THE DEVELOPMENT AND THE RESULTS OF TRANSFUSION
IN THE TREATMENT OF BATTLE CASUALTIES.

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The treatment of so-called "Wound Shock" in battle casualties has always been a major problem, and this dangerous state is the first fence that has to be surmounted along the path of a man's recovery. If the fence is not cleared, then none of the other hazards—operation, infection, asthenia, renal failure, etc.—which have also a high mortality, enter into the picture, and none of the modern methods for dealing with these later hazards—skilled surgical teams, sulphonamides, penicillin, etc.—have an opportunity to contribute to recovery. At the outset of the war, we had for our guidance the extensive experience of the 1914-18 war, as well as the experimental work which had been carried out since that time. Two main principles had been established beyond doubt. The first and most fundamental was that the chief initiating factor in the so-called "shock" of wounded men was oligemia, due to blood loss or plasma loss, or both, either externally or into the tissues, so that the volume of circulatory fluid became acutely and seriously reduced, and the cardiac action embarrassed, leading to a vicious circle of events, terminating in death. The second principle was that there were a number of contributing factors which could add greatly to the seriousness of the condition and to the rapidity with which deterioration occurred; these included pain, cold, fear and dehydration. At the beginning of the war, it was felt that the major portion, if not all, of the problem of "shock" would be met by the provision of an efficient transfusion service, coupled with ample measures for dealing with the contributing factors. Experience has justified these views, but it has also brought to light a number of new facts, ideas and principles which have clearly shown that transfusion is neither a panacea for all suffering from so-called "shock" nor by any means the complete answer to the problem. For example: though it has been found (Kekwick et al., 1941) that a man who has suffered a huge loss of blood, say two or three litres, may still survive, provided he is promptly and adequately transfused, yet, in others with far less blood loss an appropriate transfusion may fail to revive, or fail to maintain a good condition, or may restore only temporarily, so that death occurs at operation, soon after or perhaps from renal failure, some days later. Under battle conditions, the opinions concerning the merits of different methods of treatment, or of the virtues or failings of blood or blood substitutes, must be greatly influenced by the phase at which the observations are made. Thus, the Field Transfusion Unit officer will form his opinion on the immediate result, or the Field Surgical Unit officer upon how the patient stays the course of the operation. Both may be unaware that an apparently brilliantly successful case has died in another hospital, sometime afterwards, from the remote effects of the wounding or the treatment upon the renal or other functions. These aspects have to be taken into consideration when attempting to assess the results of transfusion. The most reliable deductions will obviously be derived from cases in which there has been continuity of observation, as with the special teams that have worked in the field, and it is the final reports of these teams which will be the most informative.

The Reaction of the Body to Injury.—"Shock," though a convenient and commonly used term, is one which is much misused. When stripped bare and reduced to a cold definition, it means no more than that a man looks ill, even to the point of death. Yet many may appear to be in this state from no more than a trivial injury or even a psychological cause. The term "shock" is nowadays never used by the well-trained medical officer, without a description of the clinical features which he observes at the time. This, indeed, is what is meant by "shock." It is not a specific entity, but consists of a well-known train of clinical symptoms
and signs, including lowered vitality and circulatory embarrassment, the latter manifested by pallor, peripheral coldness, sweating, cyanosis, a blood-pressure which is usually reduced and a pulse which is usually fast and of poor volume. From these variable signs, the decision has to be made as to whether to transfuse or not. Much has been learned during the war concerning the factors influencing such a decision, as well as the choice of fluid, and much has been learned of the results that may be expected, either immediate or remote. Something has been learned of the reaction of the body to different types of injury. For example, the oligæmia of the injured man may be due to blood loss, which may indeed be unbelievably large in the case of massive limb injuries, or to plasma loss, as has always been known in the case of burns, but which is now known to be a dominating feature in crush injuries, and which is apparently prominent in abdominal injuries (Grant, 1945). In the last named, blood loss was at one time thought to be more important. Gross dehydration, caused by profuse sweating, diarrhœa, vomiting and restricted fluid intake, especially in tropical countries, may also produce oligæmia, and thereby cause or exaggerate the "shock syndrome." This separation of the types of reaction to injury influences the choice of fluid which should be transfused and has brought the art of resuscitation into the realm of specialism. And similarly with the clinical picture. Though the classical case reacts to oligæmia by a lowered blood-pressure and a fast pulse, there are many, especially among fit young men, in whom the reaction is hypertension (Conway, 1945).

Selection of Cases.—It will be clear, therefore, that the assessment of a case on its superficial appearance or early observed clinical findings can be very misleading. None of the prominent features—pallor, cyanosis, sweating, blood-pressure, pulse, or mental state—can be considered reliable at the outset, but a continuing improvement, as shown by serial observations under active treatment, will indicate the optimum time, often fleeting, at which the surgeon should operate. Experience has shown that assessment at the outset should be made on common-sense grounds on two quite broad criteria—(1) probable blood (or plasma, or tissue fluid) loss, and (2) the extent of the damage. When either or both of these are adjudged to be large, the patient’s life is in grave danger, whatever his superficial appearance may be. Rapid and adequate transfusion of the appropriate fluid is always required. Conversely, however moribund the patient may seem, there is always a chance of bringing him back to life, provided his injury is not overwhelming or does not involve some vital organ. The main decision that has to be made is whether to transfuse or not. When in doubt, transfuse, in that transfusion is the most important single requirement of the seriously wounded man (Kekwick et al., 1941; Grant and Reeve, 1941).

Features Other Than Oligæmia.—It is now well known that the initial oligæmia associated with the crush syndrome is equalled in importance by the remote renal failure due to toxic substances. The re-discovery of this fact revived interest in the "toxic" theory of shock and drew attention to the importance of ultimate prognosis, as distinct from immediate recovery. The toxic theory postulates deleterious substances derived from injured tissue, which may quickly cause a disordered circulation or ultimate renal failure. Circulatory embarrassment has long been known to occur with a frank fulminating infection, such as acute gas gangrene, but, despite much experimental work between the two wars, no evidence could be found for toxæmia following simple injury. Recently, the Sheffield School (Green, 1943) have demonstrated that such toxic products may arise; they have even made some speculation as to their probable nature. There is no doubt that the greater the tissue damage, the more rapidly does this aspect enter into both immediate and remote prognosis. As a rough clinical guide, it has been suggested that whenever the amount of tissue damage exceeds the volume of two clenched fists (Grant, 1944), then toxic complications, immediate or remote, are probable. The essential treatment is to deal with the damaged tissue surgically at the earliest possible moment. Indeed, in such cases, surgery may be almost as imperative as transfusion, and may have to take place before the theoretically ideal response to transfusion has been obtained.

Another re-discovery of the war has been the frequency with which injured men develop some degree of renal impairment. Nearly all, if carefully examined, will be found to have
casts or red cells in the urine at some stage; a number develop oliguria; others die of anuria, which is apt to be wrongly attributed to incompatible transfusion. Some of this trouble is
doubtless due to kidney anoxia during the stage when the circulation is embarrassed; some
is toxic in origin. Encouragement of normal renal function is now an essential part of the
post-operative treatment of the wounded.

The importance of a neurogenic element has always to be borne in mind. An ordinary
faint is the simplest form of neurogenic "shock" and may be brought about by painful
stimuli, with or without injury, or by mental stress; these initiate a reflex mechanism, mani-
ifesting itself by a low blood-pressure and a slow pulse. This condition may be a complica-
ting factor with oligemic "shock" and cause sudden death, for example if a fracture be
roughly handled.

The Development of Transfusion.—It was appreciated at the outset of the war that the
demand for blood, as judged by civil standards, would be phenomenal. Attention had also
to be devoted to the production of blood substitutes, particularly for use in tropical climates,
and to the devising of an expendable apparatus for administration which could be used under
all field conditions. Account had also to be taken of the perishable nature of blood, the
meticulous care which was required to ensure its proper preservation and of the disasters
which would follow the use of blood of the wrong group or blood which was infected or
degenerate.

Much research was devoted to these problems, such as the prolongation of the storage
period of blood (Bushby et al., 1940), the perfection of methods for filtering plasma (Bushby
and Whitby, 1942) and of methods for drying plasma (Lanyon, 1941). Much thought and
ingenuity had to be given to the essential problem of refrigeration in the field (Lanyon, 1945).
As a result of the work, supplies of all kinds were always abundant and were freely used on
an ever-increasing scale. This can be seen from the comparative records of different cam-
paigns (Tables I and II). Despite difficulties, the number of transfusion accidents was
negligible, and no major disaster occurred, whilst the incidence of reactions was lower than
that reported from civilian sources. In the later stages of the war, by reason of supplies,
transfusion was a weapon which could be used without restriction.

The Art of Transfusion.—Transfusion is not a mechanical procedure requiring nothing
more than a pretty skill in venepuncture, though this last is essential and is best learned in
the hard school of routine blood collection. The art of transfusion lies in the selection of
cases, the choice of correct fluids and their administration in appropriate volume at an opti-
mum rate. Until the more elaborate methods of laboratory control have been reduced to
bedside procedure, reliance has to be placed upon clinical judgment of the individual case;
here the trained and experienced transfusion officer has paid a handsome dividend for his
training; he frequently could obtain a desirable result with far less material and considerably
less anxiety than his less experienced colleague.

As to selection of fluid: there have been many swings of the pendulum of opinion. Some
have stated dogmatically that when blood is lost, blood is essential. Others, equally dog-
matic, maintain that results just as good can be obtained with plasma or serum, despite their
lack of oxygen-carrying power. The broad answer, as always, is intermediate and much
depends upon the individual case as well as upon the nature of what is available. Here, one
can do no more than indicate certain principles which should guide selection. The vital
requirement in the majority is volume restoration. This can be accomplished with either
blood, plasma, or serum. At the same time, a man will stand an operation far better if his
haemoglobin is not below 60 to 70 per cent. A judicious mixture of blood and plasma will
achieve this. And there is a great difference between fresh blood (rarely obtainable in a
forward area), young stored blood and old stored blood. If only the last named is available,
it is certainly not advisable to give huge quantities (part of which is inevitably haemolysed,
and so releases pigment into the circulation) to those who are potential candidates for
renal failure. And, again, the impression at one time prevalent that abdominal wounds
required huge quantities of blood has been contradicted by Grant's (1945) precise laboratory-
controlled work, which has shown that the main danger is plasma loss rather than blood loss.
Saline infusion has also become more widely practised, partly as the result of experience, partly from American influence.

The volume to be administered and the rate of administration are individual matters. Most medical officers know that massive limb injuries may require large volumes, five or six pints as a pre-operative measure, but some are still diffident of administering at a fast rate. Anyone who has suffered a blood loss serious enough to demand instant transfusion, unless the injury is to the lung, cannot have the first three pints administered too fast. Unless the rate is fast, the response is often delayed and disappointing. With these, too, transfusion should not stop in the pre-operative ward; operation and the post-operative phase need to be supported, otherwise many deaths occur.

In principle, once a response has been elicited, the later transfusions are given in a volume and at a rate appropriate to the general condition. Of great importance is an appreciation of the urgency of surgery when tissue damage is massive. These cases can often be no more than partially restored by pre-operative transfusion. When this is so, when the patient seems to hang fire despite continued transfusion, then his only chance of life is to take the risk of immediate operation with a transfusion in progress. Likewise, with gross infection. Until the cause, the toxic focus, has been removed, little response to transfusion can be expected. Judicious transfusion has also a great place during convalescence, but in this field there have been more difficulties and tragedies than in the forward areas where the acute phase is handled. It is certainly desirable that the deliberate work of a back area should be carried out with fresh blood of appropriate group, with intra-group incompatibility (Rhesus factor, etc.) carefully excluded. A so-called "pep" transfusion, made with somewhat old Group O blood, in which the immunizing potentialities of previous transfusions have not been excluded, has occasionally and unnecessarily cost a life.

Failures, Disappointments and Disasters.—Enough has been said to show that transfusion is not a mechanical procedure and that, in some apparently straightforward cases, surgery may have to take precedence over complete response. Supplies have been so abundant that, at one phase of the war, a wounded man was almost lucky if he escaped a transfusion, and a number of unsuitable cases were undoubtedly submitted to the operation. Injuries to the brain and central nervous system respond poorly; unless there are serious injuries elsewhere, such cases are best left alone. Bone injuries now carry a risk which is recognized as relatively common; this is the precipitation of fat embolism, which should be suspected whenever unexplained pulmonary or cerebral symptoms arise during the transfusion of a case with a bone injury. The transfusion should be stopped, as it tends to increase the amount of fat in the circulation; immobilization and rest are the only effective remedies.

Certain cases should never be transfused. These include thoracic injuries with an embarrassed circulation from haemopericardium or other mechanical causes, and injuries to the lung alveoli from blast or irritant gases. Indeed, the transfusion of any chest injury should be undertaken with caution on account of the danger of pulmonary oedema. With modern projectiles, some degree of blast injury is not uncommon. When there are prominent injuries elsewhere, blast lung may easily pass unobserved until pulmonary oedema occurs. The diagnosis can often be supported by finding a ruptured tympanic membrane. Disasters from incompatible blood have been almost unknown. This is a tribute to the complete group-checking system which was rigidly enforced, whereby both agglutinin and agglutinin content of all Group O blood was carried out before release. Trouble has occasionally arisen from the use of massive quantities of somewhat old blood (supra) but the bogey of infected blood has appeared on only four small occasions, despite the fact that the armies have operated in all climates and under most difficult conditions. This again is a tribute to the efficiency of the technique of blood collection, transportation and storage under field conditions, as well as to the esprit de corps of the Service which permitted no carelessness or slackness in the handling of a potentially dangerous fluid.

Some Facts and Figures.—The records of all Forces have not yet been completely analysed, but the figures in Tables I and II give some idea of the supplies which had to be obtained and the extent of their utilization. The most constant fact, from all theatres, is that approxi-
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mately 10 per cent of wounded required to be transfused; this also was the figure found for air-raid casualties in this country.

**Table I.—Utilization.**

<table>
<thead>
<tr>
<th>Theatre and period</th>
<th>Wounded admitted</th>
<th>Number transfused</th>
<th>Per cent transfused</th>
<th>Fluids used (pints)</th>
<th>Average per case (pints)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8th Army</td>
<td>11,732</td>
<td>1,119</td>
<td>10</td>
<td>Blood: 2,171, Plasma: 1,323</td>
<td>Blood: 1.9, Plasma: 1.2, Protein: 3.1</td>
</tr>
<tr>
<td>M.E.F. (Forward Areas)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Army</td>
<td>16,674</td>
<td>1,604</td>
<td>10</td>
<td>Blood: 1,084, Plasma: 4,000</td>
<td>Blood: 0.7, Plasma: 2.5, Protein: 3.2</td>
</tr>
<tr>
<td>B.N.A.F. (Forward Areas)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C.M.F. Anzio:</td>
<td>3,904</td>
<td>414</td>
<td>10-6</td>
<td>Blood: 1,305, Plasma: 491</td>
<td>Blood: 3.1, Plasma: 1.2, Protein: 4.3</td>
</tr>
<tr>
<td>1944 (Forward Areas)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Forward Areas :</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Back Areas:</td>
<td>9,468</td>
<td>7% retransfused</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes.**—38 per cent of the cases transfused by B.L.A. required 4.5 pints total protein per case; 62 per cent of the cases transfused by B.L.A. required 6.9 pints total protein per case.

The variation in the amount of blood or plasma used in the average case is partly a function of the supplies available and partly dictated by the prevailing fashion. It will be seen that the average total protein requirement is about 4 pints per case and that, in the most experienced force—the B.L.A.—this was made up of approximately 2½ pints of blood and 1½ pints of plasma, so far as the acute phase of the wounding was concerned. In the B.L.A. there was a considerable amount of transfusion work at General Hospital level as well as in the forward areas.

As to the supplies provided (Table II): there was no period of the war in which the demand ceased to be on an increasing scale, culminating with a figure of 124 pints of protein fluid and 134 pints of crystalloids for every hundred wounded in the B.L.A.

**Table II.—Supplies.**

<table>
<thead>
<tr>
<th>Force and period</th>
<th>Total wounded</th>
<th>Blood fluid and dried</th>
<th>Crystalloids</th>
<th>Supplies per 100 wounded</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.E.F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1940 to June, 1943</td>
<td>63,190</td>
<td>10,379</td>
<td>41,383</td>
<td>Blood: 16, Plasma: 65, Crystalloids: 91</td>
</tr>
<tr>
<td>B.N.A.F.</td>
<td>16,674</td>
<td>1,094</td>
<td>5,000</td>
<td>Blood: 6, Plasma: 30, Crystalloids: 30</td>
</tr>
</tbody>
</table>

This is eloquent testimony to the inevitable waste of war. That such supplies were freely given without question is a tremendous tribute to the magnitude and constancy of the public effort, typified by the ordinary civilian blood donor, which gave to our wounded the 80 to 90 per cent chance of life which they enjoyed.

**BIBLIOGRAPHY.**


