Aspects of Plastic Surgery

The Burnt Patient: A General View

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Many burns occur in patients in whom awareness or ability to avoid the danger has not yet developed or is impaired—for example, children; the aged or infirm; alcoholics; drug addicts; and epileptics or psychotics. Some occur as a result of a domestic, industrial, or other disaster. Most patients with major burns are transported, as emergencies, directly to hospitals without prior consultation with the patient's general practitioner, who first becomes involved if a burn is minor, or when distressed relatives require help.

Expert first aid to burns is therefore often not available. If so, it should comprise the immediate cooling of the burnt area for 10 minutes with tepid water. This probably diminishes the depth of injury, which is progressive after the burning source has been removed. Cooling relieves pain and swelling so long as continued. Active washing of chemical burns from acid or alkali with water for the same period, especially if the eyes are affected, is advantageous. Subsequently wet clothing should be removed and the burn covered with clean, dry linen. Intravenous pethidine, in a dose proportional to body weight, will help to relieve the pain and anxiety of injury and transport to hospital.

Accident departments may be expected to deal with all minor superficial burns. These are best treated by removal of all loose epithelium and dressing with silver sulphadiazine applied on dry gauze and changed daily. Electrical-conduction burns are always full thickness and should be considered for surgical management.

There is a belated and welcome trend in Britain for establishing regional centres for treating major burn injury (rather than major centres for burn injury). A major burn (for example, one affecting over 10% of the body surface) presents a highly complex pathological situation. It is no longer in the patient's interest for such cases to be managed by "rule of thumb" (formula) methods applied by medical and nursing staff who meet the problem rarely. They are better referred to regional centres where facilities for medical and nursing intensive care should be available. Since they are regionally situated, such centres are often remote from the referring hospitals.

Two factors are essential for such referral. Firstly, accurate information as to the name, age, and race of the patient, together with an exact assessment of pre-existing disease and associated injuries. The date, time, nature, and extent of the burn injury should be noted and given. Secondly, an intravenous infusion should be established which will not give trouble during transport. Analgesics should be given intra-

venously. Such measures will prevent the patient arriving at the regional centre in a state of uncompensated shock.

Pathophysiology

The skin is a highly complex structure providing, among its many other functions, a barrier to bacterial ingress and mechanical trauma. It is a sensing mechanism of environmental temperature. When the skin is extensively damaged, as in burning, these functions are all disturbed proportionately to the extent of the burn.

The body becomes susceptible to pathogenic bacteria present in the environment, and in the patients' own oropharynx and bowel. "Pressure areas," if burnt, are less stable. A burnt area is wet; heat loss occurs; the patient feels cold; the metabolic rate is raised; and shivering may be stimulated. Cutaneous vasoconstriction of non-burnt areas may occur. Thus a situation may arise similar to that of a central heating plant working at maximum with all radiators turned off. A high body-core temperature develops—which may, especially in children, be sufficient to cause convulsions.

In burnt areas, and to a lesser extent, in non-burnt areas, capillary permeability is increased, with a loss of non-cellular elements from the intravascular compartment. Red cells haemolyse, and, though not disrupted, many red blood cells show pronounced changes in shape and function. In "non-priority areas" there is a compensatory "shutdown" to maintain circulatory volume, and to all tissues the availability of oxygen is reduced.

Burns caused by flame of various sorts are often complicated by inhalation of hot and irritant gases. The surfactant effect of intra-alveolar fluids is impaired, and the alveoli collapse. The alveolar membrane becomes thicker because of oedema. An exudate into the alveoli is formed, and the condition resembles hyaline membrane disease of children. Thus the gas-diffusing abilities of the lung are appreciably impaired. Moreover, in major trauma arteriovenous shunts in the lung open up, and alveolar perfusion is reduced.

Thus in a condition in which the oxygen demands of the body are maximal, poor gas diffusion and alveolar perfusion are compounded with damaged red cells and decreased tissue perfusion. The arterial PO_2 of most patients with burns falls, whether or not the lung is damaged, or the skin of the chest is burnt. Pain, anxiety, and the stress response in general, all stimulate the production of enormous amounts of mineralocorticoids, glucocorticoids, and adrenaline. Glucagon secretion is increased and a "diabetic" state results, similar to that found in Cushing's disease. Sodium is retained by the kidneys and potassium lost. Vasoconstriction occurs in the skin, muscle, gut—and even in the kidneys. Temperature control is impaired; ileus and vomiting may occur; and an electrolyte disturbance is inevitable.

CHANGES IN CELLS

In the cells low oxygen tension and unavailability of carbohydrate due to hormonal influences severely impair metabolism.

The cell membrane also suffers and the sodium pump works less effectively. Potassium is lost from the cell and is replaced by hydrogen ions. Intracellular acidosis develops. These changes also occur in the cells of the respiratory centre. In an attempt to correct this situation (and catalysed by low PO_2 levels) an increased respiratory effort is stimulated, itself increasing the metabolic load. The vital capacity, F.E.V.₁, and lung-diffusion-ability all being impaired, the result is to lower arterial PCO_2 values—an effect which is at first compensated, but compensatory mechanisms are inadequate later and the pH may rise. Thus there may be a simultaneous intracellular acidosis and an extracellular respiratory alkalosis. An arterial pH above 7.5 or a PO_2 below 60 mmHg in a burnt patient are ominous prognostic signs. A variety of biochemical changes may arise. That described is an attempt to explain one of them. The mechanism is still very much debated, but provides a rational basis for effective treatment.

A raised metabolic rate, together with the intense catabolism, result in the breakdown of large molecules of fat, carbohydrate, and protein into multiple smaller ones. This increased number of molecules therefore increases the osmolality of body fluids. Since intravenous hypo-osmolar solutions cause haemolysis, most intravenous fluids are at least iso-osmolar. An oral water load is poorly tolerated and the hyperosmolar state is difficult to correct.

Management

Management of burnt patients can be classified under several headings: replacement of fluid loss; prevention and treatment of respiratory problems; prevention and treatment of electrolyte problems; treatment of the sick-cell syndrome and the hyperosmolar state; environmental control; management of the burn wound; psychological assessment and psychotherapy; rehabilitation; and reconstruction. These will now be considered in turn.

Replacement of Fluid Loss

Plasma is lost through the vessel wall of burnt areas, and may therefore be replaced by calculated amounts of pooled plasma. Plasma is expensive to produce and among other complications carries a limited risk of serum-transmitted jaundice. In many countries the financial implications are important. In others plasma is not available. Generally speaking, in Britain it is considered best to replace lost plasma by plasma infusion. In some centres the risk of hepatitis is thought to be sufficiently significant for plasma expanders to be used. These are cheaper and more readily available. Nevertheless, microemboli of the polysaccharide molecules have been observed in the pulmonary vessels of patients so treated and renal tubular changes have also been reported.

Since the vascular system in non-burnt areas is more permeable than in burnt areas—at least in the early stages after burning—there is a case for using normal saline to replace circulatory volume. Even so, patients given this treatment may develop generalized oedema and the physiological case made for its use is, in my view, weak.

Blood is given in most cases in which more than 20% of the skin is burnt full thickness. It is also a useful adjunct in correcting the "sick cell state."

Formulae for calculating the required infusion volumes should be used only as a guide. Frequent clinical assessment together with measurement of the packed cell volume, central venous pressure, plasma electrolytes, and total blood solid and osmolality are mandatory, and enable evaluation of the adequacy of fluid replacement.

Pulmonary Pathology

Frequent sampling of arterial blood enables a developing anoxic state to be corrected or alleviated by administration of oxygen. It is sometimes impossible to achieve normal

levels of PO_2 even with 100% oxygen, but in any case such a measure is not justified since it may contribute to alveolar collapse: 70% oxygen is the maximum it is safe to use and a minimal arterial PO_2 value of 70 mm Hg may be accepted.

When acute laryngeal obstruction is a possibility, early endotracheal intubation is indicated. Present-day endotracheal tubes may be safely left in situ for up to three days, by which time the risk of acute oedema will be past. Such a tube also allows the use of intermittent positive pressure respirators, which may help in reducing pulmonary oedema. Tracheal suction is made easier.

Electrolyte Problems

Catabolism, the loss of potassium from anoxic cells, and increased secretion of mineralocorticoids all result in a considerable increase of renal potassium excretion. Sodium is retained and the urinary Na/K ratio is reversed. If uncorrected, a potassium deficit frequently develops between the third and fifth day after burning, serum potassium levels sometimes falling to lethal levels. Digitalization, or administration of insulin must be undertaken with great care.

Collection of 24-hour urine samples allow a precise measurement of urinary potassium loss and intravenous replacement is begun 24 hours after burning. For an adult about 130 mEq potassium per day is needed until about the fifth day after burning. Occasionally a hyperosmolar, hyperaldosterone-like state is found. Infusion of glucose and insulin and an aldosterone antagonist (Soludactone) is indicated to correct it.

Sick Cell Syndrome

Intracellular anoxia, impaired carbohydrate metabolism, and acidosis together with its sequelae, may often be corrected by infusion of blood, together with glucose and insulin (1 unit soluble insulin/g glucose). The effect is to increase oxygen availability and to combat the diabetogenic effects of the increased glucocorticoid secretion. Intracellular metabolism is improved, the sodium pump begins to work again, and the extracellular respiratory alkalosis resolves.

Since the glucose given is isosmolar or hyperosmolar, it might be expected to worsen the hyperosmolar state. Under the influence of insulin the movement of glucose into the cells, however, leaves the solvent water available for correcting this state.

Environmental Control

The cold, wet burn surface and exposed normal skin of burnt patients results in tremendous heat loss and catabolism. To this load is often added a large respiratory effort. The effect of such heat loss may be countered by surrounding the patient with warm air which reduces the metabolic rate. To achieve minimal heat-loss the air should be *humid*, but while comfortable for the patient, this atmosphere is most uncomfortable for his attendants and the burn does not dry. Warm dry air decreases, but does not prevent, this heat loss since a wet surface is exposed to the wet bulb temperature of the air. Fast moving sterile humidified air may decrease the heat loss and produces a dry, supple, sterile eschar.

Circumferential burns can be adequately dried only if the patient is supported on air by a support system resembling an upturned hovercraft (high-air-loss bed, or Hoverbed) of which two have been installed in this centre. The patient may be covered with a radiant-heat-reflecting surface floated above him on the current of air. He is thus enclosed in a sterile warm microclimate. The comfort of attendant staff is

ensured by the downward linear ("laminar") flow of sterile cool air, which moves sufficiently fast to prevent rising convection currents bringing dirt from floor level, and sweeps away airborne contamination from shedding of skin scales by attendant staff (see fig. 1).

no pressure areas occur. Turning and patient handling for other reasons are minimized. Attendants do not have to lift the patient and may devote their time to caring for his disordered physiology. Contamination of the burn wound is much less likely.

FIG. 1—The patient is supported on sterile humidified air. The flexible part of the bed conforms to his profile whatever his position. His burn and nakedness are covered from view and contamination, by a radiation-reflecting surface (transparent in the drawing), and the bed air escapes from beneath it. Sterile, heat-and-humidity-controlled air is displaced downwards to prevent contamination and is evacuated by extraction at ground level, or escapes through a balanced flue.

When a stable dry eschar (the natural dressing for a burn) has been produced in about 36 hours, the patient is transferred to a second support system using contained warm air, on which he is subsequently nursed (low air loss beds; see fig. 2).

Since both systems employ a flotation principle using air,

The high energy demand is also met by intravenous feeding of fat, carbohydrates, and protein in the early stages, and by supplementary oral feeding thereafter.

Management of the Burn Wound

There is no universally applicable solution to the problem of managing the burn wound. Dressings are expensive of material and time. They should be changed at least daily. This process is usually painful, and is always time-consuming. Bacteria beneath them are often resistant to chemotherapeutic agents and these are rarely effective for more than six hours. Immobilization of chest or limbs results in an increase of respiratory problems or joint stiffness. The face and perineum are almost impossible to dress. Nevertheless, dressings do reduce the risk of contamination, decrease heat loss, and prevent pain from abrasion of the wound.

Perhaps the most important recent advance in management has been the development of silver sulphadiazine, which has a good spectrum of activity and does not cause appreciable pain or electrolyte disturbance when applied.

Surgical treatment of the wound is highly demanding of surgical, nursing, and theatre time. Blood loss may be high. Postoperative morbidity and mortality are decreasing with improved anaesthetic and surgical techniques, but still occur. Early surgical treatment probably produces better scarring, earlier mobilization of joints, and shortened convalescence.

Surgery should be used in all clearly demarcated burns, involving the full thickness of skin, of less than 10% of the body surface area. The shaving off of burnt tissues until a bleeding surface is reached (tangential excision) with immedi-

FIG. 2—The contained-air-system (low air loss bed) has its own air supply. The position of the bed may be controlled by the patient. Uniform support is achieved, less lifting is necessary, and no pressure areas require treatment. The illustration shows a model operating the bed. The transparent screens are part of the laminar-flow canopy and can be removed.

ate grafting, is a technique being increasingly used soon after burning, with good results.

Each method solves only some of the problems of the burn wound. It is a large wound and a large problem. The replacement of the destroyed skin has become easier with the advent of new techniques. Freeze-dried lyophilized pig skin provides a dead, but intact, epidermis as a temporary dressing. It reduces fluid loss from 3,000 ml/m² of wound to about 1500 ml/m²/day, though its effectiveness in reducing infection is doubtful. Synthetic substitutes are so far unsatisfactory.

Tissue typing of homografts allows prolonged survival of such grafts and time for "cropping" of autograft donor sites. Clearly there is no substitute for autografts. Meshing of such autograft, or use of alternative strips of homograft, are techniques employed to help to make a little epidermis go a lot further.

Psychological Assessment and Psychotherapy

Many patients are psychologically disturbed before they are burnt. After such a major disaster, weeks of isolation, many painful dressings, and operations, we achieve in most cases a healed deformed being who will always bear not only a physical scar but a psychological one. Some degree of behavioural disturbance in children is almost inevitable. In adults irritability, depression, or impotence are common sequelae of major burns. Insufficient attention is paid to the psychology of such persons. It is easy for us to become dazzled by the manipulation of electrolytes and fluid volumes, or the flashing knife, so that we forget we are treating a human being. We propose in this centre to embark upon a major psychological and therapeutic programme to match the intensity of general medical, surgical, and nursing care.

The first a general practitioner may know of his patient's injury is when he is consulted by a distraught relative seeking emotional help. The family problems of guilt, readjustment of domestic routines, and eventual reintegration of the injured person into the family require tremendous and prolonged help from practitioner, nurse, social worker, psychiatrist, or psychotherapist, and surgeon. The stage *after* discharge from hospital is often more important than that in it. Certainly it is more prolonged.

Rehabilitation

The reintegration of a burnt person into his social network is essential. Many must work. By adopting a positive attitude a rehabilitation officer who can see both patient and employer within days of the accident can achieve, from the beginning, a hopeful patient who will return much sooner to an understanding employer. We have in this centre the unique services

of a *hospital-based* rehabilitation officer, who saves many times his salary in unclaimed sickness and unemployment benefits—and many more healthy-minded working men re-engaged early in their former employment, or resettled into another suitable one.

Reconstruction

Discharge from hospital, healed, is often only the beginning of a long reconstructive surgical road for a burnt patient which may be expected to extend over many years. This programme may be complex, and necessitates an understanding of the problem by the patient's general practitioner. At the time of discharge from hospital the surgeon should give the general practitioner a clear idea of the patient's disability; what measures have been taken in hospital to help in rehabilitation and reintegration; and what further supervision, physiotherapy, or surgical treatment is planned in the short and long term.

The general practitioner can help by giving total family support and advice. He may be expected to advise on the problem of itching in scarred areas. Antihistamines have little effect, and serve only to sedate the patient into inactivity. The patient should be advised to keep cool, since heat worsens the symptom, and application of hydrous ointment or Nivea cream may relieve the itching a little. Children may need gloves at night to prevent abrasion of the scars. Nightmares, insomnia, depression, and irritability are common sequelae which demand careful prescription. Impotence in men occasionally occurs, and reassurance that this is likely to be transitory is important. A scarred body is rarely attractive to a heterosexual partner. Patients rarely voice this particular anxiety, but direct questioning will bring the problem to light. Understanding of the problem and discussion with the partner may help a great deal.

No burnt patient should be away from appropriate work for over three months after discharge from hospital. If not properly arranged while the patient is in hospital, rehabilitation should be initiated *immediately* after discharge. This requires an active effort on the part of the practitioner, and is more time-consuming than signing a certificate of unfitness for work; it is infinitely more important. A progress report from practitioner to burns consultant at outpatient follow-up is rarely received. It would be helpful.

A close liaison and co-operation among patient, surgeon, and general practitioner, is the ultimate complement to a biochemical and surgical success. By this means the total support we give to the patient in hospital may be gradually reduced so that together we may produce a scarred, but nonetheless well-adjusted and happy human being who may again contribute to, and derive benefit from, the community in which he or she lives.