THE TREATMENT OF BURNS IN CHILDREN

ESSAY

Submitted for

THE THOMSON MEMORIAL MEDAL

by

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</table>
PART I

THE EXPOSURE METHOD OF TREATMENT OF BURNS
PART I

THE EXPOSURE METHOD OF TREATMENT OF BURNS

Since the exposure method for the local treatment of burns and scalds (Wallace, 1949) was introduced in 1947, its scope has been widened and it is now regarded as the treatment of choice in this centre.

Method

Its aims are

(a) To produce an environment unfavourable to the growth and multiplications of bacteria by (i) the production of a dry surface, (ii) exposure to light and (iii) the reduction of the temperature of the surface to below that of the body.

(b) To avoid antiseptics which cause further injury to tissue cells.

(c) To provide rest of the affected part by immobilisation.

(d) To limit oedema, where possible, by elevation.

(e) To render nursing care simple in areas where dressings would otherwise be continually contaminated, e.g. buttocks, thighs, perineum, face.

Procedure. - The area is cleaned gently with 1 per cent. cetavlon and all blisters and loose epidermis are removed. The cetavlon is then rinsed off with normal saline and the areas are dried with gauze. At this time, before oedema is established, it may be possible to estimate the depth of injury by palpation: in areas of deep /
deep destruction the skin feels thick and indurated, whereas in areas of superficial skin damage the parts feel soft.

Penicillin is given intramuscularly and penicillin powder (10,000 International Units per gram in lactose or magnesium oxide) is insufflated four-hourly until the burn is dry. The importance of omitting sulphonamide in the powder must be stressed because of the danger of absorption. The burn is exposed to the air in the general surgical ward and, while it is protected carefully from injury, no special precautions are taken to prevent airborne contamination.

Applicability.— The only limiting factor is the distribution of the burn, not its depth or extent. With ingenuity nearly all burns can be adequately exposed, and the use of a specially constructed bed, described below, makes possible the application of the method even to circumferential burns of the trunk and legs. Methods of exposing and immobilising individual areas in children have been described in the earlier publication; most of these methods can be applied equally well to adults. In a shocked child, exposure can be combined with intravenous resuscitation, but local toilet should be omitted or delayed until the general condition is stabilised. Systemic penicillin and the local application of penicillin powder should, however, be started immediately. In extensive burns, the criticism has been made that this method of treatment allows plasma loss to continue unchecked and therefore fails to limit the severity of oligaeic shock. Pressure dressings, which were designed to prevent plasma leakage, have been shown to be of little value /
value from this point of view as the pressure becomes negligible within half an hour of application of the bandages. The tanning agents may limit loss from the surface but this may be a very small proportion compared with the loss which occurs into the deeper tissues. Elevation is probably the only practicable means by which oedema formation can be minimised and in the case of a limb this procedure can be combined with exposure. No general ill effect upon the child from exposure to the cool air of a general surgical ward has been observed in any of the cases treated.

Progress of an Exposed Burn

Superficial Burns.- The surface dries in 24 to 48 hours when the exudate and powder together form a light brown, thin coagulum which gradually becomes darker. While the surface is moist there may be a slight surrounding flare, but this fades as soon as the area is dry. The temperature may be slightly elevated in the first 24 to 48 hours but returns to normal when drying is complete. An isolated spike of temperature occurring later usually coincides with the appearance of a crack in the crust due to inadequate immobilisation, which allows the temporary admission of organisms. In 7 to 15 days the crust separates leaving a completely epithelialized surface.

Deep Dermal Burns.- In deep dermal burns the surface takes longer to dry, usually about 72 hours, and when there has been initial doubt as to the depth of a lesion this observation has often proved helpful. Because of the longer period of exudation the crust tends to be thicker, and /
and every effort is made to keep it intact for three weeks. The crust is then carefully removed to reveal a pale pink dry surface on which the red dermal papillae are clearly visible. Tulle gras dressings or albucid ointment are applied and healing occurs rapidly without grafting and without subsequent scar formation.

When there is almost complete dermal loss, the most satisfactory method of approach is to consider the burn as deep, to excise the slowly healing dermis and to graft the raw bed.

**Deep Burns.**—The clinical progress is similar to that of a deep dermal burn except that palpation after about 10 days may identify areas of softening beneath the crust which indicate liquefaction of dead tissue. In a mixed burn, areas of total skin destruction can be mapped out by this procedure. When excision is carried out at the end of three weeks there is found, under the crust, a thin 'pus-like' material - frequently sterile - which is formed by the action of liquefactive enzymes. In some cases, however, and always if cracks have formed in the crust, the fluid gives a scanty to moderate growth of organisms on culture. The underlying granulations are found to be clean and healthy in spite of any bacteriological evidence of infection, and immediate grafting is possible. From this time onwards the pressure dressing technique is employed.

**Comparison of Progress of Burns treated by Exposure and by Pressure Dressings.**—A series of 200 patients with burns and scalds treated in this hospital within the penicillin era has been reviewed. The first
100 patients were treated by the pressure dressing method and the second 100 by exposure. Patients who were treated by a combination of the two methods or who were admitted after initial treatment in another hospital have been omitted, but with those exceptions the cases are consecutive and unselected.

Table I

<table>
<thead>
<tr>
<th>Progress</th>
<th>Pressure Dressings</th>
<th>Exposure Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grafting required</td>
<td>27 cases</td>
<td>9 cases</td>
</tr>
<tr>
<td>Some degree of pyrexia</td>
<td>53 &quot;</td>
<td>32 &quot;</td>
</tr>
<tr>
<td>Initial rise of temperature only</td>
<td>19 &quot;</td>
<td>32 &quot;</td>
</tr>
<tr>
<td>Temperature 100°F or over</td>
<td>31 &quot;</td>
<td>15 &quot;</td>
</tr>
<tr>
<td>Continuous pyrexia lasting 1-6 weeks</td>
<td>34 &quot;</td>
<td>0 &quot;</td>
</tr>
<tr>
<td>Streptococcal rash</td>
<td>5 &quot;</td>
<td>0 &quot;</td>
</tr>
<tr>
<td>Healing time</td>
<td>47 days</td>
<td>21 days</td>
</tr>
</tbody>
</table>

Because the clinical descriptions in the case histories were sometimes inadequate and because the initial determination of the depth of destruction is in many cases impossible, an attempt was not made to classify /
classify the two series into superficial and deep groups. Initial partial dermal loss due to heat can become whole skin loss through the application of antiseptics which are injurious to tissue cells, and by subsequent infection, and it is suggested that the difference in healing times and in the necessity for grafting is due mainly to the absence or control of these noxious agents in the second series. The number of cases studied was limited by the necessity for including only those which were treated after the introduction of penicillin, and the probability of some degree of statistical error is acknowledged. To these tabulated findings could be added another finding which is more difficult to record and that is that the children themselves are so much better under the second method of treatment. They are more comfortable and contented; they look well, eat well and sleep well, and rapidly become accustomed to any of the positions in which they find themselves.

**Bacteriology.**—A study of the surface bacteriology has been made in 50 of the more extensively burned patients treated by exposure. For the taking of specimens, ordinary sterile throat swabs were used moistened with peptone broth to encourage the picking up of organisms. They were rolled rather than rubbed on the surface to avoid so far as possible injury to the coagulum in its early stages of formation. An initial swab was taken before any cleansing was carried out, and then daily swabs were taken until the surface was completely dry and a good intact coagulum had been formed. In some cases Petri dishes, containing blood agar, were exposed to the air in the ward by the side of the burn for thirty /
thirty minutes each day.

All swabs were plated out on blood agar, Hoyle and McConkey's media, and a second series of cultures was made after 24 hours' incubation in glucose broth.

Table II shows the frequency with which the various organisms were encountered. In most cases a mixed growth was obtained, the combination of Staphylococcus albus, Staphylococcus aureus and B. coli being the most common.

From the bacteriological point of view an exposed burn is regarded as an infected wound but, from the clinical point of view, the bacteriological report is without significance. Organisms fall on the surface as they fall on the intact skin but when the surface is dry they have no invasive power and are harmless.

Table II /
In nearly all cases a mixed growth was cultured: only four swabs were sterile - these were all initial swabs taken prior to treatment.

B. proteus and Ps. pyocyanea have never been cultured from the surface of an exposed burn although they have been found frequently in Petri dishes exposed to the air by the side of the burn. Their absence is worthy of note as not only have they been found in the air of the ward, but they are, especially B. proteus, common and undesirable infecting organisms in burns treated by occlusive dressings.

Investigation of the bacteriology under the crusts is proceeding.
An attempt has not been made to treat any cases without local and systemic penicillin, but in obviously superficial lesions both are discontinued as soon as the burn is dry. Both aqueous and procaine penicillin have been given, in each case a total of 250,000 to 500,000 International Units per day, according to the size of the child and the extent of the lesion. The impression is that the former is more satisfactory and it is used now in four-hourly doses.

In another centre (Cambridge Military Hospital, Aldershot), over a smaller number of cases, Whyte (1950) states that when only systemic penicillin is given the progress and bacteriological findings are essentially the same as when both routes are used. In these cases it has been shown that the crusts and, in a deep burn, the fluid under the crusts, contain significant quantities of active penicillin.

**Methods of Exposing Difficult Areas**

When only one aspect of the body or the limbs is burned, exposure is straightforward. Circumferential burns of the arms and hands can be exposed by nail suspension, which has proved satisfactory and painless, or if two or more fingers are uninjured finger cots soaked in collodion can be applied with tapes attached to the tips; similar lesions of the legs and feet can be exposed and elevated by the insertion of calcaneal pins if the burns are severe and the general condition of the patient demands it.

Two difficult problems remain, burns of the neck and the circumferential burn of the trunk.
(1) **Neck.**— Even if satisfactory extension and immobilisation can be achieved, movement caused by chewing and swallowing still tends to encourage cracks in the coagulum during the first few days. For this reason burns of the neck should be watched with special care and penicillin powder applied more frequently than in other areas (e.g. two-hourly) until the burn is completely dry. The neck is extended by placing a firm pillow beneath the shoulders; lateral movement and rotation are checked by sandbags at either side of the head, or by a wide strip of adhesive tape applied to the forehead and pinned to the mattress at either side. Recently, the apparatus shown in Fig. 1 has been used. The cross-bar of the crucifix is used for fixation of the arms and the temples are gripped by the hinged side pieces which are adjusted and held in apposition by the padded strap. The height of the sides is less than the occipito-frontal diameter of the head so that the strap lies snugly across the forehead and prevents flexion of the neck.
Circumferential Burns of the Trunk.- The difficulty in positioning these cases has been largely overcome by the use of a bed which was made to our requirements by the Edinburgh Motor Engineering Company and Dunlopillo, Ltd. It is designed to fit the standard hospital cot and is suspended by cords attached to each corner. The frame is made of angle iron instead of tubular steel as in the ordinary Bradford frame, and the part usually occupied by canvas is replaced by sections of aluminium sheeting with flanged sides, to give strength, and is padded with sorbo rubber. The centre panel has a hole adequate for nursing purposes; if the buttocks are burned this panel can be removed entirely (Fig. 2).

The neck can be extended by inserting a section with four-inch cushioning under the shoulders and a one-inch cushion under the head. Burns of the abdomen and back can be exposed by removing the middle sections and supporting the child face-downwards by a section under /
under the costal margin and the next under the upper thighs. For nursing purposes the legs are widely abducted by anchoring the ankles to the side of the frame. It is found that almost any area can be exposed by the removal of the appropriate sections, and the soft but resilient padding entirely prevents bed sores on the weight-bearing points. Even when this bed has not been essential to obtain adequate exposure of a burn, its use has greatly facilitated nursing and has prevented undue handling and disturbance of the patient.

**The Exposure Method and Protein Loss**

The fact that many children with extensive burns who would have died early from oligaeemic shock are now surviving opens up new problems. Wasting and bronchopneumonia are now the commonest causes of death in severely burned patients who survive the first few weeks.

A sufficient number of extensive deep burns has not yet been treated by exposure to allow definite conclusions to be formed but the patients who have been treated have been followed carefully with regard to weight loss, the development of anaemia and alteration in serum protein levels.

**Weight Loss.**—It was found impracticable to attempt to weigh children who were immobilised. Circumferential measurements of the uninjured limbs were made a few days after admission and at weekly intervals thereafter. They showed a decrease of 1 to 2 cm. during the first month and then remained more or less constant: this decrease was thought to be due partly to muscle inactivity. None developed the sunken /
sunken cheeks and loose wrinkled skin associated with gross loss of weight.

**Anaemia.** - In the initial stages of treatment for oligaemic shock all the cases studied were given blood as well as plasma. Haemoglobin estimations were carried out every three days for the first two weeks and thereafter at weekly intervals. In no patient did the haemoglobin fall below 80 per cent. (Sahli) and secondary transfusion was not considered necessary.

**Serum Protein Levels.** - Estimations of serum protein levels were carried out at weekly intervals on the two most extensively burned patients who had 23 per cent. and 25 per cent. respectively of body area affected by whole thickness skin loss. The lowest level reached was 6.6g per cent. None of the children developed pulmonary complications. From the first week all the patients with extensive burns were given a high protein diet. Originally we aimed at increasing the normal protein intake for the age group by four or five times, but this was not tolerated by the children. However, most will take a diet containing 120 to 140g per day and can eat sufficient carbohydrate to balance this amount of protein. In all the cases, grafting of the raw area was begun during the fourth week. No quantitative studies have as yet been made, but we suggest that by the exposure method of treatment less protein is lost externally than when dressings are applied. Protein is utilised in the formation of the original crust but after this no further exudation occurs, whereas the continued loss of /
of nitrogenous substances into dressings, as serum and pus, and as blood when dressings are changed, must be considerable.

The well recognised delayed anaemia of burns is probably due to two main factors, protein lack and prolonged infection, and it is possible that the relative control of both these factors accounts for the fact that none of our patients developed this characteristic finding. The initial anaemia due to destruction of red blood cells in the injured area by direct heat, and to subsequent haemolysis, is corrected by the initial transfusion.

It is realised that estimations of serum protein levels may be of doubtful diagnostic value because there may be depletion of tissue protein before this is reflected in changes in the serum protein level, and because there may be a chronically diminished total blood volume in such cases, which would cause the serum protein level to underestimate the total protein deficiency. Serological findings are of value only in conjunction with the other observations.
Summary

The exposure method for the treatment of burns and scalds is described briefly and the results, in a series of patients, are contrasted with those in a series treated by pressure dressings. The findings suggest that by the exposure method, the necessity for skin grafting can be reduced, infection limited and the healing time significantly diminished.

A study has been made of the surface bacteriology exposed burns and the conclusion is drawn that the culture of organisms from the surface does not indicate clinical infection.

A bed designed to facilitate the nursing of patients with extensive burns has been described.

The suggestion is made that by treating extensive deep burns by exposure protein loss is diminished and the nutrition and general progress of the patient are thereby improved.
PART II

FLUID REPLACEMENT IN BURNED CHILDREN
PART II

FLUID REPLACEMENT IN BURNED CHILDREN

The purpose of this study was to evolve a method of estimating the nature and amount of fluid replacement required by a burned child. So that the method can be applied by those with limited experience in a general hospital, its essential features must be effectiveness, simplicity and safety.

If a burned patient is to survive, fluid therapy must be prompt and adequate; in addition it is advisable to prevent the development of oligaemic shock and so avoid the risk of the established condition. In children whose total blood volume is proportionately low, the amounts of fluid administered must be carefully controlled.

**Nature of the Local Fluid Loss**

Before a rational programme of replacement can be suggested, it is necessary to consider the nature of the loss from the circulation as a result of the injury.

(1) **Protein and Water.** Fluid with approximately half the protein concentration of plasma is lost into the interstitial spaces and from the surface. This loss is greatest during the first 8 hours and continues at a slower rate until 36 to 48 hours after injury. The protein fraction may be partially coagulated in situ, but reabsorption of /
of the extravasated fluid occurs fairly rapidly from this time onwards.

(2) Electrolytes. - The electrolyte pattern and concentration in the fluid lost from the site of injury are approximately the same as those of normal plasma (Cope and Moore, 1947).

(3) Blood. - Red cells are directly destroyed by heat in a burn sufficiently deep to coagulate the dermal capillaries. There is also a delayed haemoglobinaemia which may be due either to intravascular haemolysis of cells not completely destroyed but rendered more fragile by the same process, or to a specific haemolytic factor produced at the site of injury. This process of coagulation limits the continued exudation of fluid upon the surface: consequently, in an extensive deep burn the whole blood loss may account for as much as 40 per cent. of the total volume deficit (Evans and Biggar, 1945).

The following relative amounts of replacement fluid are suggested from consideration of the above factors.

Plasma and saline should be given in equal proportions so that the total protein and electrolyte content approximates to that of the fluid lost into the injured area (Cope and Moore, 1947).

Blood should be given in all cases of deep burns and since, as stated above, nearly half of the volume deficit may be due to whole blood loss, it is suggested that whole blood should replace up to half of the plasma-saline requirement in the first 8 hours. Increased haemoconcentration is not considered to be a contraindication to the giving of blood and is, in fact, reduced by its administration.
In established shock from any cause there is a virtual loss of whole blood from the active circulation, due to its accumulation in stagnant dilated capillaries.

When a burned patient is admitted with an already poor capillary circulation, as indicated by a slow colour return on pressure, with or without cyanosis, whole blood is given at the calculated rate until the condition begins to improve, irrespective of the depth of the injury.

In the early stages of treatment of a deep burn the administration of whole blood substantially delays and limits a characteristic anaemia which may complicate the state of healing.

Table III gives the proportions of fluid replacement required in superficial and deep burns.

<table>
<thead>
<tr>
<th></th>
<th>Plasma</th>
<th>Blood</th>
<th>Normal Saline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial Burn</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Deep Burn (First 8 hours)</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

In the patients treated, there has been no evidence that the transfused cells have been haemolysed, nor have any other ill effects been observed.
In all cases, in addition to the replacement fluid given, the metabolic requirement must be met in full by giving the required amount of fluid for the age group.

Biochemical investigation of alterations and deficiencies in the inorganic constituents of the circulating blood has not been used as a guide to fluid and electrolyte requirements, because of the necessity for simplicity, and because a functioning kidney is the best regulator of blood chemistry; the aim should be to restore function to this natural regulating mechanism by prompt and adequate restoration of the circulating blood volume.

Estimation of Fluid Requirement

Though essential, clinical observation is except to the experienced an insufficient guide to the quantity and rate of fluid administration required. A normal pulse rate, blood pressure and blood concentration may give a false sense of security, or the severely shocked child may be given dangerously large volumes of fluid because of a slow initial response to transfusion. Serial haematocrit readings have been used to estimate the amount and rate of fluid loss but the method has several disadvantages. First, there is the practical difficulty of obtaining samples of blood from a small child. In shock from burns there is always a marked degree of venospasm and it may be difficult to obtain blood even by femoral puncture. Secondly, before the initial estimation of plasma loss can be made it is necessary to wait until haemoconcentration has occurred and this is, in some cases, delayed until /
until the clinical signs of shock are well established. Thirdly, in deep burns, because there is a loss of red cells as well as of plasma and electrolytes, the haematocrit reading may greatly underestimate the total deficiency of circulating fluid volume.

An arbitrary method which provides at least a guide to the quantities required has obvious advantages. The formula which has been evolved and which is undergoing trial, is based on work previously published (Cope and Moore, 1947).

It fulfils the following requirements -

(1) The quantity of fluid given is proportional to the extent of the area into which fluid is being lost.

(2) The rate of administration is parallel to the rate of local fluid loss.

(3) The amount given is proportional to the normal blood volume of the patient.

Table IV /
Table IV
Table for Estimation of Total Fluid Requirements for First 24 Hours per 1 per cent. of Area Burned

<table>
<thead>
<tr>
<th>Age</th>
<th>Normal Saline (ml.)</th>
<th>Plasma (ml.)</th>
<th>Metabolic Fluid Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 mth.</td>
<td>5</td>
<td>5</td>
<td>160 ml. per kg.</td>
</tr>
<tr>
<td>3-6 mth.</td>
<td>7</td>
<td>7</td>
<td>100 ml. per kg.</td>
</tr>
<tr>
<td>6-9 mth.</td>
<td>8</td>
<td>8</td>
<td>80 ml. per kg.</td>
</tr>
<tr>
<td>9-12 mth.</td>
<td>9</td>
<td>9</td>
<td>50 ml. per kg.</td>
</tr>
<tr>
<td>1-2 yr.</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>2-3 yr.</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>3-4 yr.</td>
<td>16</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>4-5 yr.</td>
<td>18</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>5-6 yr.</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>6-7 yr.</td>
<td>23</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>7-8 yr.</td>
<td>27</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>8-9 yr.</td>
<td>29</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>9-10 yr.</td>
<td>31</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>10-11 yr.</td>
<td>34</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>11-12 yr.</td>
<td>37</td>
<td>37</td>
<td></td>
</tr>
</tbody>
</table>

First 24 hours 1/2 in first 8 hours post-burn
1/2 in next 16 hours
Second 24 hours 1/2 total for first 24 hours

Although patients with extensive burns require large amounts of fluid, there is a limit to the distensibility of the interstitial space. It has been shown that fluid therapy should be restricted to a 48 hours' total corresponding to no more than a 50 per cent. increase in extracellular fluid volume, which is an amount not exceeding 10 per cent. of body weight.

When /
When the first formula is applied, it is found that at any age the amount begins to exceed this limit when 30 per cent. or more of body area is involved. In such cases, the second formula is used. The nature of the fluids given and their relative proportions are the same as before. In both cases, when whole blood is indicated, it is given at the outset.

### Table V

**Fluid Replacement Formula for Burns Exceeding 30 per cent. of Body Area**

Calculate 10 per cent. of Body Weight

Fluid requirement for 48 hours = 10 per cent. of body weight plus twice daily metabolic fluid requirement.

<table>
<thead>
<tr>
<th>Time</th>
<th>Fluid Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>First 24 hours</td>
<td>3/4</td>
</tr>
<tr>
<td>8 hours</td>
<td>1/2</td>
</tr>
<tr>
<td>16 hours</td>
<td>1/4</td>
</tr>
<tr>
<td>Second 24 hours</td>
<td>1/4</td>
</tr>
<tr>
<td>24 hours</td>
<td>1/4</td>
</tr>
</tbody>
</table>

Method /
Method of Administration

From the point of view of fluid replacement, burns and scalds of less than 6 per cent. of body area can be disregarded. Burns of 6 to 12 per cent., particularly in infants, should be regarded as potentially dangerous. In such patients, the calculated amount should be given by mouth in half-hourly or hourly doses, saline being substituted for plasma and the full metabolic requirement being added.

It is suggested that as a general rule children with burns of 12 per cent. or more should be given fluid intravenously from the time of admission. Many show no clinical or haematological signs of shock at this time, but it is better to forestall their appearance by prompt treatment than to await their development.

When the child is drinking well, only the plasma, or blood and plasma, is given intravenously, the saline and metabolic requirement being given by mouth. When there is vomiting, or when drinks are refused, the whole requirement must be given intravenously and the metabolic requirement added as iso-tonic glucose solution. In infants it is always preferable to give sodium chloride solutions by mouth so that the child itself controls the rate of absorption. When this is impossible, a solution containing 0.18 per cent. sodium chloride and 4.1 per cent. glucose is given in preference to normal saline.

In all cases, the first 8 hours' requirement is calculated from the time of injury, not from the time of beginning treatment.

Example -
Example -

A child of 18 months is admitted 3 hours after injury with burns involving 20 per cent. of body surface. According to Table IV, the requirement is 10 ml. of plasma and saline for each 1 per cent. of area burned.

First 24-hours' requirement = 20 x 10

= 200 ml. plasma
+ 200 ml. saline

Therefore, first 8 hours' requirement ........... = 100 ml. plasma intravenously

+ 100 ml. saline orally, or intravenously.

Since the child was admitted 3 hours after the accident this quantity must be given in the first 5 hours of treatment, i.e. 20 ml. of plasma and of saline per hour.

Metabolic requirement at 18 months = 2,000 ml. (approximately) in 24 hours.

= 90 ml. per hour of non-electrolyte fluid orally.

Lund and Browder's charts are used for estimating surface area.
Relative Percentages Of Areas Affected by Growth

<table>
<thead>
<tr>
<th>Area</th>
<th>Age 0</th>
<th>1</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A = (\frac{1}{2}) of head</td>
<td>9(\frac{1}{2})</td>
<td>8(\frac{1}{2})</td>
<td>6(\frac{1}{2})</td>
</tr>
<tr>
<td>B = (\frac{1}{2}) of one thigh</td>
<td>2(\frac{3}{4})</td>
<td>3(\frac{3}{4})</td>
<td>4</td>
</tr>
<tr>
<td>C = (\frac{1}{2}) of one leg</td>
<td>2(\frac{1}{2})</td>
<td>2(\frac{1}{2})</td>
<td>2(\frac{3}{4})</td>
</tr>
</tbody>
</table>
Relative percentages of Areas Affected by Growth

<table>
<thead>
<tr>
<th>Area</th>
<th>Age 10</th>
<th>15</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - $\frac{1}{2}$ of head</td>
<td>5½</td>
<td>4½</td>
<td>3½</td>
</tr>
<tr>
<td>B - $\frac{1}{3}$ of one thigh</td>
<td>4½</td>
<td>4½</td>
<td>4½</td>
</tr>
<tr>
<td>C - $\frac{1}{3}$ of one leg</td>
<td>3</td>
<td>3½</td>
<td>3½</td>
</tr>
</tbody>
</table>
Table VI
Table of Average Values in Childhood

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Hb. % (Sahli)</th>
<th>PCV</th>
<th>Total PV</th>
<th>Total BV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>3</td>
<td>40</td>
<td>95</td>
<td>55</td>
<td>180</td>
<td>400</td>
</tr>
<tr>
<td>0 - 3 mth.</td>
<td>5</td>
<td>62</td>
<td>65</td>
<td>40</td>
<td>200</td>
<td>350</td>
</tr>
<tr>
<td>4 - 6 mth.</td>
<td>7</td>
<td>68</td>
<td>70</td>
<td>40</td>
<td>300</td>
<td>500</td>
</tr>
<tr>
<td>7 - 9 mth.</td>
<td>9</td>
<td>72</td>
<td>70</td>
<td>40</td>
<td>330</td>
<td>550</td>
</tr>
<tr>
<td>10-12 mth.</td>
<td>10</td>
<td>76</td>
<td>70</td>
<td>40</td>
<td>360</td>
<td>600</td>
</tr>
<tr>
<td>1 - 2 yr.</td>
<td>13</td>
<td>88</td>
<td>70</td>
<td>40</td>
<td>500</td>
<td>850</td>
</tr>
<tr>
<td>2 - 3 yr.</td>
<td>15</td>
<td>96</td>
<td>75</td>
<td>43</td>
<td>550</td>
<td>1,000</td>
</tr>
<tr>
<td>3 - 4 yr.</td>
<td>17</td>
<td>103</td>
<td>80</td>
<td>43</td>
<td>650</td>
<td>1,150</td>
</tr>
<tr>
<td>4 - 5 yr.</td>
<td>18</td>
<td>104</td>
<td>80</td>
<td>43</td>
<td>750</td>
<td>1,350</td>
</tr>
<tr>
<td>5 - 6 yr.</td>
<td>20</td>
<td>111</td>
<td>85</td>
<td>43</td>
<td>850</td>
<td>1,500</td>
</tr>
<tr>
<td>6 - 7 yr.</td>
<td>22</td>
<td>117</td>
<td>85</td>
<td>43</td>
<td>1,000</td>
<td>1,700</td>
</tr>
<tr>
<td>7 - 8 yr.</td>
<td>24</td>
<td>123</td>
<td>85</td>
<td>43</td>
<td>1,100</td>
<td>1,900</td>
</tr>
<tr>
<td>8 - 9 yr.</td>
<td>26</td>
<td>128</td>
<td>85</td>
<td>43</td>
<td>1,200</td>
<td>2,100</td>
</tr>
<tr>
<td>9-10 yr.</td>
<td>29</td>
<td>133</td>
<td>90</td>
<td>43</td>
<td>1,300</td>
<td>2,300</td>
</tr>
<tr>
<td>10-11 yr.</td>
<td>32</td>
<td>138</td>
<td>90</td>
<td>44</td>
<td>1,400</td>
<td>2,500</td>
</tr>
<tr>
<td>11-12 yr.</td>
<td>35</td>
<td>143</td>
<td>90</td>
<td>44</td>
<td>1,500</td>
<td>2,700</td>
</tr>
</tbody>
</table>
General Management of the Severe Burn

In addition to fluid replacement the following measures are adopted -

(1) Sedation.- Rest lowers the oxygen requirement of the tissues, and since oligaemic shock causes death from tissue anoxia adequate sedation is a logical procedure. This has been confirmed in practice and no ill effects on the respiratory or central nervous systems have been observed. After extensive trial of other drugs, particularly chloral hydrate and seconal, heroin has been found to be the most satisfactory. Smaller doses are required than are usual for the age and weight and the drug should be given slowly, through the intravenous cannula, to avoid the danger of accumulation and sudden absorption of successive doses from the subcutaneous tissues.

(2) Oxygen.- Administration at the rate of 3 litres per minute by means of intranasal catheters has been found the most satisfactory method. A tent, however carefully used, tends to cause overheating and prevents ready access to and observation of the patient. In severely shocked children aeration of the lungs is poor and it is possible that there may be some degree of central in addition to peripheral anoxia. The clinical impression over many cases is that its use is beneficial whether or not there is any evidence of direct thermal injury to the respiratory tract.

(3) Position.- The head-down position is adopted in the treatment of shock from burns as in the treatment of reduced blood volume and hypotension from any other cause. To be of value, the angle /
angle should be as acute as possible short of causing respiratory embarrassment.

(4) Heat.— The application of external heat in any form is strictly avoided.

(5) Local Measures.— The burns are exposed to the air as soon as possible and covered with penicillin powder: systemic penicillin is started immediately. Cleansing is omitted, or postponed, until the general condition is stabilised.

(6) Hyperpyrexia.— This is a not uncommon complication which occurs usually during the first 72 hours after injury: very high temperatures may be reached and unless immediate and vigorous steps are taken the child may die. Cold sponging of the uninjured skin combined with fanning and exposure near an open window usually reduce the temperature quickly if applied courageously. The possibility of a transfusion incompatibility should be considered in all patients who are receiving intravenous fluid although this has never been demonstrated as a cause of hyperpyrexia in any of the cases treated in this hospital.

Assessment of Progress

The following observations are recorded at half-hourly or hourly intervals according to the severity of the condition.

(1) Capillary Circulation.— The state of the capillary circulation is judged by the colour of the skin, e.g. pallor, cyanosis, colour return on pressure, and by the skin temperature, e.g. coldness of the nose and extremities.

(2) /
(2) Mental State and Behaviour. - A spasmodic restlessness occurs early in the development of oligaeemic shock and is, in itself, an indication for fluid administration: it is usually accompanied by thirst. If the condition is more advanced the child is quiet, alert and co-operative, thirst is intense and vomiting is common.

(3) Pulse. - Changes in rate are of little diagnostic or prognostic significance but fall in pulse pressure usually precedes a fall in mean blood pressure.

(4) Temperature. - The rectal temperature is recorded half-hourly so that hyperpyrexia can be treated immediately.

(5) Respiration. - In addition to watching for signs of injury to the bronchial tract, the rate and character of respiration are observed and frequent auscultation is carried out to detect the development of basal oedema due to overhydration.

(6) Blood Pressure. - A fall in blood pressure is a late sign which should be avoided, not awaited. A large percentage of patients show an elevation of pressure which may be maintained for hours or even days.

(7) Haemoglobin. - The haemoglobin level throughout an age group is more variable than the haematocrit reading so that the initial level may be of little significance unless grossly elevated. However, in an individual case changes in the level follow closely changes in the haematocrit reading and are of great value in assessing progress.

(8) Intravascular Haemolysis. - When possible the plasma is examined /
examined for signs of haemolysis.

(9) Urinary Excretion.- This is the most valuable single guide to progress and to the efficacy of treatment. It is measured by means of an indwelling catheter released at hourly intervals. The specimens so obtained are examined for albumen, casts, red blood cells and haemoglobin.

(10) Fluid Intake.- Oral and intravenous intakes are recorded at hourly intervals on the same chart.

Report on Cases Treated

Up to the time of writing 14 cases have been treated by the system of calculated fluid replacement.

Group I.

Eight patients between one and three years of age had lesions involving between 6 and 12 per cent. of body area. All were in good clinical condition on admission, although three showed a slightly increased haemoconcentration. They were all given fluids by the oral route only. In the three cases mentioned, the haemoconcentration was reduced to a stable level within five hours. In seven cases progress, as measured by the standards described above, was uneventful. The eighth was a child of one year with superficial scalds totalling 6 per cent. of body area; he remained well for five hours until an electric blanket was mistakenly applied: within 30 minutes he was pale, slightly cyanosed and drowsy, with a respiratory rate of 40, and a poor volume pulse of 180 per minute. The blanket was removed and the fluid continued /
continued, and he had returned to normal within the next hour.

This case illustrates not only the adverse effect of heat but the very unstable circulatory state in an apparently well child with scalds of limited extent.

**Group II.**

The following six patients had burns totalling 12 per cent. or more of body area.

**Case 1.**—Male, aged 9 months; admitted five hours after scalds totalling 12 per cent. of body surface.

On admission, he was pale, restless, and extremely thirsty, with a haemoglobin of 100 per cent. The blood pressure and pulse rate were within normal limits. The calculated fluid requirement was given by intravenous and oral administration: within one hour his colour was good and within 3 hours his haemoglobin had stabilised at 85 per cent. During the first 8 hours of treatment, his urinary excretion increased gradually from 8 to 14 ml. per hour. From then onwards his progress was uneventful and local treatment was carried out without any ill effect on his general condition.

**Case 2.**—Female, aged 3 years and 6 months; admitted one hour after deep and superficial burns totalling 25 per cent. of body area.

On admission, she had a greyish pallor, cyanosis of the lips, was spasmodically restless and intensely thirsty. The blood pressure was 140/80 mm. Hg, and haemoglobin 80 per cent.

Her calculated replacement requirement was given by intravenous infusion /
infusion and included 200 ml. whole blood: her metabolic requirement was given by mouth. Oxygen was given and the head-down position was adopted from the outset. She became quiet after heroin, gr. 1/96, intravenously. After 2 hours, the colour improved and by 6 hours she was pink and warm and sleeping quietly without further sedation: during this period the haemoglobin fell and became stable at 90 per cent. In this child hourly recording of the urinary output was impossible because severe burns of the perineum and vulva precluded the passing of a catheter. At 24 hours, she passed spontaneously 150 ml. urine which contained albumen, but no other abnormality. Her progress was good until the 40th hour when the temperature, which had varied between 99.5 and 101°F. rose suddenly to 105.5°F: she became unconscious and pulseless, and she developed generalised convulsive twitching. She was cooled vigorously by sponging and fanning and the temperature was reduced to 100°F. within 30 minutes, with a corresponding improvement in her condition. During the next 24 hours, the temperature tended to rise but cooling measures were adopted when it threatened to exceed 102°F. By 72 hours she was fit for local treatment with a haemoglobin stable at 90 per cent., and a blood pressure of 120/80 mm. Hg, was clear and rational and passing urine. From then onwards she made a good recovery.

Case 3. - Female, aged 3 years and 4 months; admitted 2 hours after mainly deep burns totalling 22 per cent. of body area.

On admission, she was pale, restless and thirsty, with a blood pressure of 140/100 and a haemoglobin of 110 per cent. Fluid was given /
given by the intravenous and oral routes and included 200 ml. whole blood. After one hour the haemoglobin had risen to 115 per cent., but by the second hour had fallen to 105 per cent. She became quiet, pink and warm. In the first 6 hours urinary excretion increased from 3 to 6 ml. per hour. By 20 hours the haemoglobin was stabilised at 85 per cent. and she was secreting 20 ml. urine per hour. Toilet was carried out without affecting her general condition.

Case 4.— Male, aged 2 years and 11 months; admitted 2 hours after superficial and deep burns totalling about 65 per cent. of body surface.

On admission, he was unconscious, mottled and cyanosed, pulseless, with an unrecordable blood pressure and rectal temperature of 96°F. The haemoglobin was 135 per cent.

Fluid was given according to the second formula for burns exceeding 30 per cent. and included 300 ml. blood. No urine was secreted until 6 hours, when 3 ml. was obtained. Blood pressure, pulse and colour remained unchanged. From 6 hours onwards, urinary secretion recommenced and he secreted an average of 15 ml. during the next 8 hours but there was no detectable improvement in his general condition. At the end of 24 hours haemoglobin fell to 120 per cent., he was still cyanosed but had a more rapid colour return on pressure and blood pressure became recordable at 90/40 mm.Hg. A total of 2,620 ml. of fluid had been given, all of it intravenously.

During the next 24 hours, haemoglobin fell to 80 per cent., the cyanosis /
cyanosis lessened and the capillary circulation became rather more brisk. There was at this time massive oedema of the face, neck and upper limbs, all of which were burned. Urinary excretion was maintained at 25 ml. per hour, and he began to respond to painful stimuli. During this period he developed a marked hypertension, reaching 250/150 mm. Hg at the 40th hour. Throughout the period of hypertension urinary excretion was maintained. At 42 hours, his temperature, which had been rising gradually, reached 106.5°F. and he was treated vigorously by fanning, sponging and ice packs. At the end of 48 hours his pressure had fallen slightly, he was secreting 20 ml. of urine per hour, his colour was slightly pinker and he was reacting more vigorously to disturbance. From then onwards only the metabolic requirement was given.

During the course of the 3rd day his pressure fell gradually to 160/100 mm.Hg. Haemoglobin remained constant and he secreted an average of 40 ml. of urine per hour. His colour improved slightly and he began to respond more noticeably to stimuli although he was not fully conscious.

His condition gradually improved and on the 5th day he was well enough for local treatment to be carried out. This was done without any ill effect: the blisters were cut away and loose epidermis was removed without any attempt at cleansing. The areas which had been exposed were covered by a dry coagulum but his back, on which he had been lying, was moist: this was exposed by placing him on a frame and penicillin powder was insufflated two-hourly until it dried.

On the 7th day, after being apparently well, he suddenly developed the /


the clinical signs of heart block and his pulse rate fell to 45. He lived for 48 hours after this without fully regaining consciousness, with a subnormal temperature and a failing circulation.

At post-mortem examination, a small pyaemic abscess was found in the interventricular septum with two similar lesions in the lungs and one small one in the head of the pancreas.

In this case the back provided a large area of septic absorption which probably caused death. It would have been better, in spite of his very poor condition, to have placed him on a frame at the outset to allow complete exposure of all the burned areas.

Case 5.— Female, aged 3 years and 1 month; admitted one hour after superficial scalds totalling 20 per cent. of body area.

On admission, her condition was good and the pulse, blood pressure, blood concentration and urinary excretion were within normal limits: she was not restless or thirsty.

Fluids were given by intravenous and oral routes and her condition in all respects remained unaltered. At 20 hours she suddenly became collapsed, cold and cyanosed; the air entry to the lungs became progressively less although there were no signs of mechanical obstruction. Her condition deteriorated rapidly, and she died 6 hours later.

At post-mortem examination, a very severe inflammatory congestion of the trachea and bronchi was found, with fairly extensive collapse of the lungs. The mitral, tricuspid and aortic valves were thickened and fibrosed and microscopic examination of the myocardium showed widespread infiltration /
infiltration with lesions having the appearance of syphilitic gummata.

On enquiry, it was found that the child had developed signs of acute bronchitis and a high temperature on the day preceding the accident but had been, in other respects, apparently healthy. The pre-existing bronchitis may have been exacerbated by the inhalation of steam, although there were no burns of the mouth or fauces to suggest this.

Case 6. Female, aged 4 years; admitted 3 hours after superficial and deep burns totalling 28 per cent. of body area.

On admission, she was pale, cyanosed, intensely thirsty and spasmodically restless. The haemoglobin was 75 per cent. The blood pressure could not be taken because the arms and thighs were involved, but the temporal pulse was present. The calculated fluid requirement was given and included 250 ml. whole blood given initially. Oxygen was given and the head-down position adopted, and heroin, gr. 1/48, given intravenously. After 3 hours the haemoglobin had risen to 110 per cent. but the cyanosis had disappeared and the capillary circulation was more brisk. During the 6th hour, after a period of complete anuria, she secreted 45 ml. of urine. The haemoglobin at this time had fallen to 100 per cent. and she was pink, warm, rational and co-operative, and the thirst was less intense.

At 7 hours, the burns were completely exposed and the blisters cut away and dried, without any attempt at cleansing. Penicillin powder was applied frequently. From this time onwards she made uninterrupted progress, the haemoglobin stabilising at 90 per cent. at the 16th hour, and the urinary secretion being maintained at an average /
average rate of 30 ml. per hour. The urine throughout the whole period contained no abnormal constituent.

Summary /
Summary

A method has been described for estimating fluid requirement in burned children. It is based on consideration of the extent of the surface area involved, the depth of injury, the normal blood volume of the patient and the normal metabolic requirement for the age and weight.

The progress of 14 patients treated by this method has been recorded. In the series, there were two deaths, neither of which could be ascribed to oligaemic shock.
Acknowledgements

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References


