THE DEVELOPMENT OF BRITISH SURGERY AT THE FRONT.

BY
SURGEON-GENERAL SIR ANTHONY BOWLBY, K.C.M.G., K.C.V.O., A.M.S.,
AND
COLONEL CUTHBERT WALLACE, C.M.G., A.M.S.,
CONSULTING SURGEONS, BRITISH ARMIES IN FRANCE.

IT is not possible in a few pages to do full justice to the developments of British surgery during the war, but it is reasonable to place the more salient facts on record, and to summarize, however briefly, the present position of surgical work in the British Expeditionary Force in France and Belgium.

THE REGIMENTAL MEDICAL OFFICER.

It is unnecessary to write at length on the work of the regimental medical officer, for his duties in this war are much the same as they have ever been. He shares the dangers common to the combatant officers and men, and stays with his battalion or brigade, as the case may be. His treatment can only be that of first aid, but he and his orderlies have saved innumerable lives, both by the rescue of wounded comrades from dangerous situations and by careful and rapid transport to the field ambulance sections in the support line.

THE FIELD AMBULANCE.

At this, the "advanced dressing station," there is a personnel of two or three medical officers, non-commissioned officers, and orderlies, and it is here that the first-aid dressings can be supplemented by additional dressings and by suitable splints, so as to ensure a more easy transit to the "tent section" of the field ambulance, a mile or two further back.

The field ambulance has not needed to undergo any very radical changes during the war, because its constitution and personnel proved it to be thoroughly well suited to its duties. But its surgical equipment has been very greatly improved and increased, so that it is in all respects well supplied for the performance of any urgent operation undertaken for conditions which do not require that the patients should be retained for any length of time.

The following instructions, which are amongst those issued in all the "armies" at the front, will best indicate the limitations of their work:

"(1) Only operations of emergency should be performed in field ambulances, but the following exceptions must be noted:

"(*a*) Completely smashed limbs should be removed, and the patients retained for at least a day before being sent to a casualty clearing station.

"(*b*) Haemorrhage should be arrested by ligature of bleeding points whenever possible. If this is not possible, then plugging or direct pressure on the wound itself should be resorted to. Patients should never be sent down with tourniquets on their limbs.

"(2) Abdominal wounds and all severe cases requiring early treatment at a casualty clearing station should be sent there by a special motor ambulance direct from the advanced dressing station. They should not be kept waiting for the regular convoys."

A further development of the tent section resulted from the conditions at the battle of the Somme, where, on account of the small area and the few good roads, "corps dressing stations" were created by joining up some members of the staffs of various field ambulances, so as to supply tent accommodation for a thousand or more wounded, with a staff of about thirty medical officers. A unit such as this performed the duties ordinarily performed by several separate field ambulances, and proved very successful as well as economical in medical officers and orderlies.

Motor Ambulances.

It is unnecessary to write much on a subject which is already thoroughly well known to all, but it is the supply of motor ambulances alone that has enabled us to deal adequately with the surgery at the front. One aspect of this subject, however, is very commonly overlooked, namely, the use of motor transport in saving the wounded from capture, for there can be no doubt that, had motor ambulances been supplied in large numbers, the tale of British prisoners after Mons and Le Cateau would have been very small. The first complete convoy came to the front in the middle of October, and at the first battle of Ypres was of the utmost possible value, both in getting patients quickly to the casualty clearing stations and also in saving wounded from falling into the hands of the enemy during our retirement to the ground we subsequently held.

The motor ambulance, indeed, is the very foundation on which all our surgery at the front is based. Without it the whole system would break down, for no horsed vehicles could possibly deal with the numbers of a heavy fight unless they were so numerous that they would practically block the roads for all other transport, and even then their slowness would result in such delays in delivery that surgery would be of little use. In addition, the well hung and well driven motor causes the patient infinitely less distress than the old ambulance wagon, and so delivers him in a much better condition for recovery.

THE QUESTION OF TIME.

This is a matter of so much importance to surgery that it is well to explain the time that is required to take a patient from the front trenches to the casualty clearing station. It is, in the first place, not sufficiently realized that the chief cause of delay, if it occurs, is "the enemy," for there have often been, and there still are, localities from which the wounded can only be moved under cover of darkness, so that a man may have to be kept in a dug-out the whole of a long summer's day before he can be carried to the rear. Again, in the desert of mud behind the firing line on the Somme stretcher-bearers sometimes took hours to carry a wounded man at night for several miles to the nearest point to which, in the absence of all roads, an ambulance wagon could approach. In yet other cases men lie out in the open ground on the so-called "No Man's Land" for many hours, or even for several days, before they are rescued. But supposing that none of these difficulties exist, the time occupied is very short, for, if communication trenches are good, and if a man is able to walk, he will often get to the advanced sections of the nearest field ambulance within an hour. If the communication trench is long and muddy, it may take twice that time. If he has to be carried it may take another half-hour or more, but as soon as he has got to a good road another hour will see him safely delivered to the place where his injuries can be thoroughly treated and where he can be well nursed under excellent conditions.

All this is comparatively simple if no great battle is in progress; and as great battles occur at infrequent intervals, it is evident that in most parts of the line of trenches evacuation is easy and rapid except for unusual local conditions. But in very heavy fighting, and especially when troops are advancing, it is often impossible to find sufficient stretcher-bearers in proportion to the great numbers of wounded, for only a limited number are attached to each regiment, and it is therefore necessarily true that the greater the number of the wounded who have to be carried, the longer must it be before the last of them can be brought in. No work is heavier than stretcher carrying for long distances and on difficult ground; and as men become exhausted their pace becomes slower, and they are obliged to rest at more frequent intervals. But even when all difficulties have been surmounted and the patients have arrived at the tent sections of a field ambulance, there are many who are too much exhausted for further immediate moving; and while the staff may have their hands full with dressing the wounded, they have also to care for the needs of the many men who need to be rested, fed, and warmed. While they are thus engaged on these patients, all those who require urgent treatment by operation have been taken direct to the casualty clearing stations, and thus have avoided delay.

The speed with which even patients who have to be carried can be brought in is best shown by taking the case of a consecutive series of abdominal wounds at one of the more advanced units. The following are the figures, and they show both how quickly men can be brought in when there are no unusual difficulties, and also how long it may be before a man can be rescued when an attack has been temporarily driven back.

Time of Evacuation to Casualty Clearing Station.

Under 3 hours	24	73 in first 6 hours.	134 in first 12 hours.	169 in first 24 hours.	200
Between 3 and 4 hours ...	20				
,, 4 and 5 ,, ...	24				
,, 5 and 6 ,, ...	10				
Between 6 and 9 hours ...	34	56 in second 6 hours.			
,, 9 and 12 ,, ...	22				
Between 12 and 18 hours	25	35 in second 12 hours.			
,, 18 and 24 ,, ...	10				
Over 24 hours	31				

THE CASUALTY CLEARING STATIONS.

The development of the casualty clearing stations has been the most important factor in the creation of a new school of surgery at the front, and it is not too much to say that they have saved many thousands of lives which would have been lost but for the surgical opportunities which they have provided.

Before the war the "C.C.S.'s," as they may be named for brevity, appeared only on paper and as untried units, for they did not exist at the time of the South African war. They were originally called "clearing hospitals," and their proposed function was merely to clear the field ambulances and pass the patients on to the base hospitals. Their equipment, therefore, was only very slight, and their staff of eight officers, including the command officer and the quartermaster, was less than the staff of a field ambulance. They carried 200 stretchers, and were supposed to be able to deal with the same number of patients.

It is not necessary to enter into details to show how the six casualty clearing stations, which came with the original Expeditionary Force, were overtaxed, for, in spite of this, it became very evident during the first battle of Ypres that the casualty clearing stations might well be made the nucleus around which to build an efficient organization for much more complete surgical treatment than had been contemplated when they were first planned. The first change was the supply of bedsteads and bedding and the appointment of trained nurses; the next was the addition of more surgical equipment in the way of instruments, splints, sterilizing apparatus, etc. The selection of special surgeons was a natural consequence, and before the end of the year 1914 good surgical work was being done at eight centres. Since that time there has been further development and progress, and by the end of 1916 more than fifty casualty clearing stations were at work.

These hospitals, for such we can call them, are situated behind the line of trenches along the entire front, and certain local conditions are essential for the success of their work. First, they must be at or near to railway sidings, so that evacuation by train is easy. Secondly, they must be where good roads can connect them with the front. Thirdly, they must have a good water supply.

They are arranged in practically two series: (1) Those nearest the front are at a distance of from six to nine miles from the front trenches; (2) those of the second line are from three to six miles further back, and act as a reserve during active operations, or as units for special cases during quieter times.

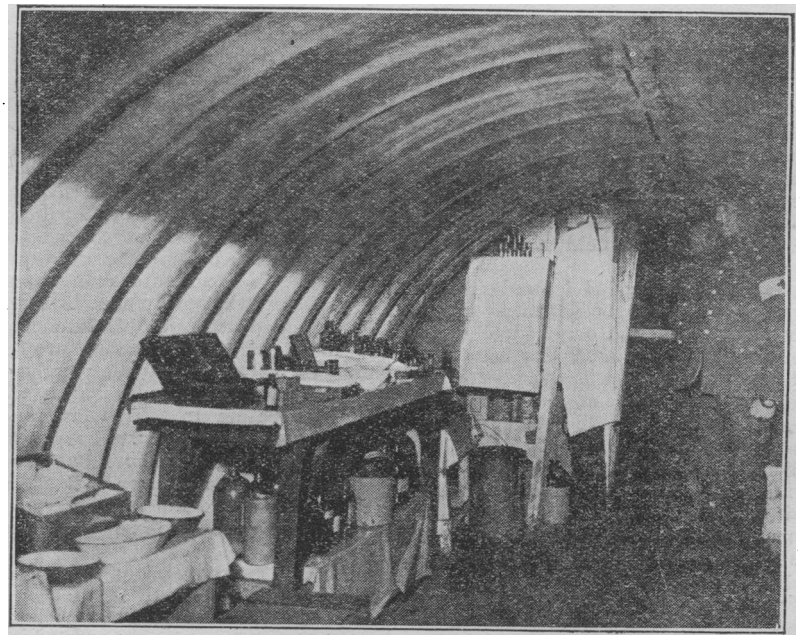


FIG. 1.—Interior of regimental aid post.

The casualty clearing stations vary greatly in their accommodation, according to the size of the buildings they may occupy, or to the amount of ground available for huts or tents when they are encamped. The smallest accommodate 400 to 500, and the largest from 800 to 1,200. Their staff is reinforced, as may be required, from other casualty clearing stations less actively employed, and from the staffs of the field ambulances.

Wherever possible the casualty clearing stations at the front are linked in pairs, and take in the wounded alternately. In this way it can be arranged that, after admitting as many as can be adequately treated, the wounded are diverted to the other casualty clearing station, and the staff is left free to treat those they have admitted, without being disturbed by fresh arrivals.

Operating Theatres.

When a casualty clearing station is housed in buildings these theatres must, of course, vary in size with the accommodation afforded. In the hutted or tented hospitals, however, which are the most numerous, the operating theatre is a hut about 60 ft. by 20 ft., giving space for four tables, and for sterilizing and store rooms. Large theatres are essential in dealing with large numbers.

The Treatment of Wounds in the Casualty Clearing Stations.

It is the object of every casualty clearing station to treat and retain all patients until they can be safely sent down by ambulance train. In times of comparative quiet there is no difficulty in attaining this ideal, and consequently, whatever standard of treatment is required from the surgical standpoint can ordinarily be attained. In times of heavy fighting, and especially when there is the certainty that many more wounded will arrive during periods extending over days or weeks, it is evident that the provision of empty beds necessitates sending patients away who might, with advantage, be retained a little longer. This pressure, however, does not prevent the performance of all really necessary operations, and these are now always performed. If the requirements of our army did not place a limit on the number of surgeons, nurses, orderlies and patients who can be retained in close proximity to the fighting line, there would be no reason why all patients should not be kept near the front, but it must be clearly appreciated both that there is this limit in every war, and also that casualty clearing stations are maintained everywhere in as great numbers as the military authorities can permit. It must also be remembered that if many hundreds of patients were kept in every casualty clearing station the staff of nurses and orderlies would be so much occupied in dressing and caring for them that they would not be free to attend to the wants of the recently wounded men coming in convoys from the field ambulances.

For more than two years it has been the deliberate policy of the British Army Medical Service to make the casualty clearing station the chief place for the treatment by operation of the dangerously wounded man who requires prompt treatment, rather than the field ambulances. The latter is too mobile and too frequently moved a unit to be thoroughly well equipped surgically, and, in addition, it

has been proved to be much better to move a patient before an operation to a place where he can be kept and nursed for several days rather than to move him directly after he has been operated upon.

Dressing and Distribution of the Wounded at a Casualty Clearing Station.

It is now the custom of all casualty clearing stations to dress their patients in large reception huts or tents as soon as they arrive, and to distribute them from this place in three classes: (1) For immediate evacuation; (2) for retention; (3) for operation. In the first class are included chiefly the slightly wounded. In the second class are patients suffering from shock, from the effects of bleeding, from wounds of the lung, from exposure to cold, etc. In the third class are all serious wounds of the soft tissues which require thorough dressing, and especially lacerated wounds due to shells and bombs; most fractures; many injuries of vessels; all perforating abdominal wounds, etc.

The proportion of cases requiring operations to the whole number of wounded will depend on many conditions —for example, the larger the proportion of shell wounds to bullet wounds the larger is the number requiring operation, and if a train is waiting to go to the base, men may be sent by it who would require operation if they had to be kept for thirty-six hours. But it may be stated in general terms that the proportion of patients treated under anaesthetics may be as high as one in four, but is more often about one in six.

The following table, compiled by Captain Hey, who is the Surgical Specialist at one of the forward casualty clearing stations, will give a very good idea of the operating work of a particular unit, and it includes a period of heavy fighting during a recent battle:

Table of Operations Performed at a Casualty Clearing Station.

A. Ligature of arteries:		
Carotid	...	5
Vertebral	...	2
Subclavian	...	2
Axillary	...	15
Brachial	...	39
Radial	...	18
Ulnar	...	8
Ext. iliac	...	2
Femoral	...	51
Popliteal	...	31
Ant. tibial	...	16
Post. tibial	...	58
Various	...	30
		277
B. For treatment of fractures:		
Skull	...	189
Vertebrae	...	18
Humerus	...	298
Forearm	...	133
Femur	...	299
Leg	...	309
Jaws	...	38
Various	...	119
		1,403
C. For treatment of joints:		
Knee	...	183
Other joints	...	64
		247
D. Amputations:		
Shoulder joint	...	14
Upper arm	...	77
Forearm	...	31
Thigh	...	186
Knee	...	10
Leg	...	76
Ankle	...	6
Various	...	31
		431
E. For drainage of pleura	...	49
F. For wounds of the abdomen	...	106
G. Removal of testis	...	33
H. For ruptured urethra	...	9
J. Enucleation of eye	...	43
K. Plastic operations	...	33
L. Tracheotomy	...	17
		280
M. Excision and cleansing of wounds:		
Head and neck	...	95
Trunk	...	309
Upper limb	...	249
Lower limb	...	765
Multiple	...	398
		1816
N. For conditions not due to gunshot wounds:		
Appendicitis	...	34
Strangulated hernia	...	1
Cellulitis	...	53
Various	...	13
		101

It will be seen that the total number of operations performed for gunshot wounds amounts to 4,554, and the total number of wounded admitted during the period in question was 20,589 in this particular unit. It will be noticed that a very large majority of the operations were for fractures of the limbs and wounds of the soft tissues which required complete surgical clearing. The proportion of abdominal operations would have been higher but for the fact that an "advanced operating centre" was near at hand, and took charge of many cases of this class.

During heavy fighting, operating work such as the above goes on continuously day and night, and consequently necessitates relays of surgeons, nurses, and orderlies. The work is exceedingly trying, and it must be reckoned on that not a few of the staff will be more or less knocked up after three or four weeks of it. But it is also quite certain that the early and thorough treatment of a very large proportion of all wounds has done more than anything else to save both much suffering and many lives.

ADVANCED OPERATING CENTRES.

It has sometimes been found that difficulties of locality have prevented the placing of so large a unit as a casualty clearing station exactly where its position should have been when heavy fighting has been expected, and in such cases a smaller unit has been placed so as to deal with the most urgent cases, and especially with those which required prompt operation. These small special hospitals of fifty to sixty beds have done excellent work, and a very large proportion of their cases have been abdominal wounds. The large number of the casualty clearing stations has prevented any necessity for creating many such units, for the casualty clearing stations are usually as well placed as is the special hospital, and the greater number of all the abdominal operations have been performed in them.

SPECIAL HOSPITALS.

Special Hospitals for Head Cases.

Operations for wounds of the head are dealt with in a subsequent section, and all that need be said here is that it has been found advisable to retain a considerable number of these cases near the front either in stationary or general hospitals, or else in a casualty clearing station of the reserve. They do not need the immediate operations required for abdominal cases, and are consequently provided for further back.

Special Hospitals for Shell Shock.

It is very desirable to remove such cases from the sound of shelling, and, as they require special treatment for some time, they also are dealt with in the rear of the front line of casualty clearing stations.

Special Hospitals for Diseases of the Skin.

These deal mainly, but not exclusively, with scabies, and the work is usually undertaken by the casualty clearing stations of the second line.

Stationary Hospitals at the Front.

A few of these units, which normally belong to the line of communication, also find a place at the front. So much of the work which would previously have been done in them is now performed by the casualty clearing stations that, in proportion as the latter have increased, the need for the stationary hospitals has diminished. Those that are at the front are commonly engaged more in the treatment of the sick than of the wounded, or else in treating some special class of case, such as injuries of the head or shell shock.

X Rays.

At the beginning of the war *x* rays were not supplied at the front, but, coincidently with the development of operating work in the casualty clearing stations, the need of these became apparent. At first mobile *x*-ray vans were supplied, but, as demands for these increased, it became necessary to supply stationary plants as well, more especially to those casualty clearing stations to whose share it fell to do most of the operations; and, not only have *x* rays been of great service in guiding the operator, but in many of the abdominal wounds where the missile has been retained they have been of the greatest service to the surgeon in deciding whether or no operation should be done at all. In many other cases, such as some of the wounds of the head or of the knee-joint, it has been found better not to undertake an operation without a preliminary *x*-ray examination, so that in the present stage of development of surgery at the front the *x*-ray plant has become essential for the work of the casualty clearing stations.

Anaesthetics.

At the beginning of the war chloroform was in general use, but it was evident that there were many objections to its universal application, and other agents were soon employed as well.

Ether has been largely used, and was formerly administered by the open method, but experience has shown that it is often inadvisable to use it thus because of its tendency to irritate the air passages. For at least six months of the year the men who are exposed to the wet and cold in the trench area are suffering in very large numbers from catarrhs of varying degrees of severity, and in many of them these are accentuated by the further exposure which follows on a wound, especially when a man falls or lies in mud or water. The result is that the administration of any anaesthetic commonly sets up so much bronchial irritation that the patient's life is endangered by an attack of bronchitis or bronchopneumonia. These complications are specially dangerous in cases of abdominal wounds where abdominal respiration is difficult and where coughing up of mucus is often impossible because of pain or intestinal distension. It is indeed a fact that a very large proportion of all the deaths following abdominal wounds and operations are due to lung complications, and these injuries are at least twice as fatal in the winter as in the summer.

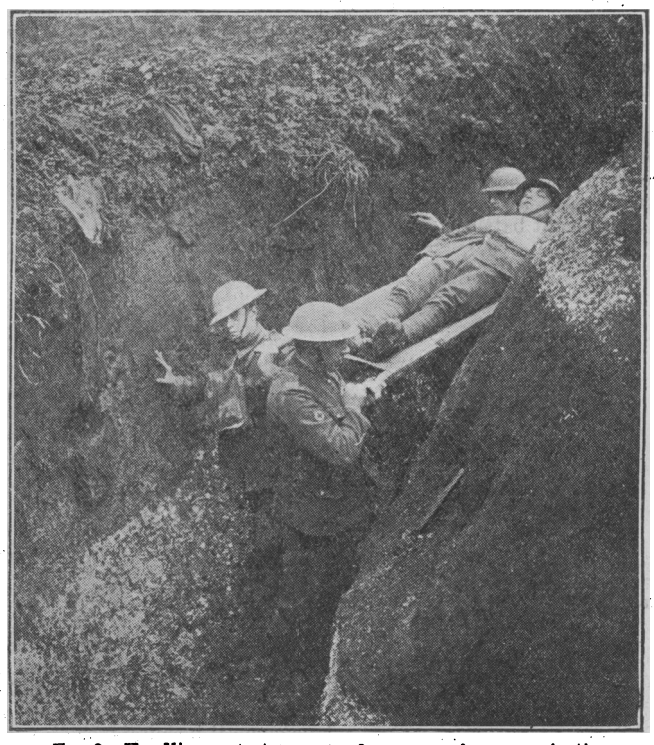


Fig. 2.—Handling a stretcher round a corner of communication trench.

Dr. Shipway's apparatus for the administration of warm ether vapour has been of the greatest value under those circumstances, and it is in common use in all the clearing stations. We have found that it possesses the following advantages:

1. There is very little secretion of mucus or saliva, and the patient is very quiet during the operation.
2. There is less sickness, probably because of the lessened quantity of mucus swallowed.
3. There is much less tendency to bronchitis and pneumonia.
4. The ether used is not more than one-third of that employed by the open method, and, as a consequence, it bulks less largely in transport.
5. Patients suffering from shock or haemorrhage can be pulled through an operation with less collapse than by other methods.
6. It can be connected with an oxygen cylinder, and the ether vapour can be administered in combination with oxygen in cases of shock.

The subject of the administration of anaesthetics at the front is decribed more fully in the paper by Captain Geoffrey Marshall printed on a later page.

The Use of Antiseptics.

It may be stated in general terms that it is the custom at the front to use antiseptics in the treatment of wounds, both at the field ambulances and the casualty clearing stations. No attempt is made to use antiseptic agents to disinfect the wounds on the field at the time of injury, for all who know the character of the wounds and the conditions of the wounded men, are agreed as to the complete futility of all such efforts, even if this had not been completely demonstrated during this war. But experience has also shown that in France and Belgium the wounds are so heavily infected from the soil that it is most necessary in all but the smallest wounds to excise very freely all the exposed and torn tissues which have been killed or else partially devitalized by the injury, and which are ingrained with dirt or portions of clothing. If this treatment is not carried out very thoroughly and carefully, and if free drainage is not secured, the gravest forms of sepsis may commence in serious wounds in a very few hours. It is common experience that if a badly wounded man cannot be rescued and brought into the field ambulance until after the lapse of twenty-four or thirty-six hours, the wound is often already so badly infected and the patient himself is in so toxic a state that surgical treatment has but little chance. It may be said truly that the most important alteration in treatment since the early days of the war is that excision of damaged tissue has become the routine method and that the earlier it is carried out the more likely it is to be successful.

"*Eusol*" and "*Dakin's Fluid.*"

Very many antiseptic agents have been employed, and there is naturally some diversity of opinion as to which is the best. There is no doubt, however, that at the present time hypochlorous acid in the form known as "eusol," or the hypochlorite of soda in the solution known as "Dakin's fluid," are more extensively used than any others. The method of Dr. Carrel has been increasingly employed for the past year, and wounds treated in this way have done exceptionally well, although it is not always possible to employ the method universally at a time when the wounded are in very great numbers. At other times there is no difficulty, and in order to establish continuity of treatment Dr. Carrel's method is freely employed on every ambulance train taking wounded to the base hospitals.

Hydrogen Peroxide.

This is not highly esteemed as a potent antiseptic, but it is of great service in loosening adherent dressings, and so preventing pain and injury to the soft tissues by forcible separation of gauze or wool.

Carbolic Acid.

At an early stage of the war, and in consequence of representations made by surgeons in England, attempts

were made to sterilize recent wounds by pure carbolic acid. They entirely failed to achieve this object, but solutions of a strength of 1 in 20 or 1 in 40 are in common use, and many surgeons have had a very favourable experience in using equal parts of solutions of carbolic acid and hydrogen peroxide.

Sodium Chloride.

The hypertonic salt solution has not proved successful at the front, and at the present time is hardly used at all. The wounds treated by it were usually very slow in healing, and the granulations were generally pale, flabby, and much overgrown. There has also been a good deal of evidence to show that secondary haemorrhage is not nearly so frequent an occurrence since hypertonic saline has been displaced by other antiseptics. This is not at all surprising when it is considered that rapid cicatrization is the best safeguard against this complication.

The salt pack largely used at Rouen is also to a great extent supplanted by the employment of "eusol" and "Dakin's fluid." It is, however, at the front a useful method of treatment of large open wounds in patients who are in transit by train. It does not need to be disturbed for several days, and when there are large numbers of wounded to dress this is a very great advantage.

B.I.P.

The mixture of bismuth subnitrate, iodoform, and paraffin, recommended by Professor Rutherford Morison for suppurating wounds (B.I.P.), has also been used for the past few months on recent wounds of the soft tissues, and also in cases of fracture. The results have been good, and encourage the further use of this remedy at the front. The fact that the wounds do not need dressing for several days gives it the same advantage as the salt pack, while its use permits of an early closure of the wound, and this is an additional advantage.

FIG. 3.—Advanced dressing station of field ambulance.

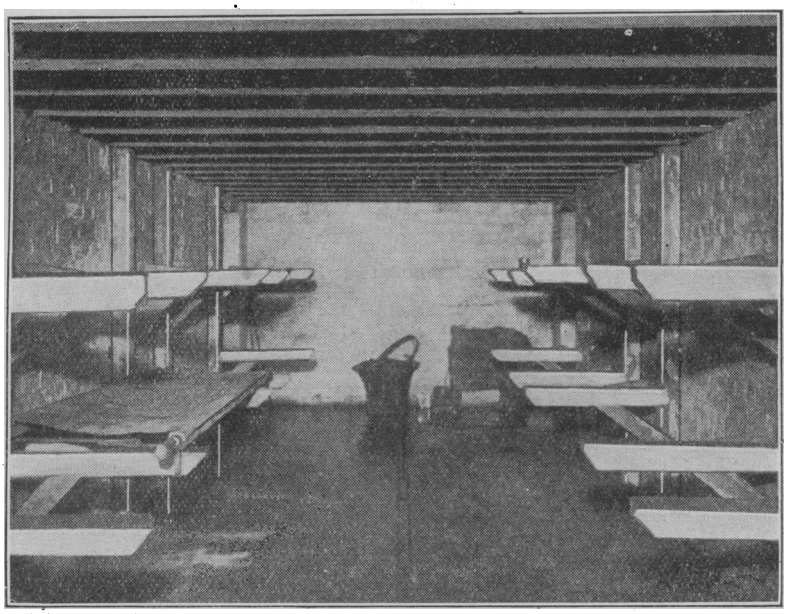


FIG. 4.—Interior of advanced dressing station.

SHOCK, AND THE CONDITION OF WOUNDED MEN.

The condition of wounded men necessarily differs as wounds are more or less severe, but in even slightly wounded men there may have been much bleeding, exposure to cold, want of sleep, or want of food. If to these are added severe pain and the exhaustion due to a hazardous journey over broken roads, it is easy to appreciate that very many patients arrive in a state bordering on collapse. Experience has shown, as a result of knowledge of these conditions, that it is not possible to estimate accurately the real condition of the patient until he has been rested and warmed, and has taken food; and especially in winter time the most important of these remedial measures is undoubtedly warmth. This may be applied by warm blankets after the removal of wet clothes, or by hot bottles. But in more severe cases we employ a "light bath" of electric lamps beneath a cradle, or else a "hot-air bath" extemporized by leading under the bedclothes a pipe connected with a primus stove. Hot liquid food is good if the patient can take it, but he is often nauseated or actually sick in the worst cases of shock, and then small enemata with brandy are very useful. Warmth and rest are, however, of more importance than nourishment, and if the patient goes to sleep, as he very often does, it is best to leave him undisturbed for some time.

PRIMARY AMPUTATIONS.

Unless a man is bleeding it is usual to treat him as has just been described before any operation is performed, but it is often necessary to postpone amputation for as long as a day, or even two days, if the removal of the limb is to be done at the thigh. Many men will survive if they are allowed sufficient time to get completely over the shock of the injury and its attendant conditions, who would certainly die if subjected to immediate operation, and the more experienced the surgeon the less is he likely to hurry on a severe primary amputation.

It is, of course, evident that delay in removing a badly smashed limb may result in dangerous sepsis, and there is no doubt that the threat of gas gangrene may necessitate operation earlier than might be wished. Much must therefore of necessity be left to the discretion of the surgeon in

each case, and, as it is only after a considerable experience at the front that really sound opinions can be formed, it is very necessary that those who have not had this experience should seek the advice of those who have before a decision is come to in a doubtful case.

Other questions concerning the treatment of shock and the use of saline infusions are dealt with in Captain Marshall's communication on anaesthetics at the front.

When the condition of the limb and of the patient permit, a primary amputation should be performed by one of the recognized methods practised in the usual circumstances of civilian surgery, suitable flaps being provided. It is, however, never right to neglect drainage of the stump, and this should always be secured by the use of a large drainage tube, at any rate for a period sufficient to ensure that no serious sepsis exists.

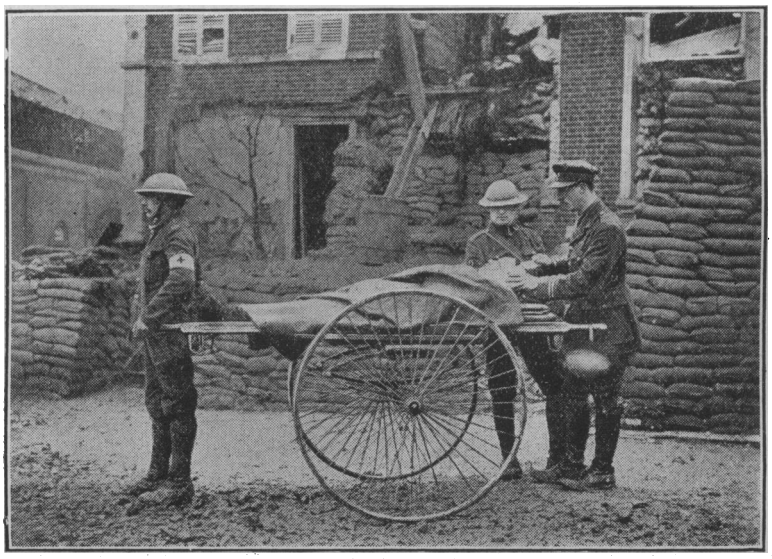


FIG. 5.—A wheeled stretcher.

The seat of amputation has been much discussed, but in our experience the best general rule is that as much of the limb as possible should be saved, quite regardless of the typical "seat of election" as prescribed in former years; primary amputations through joints are, however, as a rule to be avoided.

Departure from these ideals may be necessary, either because of the condition of the patient himself or of his limb.

If the patient is desperately ill from the combined effects of loss of blood and other complications his condition may be such that the additional shock of a high amputation may be quickly and inevitably fatal. In a pulseless patient who has a numbed and still oozing limb the best thing is to remove it as quickly as possible by cutting through the soft tissues at the site of fracture, subsequently clipping away torn and ragged tissues and tying the main vessels.

Not more than ten minutes need be spent on such an operation, and, if it is conducted under the influence of gas and oxygen anaesthesia, many apparently hopeless cases can be saved, for there is very much less shock than would be entailed by either a longer operation or by the cutting though healthy and sensitive skin and muscle higher up the limb In such a case the making of a suitable stump must be left to a future time.

In another class of case the leg or the forearm may be smashed beyond recovery, while the thigh or the upper arm is the seat of other severe wounds complicated by the presence of mud, of portions of shell, or of clothing. It is quite unwise in such a case to amputate high up the limb, and it is best to perform a "flush amputation" close above the fracture, and again leave to the future the formation of a useful stump at a time when the damaged tissues have recovered. If this is not done, not only is the patient exposed to more severe shock by a high amputation, but his stump may slough and a yet higher up removal may be necessary if he ultimately does survive.

FIG. 6.—To show how compact the wheeled stretchers are when closed.

WOUND INFECTIONS.

It is well known that in France wounds are liable to be very heavily infected by numerous pathogenic organisms, and inquiry from surgeons who have had experience in other theatres of warfare enables us to say that, especially in Egypt and in the Dardanelles, the gas gangrene and tetanus infections were notably much less common than they are in France.

While no time of year or condition of weather brings immunity, it is very evident that wet weather and mud are far more dangerous than summer weather and dust; and this danger is much increased when patients are wounded in very cold weather and are thoroughly chilled before they can be brought in. Most surgeons are also agreed, that the coldness and lowering of vitality caused by severe haemorrhage have a similar predisposing effect on microbic infection, and it will be found that wounded men are attacked by tetanus and gas gangrene in proportion as the various conditions exist which are inimical to the human organism. It has also been noted that gas gangrene has often affected wounds in patients who have subsequently developed tetanus also.

GAS GANGRENE.

This disease appeared very early in the war and was a very unpleasant surprise to the surgeons. It had not been described as a usual complication of gunshot wounds, and though seen occasionally in civil life, so that its etiology was known to a certain extent, it was sufficiently unfamiliar to render an accumulation of experience necessary for its proper treatment.

Two clinical types of the disease were recognized early and were named "gaseous cellulitis" and "massive gas gangrene." The former term was applied to the milder cases in which the cellular tissue round the wound was considered to be the primary seat of the disease; the latter

term to those cases in which the whole limb was rapidly affected and died. The milder type of the disease was treated by incisions and drainage, the severer type by amputation.

From a clinical point of view it was found that the conditions that favoured the onset of the disease were: (*a*) The retention of extravasated blood and wound secretions, (*b*) interference with the circulation, (*c*) the presence of large masses of partially devitalized or dead tissue, (*d*) extensive comminution of long bones, (*e*) the presence of particles of clothing in the depth of the wound. Each of these observations was quickly turned to account in the treatment of cases in which the disease might appear.

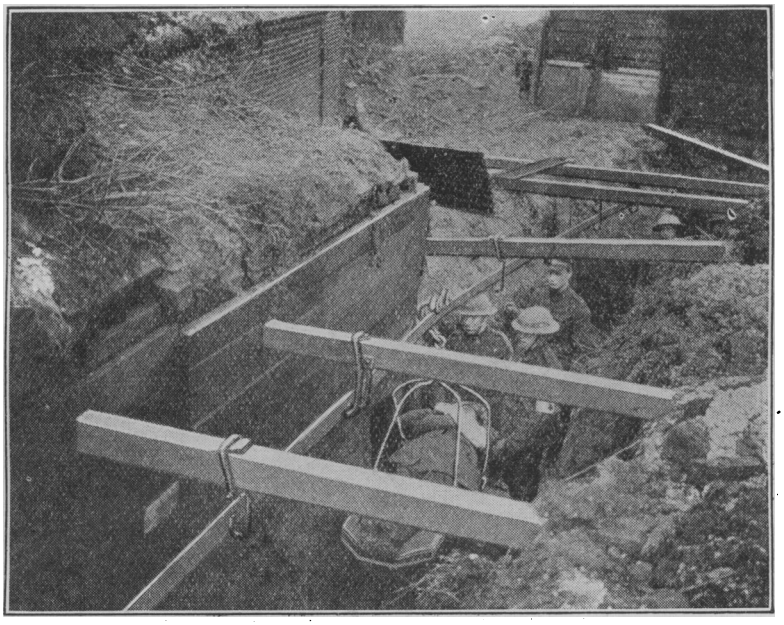


FIG. 7.—Overhead railway ambulance trolley.

RETENTION OF BLOOD AND SECRETIONS.

The avoidance of the retention of blood and secretions necessitated the employment of some sort of dressing that would not dry and cake during the transit of the patient to the casualty clearing station and from there to the base. Thus the dry gauze and wool dressing was abandoned for one that would keep moist and favour the discharge of blood and serum. It did not seem to matter what chemical was used so long as the dressing remained moist.

INTERFERENCE WITH THE CIRCULATION.

Interference with the circulation was brought about in several ways. First there was the tourniquet. Every effort was made to dispense with this instrument, and where this was not possible the patient was taken with all celerity to the nearest place where the haemorrhage could be stopped. Circular bandages were found also to be a source of trouble, especially when the bandages took the form of a gauze dressing wrapped round and round the limb, which mode of application was very tempting in treating multiple wounds.

FIG. 8.—Two light railway ambulance trolleys.

In simple flesh wounds it was easy to arrange that the bandages and dressings should be loosely applied, but in the case of fractured lower limbs it was necessary to obtain some fixation of the limb, for the movement of the bones was not only painful to the patient, but calculated to produce further damage to the soft parts. The adoption of the Thomas splint largely solved this part of the problem, but there were and still are difficulties in the way of its adoption as far forward as is desired. Some fractured lower limbs are still sent to the casualty stations with the old Liston splint; the rapid evacuation of all wounded that now pertains has, however, lessened considerably the disadvantages of this splint.

The arrest of the blood supply to a segment of a limb by the rupture or thrombosis of an artery has so far baffled the surgeon. Attempts were made by suture and the employment of Tuffier's tube to restore the circulation, but, so far, have not met with the success that was hoped. All that can be done is to favour the collateral circulation in every way.

DEVITALIZED TISSUE.

The devitalized tissue that formed a nidus for the development of the gas-producing organism was got rid of by excision through the opened wound, and as the attention paid to this mechanical cleaning of the wound became greater so did the results improve.

BACTERIOLOGY.

While surgeons were working out the best methods of treatment the bacteriologists were studying organisms found in the wounds, which were nearly all infected with many varieties of amoebic bacilli. Many bacteria were found, but the blame could not be definitely fixed on any one organism, and in many cases there was a mixed infection. The *Bacillus aërogenes capsulatus* of Welch was found present in the greater number of cases. The interesting and important observation was, however, made that the numbers of gas-producing organisms steadily decreased with the lapse of time, whilst the pus-producing organisms increased. This bacteriological fact corresponded with the clinical observation that the likelihood of gangrene occurring became steadily less as the wound became older and suppuration more obvious.

Our knowledge of the disease, both from a bacteriological

and clinical point of view, remained much in the above condition for a long time. The following points were always being debated:

(*a*) What were the organisms capable of producing the disease?

(*b*) Could any one bacterium alone cause the gangrene?

(*c*) If not, what mixture might be necessary and what part did each organism play in the clinical picture?

(*d*) What tissue was primarily and chiefly affected?

(*e*) How did the disease start, and what was the cause of the extraordinary rapidity with which the condition spread?

(*f*) What was the reason of the return of the disease after an amputation through apparently healthy tissue?

(*g*) What was the nature of the poison that caused the death of the patient?

FIG. 9.—Light railway stretcher carrying four wounded.

It cannot be said that a complete answer to any of these questions has been found, but some suggestive work has been done. For answers to the first three questions (*a*), (*b*) and (*c*), the reader is referred to the statement by Captain Herbert Henry, R.A.M.C., which will appear later.

In answer to the fourth question (*d*), Kenneth Taylor, a member of an American ambulance near Paris, stated that he believed that the disease was essentially a disease of the muscles. Some clinical observers working in the British army have supported this view It was found that gas gangrene seldom produced serious symptoms unless muscle was infected, and that the muscles might be killed and gaseous while the intermuscular planes remained little altered. It was also pointed out that single muscles and muscle groups were very apt to be picked out while others remained healthy. It was noticed that invaded muscles were nearly always muscles that had been wounded. The disease would spread up and down these, but showed little disposition to pass to their uninjured fellows. Advantage was taken of these facts to excise those muscles affected, and thus arrest the disease without recourse to amputation.

It was further recognized that crepitations and colour changes in the skin might be comparatively late manifestations of the disease and that death of the muscles might take place before these signs were evident. Vomiting, a rapid pulse, and a tympanitic condition of the limb came to be more and more relied on as symptoms of the disease and as an indication for immediate interference. It became apparent that the discoloration of the skin was due to arrest of the blood supply, brought about by the death of the underlying muscles, and that crepitation was largely due to a forcing out of the gas generated in the muscles into the intermuscular planes and subcutaneous tissue, and that the crepitation in muscle was really a very late stage in the process of disintegration.

When gangrene occurs in a segment of a limb distal to the point at which the main vessel has been obstructed, all the muscles are affected, and the process appears to be similar to that which takes place in the body after death, though the actual route by which the organisms gain entrance is undecided.

As muscle became infected it was found that the normal purple-brown colour altered to a dirty brick red, and that this change took place before the muscle became crepitant to the finger. Advantage was taken of this observation to distinguish between healthy and hopelessly infected muscles.

In some cases the connective tissue was found to be the seat of the disease, especially the retroperitoneal tissue when infiltrated with blood.

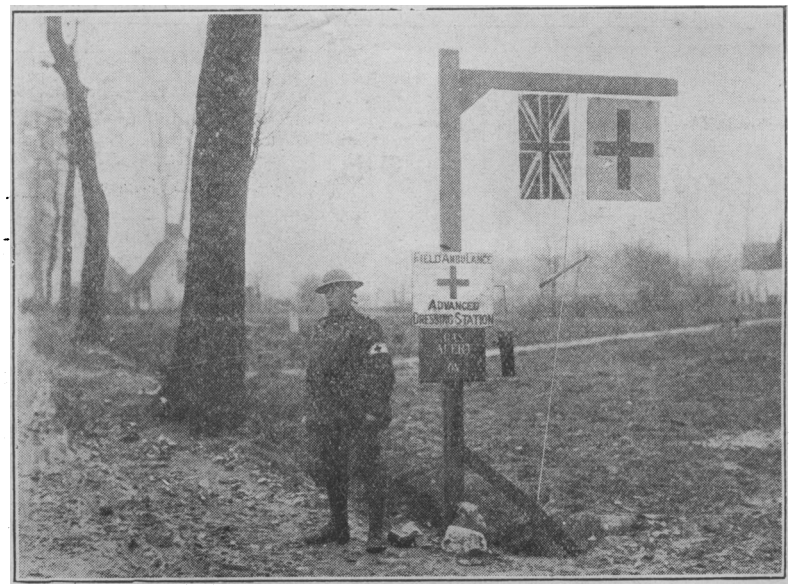


FIG. 10.—Outside an advanced dressing station. Each of such is marked with flags as shown.

Metastatic infections at the site of saline injection were described by McNee, Mullally, and other observers. This observation is important, for it may explain in part the return of the disease after amputation.

(*e*) When all wounds were infected by the gas producing organism, why should some pursue a normal course and others give rise to gangrene? If it is accepted that this disease is mainly one of muscle, some measure of explanation is afforded. The question still remains, Why do some muscle wounds lead to gas gangrene and others not?

Most observers believed that the organisms could only live in dead muscle. In every muscle wound there is dead muscle; but if the diseased condition should spread, the organism, on the assumption that the bacillus could only live in dead muscle, must be able to kill the muscle. How did it do this?

D'Este Emery, who had been impressed with the

repeated return of the disease in amputation stumps and its rapid spread, in a most suggestive paper showed that the poison produced by the *B. aërogenes capsulatus* had a powerful negative chemiotaxic influence on the leucocyte. These experiments performed *in vitro* were in strict consonance with the histological observation that there is no leucocytosis where gas gangrene is active, and that the leucocytes only appear when the disease is in process of arrest. D'Este Emery's observation appeared rather to explain the non-arrest of the disease than to account for its rapid spread.

Taylor thought that there might be two factors. In the first place, as the toxin produced by the organism was found to be little toxic, he suggested that the toxin elaborated by the breaking down of the muscle might cause the death of the contiguous muscle substance. He also suggested that the presence of the gas generated produced disintegration of the muscle, and thus made it a pabulum for the bacilli.

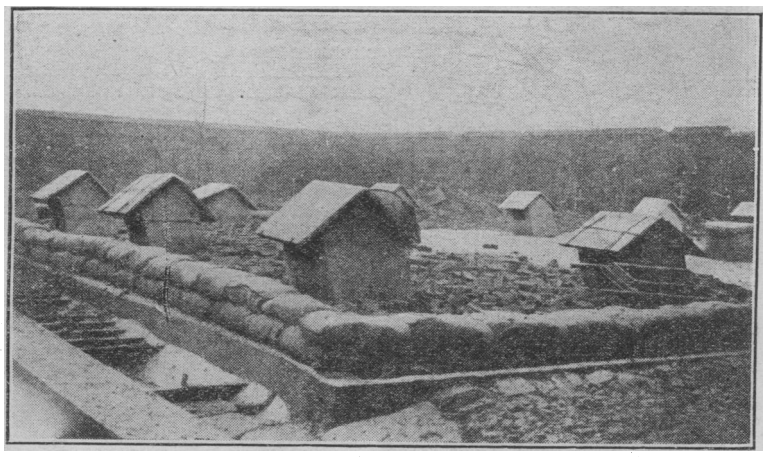


FIG. 11.—The ventilating shafts of an advanced dressing station.

McNee and Dunn have offered the following explanation:

The bacteria which are responsible for the causation of gas gangrene lead their normal existence as saprophytes in decaying organic material. When these organisms obtain access to tissues which have already been devitalized by loss of blood, they find an environment entirely suited to their growth, and proliferating readily, they produce gas and liquefaction of the tissues. This process is simply the uncontested invasion of dead material by bacteria, and it is entirely similar to what may occur in the whole body after death. The problem which has presented greater difficulties, and which possesses the graver interest, is the manner of involvement of living tissues by gas gangrene. The causal organisms are known to exhibit only slight general pathogenicity. If pure cultures of them are injected subcutaneously into animals the effects may be surprisingly slight and transient. The organisms are most frequently unable to establish themselves in the healthy undamaged tissue, and are soon destroyed by phagocytic action. The effect, however, is considerably greater if the bacilli are injected into muscle, and especially if some damage is caused at the site of injection. In this way the whole picture of a spreading gas gangrene has been produced in the leg of an animal by inoculation of a pure culture of the *Bacillus aërogenes capsulatus*.

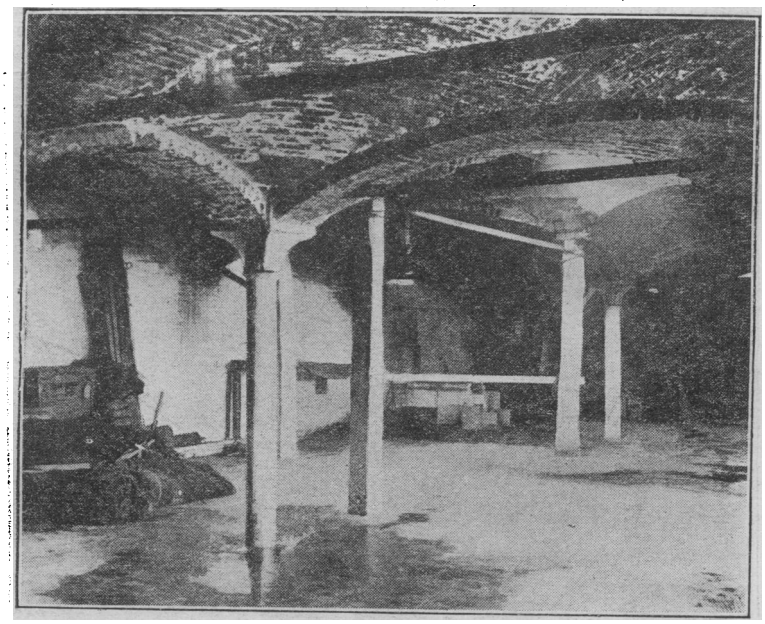


FIG. 12.—Advanced dressing station. Where the patients are received.

The mere presence of the anaërobic bacilli in the muscle does not necessarily entail death of the fibres, for the organisms have often been recognized in sections, and have been successfully cultivated from portions of muscle which were remote from the gangrenous area and still contractile. How, then, does death of the fibres arise?

The rapid spread of gas gangrene into living voluntary muscle depends mainly on the peculiar anatomical conformation of that tissue. At the advancing edge of the gangrenous process only a limited number of muscular fibres are necrosed. The dead fibres, in contrast with the normal ones around them, are separated off from their vascular sheaths by spaces filled with fluid. As the stripping of these sheaths is coincident in extent with the histological appearance of coagulation in the fibres, it is suggested that coagulation is caused by a toxic fluid permeating and filling the sheaths. At this stage organisms are not more numerous than may be found in living muscle higher up. The toxic material is presumably derived from the action of organisms on the tissues lower down. In a slightly more advanced stage the above alteration is found to extend to all their fibres and their sheaths, and bacilli are met with in greater numbers. Later still the whole of the tissue elements are invaded by the bacilli, and undergo extensive distortion and disintegration.

The above outline suggests a process which, once started, may maintain itself indefinitely, for the progressive death of the muscle permits further luxuriant growth of the organisms and extension of their lethal effects. The sugar content of muscle is favourable to the growth of the anaërobes, and the result is the production of a highly toxic fluid. The primary infection no doubt occurs in the wound in lacerated ends of fibres which are healthy in the rest of their length, and the establishment of a gangrenous process is permitted by this continuity of structure.

RECURRENCE AFTER AMPUTATION.

(*f*) In discussing the question why the disease sometimes recurs in an amputation stump when the operation has been done through apparently normal muscle, it seems necessary to distinguish between two types of amputation:

1. An amputation through the upper healthy part of muscles, the lower portions of which are gangrenous.
2. An amputation through muscles which are normal throughout their length, as in removal of the thigh for gangrene of the leg.

McNee and Dunn have shown that the *B. aërogenes capsulatus* is found in healthy contractile muscle far beyond the gangrenous edge. As the only clinical test we have of healthy muscle is its normal colour and its contractility, it may happen that an amputation through such muscle may still leave numbers of bacteria in the stump.

This explanation does not seem sufficient. The fact that metastatic infections appear from time to time shows that bacilli may be floating in the blood. Should this happen in a case submitted to amputation it is possible to conceive that they may find a resting place in the muscle damaged by the amputation and thus start the disease afresh.

(*g*) At present the nature of the poison and its mode of action are unknown.

FIG. 13.—Interior of an advanced dressing station: Operating theatre.

TREATMENT.

The treatment in vogue at the present moment, and based on the above observations, may be summarized as follows:

Preventive.

The wounds are opened up and all dead tissue and foreign bodies removed and adequate drainage provided. The circulation is encouraged in every possible way.

When the Disease is Established.

(*a*) When gangrene appears in a segment of a limb where the main blood supply has been interrupted higher up the only treatment is amputation.

(*b*) When the gangrene appears in the muscles or muscle groups actually wounded. Here the treatment must depend on the condition of the patient. If this is good the wounds are freely opened and the affected muscles or muscle groups removed. The test employed to distinguish dead from healthy muscle is the want of contractility or the presence of the brick-red colour.

Even with the gangrene localized to certain muscles amputation is the safest course if the general condition is bad, and it is seldom possible to save such a limb if the bone is broken.

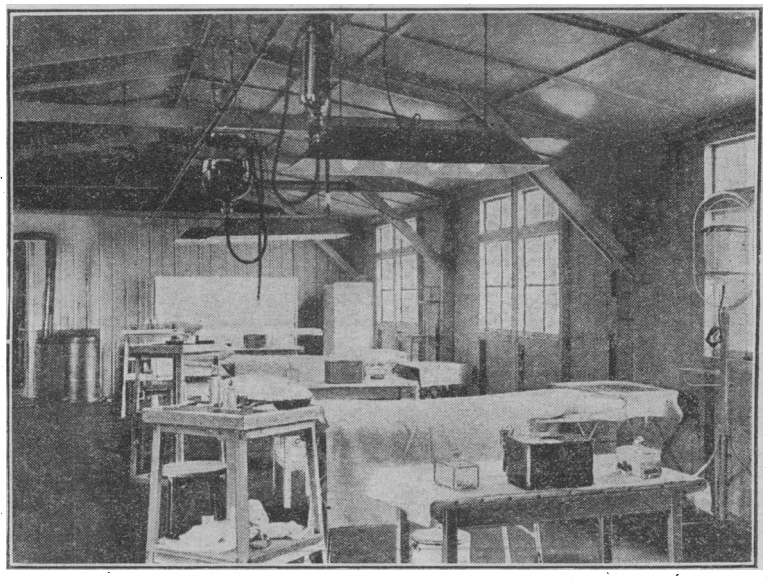


FIG. 14.—Operating theatre at a casualty clearing station.

ABDOMINAL WOUNDS.

SURGICAL OPINION WHEN THE WAR STARTED.

For many years it had been held that the operative treatment of abdominal wounds was not to be advised under war conditions. This was partly due to want of success, as in the Spanish-American war, and partly to the fact that many military surgeons were opposed to extensive operating anywhere near the firing line; as abdominal surgery, to be successful, must be done at once, it is obvious that it could not be undertaken with success where all operations had to be postponed to a late period. Although the expectant treatment was the orthodox one when the South African war broke out, many surgeons at that time hoped to prove that it was wrong. Surgeon-General W. F. Stevenson even issued an appeal for the trial of operation. The result was, however, only to confirm former opinion, though this opinion was now held on two somewhat different grounds. One school held that the expectant treatment was in itself the right procedure, the other that it was the best that could be done in war.

Some believed that wounded intestine healed sufficiently often to warrant abstention, others believed that small gut lesions were practically always fatal, and that the success obtained by the "wait and see" policy was due to the escape of the bowel from injury, although the belly had been penetrated. The opinion that it is possible for the small gut area to be traversed by a rifle bullet without injury has been proved to be correct in this war. A study of the literature of the South African war, both private and official, makes the real reason for want of success in operating at once obvious—the cases arrived too late. It was not so much a question of the success of the expectant treatment as failure of the operative, and the two strikingly successful cases of resection of small gut (Neale and Tuke) were operated on within six and twelve hours of injury respectively.

The reason for the late operation was the nature of fighting in an unsettled country of great distances. The wounded could not be quickly brought to a hospital with the necessary appliances. To operate in the veld with what appliances were at hand was too disheartening. It was impossible to get even moderately good conditions. There was little or no water, and what there was was often too filthy for words—the water of dams. In addition, there was the plague of flies that settled on everything.

The conditions were utterly different from those that pertain at the present time. This is the first time since the rise of abdominal surgery that a great campaign has been fought in a settled country, and, what is more important still, with a fixed fighting line.

The small number of cases dealt with in the South African campaign was also a source of error, for in order to form an adequate idea of the efficacy of any treatment it is necessary to strike an average over a large series of cases.

The statistics of the South African campaign are very defective. Surgeon-General Stevenson in the official history of the war was only able to collect 207 cases of abdominal wounds. Among them it is stated that there were 26 laparotomies with 18 deaths, a mortality of 69.2 per cent., and according to Stevenson the mortality was really even worse. The total death-rate of all abdominal wounds quoted—operated and unoperated—is given as 30.4 per cent.

In the same author's most recent work, *Wounds in War* (1910), the mortality is shown as 51.6 per cent. for laparotomies, the total of cases remaining the same—namely, 207. In any case the figures are really too small to have any real value.

In this present war one of the difficulties of establishing the operative treatment was the run of bad luck which any operator might have to face. Even now, with conditions as nearly ideal as possible, a series of nine consecutive fatal cases may be met with. This must have a very depressing effect on any surgeon, especially on one who is not yet convinced that the operative treatment is in the main the best of all. Now nine abdominal cases means roughly about 600 wounded men, taking a moderate estimate of the proportion of abdominal wounds to total wounds.

As a matter of fact, in the South African campaign a casualty list of 600 wounded was considered a large one, and if an operator happened to encounter such a series of fatalities, it is not a matter of surprise that he should have had doubts as to the correctness of his procedure.

Statistics in the present campaign show that an operative mortality of 50 per cent. is a good result, but such a mortality in civil practice would be considered an awful death-rate to face. And yet it means, looking on the bright side, many lives saved.

The South African campaign may, then, be said to have left surgical opinion opposed to operation, but it must always be remembered that not only were there practically no shell wounds in that campaign, but also that the ogival bullet was a much less harmful missile than the sharp-pointed bullets of the present war.

Method of Treatment in the Earlier Period of the War.

In the retreat from Mons and on the Aisne adequate provision for the performance of abdominal operations near the front was well-nigh an impossibility, and all that could be done was to send the wounded to the base with the least possible discomfort to them. When, in the ensuing winter, the line became fixed the circumstances were very different, and there soon developed a possibility of operating under good conditions. It was no longer a question of whether a man could be operated upon, but whether he should be operated upon. Still, however, a good deal of the old belief in the efficacy of the expectant treatment obtained for some time longer. A man wounded in the abdomen was sometimes kept in a dug-out in the trench system; often he was kept at a field ambulance, usually he was transferred to the casualty clearing station and there treated.

The customary mode of procedure was to put the man in the Fowler position, to improve the general condition by rest and warmth, to withhold food and water for three days and to administer morphine. The thirst, which was a distressing symptom of this treatment, was combated to a certain degree by rectal salines and mouth washes.

A tribute must here be paid to the great care and attention which the medical officers lavished on the patients. Certain officers were told off day and night to attend to them and everything possible was done to alleviate their suffering and to make them as comfortable as possible and to cheer them up. If anything could have got these men well the attention that they received would have done so, and it must be remembered that the medical officers who conducted the treatment were convinced of its efficacy.

This belief was strengthened by the behaviour of many of the patients, for some who were at first gravely ill, went through a period of improvement which often was very striking. It was in a way unfortunate, but there is no doubt that improvement did take place, and so well were many of them that after several days they were evacuated to the base and arrived there sometimes in fair condition, although more often gravely ill. But the surgeons who had seen the cases leave the casualty clearing stations apparently on the way to recovery could not at first bring themselves to believe that they did badly at the base, and if evacuation had not been necessary and it had been possible to keep patients at the casualty clearing stations the expectant treatment would not have survived as long as it did, for medical officers would have seen many such cases become worse and worse, and in the end—die.

Commencement of the Operative Treatment.

Although rest treatment was the rule, some attempts at operation had been made as early as November, 1914; but it was only when the more complete development of the casualty clearing stations provided satisfactory conditions that surgeons felt that their opportunity for operating had arrived, and during the winter of 1914–15 operations were done by several medical officers. But the early results were undeniably bad—so bad that most people abandoned the attempt, and the reasons for failure were no doubt both the late arrival of the patients at a place where an operation could be performed and the want of knowledge which later on was acquired by experience alone, for there was no literature which dealt with such injuries as the surgeons were now called on to treat, and each man had to learn the best methods for himself.

Owen Richards was the first to publish results of operative treatment in the British army.[1] His first operation was performed on January 28th, 1915, and the first successful operation, that of a resection of 2½ ft. of the small intestine, was performed on March 18th, 1915, thirty-six hours after the injury was received.

In May, 1915, an inquiry into the causes of death after abdominal wounds established the following facts:

1. That the injuries were as a rule of such a nature that recovery must be a very rare event.
2. That haemorrhage was a chief cause of early death.
3. That bullets produced very extensive injuries.

It had always been granted that haemorrhage was the chief cause of early death, but the advocates of expectant treatment seem to have focussed their attention more on the danger of peritoneal infection and the possibility of its localization or disappearance than on the possibility of spontaneous arrest of haemorrhage.

The discovery that bullets produced extensive gut injuries was also of great importance, as much stress had been laid on the smallness of the lesions produced by the modern small bore bullet, and the expectation of spontaneous recovery of gut lesions had been based on the quite erroneous assumption that such projectiles were comparatively innocuous.

The re-establishment of the fact that haemorrhage was the chief cause of early death was of great importance, as it showed that only rapid evacuation afforded any hope of combating such a condition. Arrangements were accordingly made to ensure that all patients suffering from abdominal wounds, and who were not too ill for transport, should be sent by special motor ambulances to the clearing station and not retained in the field ambulance. At the same time meetings of the medical officers of field ambulances and regiments were held at different centres, so that it could be demonstrated to them that the lesions of the hollow viscera were much more extensive than they had believed, and that in such conditions early operation gave the only chance of recovery. The result of this diffusion of more accurate knowledge was soon seen in the much earlier arrival of patients, and the greatest praise is due to all those who combined in the effort to rescue the men and convey them to the rear as rapidly as possible. The consequences of these improvements soon became apparent in the saving of many lives, and the operative treatment, now that it was placed under favourable conditions, very soon won for itself the confidence of the medical service, and quickly became universally adopted.

Where to Operate.

The British practice has been to operate a short distance behind the line, and the wisdom of this has been demonstrated. Here it is possible to operate under good

conditions and to nurse the patient among cheerful surroundings for a week or more subsequently.

The casualty clearing stations have, as a rule, been used for this purpose. If for some local reason it has not been possible to put one sufficiently far forward at any one part of the line, a small operating centre has been opened for

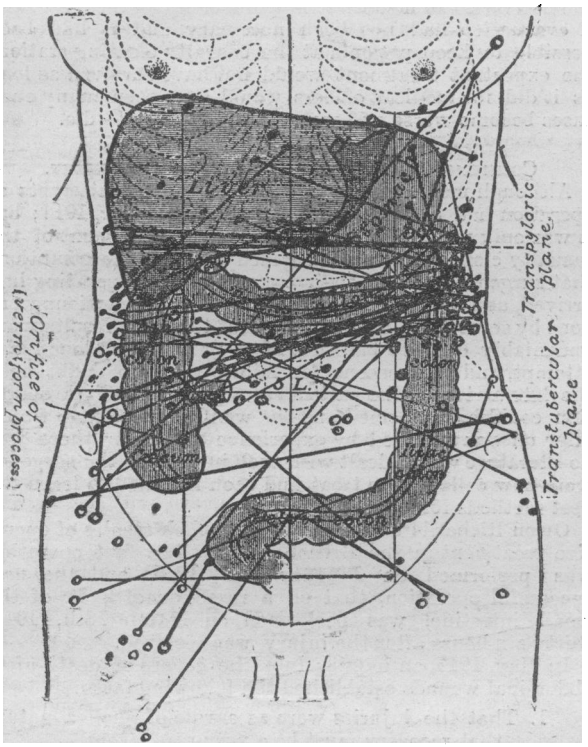


DIAGRAM 1.—No operation. Died.

the reception of abdominal and other urgent cases. The influence of time is shown very clearly in Table I.

TABLE I.—*Effect of the Time Elapsed between Receipt of the Wound and Arrival at the Operating Centre.*

Total number of cases 591.

Hours:	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	Over 20
To base ...	3	30	75	55	34	19	7	4	11	4	27
Died ...	2	30	53	59	41	23	10	12	15	11	56
Total ...	5	60	128	114	75	42	17	16	26	15	83

A very significant fact comes out from a study of the next table (II)—namely, that of 145 patients with a pulse above 120 only 16 recovered.

TABLE II.—*Prognosis from Pulse-rate.*

Total number of cases 577.

Pulse up to:	60	70	80	90	100	110	120	130	Over 130
To base... ...	1	7	23	30	108	27	37	7	9
Died	1	2	13	18	39	38	88	37	92
Total... ...	2	9	36	48	147	65	125	44	101

Table III shows that bullet wounds are highly fatal.

TABLE III.—*Relative Mortality of the Different Projectiles.*

Total number of cases 629.

	Bullet.	Shell Fragment.	Shrapnel.	Bomb.
To base	91	105	15	60
Died	106	154	40	58
Total	197	259	55	118

TABLE IV.—*Relative Number of Different Projectiles and Proportion Retained.*

Total number of cases 834.

	Bullets.	Shell Fragments.	Shrapnel.	Bombs.
Passed out ...	203	30	15	6
Retained	131	254	67	128
Total	334	284	82	134

The Most Dangerous Wounds.

The chart (Diagram 1) shows the entrance wound or the course of the projectile in cases that arrived too bad for operation.

Possibility of Escape of Hollow Organs after Penetration of the Abdomen.

Diagram 2 shows the course of the projectile or its place of entrance in those cases in which coeliotomy proved that no hollow alimentary viscus had been penetrated. In some such cases many organs were bruised.

A certain number of cases of rupture of a hollow viscus without abdominal penetration have occurred, and have made it advisable to explore the intestine in some instances even when the whole thickness of the abdominal wall was not penetrated by the missile, but where the symptoms have pointed to the probability of a lesion of one of the hollow viscera.

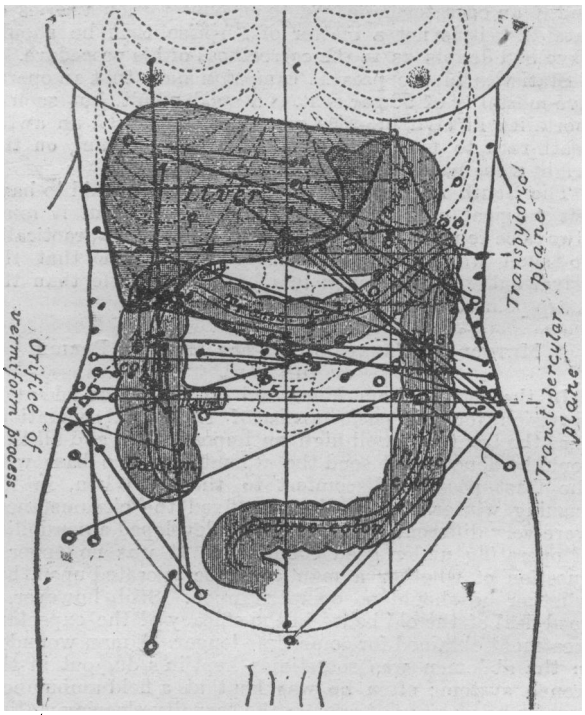


DIAGRAM 2.—Coeliotomy. No wound of any hollow viscus.

General Line of Treatment.

The practice is now to operate on all cases unless there is some reason to the contrary, and to operate on principle rather than on the indications by symptoms.

The cases on which operation has been found, as a general rule, to be inadvisable may be divided into two classes—(1) those in which solid organs alone are wounded and in which there are no signs of continuing haemorrhage, and (2) cases arriving after thirty-six hours.

The liver furnishes by far the greater number of cases in Class (1). This organ is the only solid organ in which it is possible to say from inspection that no other organ is wounded. In the other solid organs, such as the kidney and spleen, the likelihood of hollow visceral injury nearly always compels exploration. Were it not for this contingency, the solid organs would require little operative attention.

In Class (2) the time for successful interference in the

case of hollow viscera has as a rule gone by, and the bleeding, from whatever source it came, has ceased spontaneously.

Before operation a period of rest has found favour with most people. This period is used to combat shock, for which purpose heat in various forms has proved by far the most efficient means.

When the missile is retained the position of the projectile should be ascertained by an *x*-ray picture, as its localization will influence the site of the exploratory incision. The incision should as a rule be placed by the side of the mid line and be of ample length. A transverse incision is much favoured by some for exploring wounds which traverse one side only of the body.

The question of the administration of saline is important. The subcutaneous injection of saline has found favour in the past, but it is coming to be recognized that very little is absorbed in a shocked man, and that this method presents no advantages over its administration by the natural orifices. If these are not available the intravenous method should be used.

Axioms of Operative Procedure.

Celerity is of great importance. The body heat must be preserved in every way. There should be the least possible exposure of the viscera, and the intestines should be kept inside the abdomen as much as is compatible with the necessary manipulation. The least possible should be done. All the intestine should be examined. Suture of the intestine should always be preferred to resection unless the latter is inevitable, or saves time, and experience has shown that a single continuous suture, applied so as to invert the peritoneum, is quite sufficient and perfectly secure. Linen thread or thin silk are both preferable to catgut, and care is required not to draw the stitches too tight. If resection is unavoidable, end-to-end anastomosis is preferable to lateral apposition as a rule.

Solid organs should be disturbed as little as possible, unless vessels have been opened. Excision of spleen and kidney should be practised with great reserve.

Through-and-through wounds of the liver are best left alone, but if the *x* rays show a large piece of shell or bomb in an accessible position it should be removed, for if left it generally causes dangerous sepsis in the organ.

Abdominal drainage is most probably of little use except in local lesions.

Artificial ani in the colon are to be avoided if possible.

Wounds of Special Organs.

Stomach.—Wounds of the stomach, though less severe than those of the small and large intestine, have proved decidedly more dangerous than was supposed. The fatal result has largely been caused by haemorrhage and shock and by complication with other visceral injury.

Small Intestine.—In the small intestine the multiplicity of the lesions and haemorrhage from the mesentery have been the chief causes of failure. As many as twenty lesions have been met with. In one case a successful result followed a resection of 6 ft. for twenty perforations (Captain Owen Richards). In another case fourteen lesions were sutured and followed by recovery (Captain John Fraser).

Large Intestine.—The large intestine wounds have been mostly fatal from sepsis of the retroperitoneal tissue in the case of the ascending and descending colons and from complicated injuries in the case of the transverse colon.

Rectum.—The rectum proper has not been wounded so often as would be expected, but has a high mortality.

Liver.—The liver shows a large proportion of recovery after operation, but many patients would have got well without operation.

Spleen.—The spleen injuries have not been very dangerous except where the lesions have necessitated excision, and the same may be said of the kidney.

Bladder.—Intraperitoneal wounds of the bladder show a mortality of 56 per cent. where uncomplicated, but those associated with small gut injury have proved exceedingly dangerous.

Causes of Failure.

Haemorrhage, sepsis, and shock have been the chief causes of death.

Haemorrhage has come from every vessel in the abdomen except the aorta. Principally it has proceeded from the mesentery and the pelvic vessels. On two occasions a rent in the vena cava has been closed—in one by the application of forceps (Captain Taylor), and in one (by Captain Sampson) by suture. The former recovered. In one instance the vena cava was ligated, but the patient survived only ten hours.

Sepsis.—Under this head are included peritonitis, retroperitoneal sepsis, and wound infection. It is unnecessary to say much about peritonitis. It causes death in the same way as seen in civil practice. Many attempts have been made to combat the so-called obstructive symptoms by enterostomies and short circuits, but with little if any success. It must be mentioned here that a certain amount of evidence has accumulated showing that some obstructive cases have as their basis a nerveus traumatic paralysis. Retroperitoneal sepsis, accompanied or not by gas formation, has proved a great source of mortality. This has been obvious in the case of the colon injuries, but a recent series of *post-mortem* examinations by Captains McNee and Dunn has proved that such sepsis is frequently the cause of death where that death has clinically been put down to shock.

Shock.—This subject is dealt with in another place by Captain Geoffrey Marshall, but a word may be added here. It is very difficult to trace any definite relation between the amount of injury and the amount of shock. It can only be said that multiple injuries produce, as a rule, much shock. A severe intestinal lesion will not in all cases prevent a man from completing the task on which he was engaged or even from walking one or two miles, and many who subsequently die arrive at the hospitals in good condition. The pulse-rate table gives some indication of the patient's condition. Prolapse of the small gut seems to cause less disturbance than that of the stomach and colon. Haemorrhage is by far the most frequent cause of death, and as it is nearly always present, it is difficult to determine how much shock is due to this cause and how much to the accompanying injury. There is a certain amount of evidence to show that comparatively slight injuries of both kidney and liver will cause intense collapse, but such cases are not common. Sepsis of the retroperitoneal tissue without severe injury does cause the most intense shock.

Results.

The following table gives the results obtained by the operative treatment in a certain sector of the British line over a period of eighteen months. Practically every case that got to hospital is included, so that a true picture is presented, and the varying results produced by locality and different conditions are eliminated as far as possible.

TABLE V.—*Abdominal Wounds operated on in a Sector of the British Line during Eighteen Months.*

Total number of cases	1,288
Arrived moribund	250
Total mortality, excluding moribund ...	50.06 %
Total mortality, including moribund ...	60.02 %
Considered with view to operation ...	1,038
No operation advised	73
Total operations	965
Total operative mortality...	53.9 %
Total hollow viscera mortality	64.7 %
*Stomach mortality	52.7 %
*Small gut mortality	65.8 %
*Colon mortality	58.7 %

* Uncomplicated by wound of other hollow alimentary viscus.

It is very difficult to compare the present mortality with that of the pre-operative period. The whole method of evacuation has completely changed. The operative treatment has attracted to the casualty clearing stations all men wounded in the abdomen, so that those who would have died in dug-outs, at the advanced dressing stations, and at the field ambulances, now reach an operative centre.

Neglecting the more forward positions, a calculation made in the pre-operative days showed that the mortality at field ambulances and clearing stations was 70 per cent. In addition there were the deaths at the base, which raised the mortality to about 80 per cent.

There would therefore seem to have been an improvement of from 15 to 20 per cent.

WOUNDS OF THE HEART.

There has been one successful suture of a heart wound. It was performed by Captain John Fraser. The details are as follow: A bomb fragment entered immediately internal to the left nipple. There was a persistent and pulsing escape of rather dark blood. A probe passed upwards and towards the mid line evidenced a cardiac rhythm. The pulse was small and irregular; the patient distressed and cyanosed. A portion of the fifth rib and its cartilage was removed, and the fourth costal cartilage detached from the sternum. The pleura and fat were retracted, and the pericardium incised. The latter contained a quantity of dark blood. A small hole, the size of a pea, was found in the right auricle. By a suture the auricle was pulled up into the wound and the hole closed by two linen sutures. The progress was good, and the pulse, which had been 120, dropped to 90 on the fourth day.

The patient nine months later reported his health as excellent.

WOUNDS OF BLOOD VESSELS.

It may in the first place be noted that the conception of many surgeons of the size of the lumen and of the thickness of the wall of arteries in general has undergone a change in this war, and it has often been remarked by medical officers that the arteries are smaller and have slighter walls than was expected. No doubt the class of subject from which one gained an idea of the size of the normal blood vessels is so different from the class met with in war surgery that there was an exaggerated idea both of the size of the artery and of the thickness of its walls in healthy young adults.

Surgeons, knowing that they would have to deal with healthy arteries, hoped that many opportunities would present themselves for arterial suture, but unfortunately the opportunities have been few, and the injuries have rarely been of such a nature as to offer any prospect of success or even of trial of such treatment. Lateral suture both of veins and arteries has been done in a fair number of cases, and in two instances a lateral rent in the vena cava itself has been closed, although the only successful case was one in which the sides were brought together by artery forceps and not by suture. The opportunity of end-to-end suture of arteries has rarely offered itself at the front, and as far as the writers know has only been even temporarily successful in one case, that of a bullet wound of the brachial artery; and this vessel gave way and formed an aneurysm some three weeks later. In a few cases the femoral artery has been sutured, but in no case has the operation saved both the limb and the patient.

Although so far the results have been disappointing, this is not a matter for surprise if the condition of the wounded vessels is examined. The class of case in which it was hoped to try this method at the front was that of open wounds such as are generally caused by shell; but unfortunately the ends of the artery are commonly so far apart that it is found that they cannot be brought into apposition after the necessary dissection of the vessel has been done. Even in the popliteal space, where some approximation of the arterial ends can be obtained by flexion of the knee, no case has yet occurred in which arteriorrhaphy has seemed feasible, while small wounds of the limbs or neck with an arterial haematoma seem hardly suitable for this method of treatment.

It was under these circumstances that "Tuffier's tubes" offered some hope of saving limbs from gangrene when arterial suture was out of the question. They have been employed at the front on many occasions, and are, it is believed, well worth trying, as, although they become blocked within about twenty-four hours, they have appeared to tide a limb over this the most critical period before the establishment of the collateral circulation. In one case it was noticed that the tube itself remained unblocked although the artery below became obstructed by clot, and it may be that this distal clotting in the artery will always be a difficulty in practical as opposed to experimental surgery. It must be remembered that in actual practice the limb below the lesion has been deprived of blood for some time before the opportunity occurs of inserting a tube and re-establishing the circulation, and it may be that this period of starvation produces changes in the vessel walls that favour clotting.

There is another observation which may have a bearing on this subject. In civil practice, after the interruption of the main blood supply of a limb and the consequent occurrence of gangrene in its lower part, one looks for and sees the formation of a definite line of demarcation. But in the present campaign it has been found that after the destruction and ligation of an artery this line of demarcation fails to appear in the majority of cases, and the seat of the amputation has to be chosen by noting the place where the limb becomes cold and discoloured, on the one hand, and, on the other, where the capillary circulation is still active, as shown by the return of the skin blush after pressure. No doubt the primary loss of blood has something to do with the frequency of gangrene in the first place, and in the second it would appear that the nature of the injury so upsets the blood supply of the limb that the collateral circulation is slow in being re-established, and that sufficient blood does not reach the part to bring about the rapid and healthy reaction that is necessary for the formation of a distinct line of demarcation.

It is a fact at once curious and important that the arrest of the blood current at a point that is considered a favourable one for the application of a ligature in civil practice is often followed by gangrene when that arrest is caused by a gunshot wound. It may be that the laceration of muscle that so often accompanies such injury is the cause to a certain extent, but there must be other factors at work, as gangrene may follow even a small perforating wound. Wounds of certain arteries stand out as especially dangerous to the vitality of the limb, notably those of the popliteal and the anterior and posterior tibials.

INJURIES OF JOINTS.

A great change for the better has taken place in the results obtained in the treatment of wounded joints.

Experience was chiefly gained on the knee-joint, for it is the joint most frequently hit, most easy of inspection, and its infection is followed by disastrous consequences more often than in the case of other articulations.

In the early days two lines of treatment were followed. The small perforating wounds were left alone and allowed to heal, the progress of the joint being tested by aspirations if necessary. The larger wounds with escape of synovia or actual laying open of the synovial sac were drained, and at first the drains were often introduced into the joint cavity. The results of this treatment were undeniably bad, and all sorts of heroic measures were adopted for the arrest of the septic processes which ensued. But continuous irrigation or an acute flexion of a widely opened articulation gave equally poor results, and the patient was lucky if he escaped with a stiff leg.

The first improvement was the abandonment of the intra-articular drains. The next was the excision of the wound, the removal of any foreign body, the flushing of the joint, and in some cases the closure of the capsule and the insertion of a superficial drain. Closure was especially advocated by Colonel Gray in the year 1915.

The next step was perhaps a bold one. As soon as possible after the receipt of the injury—that is, in the casualty clearing station—the wound was excised, the joint opened, cleaned, and irrigated, and then the whole wound in the synovial sac and the superficial tissues was tightly closed. It was certainly astonishing how seldom infection followed such treatment, even when fragments of shell or pieces of clothing had been removed from the joint; but for its success it is essential that the incisions around the wound edges should be carried quite clear of all infected tissue, and that the strictest asepsis is assured.

Now, every knee-joint with such a wound is given the chance of healing by first intention, although the closure of the joint defect may entail the performance of a plastic operation to provide an adequate cover with a flap of synovial membrane or skin. Even if some infection does follow the closure of the joint, it is well not to be in too great hurry to lay the articulation open, for a certain number of such joints do settle down and provide a better limb than if submitted to more active treatment.

When the joint wound is complicated with fracture of bone it may still be possible in some cases to close it with success. In cases of compound fracture of the patella with loss of substance, partial or complete

removal of the fragments, and the provision of a skin flap, will often be followed by primary healing.

When the tibia or femur are involved the case becomes more serious. Of the two fractures that of the tibia is the most to be feared.

In cases of only partial loss of the articular surface of either the tibia or femur, and also in linear oblique fractures of both bones running up into the joint, it is often worth while to try to close the joint and to obtain primary union.

Where there is much comminution of bone, however, and a dirty wound it is better to abandon all hope of saving the joint and perform a limited primary excision. After such an operation the joint surfaces are usually kept apart by extension on a suitable splint, and Carrel's treatment adopted until the wound cleans, when the bone surfaces may be allowed to come into contact.

The knee is the only joint in the body in which penetration of the synovial sac is at all commonly seen without damage to the bony constituents of the articulation. It is therefore not common to have the opportunity of closing other joints, but the opportunity should be taken when it is offered.

More often the surgeon has to treat a greatly disorganized articulation, and in such cases a primary excision is most probably the best course, especially in the case of the shoulder and the elbow.

The primary treatment of wounded joints may be summarized as follows:

1. Fixation on a suitable splint. In the case of the knee this splint should be one of the varieties of the "Thomas" as used for fractured thigh.
2. Beyond this treatment nothing more is required in simple perforating wounds.
3. The taking of an *x*-ray picture in cases where there is a possibility of the retention of a missile or of fracture of the bones.
4. The excision and cleansing of the damaged tissues and the exploration and lavage of the joint.
5. The closure, if possible, of the joint cavity.

HEAD INJURIES.

At the beginning of the war surgeons called upon to treat head injuries applied the ordinary rules of civil practice and operated on them at once. They were confirmed in their opinion that operation was right, since, apart from the mere physical defects, many patients seemed to be suffering from compression.

These operations were done both at casualty clearing stations and field ambulances, but the best method of operative treatment was as yet undeveloped, and the result was that many septic complications were seen at the base. Next, it was noticed at the base that cases which, from force of circumstances, arrived there unoperated upon, did better than those operated on at the front. This was attributed at first to faulty technique, and within limits this criticism was just, as the right operation was as yet undeveloped, both at the base and the front.

The observation was next made that if patients were kept quiet at the place where they were operated upon they did well, while cases operated on and apparently doing well were reported to have arrived in bad condition at the base when evacuated early.

It thus became obvious that there were two reasons for head cases doing badly: (1) The want of a good operation, (2) early evacuation of cases well operated on.

There were then two alternatives: The cases must be either operated on at the front and kept, or else evacuated as soon as possible to the base before operation; a patient must not be operated upon and evacuated forthwith. Two procedures were therefore adopted. In times of pressure head cases were cleaned up and sent to the base at once, provided they were fit to travel, and in quiet times they were operated on and kept at rest at a casualty clearing station for a week or ten days. Even this period of rest after operation proved too short, though the results were better than in earlier evacuation.

The next step was the establishment of special hospitals for head cases at the front. Advantage was taken of the fact that a head case before operation travelled well, and the special hospitals were placed in the back part of an army area. These hospitals were never subjected to the sudden pressure that may fall on an advanced casualty station, and consequently the cases could remain there for a long time. By this means patients experienced the advantages both of early operation and prolonged rest. The actual method of evacuation is as follows: The patients are brought from the trenches to the casualty clearing station as rapidly as possible. Here they are examined and dressed. If the pulse is slow they are sent on to the special hospital. If the pulse is rapid they are put to bed and evacuated later, should they improve. No special attention is paid to the type of wound—reliance is placed on the slow pulse as a sign that the patient will bear the journey.

The type of operation that has eventually been found most beneficial has been arrived at after many changes. Workers, comparatively far apart and not in direct communication, have evolved very much the same operation. At the front a small conservative operation was formerly practised which experience has shown to have been a little too limited in scope. At the base there were two schools—one favoured an extensive removal of bone and a scalp flap, the other an enlargement of the scalp wound and a limited removal of bone. Gradually the types of operations have approximated. It has been found that the removal of bone sufficient to expose half an inch square (1.27 cm.) of uninjured dura is best suited to most cases. Opinions still differ, perhaps, as to the comparative merits of making a flap or enlarging the scalp wound. On the whole, the flap is the best as a routine, unless the wound, as in the case of a horizontal one, is so situated as to compel the use of a very large one.

The recognition of the fact that a slow pulse is not necessarily a symptom of compression (for it may occur with a wide exposure of the brain), and that the symptoms, paralytic and otherwise, are not due to depression of fragments but to a destruction or commotion of the brain matter which is not remediable by operation, has also had an effect upon procedure. In the first place, a slow pulse is welcomed as a sign that recovery may follow, and it is not taken as a sign that operation is urgently needed, but rather that it is worth doing. The recognition that depression of fragments is not the usual cause of the symptoms has also done away with the notion that their removal must be immediately undertaken.

It is true that the sooner a dirty wound is cleaned up the better, but immediate operation is in many head cases followed by a great drop in blood pressure, so that some delay may be actually beneficial on this account, and Colonel Sargent has pointed out that for at least twenty-four hours after injury the brain is liable to be oedematous, and to extrude unduly if operated on while in this condition. A moderate delay has also been said to do good in that it allows adhesions to form between the dura and the pia mater, thus lessening the chance of a spread of infection over the brain surface.

At the same time that the best type of operation as regards the scalp and bony defect was being evolved many other points were in the process of settlement.

1. Excision of the wound was soon decided on.
2. There was at first considerable discussion as to how far the brain should be explored for bone fragments on the one hand and the projectile on the other. Every one was agreed that an *x*-ray picture had become a necessity, and the opinion was gradually formed that a limited and intelligent search for bony fragments and other foreign bodies was beneficial, but that attempts to reach a missile which was deeply embedded in the brain was not justifiable. Results seem to have proved the correctness of this line of treatment, for fragments of shell are reported to have caused little trouble provided their weight was not enough to cause pressure on the surrounding brain during movements of the patient.
3. The fact that many patients with head wounds suffered from septic complications, and the general demand for the drainage of all wounds, led at first to the employment of drainage in most cases of cranial surgery, not only of the scalp but of the brain also. The results of drainage of the brain were not satisfactory, and gradually it was abandoned, at any rate as a primary measure. The introduction of tubes was first omitted, and subsequently, systematic attempts were made to cover in the exposed brain, the scalp being brought together over the defect in the bone and dura, either by simple suture, pericranial flaps, or relieving incisions formed by undercutting the scalp. A drain introduced under the scalp is still generally

employed. This covering up of the brain seems to have been a decided success, and, although septic complications are still too often met with, they are less frequent than in former times. There has consequently been a great decrease in the number of cases of hernia cerebri.

4. There is still some difference of opinion as to whether small cranial depressions and linear fractures with slight inequality of surface, uncomplicated by symptoms, should be operated on in the first instance.

5. Most surgeons have accepted the recommendation of Sargent and Gordon Holmes that depressed fractures over the longitudinal sinuses should be left alone in the first instance.

6. Most operators are of the opinion that the dura mater should not be opened if found intact. The recognition that true compression of the brain is seldom seen has helped the formation of this opinion.

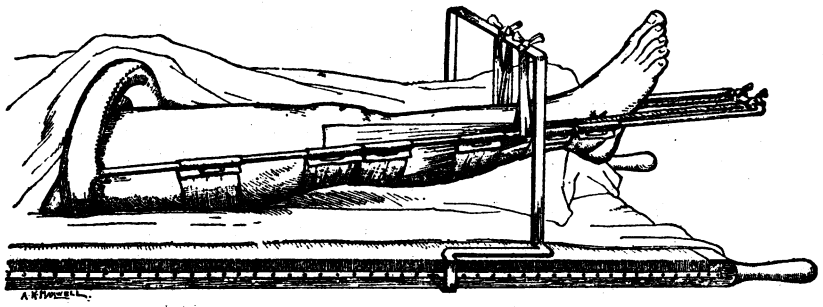
7. A general anaesthetic may with advantage be replaced by the local use of novocain and adrenalin. If this method is adopted the patient is given either hyoscine and morphine or omnopon and scopolamine an hour before the operation.

Thus, by careful individual observation, and by the comparison of results, a method of treatment has been evolved which is applicable to all cranial wounds, and capable of modification in individual cases. It may be summarized as follows:

A primary cleansing of the wound. The transmission of the patient as soon as possible to the hospital where he will convalesce. The taking of *x*-ray pictures. The excision of the scalp and bone wound. A limited and careful removal of foreign bodies. The covering of the exposed brain. The closure of the wound, with superficial drainage, and a prolonged rest in bed.

FRACTURES.

The tendency throughout the war has been to abandon all constricting splints and to trust to extension for fixation of fragments. In the first place, a bandage round a limb, which might from swelling or movement cause constriction, was found to favour the onset of gas gangrene, and in the second, the various forms of Thomas's splint, in which the limb lies on a cradle, gained more and more reputation as a means of efficient splintage. Few other splints are now used on the lower extremity. It is curious that while plaster splints, both as emergency contrivances and as a means of permanent fixation, have steadily increased in use in the French army, in our own they have as steadily fallen into disuse.



Fractured femur, with Thomas's splint and stretcher suspension bar.

The treatment of a compound fracture must be divided into two parts: (*a*) The cleansing of the wound; (*b*) the setting or reduction of the fracture, followed by its maintenance in good position. In the early stages the first is by far the most important, and on its attainment depends, within limits, the success of the second.

Total immediate reduction is good and to be aimed at, provided it can be carried out without prejudice to the cleansing of the wound, but an incomplete reduction, or even no reduction at all, may be advantageous by aiding the disinfection of the wound. Surgeons working at the front are therefore mainly concerned with the primary cleaning of the wound and with the means to transport a patient to the base with comfort and without detriment to the wounded limb.

The organisms that infect a compound fracture may be roughly divided into two classes: (*a*) Anaërobic or gas gangrene producing infection; (*b*) infection due to pus-producing organisms.

Anaërobic or gas gangrene producing infection affects chiefly the muscles, is sudden in onset and development, but tends to die out if not fatal in the early stages.

Infection by pus-producing organisms affects all the structures of a limb, is generally of slower development, and fatal at a considerably later period. The first (*a*) is the chief cause of death at the front, the second (*b*) of death at the base.

From the fact that it affects muscles, the first is more amenable to treatment by mechanical means—the excision of the affected part or part likely to be infected; but the second, giving little indication of its presence, cannot be so easily removed by such means.

At the beginning of the war fractures were treated very much as they were in South Africa. It is true that fragments of projectiles and clothing were removed, but more attention was paid to the solution of continuity of the bones than to the cleansing of the wound.

The occurrence of gas gangrene quickly called for a remedy, which was found in amputation or incisions into the limb. Then came the demand from the base for free drainage. At first small tubes were used; as these proved inefficacious, large tubes were substituted. At the same time came a more systematic search for foreign bodies. This produced an improvement, and it was reported that the cases that came down with adequate drainage, especially those with dependent drainage, stood a far better chance than those in whom such measures were not taken.

About this time attention was drawn to the fact that many flesh wounds, if freely excised, could be sutured with success. The application of this principle, though it could not be applied *in toto* to fractures, led to more extensive opening up and to better mechanical cleaning by the excision of all dead tissue and the more efficient removal of foreign bodies. These measures greatly reduced the occurrence of gas gangrene and produced an improvement in the suppurative infections. At the same time as these improvements were taking place in operative technique the adoption of the Thomas splint for the lower extremity in one of its many forms was steadily working its own good. The stretcher in the ambulance car and the cot in the train presented a difficulty—there was nothing on which to rest the splint. This difficulty was overcome by two methods. (1) A form of Thomas's splint (devised by Captain Max Page) provided with an attached foot-piece or prop was used so that the splint was raised off the stretcher and the limb lay slung, as it should, in the splint. (2) Two forms of iron bracket (devised respectively by Lieutenant-Colonel Frankau and Captain Richards), attached to the foot of the stretcher, allowed the Thomas splint to be suspended above the canvas of the stretcher.

Patients thus travelled easily in the motor ambulances, and the difficulty of the cot in the train was easily surmounted by sending the patient down on the stretcher. This latter expedient has been of great benefit to the wounded, as once placed on his stretcher at the casualty clearing station he can remain undisturbed until he reaches his bed at the base.

The fixation in a Thomas splint depends upon the extension. An efficient extension is therefore of prime importance. Sinclair's glue has provided the means. It is easily and quickly applied, and has the additional advantage that it produces no constriction of the limb. It has another advantage, it can be used when only a short portion of the leg is available, a very great gain when dealing with limbs covered with multiple wounds.

There are, of course, a few fractures of the femur that cannot be treated with Thomas's splint—namely, those in which a wound has been received on the part covered by the ring. For these the old Liston splint is used, or in some cases the abduction frame of Jones, though the bulk of the latter makes it unsuitable for work at the front.

Below the knee the Thomas splint can nearly always be used, except in those cases in which the fracture is near the ankle. Even here it is often possible to use it by the aid of the sole extension as devised by Sinclair.

In the case of fractures of the upper extremity the Thomas splint has not proved so satisfactory, but only for the reason that the straight posture of the arm is unsuited to transport except under special circumstances, as in transit by barge. The form of Thomas splint for the bent arm has not proved a success. For transport the form of internal angular splint, with a hinged back piece for the upper arm as devised by Captain Colin Clarke, is probably the best.

The development of the operative side of the casualty clearing station and the provision of *x* rays has been of inestimable benefit to the patient. There can be no doubt that the chance of the patient recovering with a good limb and of escaping a long period of suppuration depends on the attention that can be paid to his wound in the first instance. No amount of after-care can ever make up for the want of it at the first moment. A thorough and deliberate operation is all-important. There must be a free opening; the cavity must be explored by the eye, and not only by the finger, otherwise dead tissue and possibly foreign bodies will be passed over.

When first received, the wound is dirty, but the number of pus-producing bacteria is comparatively few. In a few days it is probable, no matter what treatment is adopted, that they will have greatly increased in number. If the first operation has been incomplete, a second may be necessary at the very time that the wound is in the worst possible state, and the procedure necessary to supplement the primary operation may be disastrous in exposing fascial planes to infection from a wound teeming with bacteria.

The early, deliberate and efficient cleansing of the wound is the basis of success, no matter what chemicals are used after it is completed.

REFERENCE.
BRITISH MEDICAL JOURNAL, August 7th, 1915.

PENETRATING WOUNDS OF THE CHEST AT THE CASUALTY CLEARING STATIONS.

BY
COLONEL SIR WILMOT HERRINGHAM, C.B.,
CONSULTING PHYSICIAN.

THE number of chest wounds admitted to the clearing stations is about 2 per cent. of the whole number of wounds admitted. The most favourable cases are those in which a bullet has gone right through the chest; the least favourable, those made by a piece of shell which is retained within the chest.

In cases where the missile has involved both the chest and the abdomen the prognosis is very unfavourable. Occasionally the whole stomach, or part of the intestine, is drawn up into the pleura through a wound of the diaphragm. In other cases the abdominal viscera are so injured as to prevent recovery. In any case the addition of a wound of these organs to the temporary loss of the use of one lung, which is the usual result of a wound of the chest, produces a condition from which very few recover. Injury to the spinal cord is a still more fatal complication.

The following notes are chiefly drawn from a consecutive series of 211 cases, of which careful observations were made and recorded at the time.

The patients are often much collapsed at time of admission, so that in many cases the heart cannot be felt, and in some cannot even be heard for the first twenty-four hours. With warmth, rest, and morphine, they improve greatly by the second day.

Few cases bleed dangerously from the external wound. When this occurs, it can usually be stopped by plugging the wound. There is often much distress if the external wound admits the free entry and exit of air in respiration. It is almost at once relieved if the wound be made air-tight with strapping over the dressing. For these large openings into the pleura, in which sometimes three or four ribs are smashed, and infection from the open air would be almost inevitable, a form of procedure has recently been adopted which promises well. After careful paring of the wound, removal of loose bone, and blunting of sharp edges, the skin and, where possible, the muscles are drawn together and stitched over the aperture, leaving either only a small hole for a drainage tube or none. If a tube is left in, the cavity is then filled with an antiseptic. One surgeon is using emerald green, 1 part to 1,000 of solution of gum tragacanth, for this purpose.

In all but fourteen of the series there were signs of haemothorax. It is rare for the effusion to increase in extent under observation. The chief safeguard against continued haemorrhage is collapse of the lung. In one case which died from repeated external haemorrhage the lung was found adherent to the pleura throughout. Collapse had not in consequence taken place. In another (not in this series) that died with an increase of the haemothorax, by repeated internal haemorrhage, a piece of metal was found lodged in a large pulmonary vessel which it had partially but not completely severed. The retraction of the vessel was thus prevented.

When the effusion is moderate in size, reaching not above the middle of the scapula, nor further forward than the mid-axillary line, it does not cause serious distress. These cases form the great majority. In them by the third day the pulse falls to 84, the respirations to 28, and the temperature will be falling also. Since the observations of Bradford have shown that fresh haemorrhage hardly ever occurs after the lapse of seventy-two hours from the wound, such cases were, as a rule, evacuated at the end of that time. Information from the base showed that this policy was not attended by any bad results.

When the effusion is greater than this, specially if it is complicated by pneumothorax, the patient usually shows distress. The heart is displaced, the pulse is above 100 and the respiration is over 32. Such cases are not fit to travel. They should be aspirated, and about a pint of blood and as much air as possible should be withdrawn. Some were rendered comfortable by this procedure and were able to travel without damage on the fourth or fifth day. It must be noted that the hospital was close to the train, and that though the journey might last even to thirty hours the conditions were comfortable.

It was not thought desirable at so early a stage to remove the fluid completely with the aid of oxygen replacement; that procedure was therefore left for the base hospitals.

In the latter part of the year 1916 a new method of treatment was adopted in a limited number of cases, especially in patients in whom a missile was found by *x* rays to be retained in the chest. On the second day after the injury, ribs were resected or a costal flap turned back, the pleura opened, and the missile removed. The pleura was then thoroughly washed out, and the whole wound carefully closed. The number of cases so treated is as yet insufficient to enable definite conclusions to be drawn, but experience is so far favourable.

The complications, other than mere size of the haemothorax, which prevented early evacuation, were either septic infection of the effusion on the wounded side, or some disease of the lung on the opposite or unwounded side. In many cases a missile rakes the chest and enters both pleurae. Neither lung can then be called unwounded. The term is confined to cases where one pleura alone has been injured. These complications will now be considered.

In some cases the patient may be comfortable while at rest and have no fever, but on examination there may be the signs of consolidation of the unwounded lung, and movement may produce shortness of breath and some cyanosis. In such cases the condition is that of massive collapse of part, usually at the base, of the unwounded lung. The side is often contracted, the heart is drawn over, and the *x* rays, if available, show the diaphragm raised and motionless. This condition, familiar after abdominal operations in civil life, was found by Bradford to be a frequent complication of chest wounds. It clears up in about a week.

In other cases there may be an increasing cyanosis and distress, even at rest, for which the condition of the wounded side does not account. On the unwounded side there may be the signs of bronchopneumonia. Some of these are true cases of that disease. But more of them are due to engorgement of the unwounded lung which affects the back and the lower lobe chiefly. The whole of the affected part is solid with blood, and on section presents a glistening surface of dark crimson colour. Its