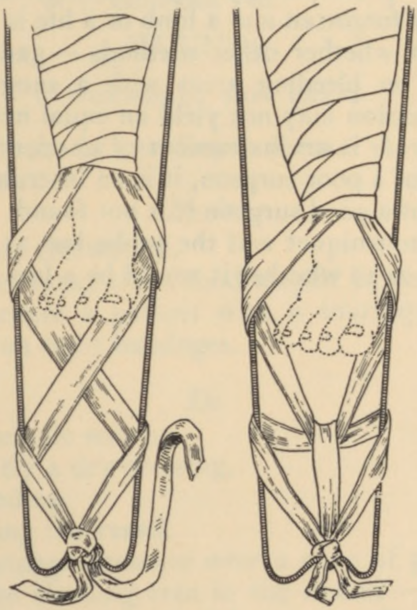


FIG. 15.—A method of keeping up the extension with the Thomas splint.

CHAPTER VII

THE TOURNIQUET AND PROBE

(*a*) The *tourniquet* is specifically mentioned to raise the question whether or not it should be discarded. The question of discard arises because in the rush of battle, despite every precaution, every warning, the tourniquet is occasionally forgotten and a limb or a life is lost. It is an open question whether other methods — gauze, or cotton pads pressed on bleeding areas with a snug bandage; or digital compression may not yield an equal net result.

(*b*) The *probe* is an instrument of unscientific curiosity. In the hands of a poor surgeon, it is an instrument of harm; in the hands of a good surgeon it is not found.

Were the tourniquet and the probe lost at sea, it would be a question as to whether it would be a loss or a gain.

PART II
Practical Points

CHAPTER VIII
WOUNDS

I. WOUNDS OF SOFT PARTS

A. In the Front Area

Don't

Don't suture the wound.
Don't try to make the wound aseptic by scrubbing.
Don't evacuate a patient with a tourniquet in place.
Don't put on tight bandages.

Do

Give antitetanic serum.
Apply lightly a dry dressing.
Arrest bleeding.
(*a*) By tying the vessel.
(*b*) By bandage pressure over a cone of gauze applied directly on the bleeding area in the wound — making sure that the circulation of the limb is not cut off.

B. At the Evacuation Hospital

Prepare the field with soap and water and shaving, then with alcohol. Excise the wound completely — as completely as if it were a cancer. Provided the wound can be kept under observation close it by using but one kind of suture — *lightly tied sutures* separated by wide spaces and including a wide margin of skin. Follow by a light dry dressing and physiologic rest.

II. HEAD WOUNDS

A. In the Front Area

Don't

Don't probe.
Don't give morphin.
Don't give stimulants.
Don't scrub the wound.
Don't shave the head.
Don't have curiosity about the foreign body.

Do

Put on a protective dressing.
Keep the patient in a sitting posture.
Evacuate promptly.

B. At the Evacuation Hospital

Make a careful *x*-ray and fluoroscopic examination.

Revise the scalp wound.

Augment the shattered point of skull penetration using the technic of Cushing; remove spicules of bone, fragments of clothing, hair and foreign bodies with absolute gentleness.

Close without drainage within the skull.

If the scalp defect prevents simple approximation then make a scalp plastic, sliding the scalp over the defect; always cover the brain.

Maintain the propped-up position.

III. PENETRATING WOUNDS OF THE CHEST

Shells, shrapnel, bullets may crash great holes through the chest, often tearing the lungs and carrying in fragments

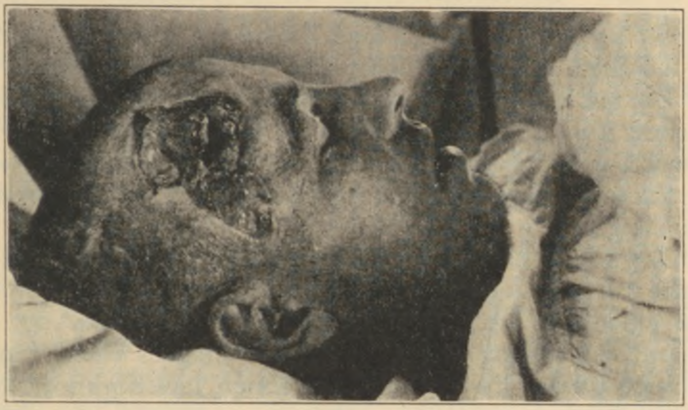


Fig. 16.—Head wound.

of clothing and metal; the lung may be torn; much hemorrhage may result and the patient is distressed, harassed, dyspnoeic. When left alone, or in other words treated expectantly chest cases do much better than one would formerly have supposed possible. In the hands of a good surgeon, on the other hand, as surprising results are secured as with surgery of the knee-joint or of the abdomen.

A. In the Front Area

If the patient is in distress and is not cyanosed, give morphin.

If the heart is penetrated or the great vascular trunks are divided death is usually prompt.

If there are bilateral openings in the chest causing a dragging exchange of air, suture them air tight. It is better to leave chest wounds wide open than to close them partially.

Place the patient in a propped up position for transport.

B. AT THE EVACUATION HOSPITAL

On arrival the chest case should be carefully studied by a skilled internist in consultation with the surgeon.

Do not aspirate except for diagnostic purposes, for if a chest full of blood is emptied by aspiration then the hemorrhage will usually be renewed and will refill the chest.

Except in urgent cases do not operate within twenty-four hours.

Operation.— Open the chest widely; pour out blood by slight turning; remove foreign body under guide of the eye aided by electric illumination; deftly clean up the pleural cavity and close without drainage. Good convalescence usually follows after infection has begun or even when it has pervaded the great mass of blood in the pleural cavity. The advent of infection may be diagnosed by microscopic examination of the blood smears twenty-

FIG. 17.—Shell wound in face.

four hours earlier than by clinical symptoms. But in the absence of the laboratory diagnosis, operation should be made on the inauguration of the earliest signs of infection. Always close without drainage — but if a second infection occurs establish drainage at once.

Penetrating wounds of the chest wall and the lung may cause a very interesting group of symptoms:

(*a*) Paralysis of the diaphragm.

(*b*) Rigidity and tenderness of the upper abdominal muscles.

(*c*) Contralateral collapse of the lower lobe.

Paralysis of the diaphragm and rigidity of the upper abdominal respiratory muscles results in fixing the lower chest; and fixation of the lower chest results in the collapse of the lower lobes.

This sequence may well be a protective *adaptation*, for among the dangers of wounds of the lung are hemorrhage into the pleural cavity and hemorrhage into the bronchial tract; and the inspiration of bronchial blood into the air vesicles results in bronchopneumonia and asphyxia. Now collapse of the lung would tend to prevent both hemorrhage and the inspiration of blood. Therefore rigidity and tenderness of the upper abdominal muscles and paralysis of the diaphragm may be looked upon as protective adaptations, just as muscular rigidity and tenderness are protective adaptations in peritonitis.

The patient is most comfortable in the bent forward sitting posture, a position which limits the movements of the chest.

Another interesting chest phenomenon is the production of hemothorax and hemoptysis by a bullet or shrapnel wound of the chest wall *without perforation*.

In operating it has been found that the best results are secured by the administration of nitrous oxid-oxygen with an apparatus by which the combined gases or oxygen alone may be administered under positive pressure. Oxygen under positive pressure will carry the patient through critical phases; and at the end of the operation the lung may be inflated so as to fill the chest and overcome the pneumothorax.

IV. ABDOMINAL WOUNDS

A. IN THE FRONT AREA

Don't

Don't probe the wound.

Don't delay evacuation.

Don't give morphin unless there is great pain and not then if the nails are cyanosed.

Don't give stimulants.

Don't give food.

Don't move patient more than is absolutely required.

B. AT THE EVACUATION HOSPITAL

There is but one absolute rule for the treatment of penetrating wounds of the abdomen — *immediate operation.* Fifty per cent of the cases recover.

Make a long, midline incision. Let there be minimum pulling — minimum exposure to air. After ample exposure, systematically, accurately, carefully, gently, inspect the stomach and intestine. *Do it once — not twice.* Be so exact in the first search that there need be no thought of a second search. Close openings with *loosely tied* silk or linen sutures. Usually the abdomen is not flushed. If the condition of the patient is critical and a given sector of intestine requires a tedious resection, temporize by bringing the loop out of the wound and complete the operation on another day.

Wounds of the *stomach* and *small intestine* require no drainage; wounds of the *large intestine* require drainage.

Suture a torn *bladder;* if the *ureters* are torn off near the bladder — implant them into the bladder.

If the *kidney* is generally shattered, remove it; if locally wounded, make a local resection and cover the field of suture with kidney fat.

Suture a bleeding *liver*, using a mattress suture and a round needle.

Excise a shattered *spleen*.

Close a rent in the *diaphragm* and be on the lookout for diaphragmatic hernia.

Drain widely a torn *pancreas* and if available apply mutton tallow about the wound.

When the missile has passed through the large intestine and through the retroperitoneal area, one of the most dangerous conditions exists, because the retroperitoneal area has a very low power of resistance to infection; if this applies to the ascending or the descending colon, then after closing the visceral injury carry the incision laterally to the exit tract, excise it, and put in Carrel-Dakin tubes, but close the abdomen. Perforations of the stomach do about as well as perforations of the small intestine — both do better than perforations of the large intestine. The associated perforations through the bony pelvis, the bladder or ureters, and the large intestine are dangerous and their treatment is difficult.

Abdominal cases must be held in the Evacuation Hospital until their complete recovery. Gas gangrene of the abdominal wall, of the liver, and of the retroperitoneal area may develop.

Visceral perforations may be caused by external injury without penetration.[1]

[1]See a report by Bowlby and Wallace in the British Medical Journal, June 2, 1917.

CHAPTER IX

COMPOUND FRACTURES

I. COMPOUND FRACTURES OF THE FEMUR, HUMERUS, FOREARM, LEG, KNEE, ELBOW

A. In the Front Area

Don't

Don't plate.
Don't make intermittent extension.

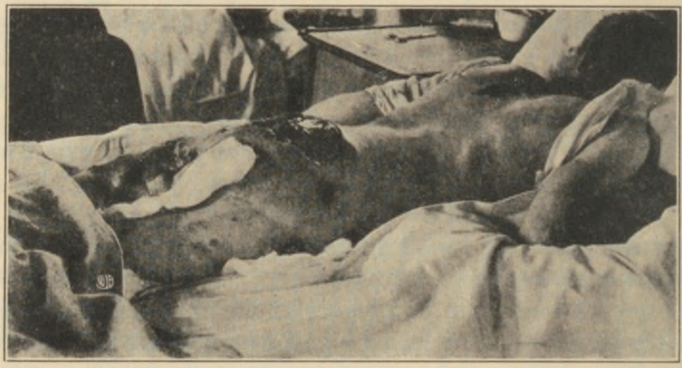


Fig. 18.—Multiple wounds.

Don't handle roughly under anesthesia.
Don't fail to investigate if there is pain.
Don't give morphin if patient is cyanosed.

Don't take off shoes or clothing before reaching the Evacuation Hospital.

Don't try to sterilize the wound before reaching the Evacuation Hospital.

Don't evacuate patient with tourniquet in place.

Don't put on tight bandages.

Don't suture.

Don't rest the heel on the stretcher.

Do

Apply lightly protective dressing on wound.

Put Thomas splint over clothes and make extension on the shoe.

Use Sinclair glue for securing extension of arm and forearm.

Suspend the splint from the stretcher.

For fractures of the femur involving the soft parts of the upper thigh and buttock the long Liston splint answers well.

Give morphin if patient is not cyanosed.

B. AT THE EVACUATION HOSPITAL

Prepare field by soap and water, shaving and alcohol.

Make complete excision revision of the wound — always cutting away an ample margin of muscle — a margin so wide that at first it seems unwarrantedly destructive. During the operation the fractured limb should be under steady, even and continuous extension.

Close no compound fracture except of the joints if the patient is to be immediately evacuated.

In a shattered knee-joint, after careful revision, removal of fragments and foreign bodies and washing with saline, close the joint without drainage, using interrupted sutures *tied lightly*. Treat further with extension and immobilization. If the patient is to be kept under continuous observation, compound fractures of the humerus, forearm, tibia and fibula — if not too complicated — may be closed; but make microscopic observations and be prepared to open promptly if the presence of streptococci is demonstrated.

The thigh may be primarily closed if the fracture is not too complicated and if the patient is to remain under continuous observation.

If B. I. P. (see footnote, p. 27) is carefully filmed into every portion of the wound, it does well in transport, but do not use B. I. P. if a foreign body remains in the wound, as

FIG. 19.—Gunshot wound of knee.

it will interfere with the later *x*-ray examination. The French obtain good results from the application of ether. Eusol packs do well, and when time and organization permit the Carrel-Dakin treatment is perhaps best of all, especially in deep inaccessible wounds; but in rush periods the Carrel-Dakin treatment cannot be carried out.

Thoroughness of surgical revision, accuracy and judgment in the application of splints, immobilization and physiologic rest are the really primary factors of success. The best antiseptic is the best surgeon.

At the Base Hospital the wound may be secondarily closed after it has become relatively sterile. As long as dead bone is present, so long will there be infection.

II. COMPOUND FRACTURES OF THE WRIST, HAND, ANKLE, FOOT, SHOULDER AND HIPJOINT

A. In Transport

In the Front Area the Thomas splint is not suitable for these cases. The shoulder is transported merely by a sling; the hand and wrist by a simple supporting splint; the ankle and foot by simple right-angled supporting splints. In transporting fractured ankles be sure to secure the upper part of the splint so that the ankle will not wobble.

B. At the Evacuation Hospital

Excision revision without suture.
Rarely make a primary closure.
Extension-suspension.
Carrel-Dakin if possible or B. I. P.
Physiologic rest.
Secondary closure.

CHAPTER X

AMPUTATIONS

In making amputations the presence of contamination and infection prevents much finesse in flap formation. In the presence of gas gangrene flaps are not considered. In cases of septic gangrene a flush amputation is safest and when the danger of infection is past then the stump may be revised.

In amputation of the thigh in septic cases Colonel Gordon Watson advises a flush transverse division of the tissue to the bone. Saw the bone off long as the projecting bone will be useful in handling the stump; some surgeons have even advised drilling a hole in the end of the projecting bone, putting a wire through, and a handle on the end of the wire.

When the infection period is over, a revision amputation is made. Do not save periosteum as periosteum facilitates excess callus formation. In high amputations nitrous oxid-oxygen anesthesia gives strikingly better results than ether or chloroform. Shattering of the mediotarsal region calls for amputation in the lower third, as do certain smashing compound infected fractures of the ankle-joint. An extensive crushing of the head of the tibia with shattering of the joint demands amputation.

In the upper extremity in contrast to the lower extremity the utmost conservatism is practiced.

Do not permanently ruin a man by several years of hospitalism to pull through a worthless remnant of a limb.

CHAPTER XI

GAS GANGRENE

The soil of the western front holds many anaërobes — Welch bacilli. These are unable to affect normal living tissue; they can successfully attack only devitalized tissue. As first pointed out by Kenneth Taylor, they operate with particular success against muscle tissue and along the path of a shell injury rather than a rifle ball injury, the reason being that shell fragments cause the greater devitalization of tissue.

After it has once started — gas gangrene may pursue a startlingly rapid course. Starting usually in a muscle it spreads along the muscle to connective tissue, involving one group of muscles after another, rapidly becoming a general septicemia, and causing death even within twenty-four hours. The gas bacilli most commonly attack deep wounds in the large muscles of the thighs, but they may attack the liver, the retroperitoneal area, the abdominal wall, even the heart. The progress of gas gangrene is marked by a mounting temperature, rapid pulse, jaundiced appearance, stupor, delirium and death.

Treatment.— The treatment of gas gangrene is preventive and curative. It may be almost wholly prevented by a complete excision of the devitalized tissue within the first twelve hours; this treatment is fairly successful after twenty-four hours; but is less successful after the gangrenous process has begun, and is hopeless in the stage of bacteriemia and delirium.

When gas gangrene is furiously under way, immediate amputation is indicated, cutting through as little muscle as possible. If in the leg, amputate through the knee-joint to avoid dividing muscle never minding the flap — operate for *life*, not for flap. When a single muscle shows a beginning infection it should be dissected out in its entirety.

The general treatment consists in giving sodium bicarbonate intravenously; and in the usual supporting treatment. A promising serum treatment has been developed by Bull, of the Rockefeller Institute.

Gas gangrene has killed almost as many soldiers as the bayonet. As we have stated it develops only in devitalized

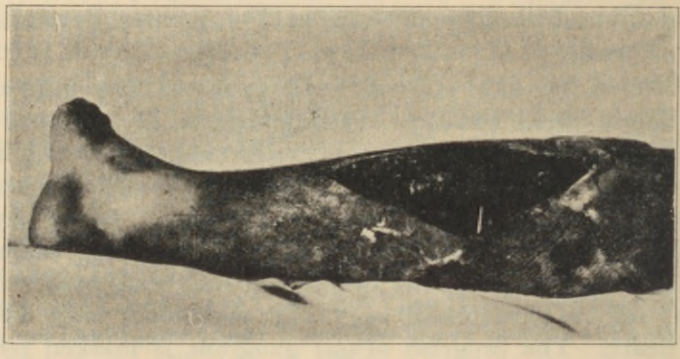


FIG. 20.—Gas gangrene. Amputation.

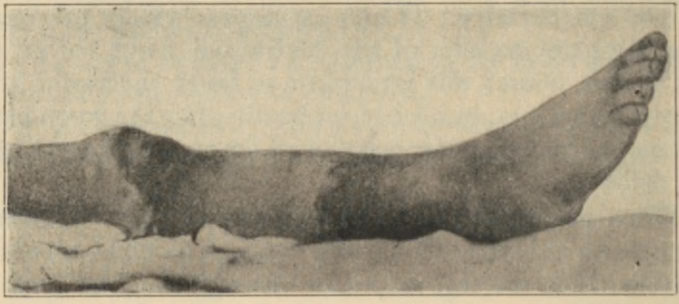


FIG. 21.—Gas gangrene showing demarcation of gangrenous area.

tissue. It cannot as yet be overcome by antitoxins, not by drugs, not by physiological rest, not by packs, not by incisions, not by amputations, but by so perfect a system of transport, by so mobile a surgical organization, by operating facilities so ample, that within the first twenty-four

FIG. 22.—Gas gangrene.

hours every injured man may have the devitalized tissue of his injury completely excised. These are the only means by which gas gangrene may be mastered.

Gas gangrene after any given battle depends upon the weather, the tide of battle, the organization of surgery and transport. If the day is cold and rainy; if the tide of battle swings back and forth; if mud, the blowing up of bridges and roads and railways, and mismanagement break down the transport, then gas gangrene may cause more fatalities than the enemy; very slight wounds may be fatal; hospitals will everywhere be filled with sallow, delirious, dying patients, many of them with wounds so slight that under fair conditions they would promptly be on the firing line again.

The treatment of gas gangrene in the American army can be met and mastered by a perfect organization of transport service; by a surgical organization ample in trained personnel, as mobile as the combatant forces; by operating areas at the front so large that every wounded man can be operated within the first twenty-four hours. In the British and French armies gas gangrene is now well under control.

The specific for gas gangrene is adequate transport and adequate surgery.

CHAPTER XII

POISON GASES

Phosgene.— Fortunately, owing to the precautions which have been adopted, there are not many cases of phosgene poisoning. Phosgene is a splendid offensive weapon because it is so slightly unpleasant. It is easily inhaled — is deeply inhaled — going down into the deepest portions of the lung. In contact with moisture it decomposes leisurely and hydrochloric acid is formed, which causes edema of the pulmonary membrane and in some cases asphyxia and death.

The treatment is threefold:

(*a*) Bleed at once — the bleeding apparently diminishes the development of pulmonary edema.

(*b*) Give oxygen continuously or at intervals as soon as symptoms appear. Should the inhalation of oxygen at air pressure be insufficient then oxygen under higher pressure should be given at intervals.

(*c*) The patient must lie down — must remain quiet. Even though he feels well, he must be cautious because of the possibility of heart failure. If the heart becomes dilated, digitalone should be given.

Occasionally there is the combination of phosgene poisoning with an injury requiring operation. In such a case inhalation anesthesia should be given with the utmost care — the decided preference being nitrous oxid-oxygen; but if local, regional or spinal anesthesia will suffice, no inhalation anesthetic should be given.

Mustard Gas.— While uncommon, cases of poisoning with mustard gas will be encountered. This agent causes blisters, swelling, conjunctivitis, photophobia and bronchopneumonia. The wounds are readily healed. Orderlies, nurses and surgeons should use heavy gloves in removing the clothing or their hands may become affected. The patient should be kept still for a rather long period. Blisters receive the usual surgical care.

CARBON MONOXID.—Oxygen is almost a specific for carbon monoxid poisoning. Should oxygen be not available or should the patient not improve then he should be bled and transfused with normal blood. In carbon monoxid poisoning the hemoglobin becomes fixed and is incapacitated for carrying oxygen. The new blood introduced by transfusion takes on this function at once.

CHAPTER XIII

VARIETIES OF FOREIGN BODIES FOUND IN WOUNDS — VAGARIES OF MISSILES

Foreign Bodies.— The supermud of Flanders sometimes becomes the missile. A 5.9 shell falls in the mud and explodes, and the explosion may sling the mud with such force as to perforate the skin and through the opening force in mud, somewhat as a sausage is stuffed. The mud may force its way along the planes of tissue, where an astonishing amount may accumulate. Deaths may result from the effects of this shell-slung mud.

The most common foreign bodies found in wounds are clothing and missiles; but among others which have been removed have been wood from ammunition boxes; pebbles; fragments of stone and of concrete; the works of a wrist watch; coins, fragments of pocket knives; medallions; bones from the body of a comrade. Tracer aeroplane bullets may be found which emit a miniature phosphorescent cloud when cut down upon and exposed.

Vagaries of Missiles.— A single missile may make many combinations of wounds — of the hand and jaw; of the hand and thigh; of all four extremities. In one unusual case a ball entered the supraclavicular space, passed through the chest, the diaphragm, the abdominal cavity and the pelvis and finally fell exhausted in the pocket of the officer who made a good recovery.

At a Casualty Clearing Station the roentgenologist found a bullet free in the chamber of the heart. His report excited general interest and the next day he screened the heart to show it to a group of surgeons but the bullet was not in the heart. With the fluoroscopic screen he therefore followed down the aorta and found the missile at the branching of the iliac artery. A through and through bullet wound of the right side of the neck caused paralysis of both the right and left arms, the right paralyzed by division of the trunks of the brachial plexus, the left by anemia of the right cerebral hemisphere from severing of the carotid artery. Nerve trunks are frequently physiologically severed by contact without anatomical lesion. The slender rifle bullet may cause incredibly large flesh wounds by first fracturing a bone like the femur and then driving the bone fragments with great force through the soft tissues; and in addition to the tearing by the bone fragments the long bullet itself may tumble and tear the tissues widely. Soldiers with penetrating abdominal and chest wounds may walk several miles before they collapse. Aviators fly home with abdominal penetrations. The receipt of wounds from high velocity missiles is painless. There is the sensation of a thump — sometimes of heat. High explosives often kill without causing external injury. Men buried under the upheaval of earth by high explosives may have petechial hemorrhages of the brain.

No Man's Land still means imprisonment for the wounded; even now wounded men may lie out in a shell hole four or five days. These cases are apt to develop gangrene unless the wound becomes filled with maggots. Maggots compete with gas bacilli for the possession of devitalized tissue. The maggot being the more powerful wins over the gas bacillus. The wriggling of the maggots causes no sensation — the host may not suspect their presence.

There is usually but little pus in these open air cases. It is not clear why — it may be due to the fact that only those survive that have the power of overcoming the infection; but this must remain merely a conjecture because surgical rounds are not made on No Man's Land!

The body temperature of surgical cases at the front as well as at the base is extremely erratic — a temperature of 103 to 105 may appear abruptly and abruptly disappear — probably because many of the wounded have various trench infections of unknown origin.

Soldiers are far better patients than civilians. The army represents a selected personnel — they have the advantage of a normal out-of-doors fighting life; they are well fed and highly nourished; they have developed a high local as well as high general resistance. For example, no one would think of closing the contaminated knee-joint of a languid civilian. The cause of death in cases of abdominal perforation is more commonly due to hemorrhage and shock than to infection; the surgical mortality in these cases is low. After a given battle the surgeon general's report is best when (*a*) the troops have been victorious; (*b*) when the army has advanced so that the prompt collection of the wounded is possible; (*c*) when the weather is warm and dry.

CHAPTER XIV

DISSOCIATION OF PERSONALITY AND NEURASTHENIA

Dissociation of Personality.— This rare condition at first received the misleading name of *Shell Shock*, because it seemed to be precipitated by the noise of battle, especially of shells. *Dissociated personality* is a medical enigma, and cannot be completely explained until the mechanism of the brain is understood. Dissociation of personality represents nothing peculiar to war, it is more common in war only because in war the psychic drive is more intense than in any but the most intense crises in civil experience — the sudden breakdown caused by the tragic death of a friend or a relative; incarceration in a burning building; financial ruin; shipwreck — any of these experiences may produce in the brain for a time facilitated paths with which no other stimulus can successfully compete, thus producing a temporary dissociation of personality. Indeed in the life of everyone there are certain stimuli which for a short period completely dominate the brain so that no other stimuli can immediately dispossess them. Multiples and intensifications of these lighter, shorter civil dissociations are equal to those which occur in war — not always during shelling — not always due to explosives, but sometimes to other incidents of war as well.

That this condition is not more common indicates a peculiar susceptibility of the victim. In unconscious possession of such a susceptibility the civilian leaves his quiet civil pursuits and reaches the front line by such stages as enlistment; putting on uniform; drilling; firing; bayoneting; day and night trench duty; bomb throwing; gas attacks. Each new experience is a little more exciting than the last; he has doubts — misgivings, but he is in the stream and must go on. Finally he leaves the training ground for the real arena where the dissociation is achieved. Here he encounters such incidents as the noise of the approaching and exploding shell; the narrow escapes; the witnessing of the fragmentation of comrades. He becomes convinced that over the top is certain death and he shudders at the thought that some day he must penetrate this fateful zone; the thought of death becomes his constant companion. If he be an officer he perhaps fears that he may fail to meet his responsibility on the great day. Thus sleepless, doubting, waiting, he becomes more easily startled; he loses rest, loses appetite, loses energy, loses confidence; he contrasts his execution as a coward with the bayoneting by the enemy; these doubts tell him he has suffered a physical and moral defeat; in the sanctuary of his own conscience he stands disgraced — dishonored. At last the day comes and amid the terrifying scenes his threshold is thrust down until his duties and responsibilities toward himself and toward his officers lose command of the final common path; and the shell keeps it — holds it against all others. The man becomes an automaton — a shell-dodging automaton — oblivious to everything else; he no longer experiences fear; he exhibits only its outward mimicry. The mechanism of fear is apparently dissociated from the organs that metabolize, that fabricate fear; he is a dissociated emotion — a manikin of an emotion. He has been dispossessed of all his brain mechanism except the auditory nerves and the nerve-muscular reaction of dodging shells; that is — he has lost speech, common sensation, understanding, reason, memory, sight, touch, taste, smell, he is divided into two parts — one a monotonous auditory nerve-muscular mechanism dissociated from the remainder of his personality — the other a suppressed remainder now silent. Putting the finger in the eye or into the larynx cannot compete with the shell-facilitated path; spoken and written language cannot compete; the eyes see nothing; the nose smells nothing; in vain the skin may be pricked and pinched and cut; all the avenues leading *into the brain are blocked except one* — that of rough sound; all the avenues leading out of the brain are closed but one — that of dodging shells.

How can this extremely facilitated shell-dodging mechanism be conquered. Only by strong competition — urgent persuasion, physical injury, strong electric shock, anesthesia, impressive methods. When the barrier has once been broken at one point then usually the whole brain mechanism is reclaimed. The most successful method is by the use of one of the strongest mechanisms — that of speech The following case history illustrates how this may be accomplished: The patient was like a wild animal, shaking, staring, decerebrate, crouching, trembling, wild. He was constantly dodging shells, acting as if at bay—dodging his enemy. When his arm was pinched he felt no pain. His appearance was wholly abnormal; his face was earnest but portrayed not a sign of emotion — not a sign of intelligence. When asked his name he could not answer. "Do you belong to the Second?" Only a jerky respiratory sound in response, no word, no nod. "To which battalion?" A wheezing idiotic "No." "To the Third, the Fourth?" Finally when "the Tenth" was mentioned he became greatly excited and with a trembling forefinger marked "10" on a board. For half an hour the medical officer struggled to teach him to say "a." He whispered the letter in his ear; shouted it, showed his own expression while pronouncing it. Slowly and gradually he reopened the action patterns, while all the time the patient was dodging shells and enemy, constantly throwing up his arms and ducking his head. Finally he was made to cough the sound "a." As this action pattern began to open the idiotic face began to clear. The medical officer put a laryngoscope down the throat, there was no cough, no laryngeal reflex, but finally he was made to say "a" then "e" while the larynx was irritated. This achievement marked the beginning of steady improvement. Soon he could fabricate all the vowels, then the consonants. Under patient encouragement he was made to recall the name of his regiment and his regimental number. Gradually one after another of the normal paths of conscious action became predominant over the primal self-preservation path and a normal expression of face, and normal reactions were established. It was as if an infant had grown up to a child of ten in an hour, as if a sculptor gradually put a mechanism into a marble statue until finally it climbed down from its pedestal and talked with him. In effect the life of the patient was recapitulated in an hour — in this period he was taught to speak, to count, to spell, to read; he was taken through the kindergarten, the grammar school, the academy.

These cases are infrequent; and the end-results are good.

ACUTE NEURASTHENIA.— Not all soldiers whose mechanisms fail under the acute drive of war suffer *dissociation of personality*. In some there is first a lowering of threshold for all stimuli such as is seen in intense overwork in other situations in which excessive activity leads to exhaustion. The characteristics are diminished muscular and mental power, tremors, sweating, trembling, insomnia. These cases are treated like acute neurasthenia from other causes.

PART III

A Suggested Plan of Clinical Organization of the Medical Service

CHAPTER XV

ORGANIZATION

ORGANIZATION and cohesion and well-trained men can achieve the impossible. It is obvious that a common training, a common experience alone, will give the necessary professional cohesion by which we can successfully meet our strongest enemy. This cohesion can be fully achieved only by the establishment of a permanent civilian military organization co-ordinating with the Surgeon-General. Such hospital organizations as have heretofore been created by the Surgeon-General in time of peace should be expanded to include Evacuation and Field Hospitals and Field Ambulances. Thus one or more Base Hospitals with Evacuation and Field Hospitals and Field Ambulances in that portion of the fighting area which can properly be covered from one center would constitute a *Clinical Sector* officered by a given University, that is, a given University would be responsible for the professional work of a Sector. A Clinical Sector would include one or more army divisions. The hospitals and the ambulance organization of each sector would be under the clinical organization of the University Chiefs of Medicine and Surgery. During war the University Chiefs of Medicine and of Surgery would be the consultants or professional Inspectors or Directors of the Sector.

At the Base Hospitals there should be established a *pool of medical officers, nurses and orderlies* from which the regular personnel of the Base Hospitals, the Evacuation Hospitals, the Field Hospitals and the Field Ambulances would be re-enforced. Thus uniformity and continuity of method would be established; the optimum clinical results would be achieved; strategic mobility would be secured; and the posts of advantage and disadvantage would be equalized.

The co-ordination of these clinical sectors and their relation to the administration division of the Army would be made through the office of a Chief Consultant or Professional Inspector on the Headquarters Staff. *In peace as well as in war the ultimate authority must be vested in the administrative officer.*

During time of peace the senior students in the medical school should receive instruction in military surgery from

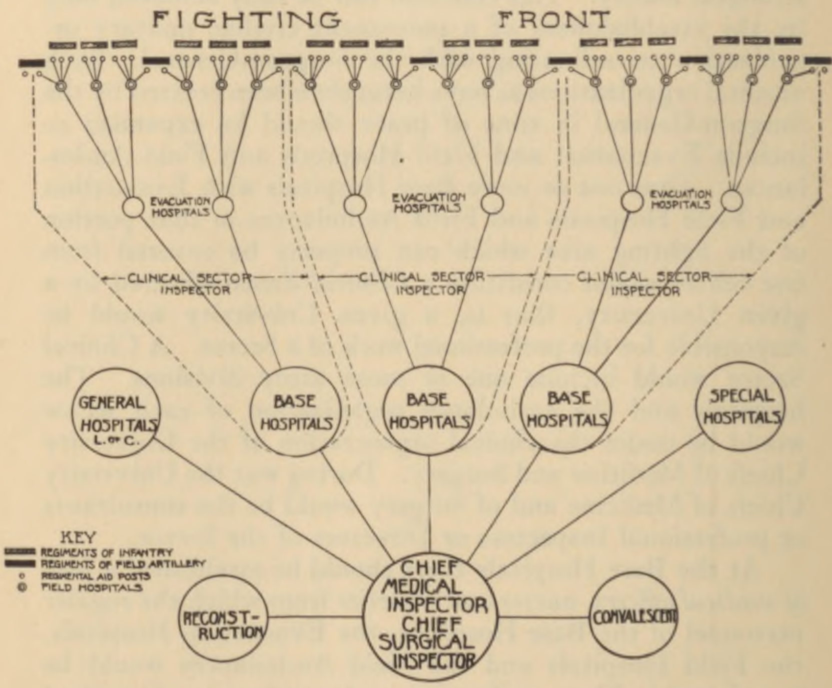


FIG. 23.—Diagram illustrating a suggested plan of clinical medical organization.

regular army officers and from the University staff. With perhaps only minor changes the civil hospital would use the same methods, appliances, and anesthetics and the same organization at home in time of peace as would be employed in time of war; and should have ready in store a completely equipped portable hospital.

In time of war, Field Training Schools for surgeons, nurses, and orderlies should be established by these militarized hospitals. The Base Hospital would serve as a training school for men entering the service; would be a center for the *prosecution of research;* would serve as a testing station and clearing house for *methods of treatment, instruments and appliances.*

Obviously the administrative and the clinical services during war should be separated. Whether he be of the regular army, or from civil status, each officer with the exception of the Regimental and Field Officers, should assume exclusively one or the other role. The clinician should leave administrative matters to the administrator; the administrator should leave purely clinical matters to the clinicians.

In actual practice the work and responsibility of the clinical organization would be apportioned as follows, beginning with the Regimental Medical Officer:

THE REGIMENTAL MEDICAL OFFICER

The work and the responsibility of the Regimental Medical Officer would be dual in character.

As the friend of every soldier and officer the Regimental Medical Officer should exert one of the finest moral forces in the Field. It is to him the men look for protection when they go "over the top." The Regimental Medical Officer should be able to differentiate easily the real disability from the malingering of the soldier; he should know the war phenomena accurately, because he experiences them himself; he is subjected to the same high explosives; to the same barrages and bombings; to the same poison gases; to the same hunger and thirst as his men. For the line he could be the most important medical man in the army.

For matters pertaining to records, to paper work, etc., the Regimental Medical Officer would be *responsible to his superior administrative officer.*

For the kind of splint and its application; the method

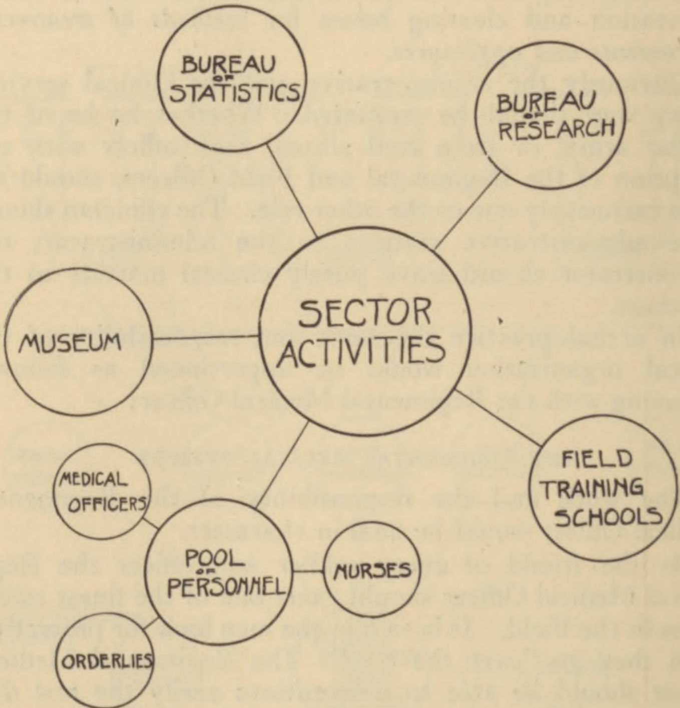


FIG. 24.—Diagram illustrating sector activities in a suggested plan of clinical medical organization.

of controlling hemorrhage; in what cases to give morphin and how much; the material and method for making a first dressing; the treatment of exhaustion; the management of gassed cases; he would be *responsible to his superior Clinical Officer*, the Professional Inspector of the Sector.

FIELD AMBULANCE AND FIELD HOSPITAL SURGEONS

Like the Regimental Medical Officer the Field Ambulance and Field Hospital Surgeons would have a dual responsibility:

In matters pertaining to hours of duty, collection of the wounded, transportation of wounded, etc., the Field Ambulance and Field Hospital Surgeon would be *responsible to his superior administrative officer.*

In all that pertains to the treatment of wounds — operations, splints, anesthetics, medication, treatment of gassed cases, etc.— he would be *responsible to his superior Clinical Officer*, the Professional Inspector of the Sector. The Regimental and Field Medical Officers would be entitled to seek information on all pertinent matters from their clinical superior officer.

PERSONNEL OF THE EVACUATION HOSPITALS

The Evacuation Hospitals would be the great operating posts thrown forward by the Base Hospital. The administrative and the clinical work would be divided here as in the Base Hospital. The Evacuation Hospital would be commanded by the administrative officer; its clinical work would be controlled by the Director.

In periods of great stress the personnel of the Evacuation Hospital would be re-enforced not only from its parent Base Hospital but also by teams from other Base Hospitals. These borrowed teams would be fully under the jurisdiction of the officers of the Sector during their tour of duty.

The permanent professional personnel of the Evacuation

Hospitals would be appointed on the recommendation of the Professional Inspector of the sector — the mobile units by the Chief Professional Inspector.

While the Evacuation Hospitals could have no fixed permanent personnel the minimum personnel of each should include surgical teams, one internist, one roentgenologist, one pathologist. No maximum limit should be set, for the size of the staff, whether it be ten or two hundred, should be as mobile as that of the armies in front of them — as mobile as the number of casualties they receive.

BASE HOSPITALS

One of the Base Hospitals would be the headquarters of the Professional Inspector of a Sector. From this Base Hospital he would direct the clinical activities of the Sector up to the Regimental Aid Posts. This Base Hospital should be the teaching and training center for the Sector. Moreover, it should be the connecting link not only between all portions of its own Sector, but also between its own and other Sectors.

THE PROFESSIONAL INSPECTOR OF THE SECTOR

The Professional Inspector of the Sector would be responsible for the training of medical officers, nurses, and orderlies; for the organization and maintenance of a school for training anesthetists; he would also organize and control schools of treatment for the instruction of his medical officers in the most advanced and approved methods. He should initiate new lines of clinical and experimental research as they are suggested by the exigencies of his service at the Base or at the Front; and he would correlate the work of the laboratories at the Base and at the Evacuation Hospitals. He should also maintain a Bureau of Statistics.

He should have associated with him an assistant who would share the direction and oversight of the clinical work throughout the Sector.

CHIEF PROFESSIONAL INSPECTOR

The duties of the Chief Professional Inspector would be:

1. To act as a member of the Medical Sector of the Council of National Defense, serving on the Committee of Research and the Committees of Standardization of methods, apparatus, and instruments.

2. To act as a Liaison Officer with the Council of Defense, with the Red Cross and with the corresponding officers of the Allies.

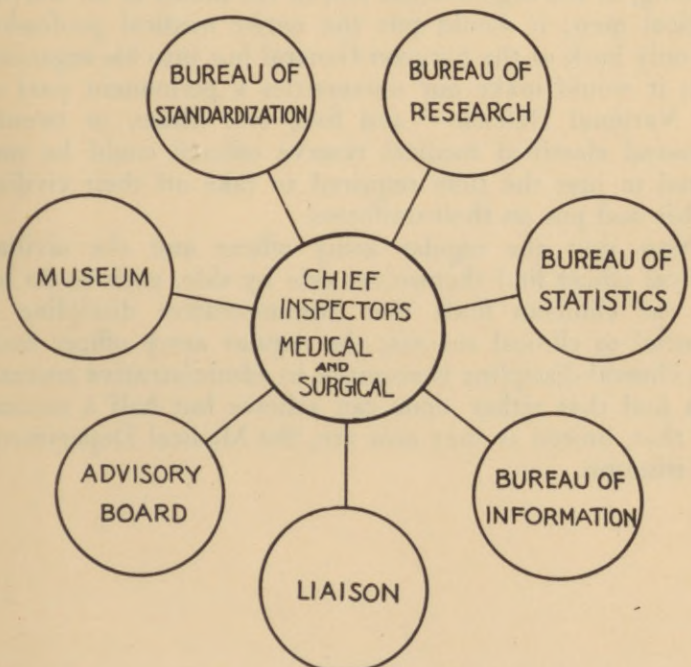


Fig. 25.—Diagram illustrating the activities of chief inspectors in a suggested plan of clinical medical organization.

3. To organize new units as authorized.

4. To correlate the clinical data of the various units.

5. To collect, contribute, and distribute information useful to the Directors of Units and Sectors.

6. To establish and direct researches on all lines of injury and disease.

7. To be responsible for the general policy governing the care of patients.

Such an organization of perhaps eighty university medical schools would cover the clinical needs of an army of approximately 3,200,000; it would enable the Surgeon-General to have his military viewpoints established in the training, in the organization and in the minds of all worthy medical men; it would put the entire medical profession not only back of the Surgeon-General but into his organization; it would make our universities a permanent part of our National Defense — and five, ten, fifteen or twenty thousand classified medical reserve officers could be mobilized in just the time required to take off their civilian clothes and put on their uniforms.

Now that the regular army officer and the civilian medical officer find themselves side by side, each to do his bit, the clinician finds that administrative discipline is essential to clinical success; the regular army officer finds that clinical discipline is essential to administrative success; both find that either alone can achieve but half a success and that, united as they now are, the Medical Department will triumph.