causation is not clear, but the situation argues failure of the pulmonary circulation.

Unquestionably, however, if the cases be followed through, the most common complication of chest wounds is infection of the haemothorax. When cases are sent down on the fourth day not many infected cases are seen at the clearing station. It is, however, important that the medical officer should be quick to mark its symptoms. The face is pale, though there may be a local flush, the expression anxious, the tongue dry, the appetite bad, and there may be vomiting. The pulse and respiration usually quicken and the temperature rises. In many cases gas formation within the thorax is shown by the alteration of the physical signs and the displacement of the heart. But this does not always occur, nor are any of the other symptoms constant.

Briefly speaking, whenever the medical officer is dissatisfied with the progress of the patient and cannot otherwise explain it, he should always suspect septic infection. If suspicion is aroused, aspiration should be performed at once. Sometimes the fluid will be found to stink, or it may be seen to contain pus, or the froth may remain permanently crimson from haemolysis. Any of these signs is sufficient to indicate that a free opening should immediately be made. If doubt remains, it is well, after drawing off a pint of the effusion, to leave the patient for a day, and, unless he has by then obviously improved, to operate. Bacteriological evidence, when forthcoming, is valuable as a confirmation, but it is on the one hand uncertain, for the infection may be confined to a certain part only of the pleura, and on the other, may cause considerable delay. Clinical evidence should always be trusted, and action taken upon it without hesitation.

Five cases of septic infection occurred before the fifth day after the wound in the present series of cases. In all a free opening was made at the clearing station, and all these patients, though some of them were very ill for a time, recovered sufficiently to be evacuated.

In the whole series there were twenty-two deaths, of which two were due to wounds of the heart, ten to conditions of the pleura and lungs, and ten to wounds of the spine or abdomen. The remainder were evacuated.

THE ADMINISTRATION OF ANAESTHETICS AT THE FRONT.

BY

CAPTAIN GEOFFREY MARSHALL, R.A.M.C.(S.R.).

FROM the point of view of the anaesthetist, wounded men may be divided into three main classes:

1. The lightly wounded.
2. Those suffering from serious wounds with more or less shock and haemorrhage, the two factors being commonly associated.
3. Those suffering from a severe degree of sepsis, especially anaerobic infection.

The choice of anaesthetic depends on which of these classes the patient belongs to, as well as on the region of the body injured.

1. THE LIGHTLY WOUNDED.

These patients are good subjects for anaesthesia, so that the chief desiderata are safety, speed, and convenience. The ideal anaesthetic is one with which induction is rapid, and recovery complete a few minutes after operation, so that the patient is in fit condition for early evacuation by ambulance train.

Gas and oxygen anaesthesia meets these requirements best. With its help a greater number of these cases can be dealt with satisfactorily in a limited time than with any other anaesthetic. When this method is not available, ether should be used. The ether is best administered as a warm vapour by "Shipway's apparatus," as both induction and recovery are more rapid than with the open method.

Local anaesthesia can only be employed in a small number of cases, on account of the multiplicity of wounds and their lacerated and soiled condition.

II. THE SERIOUSLY WOUNDED.

In the more serious cases the one consideration is safety. In other words, we require an anaesthetic which will not be harmful to a patient who is still suffering from the shock of injury, and one which will minimize the shock of operation.

Spinal Anaesthesia.

It has been urged that spinal anaesthesia would meet these requirements, especially in wounds of the legs and thighs, and would therefore be of great value in military surgery. In practice, however, it is found that the intrathecal administration of stovaine has dangers of its own when applied to men whose wounds are recent. In a large

In the charts the continuous line represents blood pressure in millimetres of mercury. The dotted line represents pulse rate per minute.

CHART I.—Spinal anaesthesia. Group A. Stovaine 0.075 gram. Wounds of leg and buttock twenty-one hours. Haemoglobin 85 per cent. Operation conservative. Death twenty-four hours later from gas gangrene.

proportion of these cases the administration is followed by a great fall of blood pressure and symptoms of cerebral anaemia, that is, pallor, vomiting, loss of consciousness, and occasionally convulsions. The syncope is sometimes fatal. It is in the man who has lost blood, and whose wounds are less than forty hours old, that spinal anaesthesia is

CHART II.—Spinal anaesthesia. Group B. Stovaine 0.1 gram with glucose. Wounds of thigh sixteen hours. Haemoglobin 102 per cent. Operation conservative. Recovered.

dangerous. This is shown by an analysis of fifty consecutive cases operated on at a clearing station under stovaine spinal anaesthesia.

All the patients had wounds of the lower extremities. In each case the percentage of haemoglobin in the patient's blood was estimated before operation; a low percentage of haemoglobin in a man whose wounds are recent may be taken to indicate that the patient has bled. The fifty cases fall into three groups:

Group A.—Men operated on within forty hours of receiving their wounds, and whose blood was dilute (indicating haemorrhage).

Group B.—Men operated on within forty hours of receiving their wounds, whose blood was *not* dilute.

Group C.—All cases in which a greater interval than forty hours had elapsed between wounding and operation.

CHART III.—Spinal anaesthesia. Group C. Stovaine 0.1 gram with glucose. Wound of thigh and femoral artery twenty-three days. Haemoglobin 45 per cent. Gangrene of leg. Amputation lower third thigh. Recovered.

In Group A there were twenty-two cases. Of these, nineteen showed symptoms of collapse after injection of the anaesthetic. The average fall of blood pressure was 57 mm. of mercury; in only three cases was the fall of pressure less than 35 mm., the greatest fall was 99 mm.

In Group B there were sixteen cases. Of these, only three developed any untoward symptoms after injection, and these were trivial—in one case nausea and in the other two pallor only. The average fall of blood pressure was 17 mm., the greatest 33 mm.

In Group C there were six cases. None showed any symptoms of collapse. The average fall of blood pressure was 19.7 mm. and the greatest 35 mm.

For the prevention or combating of the collapse the most important factor was found to be the position of the patient; the symptoms are alleviated by raising the legs and lowering the head. It is safe to lower the head fifteen minutes after injection. Neither strychnine nor pituitrin were of any use in combating the collapse, nor did preliminary injection of strychnine prevent it. The dose of stovaine given varied from 0.05 to 0.1 gram, and within these limits the fall of blood pressure was not proportional to the dose of the drug. Some of the greatest falls of pressure were associated with the smallest doses of stovaine and vice versa. With doses smaller than 0.05 gram, the anaesthetic effects were so slow and uncertain as to make the method impracticable at a clearing station.

Wounds of the Limbs Necessitating Amputation.

There are few more unfavourable subjects for anaesthesia than the man who is suffering from the shock of a recently shattered limb, and who has to undergo the further shock of amputation. The mortality of these cases can be greatly reduced if correct procedure be followed.

In the first place, the patient must be put to bed and surrounded with hot bottles or a hot-air bath. However urgent operation may be surgically, it is useless to perform it before the patient has been thoroughly warmed up.

In the second place, morphine should be withheld before operation or given only in small doses.

In the third place, gas and oxygen should be the anaesthetic used for operation. Results are so much better with this mixture that no other anaesthetic is justifiable.

If chloroform be used, the patient's condition will deteriorate during the administration, and he will not rally afterwards. With inhalation ether the condition may improve and the blood pressure rise during operation, but there will be a collapse during the next two hours. With intravenous ether the temporary improvement is more striking and the after-collapse more profound and more often fatal.

Shock.

Shock is a condition which still evades precise definition, although seen so commonly in wounded men. The injuries which cause it are almost invariably severe in themselves, that is, they involve important structures or extensive areas of tissue. In a typical case there is dusky pallor of the face, the radial pulse is flickering or imperceptible, and the surface temperature low. There is repeated vomiting, but the patient shows remarkably little mental disturbance, and may be fully conscious and intelligent within a few minutes of death. The arterial blood pressure is often higher than might be expected from the character of the pulse, and shock is usually profound if associated with a systolic pressure lower than 80 mm. of mercury; we refer to readings taken by means of a Riva-Rocci sphygmomanometer with auscultation over the brachial artery. The blood in the capillaries of the extremities is dark and cyanotic. In cases of shock unassociated with haemorrhage we have found the blood to be more concentrated than normal.

Treatment of Shock before Operation.

We have stated that, however urgent it may be, operation should not be performed on a patient suffering from shock until means have been taken to mitigate this condition.

The one measure which commonly produces definite improvement is the application of external warmth. Excellent results have been obtained by the application of heat from electric light lamps or by the use of an improvised hot-air bath, and if such a patient as we have described be put to bed and treated by these methods, or surrounded with hot bottles, his surface temperature rises, his colour improves, and his arterial blood pressure will as a rule go up steadily for several hours. He will then be much less likely to succumb if subjected to a severe operation.

Fluids are best given either by mouth or rectum. Subcutaneous infusion produces no measurable effect in this type of case; and if death occurs as late as thirty hours after infusion, the bulk of the fluid will still be found in the subcutaneous tissues. The intravenous administration of saline is of little use before operation. It causes a temporary rise of blood pressure and slowing of the pulse rate, but does not render the patient less susceptible to further shock. The blood pressure falls again as soon as operation is begun. Transfusion is best done towards the end of operation; it will then often cause a lasting improvement in the patient's condition. We have found that hypertonic saline produces a more lasting elevation of blood pressure, slowing of the pulse, and dilution of the blood than does the normal solution. Transfusion with blood gives still better results. The use of artificial viscous fluids is still under trial.

The Limitation of Shock during Operation.

The recently injured patient is particularly susceptible to further shock, and this susceptibility is increased by certain drugs used in the production of anaesthesia, for example, chloroform, ether, and morphine in large doses. These drugs should therefore be avoided in dealing with a patient who is suffering from recent wounds and who has to undergo a severe operation such as amputation through the thigh. Chart IV shows the serious fall of blood pressure which occurred an hour after amputation under ether vapour anaesthesia. Charts V and VI illustrate the

still greater collapse after intravenous ether. Chart VII shows how trivial is the effect on pulse rate and blood pressure when the operation is done under gas and oxygen.

We have already indicated that amputation is a much

CHART IV.—Anaesthesia by ether vapour. Wound of leg thirty-six hours; tibia shattered. Haemoglobin 62 per cent. Amputation lower third thigh. Recovered.

less dangerous procedure to a patient who is not already suffering from shock or haemorrhage. Chart III was an example of amputation under spinal anaesthesia, and Chart VIII under intravenous ether, both in cases of severe sepsis but in which the initial shock of injury had passed off. Chloroform is dangerous even in this type of case; Chart IX illustrates a fatal example.

Wounds of the Head.

Operations on the head may be performed under local anaesthesia. All tissues of the scalp are infiltrated in a circle surrounding the site of operation with a solution of

CHART V.—Anaesthesia by intravenous ether. Wound of thigh twenty-two hours; femur fractured. Haemoglobin 84 per cent. Operation conservative. Recovered.

novocain and adrenalin. No pain is felt even when bone and dura are dealt with. On the other hand, the forcible cutting of bone is disturbing to the patient, so that where mentality is unimpaired, hyoscine and morphine should be given an hour before operation. If general anaesthesia is preferred, this may be obtained safely and conveniently with Shipway's apparatus. A warmed mixture of ether

and oxygen is administered through a catheter passed down the more patent of the two nostrils.

Wounds of the Chest.

Ether should not be administered to a patient with a perforating wound of the chest, as it usually provokes fresh intrathoracic haemorrhage. For small operations,

CHART VI.—Anaesthesia by intravenous ether. Wound of leg six days. Secondary haemorrhage seven hours before operation. Amputation mid-thigh; collapse and death eighty minutes after.

such as the resection of a rib, local anaesthesia should be employed. The intercostal nerves of the rib to be resected and the rib above are blocked by injection of a solution of novocain and adrenalin into the subcostal grooves close to the angles of the ribs. For more extensive operations, requiring general anaesthesia, we give a preliminary injection of morphine gr. $\frac{1}{2}$, hyoscine gr. $\frac{1}{100}$, and atropine gr. $\frac{1}{100}$, and follow this with a minimal amount of warm chloroform vapour with oxygen.

Wounds of the Abdomen.

For these cases we have found the most satisfactory anaesthetic to be a warmed mixture of ether vapour and oxygen. Compared with "open ether," we find that the warm vapour gives a more rapid and quiet induction, easier breathing, and diminished heat loss during operation and less vomiting afterwards.

CHART VII.—Anaesthesia by gas and oxygen. Wound of thigh twenty-one hours; femur shattered. Patient pale and vomiting. Haemoglobin 82 per cent. Amputation mid-thigh. Recovered.

Men wounded in the abdomen are especially liable to develop bronchitis, perhaps owing to deficient movement of the lower part of the chest. In a series of these cases anaesthetized with open ether, 54 per cent. developed bronchitis after operation. In a comparable series anaesthetized with warm ether vapour, the percentage of bronchitis was only 14.7.

Blood Pressure during Operations on the Wounded Abdomen.

During the course of an ether vapour anaesthetic the blood pressure shows a tendency to rise, but if there is much manipulation of gut and mesentery, it will gradually fall. The process may be continued for hours without the pressure falling to a dangerous level. Exposure of gut

CHART VIII.—Anaesthesia by intravenous ether. Wounds of both thighs fifteen days. Left thigh amputated thirteen days. Severe sepsis, persistent hiccup and vomiting. Amputation lower third right thigh. Recovered.

outside the abdominal cavity produces a much more serious effect. If more than two or three feet are exposed, the blood pressure will commence to fall after a few minutes, and will continue to fall rapidly until the gut is replaced. This effect is seen when stomach and omentum are exposed, and even with great omentum alone. The indication is that surgeons should make big incisions, and work as far as possible with the gut lying inside the abdomen. Covering the exposed gut with pads wrung out in hot saline does not prevent the fall of blood pressure.

Exposure of gut produces far less effect if the patient is not under an anaesthetic. We have seen men arrive from

CHART IX.—Anaesthesia by chloroform vapour. Wound of leg seven days. Secondary amputation lower third thigh. Death ten hours after operation.

the line with several feet of intestine prolapsed through a wound, yet their blood pressure was within normal limits. In one case more than two-thirds of the small gut had been outside the abdominal cavity for at least four hours, and this man's blood pressure was 142 mm. of mercury, and his pulse rate only 108. The patient recovered.

Apart from copious haemorrhage, there is one other procedure which causes rapid fall of blood pressure in abdominal operations. This is turning the patient on his

side. The effect is only seen if the patient has been under the anaesthetic for a considerable time before being turned. At the end of an abdominal operation the patient may be in good condition. He is then turned on the right or left side so that the surgeon may excise a wound in the back. In a few minutes there is a great fall of blood pressure, and the radial pulse disappears. It may be hours before the patient recovers this lost ground. If possible, wounds of the back should be dealt with before laparotomy, as turning the patient has no ill effect during the first half-hour of an ether anaesthesia.

If chloroform be used in these abdominal operations, the blood pressure will fall during administration and for some hours afterwards. This drug is therefore to be avoided except where ether is contraindicated, as in cases in which projectiles have penetrated the chest as well as the abdomen.

The intrathecal administration of stovaine is unsafe, and should not be employed.

III. PATIENTS WITH SEPSIS.

The patient whose condition is rendered grave by sepsis will stand an amputation far better than the man who is suffering from shock. In the septic case, gas and oxygen again gives excellent results, but spinal anaesthesia, warm ether vapour, and intravenous ether are also comparatively safe. Chloroform, however, is to be avoided, as it is often followed by a slow fall of blood pressure which ends in death during the twelve hours succeeding operation.

THE COLOUR CHANGES SEEN IN SKIN AND MUSCLE IN GAS GANGRENE.

[WITH COLOURED PLATES.]

BY

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A SHORT time ago¹ I ventured to support Kenneth Taylor's statement that gas gangrene was primarily and mainly a disease of muscle. Further work and observation have only strengthened this belief. It is the object of this paper to describe the naked-eye alterations in the appearances of the skin and muscle in the sequence in which they occur.

Through the kindness of the Medical Research Committee I am able to illustrate some of the changes by the reproduction of coloured drawings made by Sergeant A. K. Maxwell, R.A.M.C. I should like to take the opportunity of congratulating him on the skill he has displayed in catching the delicate tints in the colour changes.

Colour Changes in the Skin.

The changes in the skin of an affected limb may share in the general icteric tint that affects the whole body in some cases. This has been well portrayed elsewhere,² and need not detain us here. Coming to the more local lesions, it is first necessary to state that the skin of an affected limb may appear, and usually is, perfectly normal in the early stages; even under a normal skin, however, the disease in the muscles may be so far advanced as to necessitate amputation. The first essential change in the colour of the skin is due simply to the swelling of the limb. At this stage the skin looks somewhat tense, just as it does over any deep-seated swelling, and is paler than normal, owing to the blood being driven out of it by pressure. Resonance to percussion, and even crepitations, may be perceptible at this stage. Simple pallor of the skin is succeeded by a dirty cream tint, which may be taken to indicate that gangrene is certainly established. Up to this stage examination through an incision may reveal only partial or complete involvement of a single muscle, or of a limited group of muscles, so that the condition may be suitable for treatment by local excision.

The subsequent changes in the skin are quicker and more dramatic. Areas of purple staining appear, which enlarge and coalesce. The margins of these are fairly distinct but irregular, and the intervening skin is greyish-white in colour. Soon there appear blebs filled with fluid