EMERGENCY MANAGEMENT OF SEVERE BURNS

BRITISH BURN ASSOCIATION

AUSTRALIAN & NEW ZEALAND BURN ASSOCIATION
E.M.S.B.

U.K. Course Pre-reading

The Education Committee

of the Australian and

New Zealand Burn Association Limited
ACN 054 089 520

Emergency Management of Severe Burns

(EMSB)

COURSE MANUAL

UK version for The British Burn Association

18th Edition

January 2020

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CONTENTS

The Australian and New Zealand Burn Association Limited

The Association was formed in 1976 by a group of medical and nursing staff who were drawn together by their common interest in improving the quality of care that their burn patients received.

Since then this group has expanded to now include a truly multidisciplinary group of burn care professionals who are interested in teaching, care, research and prevention of burn related problems.

The multidisciplinary nature of the Association is an extension of every day burn care philosophy, as practiced in burn units throughout Australia and New Zealand.

The Association has an important role in the promotion of the Minimum Standards of Burn Care in Australia and New Zealand and it is in this context that this publication and the related EMSB course have been developed. It is hoped that this initiative will improve standards of burn care for the severely burnt patient.

Contributors to this Manual

The following, who are members of the Education Committee of the Australian and New Zealand Burns Association, have generously given of their time and expertise in the development of this course:

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A special thanks is owed to Mani M. Mani, M.D., Kansas USA

The EMSB Course has now been established in the following countries: Australia, New Zealand, Great Britain, The Netherlands, South Africa, Bangladesh, Papua New Guinea, The Pacific Islands, Malaysia and Hong Kong. Each of these countries has a license to provide the EMSB Providers' Courses and the EMSB Instructors Course in their area under supervision of ANZBA. The EMSB Manuals and Courses have been adapted to address country specific needs and occurrences within the Burns Injuries field, whilst retaining standardized examination processes and pass marks throughout the world. In addition, ANZBA has organised several courses in differing countries with a multinational faculty and ANZBA will endeavour to continue this approach. An EMSB certificate is therefore valid worldwide and is an expression that the recipient is knowledgeable in the initial treatment of burn injuries.

Since the original course was written and in accordance with this being a consensus course, repeated updates and refinements have been made by numerous members of the teaching faculty, and some candidates.

For suggestions please contact: The BBA secretariat.

This edition has been edited to reflect U.K. practice by the EMSB Senate under the auspices of the British Burn Association and agreed with the ANZBA Education Committee. We would like to acknowledge and to thank all Senate members, past and present, who contributed to this manual.

Sarah Pape, Newcastle
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U.K. burns data supplied courtesy of the International Burn injury Database (*iBID*).

EMERGENCY MANAGEMENT OF SEVERE BURNS COURSE

Outline and Timeline

PART ONE		**LECTURES**
0730		Registration
08.00-08.10		Welcome and & Burn Pathophysiology
08.10-08.25		Burn Size and Depth
08.25-08.55		Emergency Examination and Treatment
08.55-09.05		**Break**
PART TWO		**SMALL GROUP LEARNING**
09.05-11.20		**(25 minutes each)**
Station 1	ROTATE ROOMS	Burn Area and Fluid Requirements
Station 2		Referral & Transfer
Station 3		Escharotomy
Station 4		Wound Assessment & Management
Station 5		Airway Management
11.20 – 11.35		**Coffee / Tea break**
PART THREE		**SMALL GROUP LEARNING**
11.35-13.21		**(25 minutes each)**
	ROTATE ROOMS	1. Paediatric
		2. Chemical
		3. Electrical
		4. Multiple Injuries
13.21-14.05		**Lunch**
14.05–14:20		**DEMO OF SIMULATION**
PART FOUR		**MULTIPLE CHOICE EXAM AND SIMULATIONS**
14.20-17.10		
14.20-15.40		Group A Exam Group B Simulations
15.40-15.50		**Break**
15.50 - 17.10		Group B Exam Group A Simulations
17.10 – 17.25		Resits of Simulations if required
17.25-17.40		Summation and Presentations
17.40-18.10		Faculty Meeting

CHAPTER 1

Introduction-
Epidemiology and Aetiology

Introduction

The patient with burns presents a difficult challenge to most health care personnel. Apart from the serious nature of the injury, there is the patient's discomfort, the distress of the patient and their relatives, the loss of income and the compromise of their employment future, and their uncertainty about the future. In addition to these factors, the well-known surgical maxim that the trauma patient who is seen, assessed and treated early by skilled personnel heals more quickly than the patient whose treatment is delayed, is as true for the burn patient as it is for any other trauma patient.

This course is based on the principle that timely emergency assessment, resuscitation and transfer provide the best chance of recovery in our patients with burns. The patients that we will manage with burns, and perhaps with associated severe injuries, ultimately should benefit from this course.

The aim of this course is to provide sufficient factual information regarding the presentation, diagnosis and initial management of the patient with severe burns, to enable medical and nursing practitioners to deal competently with this urgent and often life threatening problem.

Members of the Association's Education Committee wrote this course, each individual chapter being written from members' personal (and considerable) experience in different areas of burn care. All the contained material is original material that has not been published in this form before.

The course follows the trauma management protocols as taught by the Royal Australasian College of Surgeons in their Emergency Management of Severe Trauma course (EMST), as this course is the accepted trauma management teaching system for medical practitioners in Australia and New Zealand. These are similar to those taught in Advanced Trauma Life Support (ATLS) course in the U.K.

The Emergency Management of Severe Burns (EMSB) course provides trauma management guidelines and protocols specific to burns, that are additive in content to EMST or ATLS. While EMSB is designed to be a "Stand Alone Course", which provides sufficient information to define the Minimum Standards of Emergency Burn Care (of the Australian and New Zealand Burn Association and the British Burn Association), the course can also be taught in conjunction with the EMST/ ATLS, providing extra information specific to the management of burns.

EMSB covers the principles of the emergency management of severe burns in the U.K. The course is appropriate for medical staff, nurses and health care practitioners working anywhere in the field of burn care, from members of the burns unit, to medical and nursing staff in isolated areas. Apart from teaching the material contained, the course seeks to emphasise the benefits of all emergency care givers having knowledge of the same protocols of emergency burn care, as this facilitates primary care and appropriate referral; the ultimate beneficiary of this approach being our patient with burns.

The information is taught in six separate and complimentary sections:

1. **Course Manual**

This manual contains the complete syllabus of the course and is sent to all students before each course. Students are expected to read the manual, twice if possible, before attending the course, and a study guide is provided to assist in the recognition of the most important aspects of the course.

2. **Formal Lectures**

These take place at the beginning of the course. They will outline the course principles and will reinforce your reading of the manual. They are not a substitute for the manual, and will vary to include the individual clinical experience of the lecturers.

3. **Skill Stations**

These will teach important practical aspects of the course and provide students with the opportunity to apply the knowledge they have gained from the manual and lectures.

4. **Interactive Discussion Groups**

This section will teach special areas of burn management in an interactive small group environment to maximise the opportunities for students to discuss these topics, and to use their own clinical experience, at their own level, to explore these topics.

5. **Simulated Burns Cases**

In this section, volunteers who have been made up to simulate clinical cases of burns will be used to give you some practical experience of management of the severe burn. This section will tie the course together, and make it clinically relevant.

6. Examination and Clinical Test

At the end of the course, students will be asked to take a multiple choice exam paper, as well as a clinical case test, (using a simulated burn case), to examine students level of knowledge and the effectiveness of our teaching.

You will be notified of your results from this course by letter, and successful students will receive an official certificate from the British Burn Association.

The Team Concept of Burn Care

Since the Second World War, significant advances in burn care have resulted in the gradual decrease in mortality and morbidity from severe burns.

Intravenous resuscitation, improved nutrition, the introduction of topical antimicrobials, and the introduction of protocols for surgery that promote early closure of the burn wound have all contributed to this remarkable improvement in survival.

Burn Services

With these improvements in burn management has come the realisation that specially trained staff are able to operate more effectively within a purpose built acute facility. These facilities allow higher quality care to be available even for minor burns than is available outside a burn service.

The concentration of specialist team members within one facility has the added advantage of being more cost effective, and the sharing of knowledge in a team environment allows the development of high levels of expertise by individual team members. This ensures that patients receive the best care possible. The support that team members give each other during times of stress contributes to staff morale, and maximises staff retention.

Burn services in the U.K. have adopted a three tier model of care outlined in the National Burn Care Review of 2001. A small number of patients with the most severe injuries are cared for in Burn Centres, a larger number with significant burns in Burn Units and more minor injuries in Burn Facilities.

Burn Team

The Burn Team consists of a multidisciplinary group whose individual skills are complementary to each other. Team members recognise the benefits of interdisciplinary cooperation in providing the best quality care to the patient with burns.

Pre-hospital Clinicians
Ambulance and retrieval service personnel provide essential pre-hospital care for burn patients by airway stabilisation, establishing fluid resuscitation and transferring the patient to definitive care. The early management provided pre-hospital assists the burns patients' chances of survival and optimal outcome.

Emergency Department
Many burns patients will receive treatment in an Emergency Department, whether in a hospital with a burn service, a DGH or a teaching hospital. Patients are assessed and receive initial treatment. A high quality working relationship between the burns service and emergency department is essential to provide top quality care.

Surgeons
Burn Surgery has become a sub-specialty of Plastic Surgery. Burn Surgeons have a particular interest in the management of the seriously injured burn patient, in wound healing, rehabilitation, and related research.

Nurses
The Burn Nurse is the lynch pin of the team, providing day to day continuity of care. Burn nurses have specialist expertise in wound care, skin graft care, critical care of the severely burned patient, psychiatric nursing and discharge planning.

Anaesthesia
Burn surgery requires specialised anaesthetic techniques to assist the surgeon in treating the severely ill patient, managing severe blood loss, and maximising the area of burn wound surgery that can be treated at any one time. This contributes to early burn wound closure.

Intensive Care
Many severely burned patients will be cared for at some stage of their hospitalisation in Intensive Care. A high quality working relationship between the Burn service and Intensive Care units is essential to provide optimal care.

Physiotherapist, Occupational Therapist
Therapists play an indispensable role in the care and rehabilitation of the burn patient. This begins at the time of admission to the burns unit, and continues well into the outpatient treatment after discharge. Burn therapy is a specialised sub-discipline and is not available to patients outside burn units.

Speech Therapist
The Burns Speech Therapist provides comprehensive clinical assessment and management of severe burn patients with swallowing, voice and communication disorders as a result of the burn injury or secondary complications including sepsis, debility, orofacial contractures or presence of a tracheostomy

Dietitians
Optimal nutrition is necessary to counteract the extreme catabolic response that occurs with burns. This is available in the burns service with specialised dietetic staff.

Psychosocial
Social Workers, Psychiatrists, Psychologists and Chaplains form part of the burn team. They provide necessary support and treatment for the wide variety of psychosocial problems that all burn patients have. Special expertise is required to manage these difficult problems. The patient's ability to function in society in the long term is as dependent on this psychosocial adjustment as it is on the quality of the physical result.

Rehabilitation

Post burn rehabilitation begins at the time of admission, and in the minor burn can usually be managed as part of outpatient care. Severely burned patients may require more intensive rehabilitation to enable the attainment of maximum function, allowing return to daily living activities and employment. A close relationship with rehabilitation personnel facilitates this.

The burn team provides optimal quality of care utilising shared management protocols which provide individual support for team members, optimise professional attainment, and provide the highest quality of care for the patient with burns.

The Epidemiology and Aetiology of Burns

Epidemiology

Burns are a common form of trauma. Some burns occur as genuine accidents, but most are caused by carelessness or inattention, pre-existing medical conditions, the presentation of which may be a collapse, or they may follow alcohol or drug abuse (see Table 1).

Each year 0.5% of the population of UK (250,000) suffer burns. Of those, 50% will suffer some daily living activity restriction, 10% will require hospitalisation, and 10% of those hospitalised will be burned sufficiently severely for their life to be threatened.

A severe burn may cost in the order of £500,000 for acute hospital treatment, and the additional costs of rehabilitation, time off work, and loss of earning represent a substantial cost to the community.

TABLE 1: Predisposition to Adult Burn Injury (%)

Commonest causes only presented.

Carelessness	35
Alcohol	11
Smoking	6
Epilepsy	4
Motor disability	3
Assault	3
Self-inflicted	3
Sensory disability	2
Illicit Drugs	2
Arson	1
Dementia	1
Learning difficulty	1
Suicidal	1

Types of Accident	
Accidental: recreation	32
Accidental: work related	8
Accidental: not work related	18
Accidental: unspecified	28

(International Burn Injury Database (iBID), 2003-2015)

In both adults and children, the commonest place to be burned is the home. In children, over 75% of accidents occur in the home. The most dangerous places in the home are the kitchen and the bathroom, as most scalds in children and the elderly occur in these two rooms. In addition, the laundry contains dangerous chemicals and the garden shed or garage contains chemicals and dangerous flammable liquids.

TABLE 2: Adults Place of Burning (%)

Home	55
Work	6
Roadway	1
Outdoors	4
Institutions	2
Other	28

(iBID, 2003-2015)

Injuries caused at work often involve carelessness, and are caused occasionally by unsafe work practices, particularly the careless handling of flammable liquids. Attention to occupational health and safety policies has the potential to make these become less frequent.

Military burns

Two thirds of military burns are non-battle related casualties. These occur in the same manner as they do in civilian life.

Burns as battle casualties comprise 10% of total battle related casualties. Military burns with a blast component have a high risk of producing an inhalation injury as well as a skin injury. Multiple trauma is likely to coexist.

The contingencies of battle, the evacuation plan and the casualty holding policy at the time, together with the logistics of re-supply, may impose very different management protocols on burns in wartime compared with the optimal treatment in peacetime. Every effort must be made to ensure that injured soldiers receive emergency and definitive care that is of the same standard as their civilian counterparts.

Aetiology

Table 3 lists those factors that caused burns in adult patients admitted to hospital from 2003-2010.

TABLE 3: Causes of Adult Burns (%)

Flash/ Flame	43
Scald	27
Contact	15
Chemical	9
Electrical	3
Radiation	1
Friction	2

(iBID, 2003-2015)

The causes of burns in adults and children differ in that flame is the most common cause in adults, and scalds are the most common cause in children. As children become older so their patterns of burn causation become more like the adult.

As adults become older, so too do their patterns change. The elderly are particularly at risk of injury from scalds caused at home, or as residents of care institutions.

TABLE 4: Causes of Children's Burns (%)

Cause of Burn	
Scald	66
Contact	18
Flame	8
Flash	3
Chemical	2
Electrical	1
Friction	2
Radiation	0.1
Non skin burn	0.1

Cause of Scald*	
Tea Scald	31
Hot Water Scald	14
Bath Scald	8
Kettle Scald	10
Coffee Scald	10
Milk Scald	1
Soup Scald	3
Steam Scalds	1
(*Top causes only shown)	

(iBID, 2003-2015)

All age groups are likely to be injured in conditions of social disharmony or disruption. This is particularly true of children, especially infants and toddlers, who are dependent on surrounding adults for care and security. Injuries from carelessness, inattention, poor parenting, and unfortunately from assault (burning is a common method of child abuse) occur frequently, and need investigation when suspected.

Summary

1. Burns affect 0.5-1% of the U.K. population per year.

2. Burns are frequently caused by carelessness and inattention, or the influence of intoxicating drugs.

3. The majority of burn injuries in all age groups occur in the home.

4. Burning is a frequent method of assault in adults, and a frequent method of child abuse. The correct diagnosis of these injuries requires vigilance, and accurate reporting can ensure that appropriate help is given to patients and relatives.

CHAPTER 2

Emergency Examination and Treatment

Introduction

When medical personnel first see the survivor of a burn injury, rapid assessment and treatment can be lifesaving. While most patients with minor burns will not have associated injuries, such injuries are more likely in patients with major burns. Whatever the size of the burn, the patient will fall into one of two categories; those whose non-burn injuries are obvious, and those whose other injuries are concealed. Patients who have minor burns with non-burn injuries usually fall into the first category. However, it is common for life-threatening injuries to be missed when a significant burn is present because the obvious burn injury catches the attention of the treating doctor.

The history should alert the medical personnel to the possibility of co-existing injuries:

- road traffic accident, particularly with ejection or at high speed
- blast or explosion
- electrical injury
- jump or fall while escaping

Non-communicative patients, whether unconscious, intubated, psychotic, or under the influence of substances, should be regarded as potentially multiply injured and treated accordingly.

Staff should wear personal protective equipment (PPE) such as gloves, goggles and aprons prior to attending any patient.

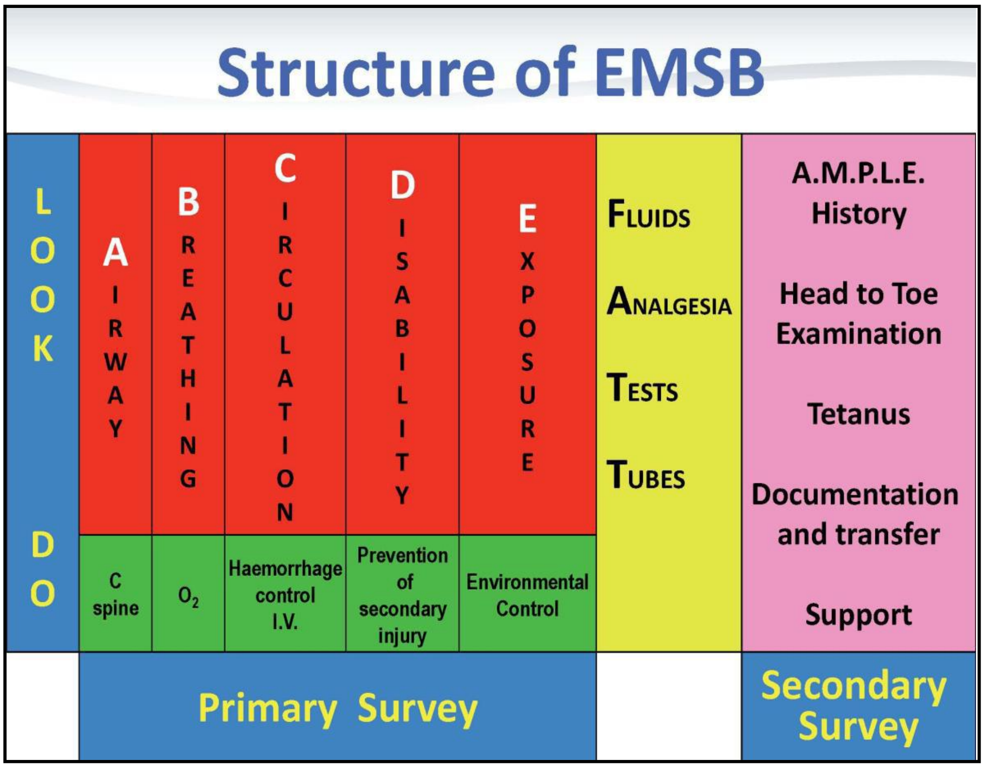
After **immediate** first aid has been given, the principles of primary and secondary survey and simultaneous resuscitation should be followed.

First Aid

First aid consists of:

- stopping the burning process
- cooling the burn wound

This is effective within the first 3 hours from the time of burn.



Primary Survey

Immediately life-threatening conditions are identified and emergency management begun. Do not get distracted by the obvious burn injury.

A. Airway maintenance with cervical spine control

B. Breathing and ventilation

C. Circulation with haemorrhage control

D. Disability - neurological status

E. Exposure + environmental control

F. Fluid resuscitation proportional to burn size

A. Airway Maintenance with Cervical Spine Control

- Check for a patent airway, initially by speaking to the patient. If the airway is not patent clear any foreign material and open the airway with chin lift/jaw thrust. Keep movement of the cervical spine to a minimum and never hyperflex or hyperextend the head and neck.

- Control cervical spine (with rigid collar, sandbags and tape) as injuries above the clavicle, such as facial injuries, or loss of consciousness, are often associated with cervical fractures.

B. Breathing and Ventilation

- Expose the chest and ensure that chest expansion is adequate and equal
- Always provide supplemental high flow **oxygen** (100%) via non-rebreathing (trauma) mask
- Ventilate via a bag and mask or intubate the patient if necessary.
- Carbon monoxide poisoning may give a cherry pink, non-breathing patient.
- Beware a respiratory rate <10 or > 30 per minute in adults.
- Beware circumferential chest burns - is escharotomy required?

C. Circulation with Haemorrhage Control

- Check the central pulse - is it strong or weak?
- Capillary refill - normal return is two seconds. Longer indicates hypovolaemia, hypothermia or possible need for escharotomy on that limb; check another limb and centrally.
- Insert 2 large bore peripheral IV lines, preferably through unburned tissue. Consider intraosseous (I.O.) access if difficult.
- Take blood for: FBC/U&E/Coagulation screen/Amylase/X-match/ Carboxyhaemoglobin/ βHCG.
- Stop visible bleeding with direct pressure.
- If shocked commence fluid resuscitation with 250ml Hartmann's boluses according to ATLS guidelines to attain a radial pulse.
- Pallor occurs with 30% loss of blood volume.
- Mental obtundation occurs with loss of 50% of blood volume.

The early appearance of clinical signs of shock is usually due to another cause. Find it and treat it.

D. Disability: Neurological Status

- Establish level of consciousness:

  A - **A**lert
  V - Response to **V**ocal stimuli
  P - Responds to **P**ainful stimuli
  U - **U**nresponsive

- Examine the pupils' response to light. They should be brisk and equal.
- Check blood glucose.
- Be aware that hypoxaemia and shock can cause restlessness and decreased level of consciousness.

E. Exposure with Environmental Control

- Remove all clothing and **jewellery** including piercings and watches.
- Log roll the patient to examine the posterior surfaces
- **Keep the patient warm -** it is safe to use forced air warmers.
- Area of burn is assessed using the Rule of Nines or palmar method.

F. Fluid Resuscitation
(see Chapter 6)

Fluids are given initially as per Modified Parklands formula:

3-4mls Hartmann's solution / kg / % burn TSBA + maintenance for children < 30kg

- Half of the calculated fluid is given in the first eight hours; the rest is given over the next sixteen hours.
- The time of injury marks the start of fluid resuscitation.

- If haemorrhage or non-burn shock treat as per trauma guidelines.

- Monitor adequacy of resuscitation with:
    - Urinary catheter with hourly urine output measured
    - ECG, pulse, blood pressure, respiratory rate, pulse oximetry or arterial blood gas analysis as appropriate
- Adjust resuscitation fluids as indicated.

Analgesia

- Burns hurt: give intravenous morphine 0.05-0.1 mg/kg
- Titrate to effect, smaller frequent doses are safer.

Tests

- X-Ray
    - Lateral cervical spine
    - Chest
    - Pelvis

- Trauma CT or other imaging as clinically indicated

Tubes

Insert nasogastric tube for larger burns or if associated injuries; gastroparesis is common.

Secondary Survey

This is a comprehensive, head to toe examination that commences after life threatening conditions have been excluded or treated.

History:

A - **A**llergies
M - **M**edications
P - **P**ast illnesses
L - **L**ast meal
E - **E**vents / **E**nvironment related to injury

Mechanism of Injury

As much information regarding the interaction between the person and their environment should be obtained:

Burn

Duration of exposure
Type of clothing worn
Temperature and nature of fluid if a scald
Adequacy of first aid measures

Penetrating

Velocity of missile
Proximity
Direction of travel
Length of knife blade, distance inserted and direction.

Blunt

Speed of travel and angle of impact
Use of restraints
Amount of damage to passenger compartment
Ejection?
Height of fall
Type of explosion or blast and distance thrown

Examination

Head

Eyes -penetrating injuries are often missed
- check visual acuity
Scalp - lacerations, boggy masses

Face

Stability of mid-face
Missing teeth
Malocclusion
CSF leak from nose, ears or mouth
Soot, blisters, oedema of the tongue or pharynx

Neck
Inspect, palpate, x-ray. Always suspect cervical fracture
Lacerations deep to platysma - operating theatre or angiography

Chest
Examine whole chest - front and back
Ribs, clavicles and sternum
Check breath sounds and heart sounds
Circumferential burns may need escharotomy if restricting ventilation
Cough productive of soot
Altered voice or brassy cough

Abdomen
Requires frequent re-evaluation especially for increasing tenderness and distension.
If there is a seat belt bruise, assume intra-abdominal pathology such as ruptured viscus.
If assessment of the abdomen is unreliable, equivocal or impractical, for example in the presence of an extensive abdominal burn, then further investigation with a CT scan or Focussed Assessment with Sonography for Trauma (FAST) scan is mandatory in multiply injured patients.

Perineum
Bruising, meatal blood.

Rectal
Blood, lacerations, sphincter tone, high riding prostate.

Vaginal
Foreign bodies, lacerations.

Limbs
Contusion, deformity, tenderness, crepitus.
Assess extremity pulses regularly. In constricting circumferential extremity burns with developing oedema, the eschar initially obstructs venous return which in turn embarrasses arterial inflow producing tissue ischaemia. This may produce the classic signs of decreasing limb perfusion of **pain, paraesthesia** (or numbness)**, pulselessness** and **paralysis**. When venous return from an extremity is obstructed by oedema, an **escharotomy** is indicated to restore adequate circulation (see Chapter 7).

Pelvis
Rapid access to radiology in most emergency departments/ trauma units precludes the need to test pelvic stability by springing the pelvis. If radiology not readily available this should be done once only by a senior clinician.

Neurological
Glasgow Coma Scale (see Figures 2.1 & 2.2)
Motor and sensory assessment of all limbs
Paralysis or paresis indicates a major injury and immobilisation with spinal boards and semi-rigid collars is indicated.

Note: In burned patients, paresis of a limb may be due to vascular insufficiency caused by rigid eschar for which escharotomy is necessary.

Decreased level of consciousness could be due to:

- hypovolaemia from undiagnosed bleeding or under resuscitated burn shock
- hypoxaemia or poisoning
- intracranial injury expanding space occupying lesion
- drug or alcohol intoxication

Documentation

Take notes
Seek consent for photography and procedures.
Give tetanus prophylaxis if required (see appendix)

Re-evaluate

Re-evaluate the Primary survey- particularly

- respiratory compromise
- peripheral circulation insufficiency
- neurological deterioration
- adequate fluid resuscitation
- review imaging and blood tests
- check urine colour for haemochromogens

Laboratory investigations:

- Haemoglobin / haematocrit
- Urea / creatinine
- Electrolytes
- Urine microscopy and drug screen
- Carboxyhaemoglobin
- Blood sugar
- Arterial blood gases

Chest x-ray
Electrocardiogram

FIGURE 2.1: Glasgow Coma Score

	RESPONSE	SCORE
Eye Opening	Spontaneous	4
	To name	3
	To pain	2
	None	1
Best Verbal Response	Oriented	5
	Confused	4
	Inappropriate	3
	Incomprehensible	2
	None	1
Best Motor Response	Obeying	6
	Localizing	5
	Withdrawal	4
	Abnormal Flexion	3
	Extension	2
	None	1
Best Total Score		15

FIGURE 2.2: Severity of Head Injury

Severe	GCS < 9
Moderate	GCS 9-12
Minor	GCS 13-15

Emergency Burn Wound Care

(see Chapter 7)

As burn wounds are sterilised at the time of burning, extensive burn wound care involving complicated dressings is unnecessary and causes unwarranted delays. The appropriate treatment of the burn is to cover the wound with plastic cling film or a clean sheet and arrange for evacuation.

In the U.K. transfer to a burns service should normally not take more than 6 hours. If the referral of the patient is delayed more than 8 hours, or if the wound has been extensively contaminated with polluted water or industrial waste, then **a topical antimicrobial should be considered only after discussion with the accepting burn service**. Clean the wound with antiseptic and apply a silver dressing like Acticoat®, Urgotul Ag® or silver sulphadiazine cream.

Do not constrict limbs with compromised circulation by using tight dressings. Dressings should be checked frequently to exclude compression.

Electrical Injuries

(see Chapter 10)

Conduction of electrical current through the mediastinum (from arm to leg or from arm to arm) may cause myocardial damage. These patients require continuous ECG monitoring for 24 hours, especially if loss of consciousness at time of incident or abnormal ECG on arrival in hospital. This is more likely to occur if the patient has pre-existing myocardial disease that may be aggravated by small amounts of current damage.

Remember that small entrance or exit wounds may be associated with severe deep tissue damage.

Chemical Burns

(see Chapter 11)

While there is residual chemical on the skin, burning continues. Therefore contaminated clothing should be removed and the burn washed with copious amounts of water for a long time. Seek advice for special chemicals from National Poisons Information Service (0844 892 0111).

Chemical burns to the eye require continuous flushing with water. Swelling of the eyelids and eyelid muscle spasm due to pain may make adequate washing difficult. Careful retraction of the eyelids will facilitate correct irrigation. An early ophthalmological opinion is necessary in these cases.

Support and Reassure Patients, Relatives and Staff

Burns are associated with significant emotional overlay in the patient and also their relatives and friends.

Feelings of grief and loss are common and are normal accompaniments of burns. In addition feelings of guilt, self reproach, fear, depression and often anger in the victim and their relatives need to be addressed.

Burning is a frequent method of successful and attempted suicide. Patients with mortal injuries require sympathetic handling and counselling during the brief lucid period before death. Large doses of opioids or inappropriate endotracheal intubation prevent this important aspect of terminal management. It also makes the important final rapport with grieving relatives impossible. Every effort must be made to facilitate this communication.

Patients with non-fatal injuries will require psychiatric assessment and this may be needed urgently to prevent immediate further suicide attempts.

Some patients with abnormal personalities or under the influence of intoxicating substances may be violent during their emergency management and staff need to take care to avoid personal injury. Assistance from other hospital staff may be necessary to safely manage difficult patients. Psychiatric consultation is routine management in these circumstances.

When a reasonable explanation of the mechanism of the burn is lacking in children or vulnerable adults the possibility of non-accidental injury must be considered. Accurate documentation is important and reporting to the appropriate authority will enable proper investigation.

Definitive Care

Definitive burn care is described elsewhere in this manual. Transfer to a Burn service where other specialised services are available is indicated in accordance with national burn referral criteria (see Chapter 8).

Summary

1. The burn injury may only be part of the problem. Other injuries may also be present and should be dealt with according to the principles of rapid primary assessment with simultaneous attention to immediate life threatening conditions, followed by rapid resuscitation with oxygen and intravenous fluids. An ordered and complete "head to toe" examination of the patient should then be undertaken. Definitive care and transfer follow.

2. In the multiply injured burn patient the following points should be the focus of regular re-evaluation:

- Adequacy of fluid resuscitation
- Airway or respiratory embarrassment from inhalation injury or constricting eschar
- Peripheral circulatory insufficiency from constricting burn wounds, dressings or oedema
- Neurological deterioration
- Concealed (intra-cavity) bleeding

CHAPTER 3

Local and General Response to Burn Injury

A. Local Response

Based on the experimental work undertaken in the 1950's by Jackson in Birmingham, a burn wound model was described which aided the understanding of the pathophysiology of a burn.

Jackson's Burn Wound Model

Figure 3.1

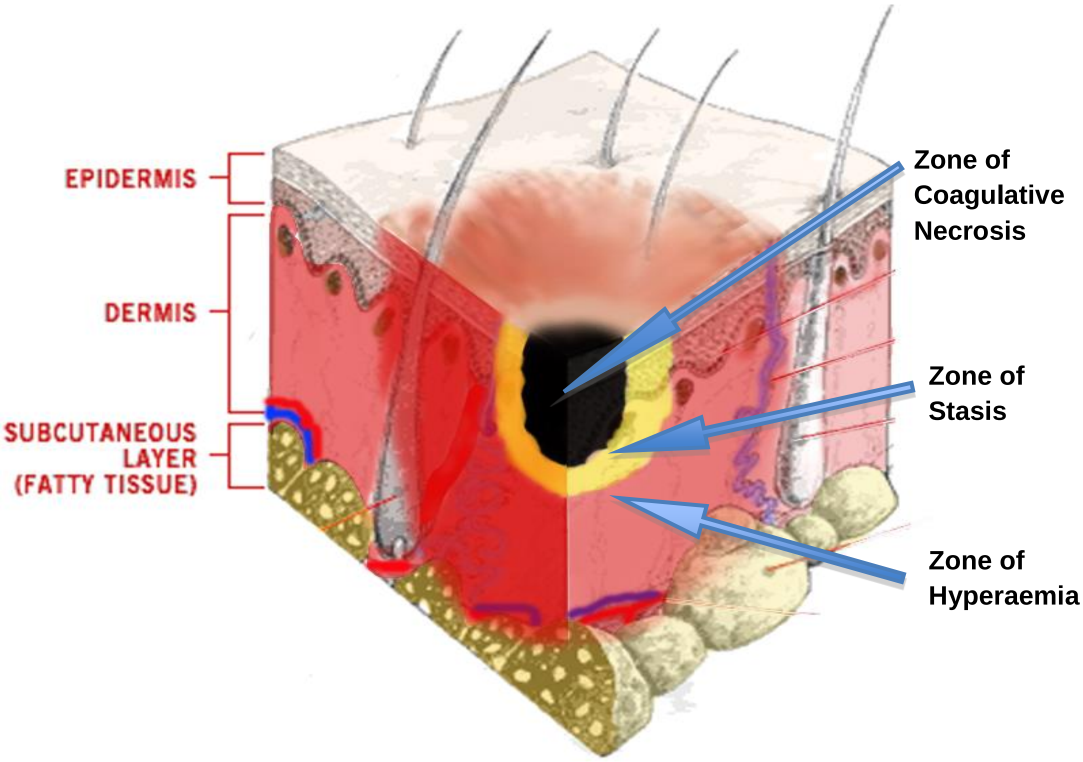


Figure 3.1 depicts this wound model. Nearest the heat source (or other injuring agent) where the heat cannot be conducted away rapidly enough to prevent immediate coagulation of cellular proteins, there is rapid cell death. This central zone of tissue death is best called the **Zone of Coagulative Necrosis** but is also referred to as the Zone of Coagulation.

Surrounding the Zone of Coagulative Necrosis is an area of tissue where the damage is less severe than that required to produce immediate cell death, but the circulation in this area of skin and subcutaneous tissue is compromised due to damage to the microcirculation. Because the circulation to this area is sluggish, it is called the **Zone of Stasis**. Untreated, this relatively narrow zone will undergo necrosis as the inflammatory reaction progresses under the influence of mediators produced by the tissue's response to injury. Clinically this is seen as progression of the depth of burning. This produces the phenomenon of areas of burn that appear viable initially but subsequently (3-5 days after burning) become necrotic.

Surrounding this region of compromised vasculature is a zone where damage to the tissues causes production of inflammatory mediators which cause widespread dilatation of blood vessels. This zone is called the **Zone of Hyperaemia.** Following the resolution of this hyperdynamic vascular response, the tissues of this area return to normal. In a burn that covers more than 25% of the total body surface area (TBSA), the Zone of Hyperaemia may involve virtually the whole of the body.

The contribution of each of these three zones (Coagulative Necrosis, Stasis and Hyperaemia) to the overall burn wound depends upon the circumstances of the burn itself. On occasions the Zone of Stasis may include the mid dermis, but progressive vascular compromise extends the Zone of Coagulative Necrosis producing a deep burn (see Figure 5.4). This is particularly likely to occur in the elderly patient and in those patients in whom appropriate treatment of post-burn shock and sepsis is not undertaken. Thus timely and effective emergency care of the burned patient can promote wound healing.

B. The General Response

1. Normal Capillary Exchange

(i) Substances pass through the capillary wall in one of three ways: diffusion, filtration, and large molecular transport.

a) Diffusion is the mechanism of transfer of very small particles such as oxygen, carbon dioxide or sodium. It implies that these particles cross the capillary wall (membrane) easily and so move in the direction of concentration ("downhill" from more concentrated to less).

b) Filtration is the mechanism of transfer of water and some other substances. The amount of water filtered through the capillary depends on the forces pushing water in and out across the capillary wall, as well as factors in the capillary wall. The forces causing movement across the capillary wall are summarised by Starling's Hypothesis (see Box 3.1).

c) Large molecule transport is less well understood. Large molecules probably cross the capillary wall mostly by passing through spaces between the endothelial cells. Most capillaries are fairly impervious to large molecules, which is why they are called "semi-permeable" (easily permeable to water and small particles such as Na^+, Cl^-, but relatively impermeable to large molecules such as albumin). Even so, each day

50%-100% of the body's serum albumin crosses the capillaries and is returned to the blood via the lymphatic system.

Box 3.1

Starling's Hypothesis states that net fluid movement is the difference between the forces moving fluid out (hydrostatic pressure in the capillary pushing fluid out plus the colloid osmotic pressure in the interstitial fluid pulling fluid out) and the forces moving fluid in (hydrostatic pressure in the interstitial space pushing fluid back in and plasma colloid osmotic pressure pulling fluid in).

(ii) Normal variations in filtration occur because of factors in the capillary wall (e.g. kidney capillaries let out much more water than muscle capillaries) as well as the factors mentioned in Starling's Hypothesis. The capillary hydrostatic pressure depends on the pressure of the blood flowing in as well as the resistance to blood flowing out (controlled by the pre- and post-capillary sphincters respectively).

Normally most capillaries undergo cycles of active blood flow, interspersed by long periods of low flow and hence low pressure. The colloid osmotic pressure of the plasma is almost totally dependent on the serum albumin concentration. The colloid osmotic pressure of the interstitial fluid is due to the small amount of albumin and the ground substance present between cells.

2. Abnormal Capillary Exchange

These changes are caused by inflammatory mediators released by damaged endothelial cells, by platelets, and by leucocytes.

(i) Vasodilatation is one of the major vascular responses to inflammation and causes:

a) Increase in capillary hydrostatic pressure.
b) Opening up of all capillaries instead of only a few.
c) Stretching of the capillary wall which increases the surface area of the capillary membrane and opens the spaces between endothelial cells.
d) Pooling of blood in small veins.

(ii) There is a marked increase in the permeability of the capillary membrane. This causes increased transport of substances by all three mechanisms, diffusion, filtration and large molecule transport. However, large molecule transport is most affected, and there is a dramatic increase in the movement of albumin across the capillary membrane. This causes mass movement of albumin out of the circulation and into the interstitial space producing oedema.

(iii) Tissue damage by burning may produce breakdown of intercellular ground substance. This can contribute to a rapid increase in the colloid osmotic pressure of the interstitial space, which has been observed experimentally. Another effect of burn injury on the intercellular ground substance is uncoiling of long molecules which are thought to cause expansion of the space and thereby lower its hydrostatic pressure.

3. Effects of Burn Injury on the Whole Body

There are changes in virtually every organ system in the body after a burn injury. When the burn is less than 20% TBSA these effects may not be of great practical significance.

The cause of these changes is release of inflammatory mediators and neural stimulation. The result is that there are major changes in control of body functions as well as direct reactions in some organs to circulating mediators.

(i) The most profound and immediate effect is on the circulation. Hypovolaemia is principally due to loss of protein and fluid into the interstitial space. Loss of albumin alters capillary exchange at sites remote from the burn. If the burn involves more than 25% TBSA the whole body is affected by circulating mediators so that capillary permeability is generally increased. **Correction of hypovolaemia is a life saving task in the first hours after major thermal injury.**

(ii) As a result of the injury a hypermetabolic state is caused by the secretion of the stress hormones- cortisol, catecholamines and glucagon.

In addition the suppression of or resistance to anabolic hormones (growth hormone, insulin and anabolic steroids) and neural mechanisms cause profound catabolism resulting in muscle protein breakdown. Clinically these changes are expressed as tachycardia, hyperthermia and protein wasting.

(iii) Immunosuppression is due to depression of many facets of the immune mechanism, both cellular and humoral. This is why infection is still the leading cause of mortality in burn patients.

(iv) The barrier function of the gut is greatly impaired, as part of the reaction to injury and shock, leading to an increase in bacterial translocation. This can be minimised by beginning very early enteral nutrition.

(v) The lungs frequently suffer from the changes of the post-burn systemic inflammatory response (Acute Respiratory distress Syndrome- ARDS) even in the absence of inhalation injury.
(vi) Widespread whole body changes in growth also occur and persist for months or years after healing of the burn wound. There is increased central deposition of fat, decreased muscle growth, decreased bone mineralisation, and decreased longitudinal growth of the body. Although growth velocity may return to normal after 1-3 years it does not exceed normal growth so that catch-up does not occur.

Summary

1. The local effect of thermal injury on the skin and subcutaneous tissues causes three zones of injury. Progression of the intermediate zone to necrosis tends to occur.

2. Normal capillary exchange is disturbed leading to oedema formation and loss of albumin from the circulation.

3. Burn injury also causes widespread general effects on the circulation, the metabolism, temperature control, immune competence, and function of the gut and lungs as well as long-term growth changes.

CHAPTER 4

Inhalation Injury

Inhalation of hot gases and the products of combustion injure various parts of the respiratory tract in different ways. In addition, the absorption of the products of combustion may lead to serious local or systemic toxic effects.

Inhalation injury increases mortality in all burns. For example, in a middle-aged man with burns, an inhalation injury may increase the mortality rate by 30% and increases the risk of pneumonia. If pneumonia supervenes, the mortality rate may rise by up to 60%. In children it has been reported that a 50% TBSA burn with associated inhalation injury carries the same mortality as a 73% TBSA burn without an associated injury.

Inhalation injury, previously known as respiratory tract burns, is most likely to be associated with burns of the head and neck. 45% of patients with burns to the face have an inhalation injury.

Classification of Inhalation Injury

An inhalation injury can be broadly classified according to the site of the injury.

1. Airway Injury above the Larynx
2. Airway Injury below the Larynx
3. Systemic Intoxication Injuries

A patient may have one or a combination of these types of injury.

Management of the airway aims at providing a patent and protected airway first and foremost. The airway may also need to be secured to improve oxygenation and ventilation in the setting of respiratory failure.

1. Airway Injury above the Larynx

These are thermal burns produced by the inhalation of **hot gases**, and so occur in those patients who have no alternative but to breathe these gases. This is most likely to occur when a person is in an enclosed space, if trapped in a fire, or with the inhalation of steam.

These burns produce the same pathophysiological changes that are produced by thermal injury to skin with damage proportional to exposure. Inflammatory mediators cause oedema of the tissues that leads to obstruction initially, and later loss of the protective functions of the mucosa.
Respiratory obstruction often develops as a result of soft tissue swelling and may persist beyond the time of maximal wound oedema (between 12 and 36 hours).

A burn to the skin of the neck may aggravate this obstruction by producing neck oedema. The latter is much more likely to occur in children who have relatively narrow airways and short necks with soft tissues that are readily distorted by oedema.

Remember that burns involving more than 25% TBSA result in a systemic inflammatory response even when there is no direct damage to the tissues. The airway mucosa may become oedematous especially if large volumes of fluid are required for resuscitation further compromising the airway.

The upper respiratory tract has such an efficient ability to conduct heat away that it is only after extreme heat exposure that direct heat damage to the lower respiratory tract occurs.

2. Airway Injury Below The Larynx

These burns are produced by the inhalation of the products of combustion. Fires cause the oxidation and reduction of compounds containing carbon, sulphur, phosphorus and nitrogen. The list of chemical compounds produced includes carbon monoxide and dioxide, cyanide, esters and complex organic compounds, ammonia, phosgene, hydrogen chloride, hydrogen fluoride, hydrogen bromide and the oxides of sulphur, phosphorus, and nitrogen. Polyvinyl chloride (PVC), for example, produces at least 75 potentially toxic compounds when burnt.

Acids and alkalis are produced when these compounds dissolve in the water contained in respiratory mucous and tissue fluids. These compounds produce a chemical burn. In addition, the particles of soot$<1\mu m$ are aerosolised. They also contain irritant chemicals and can produce damage to the alveoli. These chemicals contact the airway mucosa and lung parenchyma initiating the production of inflammatory mediators and reactive oxygen species. This results in oedema and possible shedding of the tracheobronchial mucosa forming casts. The lower airways may become plugged with debris resulting in distal airway obstruction.

The lung parenchyma may be affected with disruption of the alveolar-capillary membrane and the formation of inflammatory exudates and loss of surfactant. This results in atelectasis and interstitial oedema causing hypoxaemia and reduced lung compliance.

Factors implicated in the pathogenesis of lung injury include:

Bronchorrhoea	Pulmonary Oedema
Bronchiolar Constriction	Interstitial Lung Oedema
Cast formation and Air Trapping	Alveolar Vessel Shunting
Emphysematous Alveolar Injury	Acute respiratory distress syndrome (ARDS)
Alveolar Collapse	Impaired Gas Exchange
Secondary Bacterial Pneumonia	

3. Systemic Intoxication Injury

The two most common intoxications occurring in association with inhalational burns are caused by **carbon monoxide** and **cyanide.**

Carbon Monoxide

This is produced by incomplete oxidation of carbon. Carbon monoxide (CO) is a colourless and odourless gas that diffuses rapidly into the blood stream. It combines very readily with haemoglobin, having a greater affinity for haemoglobin than oxygen (240 times greater) forming carboxyhaemoglobin (COHb). CO reduces the oxygen carrying capacity of the blood hence causing tissue hypoxia by reduced oxygen delivery and utilisation at cellular level. It dissociates less readily then oxygen and so occupies an oxygen-binding site for a long period of time.

In addition to binding preferentially with haemoglobin, CO also binds with great affinity to other haem containing compounds, most importantly the intracellular cytochrome system. This causes abnormal cellular functioning that is a major component of CO toxicity. Post intoxication encephalopathy may be a serious sequel of poisoning; the exact mechanism of how this develops is not fully understood but may be due to cerebral lipid peroxidation.

The dissolved oxygen in the plasma remains unaffected so the PaO_2 remains normal. Standard pulse oximeters are unable to distinguish between oxyhaemoglobin and carboxyhaemoglobin and are of limited use in assessing CO poisoning. Blood gas analysers using co-oximetry or pulse co-oximeters are required. Carboxyhaemoglobin dissociates slowly, having a half-life of 250 minutes in a patient breathing room air, and 40 minutes in a patient breathing 100% oxygen.

Patients who have CO intoxication are often confused and disorientated exhibiting symptoms similar to those of hypoxia, head trauma and alcohol intoxication. It is important to ensure that CO intoxication is excluded before the diagnosis of alcohol intoxication or other diagnoses are made.

TABLE 4.1: Carbon Monoxide Intoxication

Carboxyhaemoglobin %	Symptoms
0 – 15	None (Smokers, long distance lorry drivers)
15 – 20	Headache, Confusion
20 – 40	Nausea, Fatigue, Disorientation, Irritability
40 – 60	Hallucination, Ataxia, Syncope, Convulsions, Coma
> 60	Death

Patients with an altered state of consciousness after burns have CO intoxication unless proven otherwise.

Cyanide Poisoning

This may occur because of the production of hydrogen cyanide from burning plastics. It is rapidly absorbed through the lungs, and binds readily to the cytochrome system, inhibiting its function resulting in anaerobic metabolism. It causes loss of consciousness, neurotoxicity and convulsions. It is gradually metabolised by the liver enzyme rhodanese. Blood cyanide levels are not readily available and their usefulness debated. Smokers will often have levels of 0.1mg/L, while lethal levels are 1.0 mg/L. In practice, pure HCN poisoning is rare, most patients suffering mixed HCN and CO poisoning.

Diagnosis of Inhalation Injury

All cases of burns should be examined with a view to excluding the diagnosis of inhalation injury. As the clinical signs and symptoms may evolve over a period of time, as with all trauma patients, there must be repeated re-evaluation. **This is a potentially fatal injury.**

Patients with severe inhalation injury may present early with marked respiratory distress or obtundation at the scene of the fire. Early death may occur and emergency resuscitation at the scene may be required to save life. The respiratory distress seen at the scene of the fire may be due to anoxia, as the fire consumes oxygen. CO intoxication is however thought to be responsible for the majority of deaths occurring at the scene of the fire, the scenario of “being overcome by the fumes”.

A common presentation of inhalation injury is one of increasing respiratory obstruction, occurring over several hours. This requires on going vigilance to detect and is due to thermal injury above the larynx. Increasing abnormalities in oxygenation as shown by increasing restlessness and confusion suggest injury below the larynx.

History

A history of burns in an enclosed space, such as a house, a motor vehicle, an aeroplane or an armoured vehicle, or burns with an associated explosion resulting from a petrol or gas fire, from shells or bombs, should alert medical personnel to the likelihood of an associated inhalation injury.

Examination

The following clinical findings are the signs suggestive of inhalation injury:

Observe for	Listen for
Burns to mouth, nose and pharynx	Change of voice
Singed nasal hairs	Hoarse brassy cough
Sputum containing soot	Croup-like breathing
Flaring of nostrils	Inspiratory stridor
Respiratory difficulty	Productive cough
Tracheal tug	
In-drawing supraclavicular fossae	
Rib retraction	

The symptoms and signs of an inhalation injury change or evolve over time according to the particular site and type of the injury. An indication of this change is given in Table 4.2.

TABLE 4.2: Change in Clinical Presentation of Inhalational Injury over Time

Type of Inhalation	**Timing**	**Signs/Symptoms**
Above the Larynx	4 - 24 hours	Increasing stridor
		Hoarseness or Weak Voice
		Brassy Cough
		Restlessness
		Respiratory Difficulty
		Respiratory Obstruction
		DEATH
Below the Larynx	Immediate	Restlessness
		Life threatening anoxia
		DEATH
	Gradual Onset	Increasing Hypoxia
	12 hrs to 5 days	Pulmonary Oedema/ARDS
		Respiratory Failure
Intoxication	At scene	DEATH
	Worse initially	Obtundation/Unconsciousness
		Stupor
	Improves with time	Confusion
		Drowsiness
		Poor mentation
		Visual disturbances
		Headache

After the initial assessment the subsequent clinical course can be altered by the onset of the known complications of inhalation injury.

These include:

- airway obstruction

- deteriorating consciousness
- retained secretions
- deteriorating oxygenation
- respiratory failure.

Diagnosis of Inhalation Injury Producing Systemic Intoxication

Diagnosis of systemic intoxication is made initially by clinical suspicion. Any patient, who is confused or has an altered state of consciousness after being burned, or inhaling products of combustion, is deemed to have carbon monoxide intoxication until proven otherwise.

The diagnosis is confirmed by the presence of COHb in the blood. CO levels estimated on arrival in hospital may not correlate well with the severity of the CNS symptoms of CO intoxication. They may appear to be too low. This is due to the washout of CO from the blood between exposure and arrival in hospital, and although the COHb level may appear to be low, the value of the test is that it confirms that this type of inhalation injury has occurred.

Treatment of Inhalation Injury

The management of inhalational injury is focussed on the following priorities:

- Ensure a patent airway
- High flow oxygen
- Frequent monitoring for respiratory deterioration
- Discussing suspected systemic intoxication with the National Poisons Information Service (0844 892 0111) for expert advice

During initial assessment (the Primary Survey), it is important that all patients with burns be given high flow oxygen by non re-breathing mask at 15 litres per minute. This will facilitate maximum tissue oxygenation while emergency assessment and management continues. Remember a patent airway is needed to deliver oxygen to the lungs.

1. **Treatment of Inhalation Injury above the Larynx**

All patients with suspected inhalation injury should be under close observation. The equipment for emergency intubation should be readily available because early and rapidly progressive respiratory obstruction is likely (particularly in children who have relatively small airways). Frequent reassessment of the patient's clinical condition is vital. As soon as increasing airway obstruction is detected the airway must be secured by endotracheal intubation.

Cervical spine protection is mandatory.

Endotracheal intubation should be performed as soon as possible. Delay may allow further airway oedema to occur and make subsequent intubation impossible. Stridor and respiratory distress are definite indications for intubation.

The indications for intubation are:

Impending airway obstruction	Unconsciousness
Deteriorating oxygenation	To facilitate safe transfer

If in doubt, intubate.

2. Treatment of Inhalation Injury below the Larynx

Treatment in this category is primarily that of respiratory support:

(i) High Flow Oxygen

All burn patients should receive high flow oxygen at 15 litres per minute via a non-rebreathing mask. This is made even more necessary in the face of parenchymal lung injury.

(ii) Intubation

Endotracheal intubation may be necessary to perform bronchial toilet to clear secretions, or to allow higher oxygen concentrations to be given.

(iii) Intermittent Positive Pressure Ventilation (IPPV)

This may become necessary if a patient's oxygenation is not responding to the administration of oxygen and simple securing of the airway. This can be achieved by manual ventilation with a bag attached to the endotracheal tube and the oxygen supply, or by a mechanical ventilator.

3. Treatment Of Inhalation Injury Producing Systemic Intoxication

(i) Respiratory Support

As above, it is important to ensure that burned tissue is perfused with as much oxygen as possible. High flow oxygen by mask should be administered.

(ii) Protection of the Unconscious Patient

As a result of systemic intoxication patients may be unconscious. Emergency treatment consists of rolling the patient into the left lateral coma position and administration of oxygen. **Cervical spine protection** should occur at all times. The airway should be secured, firstly by chin lift/ jaw thrust then an oropharyngeal airway, but in most instances endotracheal intubation will be necessary.

(iii) Natural Washout Effect with Time

Carbon monoxide (CO) is gradually removed from the blood by diffusion in the alveoli. The time taken for this to occur is slowest breathing room air at atmospheric pressure but can be reduced by increasing the concentration of the oxygen administered. Hyperbaric administration of high oxygen concentrations will increase the speed of CO washout although evidence is conflicting as to whether this results in improved neurological outcomes. Logistics are complicated in a critically ill patient with major burns.

(iv) Oxygen

The standard emergency treatment is breathing 100% oxygen by mask. This should be continued until COHb levels return to normal. The secondary washout of CO that occurs from the cytochrome binding may cause a smaller secondary rise of COHb 24 hours later, and oxygen should be continued.

(v) Oxygen + IPPV

This may be necessary in the unconscious patient, or in the patient who has other types of inhalation injury apart from systemic intoxication.

(vi) Cyanide Intoxication

Cyanide intoxication is often fatal. Washout of cyanide from the blood by metabolism in the liver is slow. Whilst cyanide antidotes such as those containing hydroxycobalamin have been advocated, these are not readily available in all Emergency Departments.

(vii) Hydrogen Fluoride Intoxication

HF when absorbed systemically in significant amounts efficiently binds serum calcium. Hypocalcaemia is likely to develop which can be fatal. Infusion fluids should contain added calcium to counteract this.

Seek advice for inhaled substances such as cyanide, etc from the National Poisons Information Service (NPIS).

Summary

1. Inhalation injury and the related systemic intoxication are potentially fatal injuries. Their diagnosis depends upon the clinical suspicion of their occurrence, and the recognition of their signs from the history and examination.

2. Emergency treatment consists of providing respiratory support with oxygen and securing of the airway, undertaking endotracheal intubation if necessary.

3. Patients with an inhalation injury or suspected inhalation injury should be referred to a burns service for ongoing care after initial emergency stabilisation.

CHAPTER 5

Burn Wound Assessment

Introduction

Whatever the cause of burns, whether they be thermal, chemical or electrical, the amount of tissue damage and particularly the depth of burning, is related to the temperature or strength of the injuring agent, and the length of time that the agent has been in contact with the skin.

Temperature above 50ºC will produce tissue necrosis, particularly when the skin is thin as in children and the elderly.

1. Estimation of the Area of the Burn

The two important determinants of the seriousness of the burn injury are the area and depth of the burn. The likelihood of mortality following burns is a function of the:

- Age of the patient
- Percentage of the total body surface area burned (% TBSA).

The greater the surface area of the body injured, the greater the mortality rate.

Accurate assessment of the area of the burn requires a method that allows easy estimation of the size of the burn as a percentage of the body surface area. This is readily accomplished using the "Rule of Nines" (see Figure 5.1).

The **"Rule of Nines"** divides the body surface into areas of nine percent or multiples of nine percent, with the exception that the perineum is estimated at one percent. This allows the extent of the burn to be estimated with reproducible accuracy. In addition to calculating the area burned it is useful to calculate the area not burned and to check whether both calculations add up to 100%.

A method of estimating small burns is to use the area of the palmar surface (fingers and palm) of the patient's hand, which approximates to 1% body surface area (see Figure 5.2). This method is useful in non-confluent burns that do not lend themselves to a "Rule of Nines" method.

The Rule of Nines is **relatively accurate in adults**, but may be **inaccurate in small children**. This is because the child has different body surface area proportions than the adult. Children have proportionately smaller hips and legs and larger shoulders and heads than adults. Using the "Adult Rule of Nines" may seriously under or over estimate the size of the burn wound of a child, and lead to inaccurate intravenous fluid resuscitation.

For these reasons the **Paediatric Rule of Nines** should be used (see Figure 5.3). This can be modified for different ages to enable accurate surface area calculations (see Chapter 9).

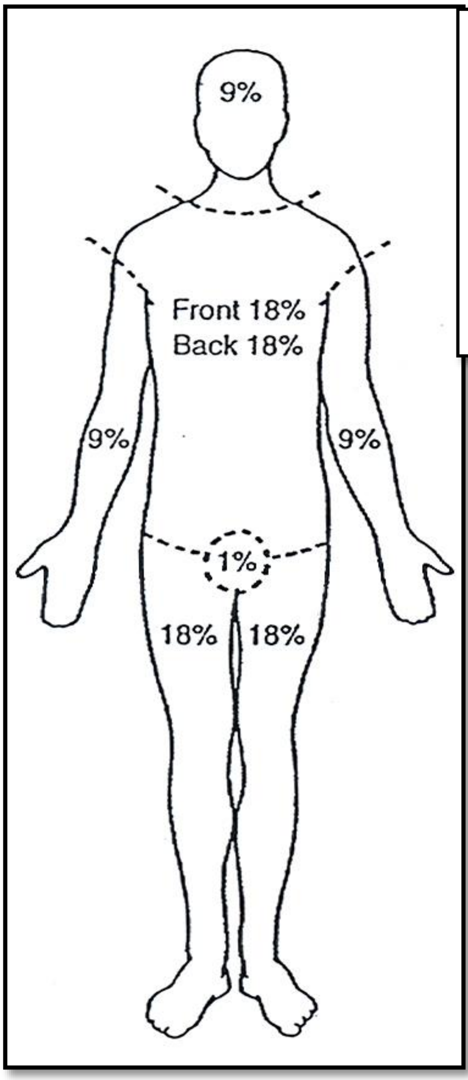


FIGURE 5.1

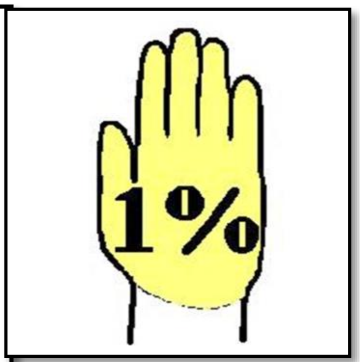


FIGURE 5.2

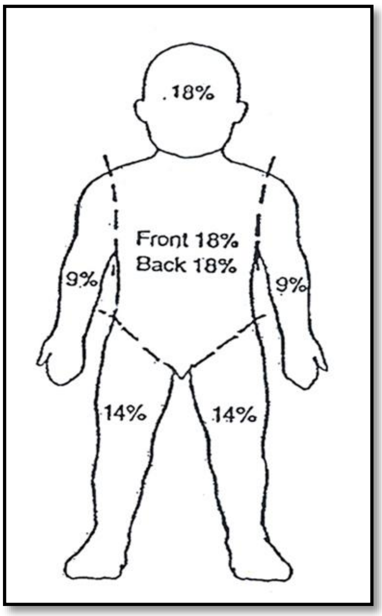


FIGURE 5.3

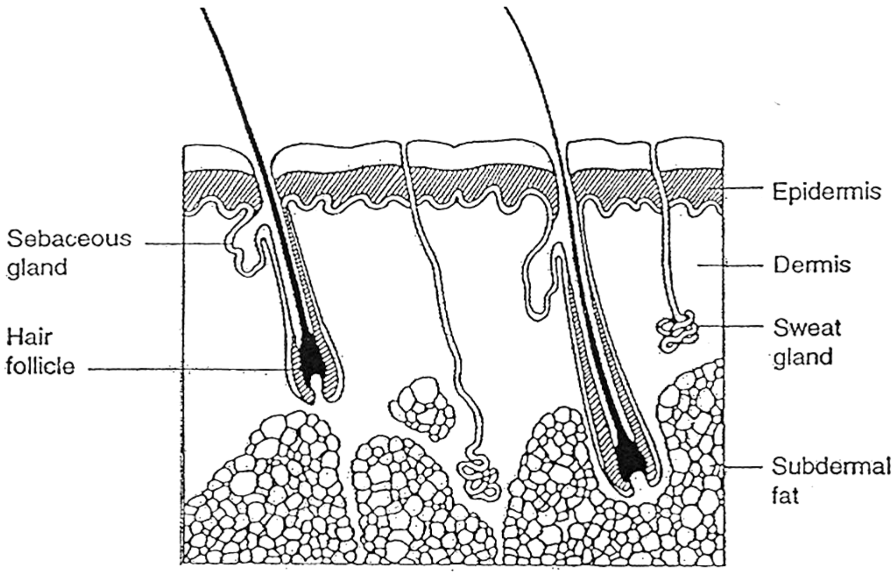
2. Estimation of the Depth of the Burn

The Structure and Function of the Skin

The skin consists of two parts, the **epidermis** and the **dermis**. The epidermis is the superficial thinner layer that is responsible for limiting the evaporation of water from the body, and is constantly being reproduced by division of the basal layers of the epidermis (see Figure 5.4).

FIGURE 5.4

CROSS-SECTION OF NON-SPECIALISED SKIN



The dermis is the deeper, thicker layer that provides the strength and durability of the skin. The dermis contains the blood supply and the sensory nerves of the skin. The dermis also contains the epidermal adnexal structures: hair follicles and their epidermal lining, sebaceous glands, and sweat glands with their ducts. These reservoirs of epithelial cells under the control of growth factors will undergo mitosis and can produce an epithelial covering that will heal a partial thickness wound. This process is called **epithelialisation.**

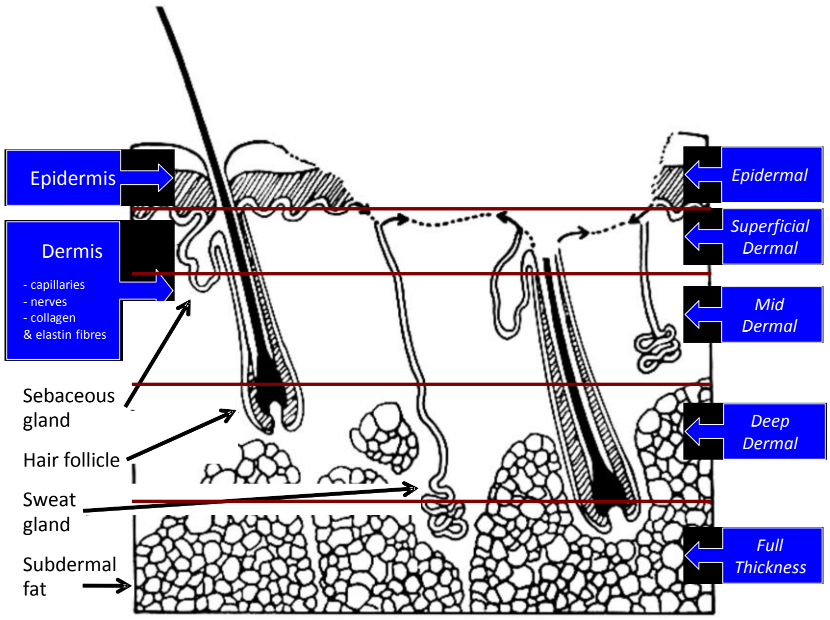
Underneath the dermis lie the padding layers of subcutaneous fat and fascia that separate the skin from the deeper muscular and bony structures. These layers provide important cushioning from trauma and their damage in burns means inevitable tethering of skin to deeper structures.

The anatomy of the skin of the nose and external ears is different from elsewhere in the body, as here the skin is very closely applied to the underlying cartilage with little subcutaneous fat. The blood supply for both the skin and cartilage runs between the two. Burns to the nose and pinna may therefore produce damage to the blood supply of the skin and cartilage. Skin and cartilage loss may cause significant deformity, particularly if bacterial chondritis supervenes.

Depth of Burn Injury

Depending upon the depth of tissue damage, burns may be classified as either superficial or deep (see figure 5.5 and table 5.1). In practise all burns are a mixture of areas of different depth.

FIGURE 5.5: Depth of Burn



A. Superficial Burns

Superficial burns are those that have the ability to heal themselves spontaneously by epithelialisation. These superficial burns may either be **epidermal** or **dermal** in depth.

1. Epidermal Burns

Epidermal burns include only the epidermis. Common causes of this type of burn are the sun and minor flash injuries from explosions. The stratified layers of the epidermis are burned away and healing occurs by regeneration of the epidermis from the basal layer. Due to the production of inflammatory mediators, hyperaemia is produced so these burns are red in colour and may be quite painful (see Table 5.1). They heal quickly (within seven days), leaving no cosmetic blemish. Hospital admission may be required for pain relief.

Pure erythema (epidermal burn) is not included in estimations of the total body surface area burnt. Differentiation between pure erythema and superficial dermal burn may be difficult in the first few hours after injury.

2. Superficial Dermal Burns
Superficial dermal burns include the epidermis and the superficial part of the dermis - the papillary dermis. The hallmark of this type of burn is the **blister**. The skin covering the blister is dead and is separated from the viable base by the outpouring of inflammatory oedema. This oedema tents up the necrotic roof forming a blister. This blister may burst exposing the dermis that following exposure may desiccate and die. This causes increased depth of tissue loss. The exposed papillary dermis is pink to white. Because sensory nerves are exposed, the burn is usually extremely painful. Under suitable conditions epithelium will spread outwards from the adnexal structures (hair follicles, sebaceous glands and the ducts of sweat glands) and join neighbouring islands of epithelium to cover the dermis (epithelialisation).
Superficial dermal burns should heal spontaneously by epithelialisation within 14 days leaving only a colour match defect. No scarring should be produced in this type of burn. If healing is delayed it means that the burn is deeper than originally diagnosed.

TABLE 5.1: Diagnosis of Burn Depth

Depth	Colour	Blisters	Capillary Refill	Sensation	Healing
Epidermal	Red	No	Present	Present	Yes
Superficial Dermal	Pale Pink	Small	Present	Painful	Yes
Mid-Dermal	Dark Pink	Present	Sluggish	+/-	Usual
Deep Dermal	Blotchy Red	+/-	Absent	Absent	No
Full Thickness	White	No	Absent	Absent	No

B. Mid-dermal Burns

A mid-dermal burn, as its name suggests, is a burn injury that lies between a superficial dermal burn (described above) which will heal relatively rapidly, and a deep dermal burn (described below) which will not. At the mid-dermal level, the number of surviving epithelial cells capable of re-epithelisation is less due to the deeper burn wound and so rapid spontaneous burn wound healing does not always occur.

Clinically, the appearance is determined by damage to the dermal vascular plexus of varying degrees. Capillary refill may be sluggish, and tissue oedema and blistering will be present. The burned area is usually a darker pink than that of a superficial dermal burn’s light pink, but not as dark as a deep dermal burn’s blotchy red. Sensation to light touch may be decreased, but pain persists, reflecting the damage to the dermal plexus of cutaneous nerves.

C. Deep Burns

Deep burns are more severe. They will either not heal spontaneously by epithelialisation, or only heal after a prolonged period with subsequent significant scarring. They may be either **deep dermal** or **full thickness**.

1. Deep Dermal Burns

Deep dermal burns may have some blistering, but the base of the blister demonstrates the character of the deeper, reticular dermis often showing an appearance of a blotchy red colouration. This red blotchy colouration is due to the extravasation of haemoglobin from destroyed red cells leaking from ruptured blood vessels. The important hallmark of these burns is the loss of the **capillary blush phenomenon**. This demonstrates that the burn has destroyed the dermal vascular plexus. The dermal nerve endings are also situated at this level and so in these burns sensation to pinprick will be lost.

2. Full Thickness Burns

Full thickness burns destroy both layers of skin (epidermis and dermis), and may penetrate more deeply into underlying structures. These burns have a dense white, waxy, or even a charred appearance. The sensory nerves in the dermis are destroyed in a full thickness burn, and so sensation to pinprick is lost. The coagulated dead skin of a full thickness burn, which has a leathery appearance, is called **eschar**.

Summary

1. The seriousness of a burn is determined by the depth and area of patient burned. The mortality from burns is related to the age of the patient and to the extent of the burns.

2. The Adult and Paediatric Rule of Nines enable a reproducible assessment of burn extent to be calculated.

3. Clinical examination of the burn wound aids diagnosis of the depth of the burn.

CHAPTER 6

Burns Shock and Fluid Resuscitation

Burn injury precipitates a large amount of fluid sequestration into the area of injury and when the size of the burn exceeds 20-30% TBSA, this process becomes generalised. Oedema is formed in great quantity, and when combined with on going evaporative loss from the moist burn surface, results in significantly decreased plasma volume. This in turn leads to intravascular hypovolaemia that, if not corrected, precipitates organ system failure, especially acute kidney injury.

This chapter will expand on the pathogenesis of oedema formation and post-burn hypovolaemic shock, fluid resuscitation and monitoring.

Thermal injury causes marked changes in the microcirculation both locally at the site of injury and elsewhere. A full thickness burn develops three zones of decreasing injury (Figure 3.1 Jackson's Burn Wound Model):

1. Central zone of coagulative necrosis.
2. Intermediate zone of injury characterised by stasis of blood flow.
3. An outer, peripheral zone showing vasodilatation, increased blood flow and hyperaemia.

Mediators are produced and released at the burned site that alter vascular membrane integrity and so increase permeability. These mediators include histamine, serotonin, prostaglandins, bradykinin and potent vasoconstrictors such as thromboxanes and angiotensin.

In large burns (>20 - 30% TBSA), the quantity of these mediators produced at the burn site is so great that they induce widespread increased vascular permeability that leads to generalised oedema formation. Hypovolaemic shock soon follows. In addition to this, an anatomical derangement of the endothelial lining of the microvasculature can be detected on electron microscopy.

Evidence in favour of one resuscitation fluid in comparison with another is conflicting. From a practical point of view the ready availability of crystalloid solutions such as Hartmann's Solution (Lactated Ringers) has made them the internationally accepted choice for initiation of resuscitation. Other suitable similar solutions are becoming available in the U.K. but are not readily available in all hospitals.

Children have limited physiological reserve and greater surface area to mass ratio compared to adults. The threshold at which fluid resuscitation is required in children is lower than for adults (approximately 10% burn) and they tend to need a higher volume per kilogram. This increased need for fluids equates with the volume of normal maintenance requirements over that calculated by fluid resuscitation formulae. Inhalation injury further increases fluid requirements. Oedema formation ceases between 18 - 30 hours post-burn. Therefore, the duration of resuscitation is variable but can be recognised when the volume needed to maintain adequate urine output is equal to maintenance requirements.

Estimation of Fluid Needs

The extent of the burn is calculated using the “Rule of Nines” or a burn body chart if available. If possible the patient is weighed or weight obtained during history taking. These data are then used in a fluid resuscitation formula:

Adults: 3ml Hartmann's solution* /kg body weight/% burn

Children: 3ml Hartmann's solution*/ kg body weight/% burn
Plus
Maintenance with 5% Glucose in 0.45% (1/2 normal) saline.

Maintenance calculated as 100 ml/kg up to 10 kg **plus**
50 ml/kg from 10 -20 kg **plus**
20ml/kg for each kg over 20 kg

*Other similar suitable solutions are available but not widely in use in U.K.

NOTE: The calculation of fluid requirements commences at the time of burn, not from the time of presentation.

The calculated volume is that estimated for the first 24 hours. As oedema formation is greatest soon after injury:

- Half the calculated volume is given in the first 8 hours and the remaining half given over the subsequent 16 hours.
- Maintenance fluid for children is given at constant rates over 24 hours.

This step-down does not match the gradual decrease in oedema formation and emphasises that these formulae are only guidelines that may need to be altered to match individual requirements.

If urine output is not adequate, give extra fluid:
- Bolus of 5-10 ml/kg and/or increase the next hour's fluids to 150% of planned volume.

In the second 24 hours post burn, colloid fluids can be added to help restore circulating volume using the formula:
- 0.5ml of 5% albumin **x** kg body weight **x** % burn.

In addition, electrolyte solution should be provided to account for evaporative loss and normal maintenance requirements. Vomiting is commonplace and such losses should also be replaced.

Fluid should be administered via *two* large cannulae (at least 16g in adults), preferably inserted through unburned skin. Consider I.O. access if needed.

Monitoring Adequacy of Fluid Resuscitation

The best, easiest and most reliable method of monitoring fluid resuscitation is by following urine output:

Adults	0.5 ml/kg/h = 30 – 50ml/hour
Children (< 30kg)	1.0 ml/kg/h (range 0.5 – 2 ml/kg/h)

If urine output is kept near these levels then adequate organ perfusion is being maintained. Large urine output indicates excessive fluid resuscitation with unnecessary oedema formation; low urine output indicates poor tissue perfusion and likely cellular injury.

Clearly, a **urinary catheter is vital** for accurate monitoring and should be inserted for burns

- > 10-15% TBSA in children
- > 20% TBSA in adults

Central invasive haemodynamic monitoring is only occasionally indicated and is used for those with pre-morbid cardiac disease or coexistent injuries causing blood loss such as multiple fractures.

Significant acidaemia (pH < 7.35) detected on arterial blood gas analysis commonly indicates inadequate tissue perfusion and is usually due to lactic acidosis. Increased fluid resuscitation is indicated. Acidosis may also indicate the need for, or inadequacy of, escharotomy.

Blood pressure readings with a sphygmomanometer are notoriously inaccurate due to oedema formation and accurate measurements can only be obtained via an arterial line. These are recommended in large burns.

The heart rate is usually raised in burn patients due to pain and emotion and so is a poor indicator of adequacy of fluid resuscitation

Serum electrolytes should be measured initially and at regular intervals. Mild hyponatraemia is common due to dilution by the infusion depending on the sodium concentrate of the crystalloid solution used (Hartmann's solution Na^+ concentration is only 130 meq/l). Hyperkalaemia commonly occurs with deep tissue injury in electrocution. Glucose plus insulin may be required to correct this problem.

Restlessness, mental obtundation, and anxiety are often indicators of hypovolaemia and the first response should be to look to the adequacy of fluid resuscitation.

Haemoglobinuria/ Myoglobinuria

Tissue injury, particularly muscle tissue, from electrocution, blunt trauma or ischaemia (escharotomy!) causes release of myoglobin and haemoglobin. These haemochromogens colour the urine a dirty red. Acute kidney injury will soon ensue as a result of deposition of these haemochromogens in the proximal renal tubules, and prompt treatment is required:

- Increase urine output to 2 ml/kg/h
- Mannitol 12.5 g/litre resuscitation fluid

Problems with Resuscitation

Formulae only estimate requirements and the individual patient must be closely monitored.

Oliguria
Low urine output indicates inadequate fluid resuscitation. The appropriate first response is to increase the rate of infusion. Diuretics are rarely necessary and should not be considered until after consultation with a burn unit. They are used in patients with haemochromogens in the urine and occasionally in patients with very large burns.

The following patient groups routinely require extra fluid resuscitation:

- Children
- Inhalation Injury
- Electrical Injury
- Delayed resuscitation
- Dehydration – fire-fighters, intoxicated patients

Infants, the elderly and those with cardiac disease should be monitored closely as fluid overload is easily precipitated. Fortunately, pulmonary oedema is uncommon due to disproportionately greater increase in pulmonary vascular resistance than systemic vascular resistance. It occurs in those with myocardial hypokinesia and often requires invasive monitoring, inotropic support, ventilation and difficult alterations in fluid management.

Over resuscitation
Over resuscitation is as dangerous, possibly more so than under resuscitation. If urine output is consistently high for a number of hours need to reassess the clinical picture and may need to reduce the resuscitation fluids. This should be done with senior/expert advice/supervision.

Children
Children are prone to **hypoglycaemia**, fluid overload and dilutional hyponatraemia due to limited glycogen stores, higher surface area to weight and

intravascular volume ratios. Blood **glucose** and **electrolyte levels** should be measured regularly. Free water should be limited and a source of carbohydrate instituted early. This could be enteral feeding or addition of dextrose to the electrolyte solution.

Abdominal Compartment Syndrome
This rare but serious secondary complication can occur in large burns in adults as well as children especially when the calculated fluid requirements have been exceeded to achieve adequate urine output. It is suggested that if the presence or development of Abdominal Compartment Syndrome is being considered that bladder pressure monitoring can give valuable information.

Summary

1. Fluid resuscitation is necessary for survival. Formal resuscitation with intravenous fluids are indicated for:

- Children >10% TBSA
- Adults >15% TBSA

Two large bore peripheral cannulae should be inserted.

2. The calculation fluids commences at time of injury:

- Child (<30kg) 3 ml Hartmann's/ kg/% burn *plus* maintenance
- Adult 3ml Hartmann's/kg/% burn
- Half in first 8 hours, rest over next 16 hours

3. Monitor resuscitation - insert a urinary catheter.

4. Haemochromogens: increase fluid resuscitation to double urine output.

CHAPTER 7

Management of the Burn Wound

Introduction

In order to manage a burn wound it is essential to understand the mechanism of injury and to be able to assess the extent of that injury. This establishes a starting point for treatment, the object of which is the best possible functional and cosmetic outcome.

A wound is a disruption of tissue architecture and cellular processes. In a burn the denaturing of proteins and disruption of cellular structures is due to thermal insult (either heat or cold), electricity, chemical action or radiation. The burn wound is significant because it interferes with all seven major functions of the skin:

- Aesthetic and psychological interface
- Temperature regulation
- Sensory interface
- Immune response
- Protection from bacterial invasion
- Control of fluid loss
- Metabolic function

The aim of treatment is to minimise the interference with function both locally and systemically.

It is important to understand that the wound is dynamic and often heterogeneous. **DO NOT** assume that all areas of the burn are equally deep.

First Aid

The principles of first aid are to

- stop the burning process
- cool the burn wound.

Stopping the burning process reduces tissue damage. Cooling the surface of the burn wound reduces the production of inflammatory mediators (cytokines) and promotes maintenance of viability in the zone of stasis. It therefore helps to prevent progression of damage that occurs in an untreated burn in the first 24 hours after the injury.

Stop the Burning Process

In flame burns the flame should be extinguished by the patient rolling on the ground, either actively or passively, using the “Stop, Drop, Cover (face) and Roll” technique. Hot charred clothing should then be removed as quickly as possible. It does not help the patient if observers or assistants have burned hands so it is important that any assistance be rendered in such a way that the helpers are not themselves injured.

In a scald burn the clothing soaked with hot fluid acts as a reservoir of heat and so removal of clothing as rapidly as possible will stop the burning process.

In addition to removing the clothing, all jewellery should be removed. If clothing is firmly stuck to the surface of the skin cut around the area leaving the adherent cloth in place, but most melted synthetic compounds adhere to the surface of the skin that is non-viable and will come away quite easily. As this skin is non-viable this is of no disadvantage to the patient.

Cooling the Burn Surface

The burn surface should be cooled with cold running water. The ideal temperature is 15^0C and the range that is useful is between 8 and 25^0C. Cooling the surface reduces the inflammatory reaction and can therefore stop progression of necrosis in the zone of stasis.

The best technique is to apply flowing cool water over the burn wound. Methods such as spraying or sponging over the wound, wet towels or hydrogel are not as efficient and should only be used where water is not available e.g. in transit. Wet towels are less efficient as they are not in contact with the burn wound in all areas, and quickly heat up due to proximity to the body: if used, they must be changed frequently.

The duration of application should be for twenty minutes unless some other factor prevents this from happening. For example, the patient may have multiple injuries and there may not be personnel available to perform first aid for this length of time. First aid is effective within 3 hours following the burn injury.

Small children are at significant risk of becoming hypothermic and if this is detected either by taking the temperature or by clinical assessment of the blue shivering child, application of cold water should cease. To reduce the risk of hypothermia it is desirable to raise the ambient temperature to over 30^0C and to keep the rest of the child well wrapped.

Ice or iced water should not be used. The extreme cold causes vasoconstriction and experimentally has been shown to deepen the tissue injury. There is also a greater risk of hypothermia.

Cooling the surface of the burn is also an extremely effective analgesic. If pain re-appears within minutes of ceasing cold-water application and there is no other factor preventing its continued application, it may be continued for its analgesic effects.

Hypothermia should be prevented at all costs.

Early Management

Once first aid has been completed the burn wound can be covered with a clean dry cloth while other aspects of the patient's care are performed. If the burn wound has not had cold fluid applied and the lapse of time since the accident is greater than three hours, application of cold water does not have a beneficial effect. The wound should therefore be washed and this can be done with saline, soap and water, or chlorhexidine 0.1% solution. Other antiseptics should not be applied.

In preparation for transport the patient may need a dressing on the burn wound. Depending upon the time between injury and transport and the expected time taken during the transporting process, it may be necessary to apply something more than simply wrapping the area in a clean cloth. Cling film can be used and is particularly useful in children because it limits evaporation and hence heat loss. Jelonet or Bactigras (chlorhexidine impregnated tulle gras) held on with a light bandage is suitable for patients who are going to take some hours during the transport process. The use of topical agents on the burn wound is reserved for those patients in whom there is significant delay or prolonged transport time and should be done in consultation with the receiving burn centre. The use of Acticoat, SSD or Bactigras is suggested.

Elevation

Elevation of the part is useful during initial treatment and transport, as it tends to limit swelling. In the limbs this may make a difference between the need to perform escharotomies or not. There is also a theoretical possibility that tissue nutrition is impaired by oedema increasing the diffusion distance between the capillaries and the cells.

Special Areas

As mentioned in the section on respiratory burns, thermal burns of the upper airway are often associated with rapidly accumulating swelling and early intubation is necessary.

- Burns of the perineum require early urinary catheterisation in order to prevent contamination. Delay in catheterisation may cause extreme difficulty in insertion of the catheter once swelling has become established.
- Burns of the head and neck should have elevation of the head to limit upper airway swelling. Children with extensive burns or with burns of the head and neck benefit from the head up position because they have a greater risk of cerebral oedema with fluid resuscitation.

Escharotomy

When the burn injury affects the whole of the dermis the skin loses its ability to expand as oedema progresses. It therefore may become necessary to release the burn wound surgically by incising the burned skin down to the subcutaneous fat. This procedure is called escharotomy.

Trunk

When the trunk is extensively burned rigidity of the chest wall decreases compliance and this may reduce ventilation. In adults this problem is seen with circumferential burns of the chest with or without involvement of the abdomen. In children whose breathing is principally diaphragmatic, the problem can be seen when the anterior aspect of the chest and abdomen are burned without the injury extending to the posterior aspect.

The incisions should run longitudinally along the anterior axillary lines to the costal margin or to the upper abdomen if this is burned. In severe cases it may be beneficial to connect these incisions by two cross incisions that may be convex upwards across the upper chest below the clavicles and across the upper part of the abdomen.

Extremities

When a limb is burned circumferentially the increase in pressure due to the accumulation of oedema under the rigid burned skin may interfere with circulation and cause death of tissue in the distal part of the extremity. The onset of circulatory embarrassment is slowly progressive and subtle if not sought. The increase in pressure may be detected by the appearance of one or more of the following:

- Deep pain at rest
- Pain on passive movement of distal joints
- Loss of distal circulation
- Pallor
- Loss of capillary return (especially in the nail beds)
- Coolness
- Decrease in pulse pressure as detected by Doppler ultrasound
- Loss of palpable pulses
- Numbness
- Decreased oxygen saturation as detected by pulse oximetry

The interpretation of these signs may be made difficult by the presence of burned skin (which makes feeling the pulses difficult), by cold (which gives the appearance of decreased capillary return), and by hypovolaemia. The most accurate method of assessment is the use of Doppler ultrasound. The earliest changes will be loss of Doppler signals from the digital vessels. Escharotomies should be performed before pulses are lost but when there is evidence of decreasing circulation.

The incisions should extend by a few millimetres onto normal skin above and below. The incisions are in the mid-axial lines between flexor and extensor surfaces. Avoid incisions across the flexural creases of joints. They should be carried down to the fat sufficiently to see obvious separation of the wound edges. Running a finger along the incision will detect residual restrictive areas. Sometimes one incision is enough but often incisions on both sides are necessary to restore circulation. The palpable softness of the limb is a useful guide.

The danger of escharotomy is to structures under the skin. In particular medially at the elbow the ulnar nerve is vulnerable and laterally at the knee the common peroneal nerve is at risk. Transverse incisions in the limbs should not be made.

The distal extent of escharotomy is sometimes difficult to assess. In the upper limb the medial incision can pass along the medial border of the hand to the base of the little finger. On the lateral aspect the incision can come down to the proximal phalanx of the thumb. Occasionally further hand incisions may be necessary but before embarking on this the burn referral unit should be contacted.

Diagrams of appropriate lines of incision are included in the manual as Appendix 3 and can be rapidly supplied by fax.

Procedure Plan

The first step is to define the lines of incision. If the operator is not familiar with the procedure they can usually be drawn in with a skin marker with the limb held in its anatomical position and then inspected before a final decision is made. When the arm is burnt, the forearm lies in pronation so needs to be supinated before marking and incising. In the upper limb the incision should go in front of the medial epicondyle to avoid damage to the ulnar nerve.

In the lower limb the medial incision passes behind the medial malleolus avoiding the long saphenous vein and saphenous nerve. If a second incision is required laterally, care should be taken to avoid the common peroneal nerve where it crosses the neck of the fibula. This incision is in the midlateral line.

The equipment needed is a scalpel or cutting diathermy and some means of haemostasis. Artery forceps and ties, diathermy or topical haemostatics such as calcium alginate are useful. Blood loss can at times be extreme.

Anaesthesia is usually not necessary. Sometimes local anaesthetic is necessary at the edge of the burn to extend up into normal tissue adequately. Many of these patients may already be intubated and therefore sedated under which circumstance a little extra sedation can be given.

Dressings should be available to dress the area once the incision is performed. The area is prepared as for a surgical procedure and performed in a sterile fashion. Light dressings are applied as firm dressings may interfere with the effectiveness of the procedure.

If the patient is conscious the procedure should be explained to them and consent obtained prior to commencement.

Summary

1. Burns interfere with all functions of the skin.

2. First aid consists of stopping the burning process and then cooling the burn wound.

3. Immediate treatment of the wound should be kept simple.

4. Rigid eschar may interfere with body functions so escharotomy may be needed on the chest to allow ventilation or on the limbs to prevent distal circulatory obstruction.

CHAPTER 8

Indications and Procedures for Referral

Introduction

The patient with electrical, chemical, or thermal injury requires immediate assessment and stabilisation at the nearest hospital**.** There is no case for the “occasional” burn surgeon in the U.K., as expert multidisciplinary care is readily available at regional burn services. All patients have the right of access to quality burn care. Initial treating personnel should complete a primary and secondary assessment and evaluate the patient for potential referral and transfer. Burn injuries may be a manifestation of multiple trauma, and the patient must be evaluated for associated injuries. All procedures and treatments administered need to be documented to provide the receiving burn service with a record that includes a flow sheet of observations, medications and treatments.

Influence of Geographic Situation

1. Urban Areas

In cases of burns that occur in those cities across the U.K. that have an established burns service, patients requiring hospital admission should be transported to that service without unnecessary delay, so that resuscitation and definitive care can begin as soon as possible.

The only exception to this rule is in those cases that require immediate life saving intervention, such as endotracheal intubation. When the definitive care unit is within one hours ambulance ride, unnecessary delays caused by inappropriate decisions to begin IV fluid resuscitation at a first line hospital (or even at a teaching hospital) on the way to the burn service, are not in the patient’s best interests and should not occur. This is of greater significance in children and the elderly, in who long delays in beginning fluid resuscitation can compromise care and prejudice outcome.

2. Rural and Isolated Areas

In isolated and rural areas, because of distance and sparse facilities and also because of logistic problems, it may not be possible to transfer the patient immediately but this is exceptional within the U.K. Twenty-four hours of treatment may be required before transport is possible. It may occasionally be necessary to treat patients for longer than 24 hours (see Chapter 12). In these circumstances it is the responsibility of the local treating medical and nursing staff to liaise with the staff at the regional burns service regarding appropriate emergency management, so that when the transfer occurs the patient is in optimal condition. Only in the most exceptional circumstances are the patient's best interests served by continuing treatment at local or a district hospital. Sacrificing good physical care for the perceived advantages of "keeping the family together" is detrimental, particularly as the emotional care of the burned patient is as specialised and as important to their long term outcome as the physical care. All specialised burn units recognise this need and have facilities for relatives to stay as well as personnel trained to help both patient and family achieve an optimal emotional outcome.

In all events, make contact with your burn centre EARLY.

Referral Criteria

There are nationally agreed referral guidelines produced by the National Network for Burn Care and endorsed by the British Burn Association (for full guidelines see Appendix 1).

All patients with injuries such as those listed in Table 7.1 should have early consultation with a burn service. If there are local resources that are appropriate, some patients may not need transfer, but by and large, all patients listed will need transfer.

Table 7.1

Burns greater than 3% Total Body Surface Area (TBSA) (>2% in children)
Burns of Special Areas – Face, Hands, Feet, Genitalia, Perineum and Major Joints
Full Thickness burns
Electrical burns
Chemical burns
Burns with an associated inhalation injury
Circumferential burns of the limbs or chest
Burns at the extremes of age - children and the elderly
Burn injury in patients with pre-existing medical disorders which could complicate management, prolong recovery or affect mortality
Burn injury in pregnant women
Any burn patient with associated trauma
Non-accidental burns

If the patient has a pre-existing disorder that could make management more difficult or the risk of injury greater, a specialised team is needed to give maximum chance of an optimal result.

Those patients with concurrent trauma should be admitted to a burn or a trauma centre depending upon the severity of the associated trauma and the seriousness of the burn. A balance needs to be struck based on the clinical findings at the time of emergency assessment and following discussion between the local trauma team and the burn service personnel. If the associated trauma poses the greater immediate risk the patient may initially be treated in a trauma unit until stable, prior to transfer to the burn service.

This may particularly be the case for patients with head injuries requiring neurosurgical intervention.
Burn care must be provided concurrently and transfer arranged after the patient has recovered from the immediate effects of the multiple trauma. Should the burn injury present the dominant threat to mortality and the greatest risk of morbidity, then primary transfer to the burn service is correct. The priorities are a matter for medical judgement and should be discussed by the referring doctor, the burns specialist and the trauma or intensive care specialist, bearing in mind that patients at the extremes of age have a higher mortality and morbidity after a burn injury. Their pathophysiological responses are less predictable so they need the benefit of a specialised team.

The burn team approach of bringing together doctors, nurses, physiotherapists, occupational therapists, psychiatrists, psychologists, social workers and dietitians in a management team has a significant and beneficial effect on the outcome of major burn and electrical injuries.

Preparation for Transfer

Patients who are physiologically stable are capable of safe transfer over long distances, even after massive injury. It is therefore essential for the patient to be stabilised prior to starting their journey. Stabilisation involves all the aspects of resuscitation and management outlined above.

1. Respiratory System

- All patients with major injuries should continue to be given high flow oxygen at 15 l/min.
- Since upper airway obstruction can progress rapidly and its effects peak at a time when the patient is likely to be in the process of transfer, it is essential to consider and decide about the need for endotracheal intubation **BEFORE** the journey is started.
- Infraglottic injury is less likely to be a problem during transport.

2. Circulatory System

The principles of treatment of the predictable shifts in fluids and electrolytes given above are valid for the stabilisation of the patient prior to transport.

- If insertion of 2 cannulae (16 gauge in adults, 20 gauge in children) is not possible, other routes of access should be considered and their feasibility discussed with the receiving unit.
- The method of vascular access will largely be determined by the experience of the team at the peripheral site or the experience of the transfer or retrieval team.

- The routes available are percutaneous central venous line (femoral, subclavian, or internal jugular), intra-osseous needle in children or adults, or more rarely peripheral cut down.

The fluid regime is discussed in Chapter 6. In summary, commence resuscitation with

- 3 - 4 ml Hartmann's solution/kg/% Burn TBSA in 24 hours, 50% of which is given in the first 8 hours post burn
- Add maintenance fluid for children < 30kg
- Adequacy of resuscitation is determined by observation of the patient, particularly the urinary output (via an indwelling catheter), aiming for 30 - 50 ml/h in adults, and 1 ml/kg/h in children up to 30 kg.
- If haemochromogenuria occurs, as is common after high voltage electrical injury, the aim is 1ml/Kg/hr (75 - 100 ml/hr) in adults, or > 2 ml/kg/h in children.

3. Burn Wound

- The burn wound should be washed with chlorhexidine solution 0.1% or normal saline and then covered with cling film or a clean dry sheet if evacuation is to occur quickly.
- Cling film is also useful as a cover for burn wounds as it reduces evaporation thus preserving heat and preventing desiccation.
- Only if transfer is to be significantly delayed should more formal dressing be undertaken. This should only be after liaison with the receiving burn service.
- Check with your local burns centre what their dressing protocol is.

4. Pain Relief

- Burn injury is extremely painful. Even though skin sensation may be lost locally over a deep burn, the surrounding area is very painful, so all burned patients need adequate pain relief.
- In all but the most minor burns, it is essential for opioid analgesia to be given **intravenously**. Doses are given in increments allowing 3 - 5 minutes between each, the final dose being determined by the patient's response.
- Any pre-existing disease or associated injury should be born in mind when calculating doses, but a starting dose of morphine is 0.05-0.1 mg/kg.
-

5. Gastro-Intestinal System

- While early enteric feeding is desirable (either oro-gastric or nasogastric) the transfer process is usually safer if the stomach is empty to minimise the risk of vomiting and aspiration.

- A nasogastric tube, regularly aspirated and on free drainage, is needed for adults with burns > 20% TBSA, and for children with burns > 10% TBSA

6. Tetanus

- Tetanus prophylaxis should be given at the first point of medical contact. Details are in Appendix 2.

In order to ensure that optimal treatment is continuous between the point of first contact and the receiving burn service, documentation must be complete and should include details of all the above aspects.

Transfer Mechanism

Early telephone contact with a receiving burn service should be initiated when any patient who may need transfer presents. Once the decision to transfer has been made, the receiving service will be responsible for arranging a bed and the referring service will be responsible for arranging transport. Transfer procedures should be followed in accordance with local protocols.

The responsibility of the referring centre is to document the findings of the primary and secondary survey, and the care given. Times of events, tests, fluid balance and treatment, including doses of medications, are important.

The referral centre and the transfer or retrieval team, who in turn rely on the advice from the receiving centre, determine the method of transfer.

If there is no bed available within the local network the National Burn Bed Bureau (telephone 01384 215576) will be able to identify beds elsewhere in the U.K. (see Appendix 4).

Summary

1. Patients with electrical, chemical, or thermal injuries that meet the national criteria for referral to a burn service should be assessed and stabilised while referral is initiated.

2. Transfer is the responsibility of the referring service. The transfer or retrieval team, if available, will provide help in the stabilisation of the patient and the receiving service will provide advice.

3. Documentation is essential for the successful transfer of care from the referring hospital to the Burn Service.

CHAPTER 9

Burns in Children

Introduction

Many of the basic concepts of emergency burn care in adults also apply in children. Children with burns should be assessed and treated in the same way using the Primary and Secondary survey. As in adults, a primary survey should detect and correct immediately life-threatening conditions. This should result in the child having a secure airway and adequate circulation that will need to be monitored by continual reassessment. This should include continual re-assessment of fluid input, based on an adequate urinary output.

The significant differences between children and adults are:

- the size and body proportions of the child
- fluid dynamics
- the thickness of the skin
- the different social and emotional development of children

Epidemiology

There is a higher proportion of the paediatric population which suffer burns compared to adults, and causation of paediatric burns differs from adults, as shown in Table 9.1.

Table 9.1 Causes of Children's Burns (%)

Scald	66
Contact	18
Flame	8
Flash	3
Chemical	2
Electrical	1
Friction	2
Radiation	0.1
Non skin burn	0.1

(iBID, 2003-2015)

Younger children have a higher proportion of scalds while flame burns are more common in older children.

History

As in all burns an accurate history is essential. This should include a history of the mode of injury and the time of the accident. Particular notice should be taken of any part of a history in which there are inconsistencies with the physical findings or a delay in presentation as these may point to non-accidental injury. Occult airway problems such as sleep apnoea or asthma should be identified, and the history is important in forming a basis for the psychological care of the child and family.

It is also useful to find out what first aid was given and in the case of scalds how hot the fluid may have been at the time of the incident and what clothes the child was wearing. This will help give an indication of the possible depth and whether any education might be required.

Body Size and Proportions

The child differs from the adult in its overall surface area to body weight ratio, and in the relative size of different body parts compared with others.
The higher surface area to body weight ratio means that for a given body weight there is a:

- higher metabolic rate
- greater evaporative water loss
- greater heat loss

All of these are highly relevant to the care of the burned child as formulae for fluid resuscitation are based on weight rather than surface area. Use of formulae based on surface area is complex and therefore too difficult for universal usage, but from a practical standpoint the burned child is more likely to need variations from the calculated volumes than is an adult.

In a child the head and neck are comparatively larger proportions of their body than in an adult, and the legs are comparatively smaller (see Figure 5.3). In a child up to one year of age the head and neck are 18% of the total body surface area whereas each leg is approximately 14%. For every year of life above the first, the head decreases in relative size by approximately 1% and each leg gains 0.5% in comparison with total body surface area. Using this rough modification of the rule of nines it can be seen that for practical purposes the adult proportions are attained at ten years of age. Obviously there is the chance of seriously miscalculating the size of the burn and hence the fluid resuscitation if this factor is not borne in mind.

The Depth of Burn

The depth of the burn is proportional to the amount of heat applied and the duration of its application, and inversely proportional to factors that resist tissue damage. The chief of these factors is the thickness of the skin. In children the skin is much thinner than in adults. For this reason a given thermal injury is more likely to result in a deep partial thickness burn in a child than in an adult.

An example of this is that water of 60ºC will cause

- In infants, a full thickness burn in less than a second
- In older children, they can tolerate up to five seconds of immersion at this temperature.
- In an adult, they will only receive a deep burn after twenty seconds.

Children's Avoidance Reactions

Children's reactions to painful stimuli are not as rapid or as consistent as adults. A toddler standing in hot water or on hot embers may not attempt to move away, thus sustaining a deeper burn.

Burn Depth Assessment

The assessment of depth of a burn in children is more difficult than in adults. In children scald burns are more common than flame burns, and the depth of the scald burn is more difficult to assess. The child's thin skin makes the depth of the burn more difficult to assess. The colour changes in burned skin in children are not always the same as those in adults. In particular a dark lobster red with slight mottling in a child is indicative of a deep dermal or full thickness burn, and in a few days will usually become an opaque even yellow colour of an obviously deep burn.

First Aid and Initial Transport

The principles of first aid - remove the heat source and apply cold water - are the same in children as in adults. However, hypothermia is a much greater risk in children than in adults.

Hypothermia in children is due to a number of factors. The larger body surface area to mass ratio is of particular importance. Children under one year of age do not have a shivering reflex. Older children may have a shivering reflex but their muscle bulk is much smaller. Total body mass and therefore heat content is much smaller.

The risk of hypothermia should be born in mind whilst applying first aid during initial emergency transport. Good first aid is as important as in an adult but care must be taken to keep cool water applied only to the burn surface and to keep the rest of the child warmly wrapped. If there is an extensive burn it may be necessary to reduce the period of application of cold water from the optimal twenty minutes in order to prevent hypothermia. **Ice should never be used.**

During initial stabilisation and transport a space blanket is very useful to reduce heat loss. Parts of the body exposed at the time should be covered, preferably with a moisture-proof sheet such as plastic, to reduce heat loss from evaporation and convection.

Fluid Management

1. **Differences between Children and Adults**

Fluid dynamics and body compartment sizes differ in children and adults. In the child a higher proportion of body water is extra-cellular. Blood volume in children is 80ml/kg compared with 60-70ml/kg in adults. Renal tubular concentrating capacity in very young children is reduced compared with adults. For all these reasons the proportion of fluid loss that can occur in a child is greater and may be more rapid than in an adult, and excessive fluid intake is less easily handled. On the other hand, occult depression of functional cardio-respiratory and renal reserve does not usually occur in children as it does in adults. Therefore, unless there is a known pre-existing disease, the physiology of the child can usually be relied upon to cope with a rapid fluid load although large excesses are less easily dealt with as mentioned above. Cerebral oedema is more likely in children with fluid overload particularly with hyponatraemia and hypotonic fluids must be avoided. This risk can be reduced by the use of colloid after the first eight to twelve hours and by the use of the “head up” position in the first 24 hours.

Due to these differences **fluid resuscitation is started in children with 10% burns rather than 15% as with adults.**

2. **Assessment of Fluid Status**

Good compensatory mechanisms in a child mean that circulation is apparently well maintained in the face of fluid deficit. **Thus little overt warning of circulatory collapse is given until late in the progression of shock.** Furthermore, useful signs of shock and hypoxia in the adult, such as agitation and tachycardia, are less useful in children because they can occur for other reasons. The observer may therefore not appreciate their significance. Thus tachycardia may be due to distress or the hypermetabolic response of an early burn, and visible agitation may be due to pain or anxiety.

Hypotension is a late sign of hypovolaemia and indicates decompensating homeostasis: by the time it occurs the patient is rapidly accelerating down the slippery slope that leads to irreversible shock.

More reliance must be placed therefore on the subtle signs of decreased circulation. The following indicators of compromise are recommended by the Advanced Paediatric Life Support (APLS) course:

- Tachycardia (age appropriate)
- Capillary refill
- Mottled or pale cool peripheries
- Organ dysfunction: tachypnoea, altered mental state

3. Urine Output

The most reliable parameter of adequate resuscitation is the urinary output. However this measurement is more difficult in children as mechanical obstruction of fine urinary catheters occurs more easily, and the collection of a few more millilitres of urine in large bore drainage tubing can cause errors of assessment. It is important to keep output as close to 1ml/kg/h as possible, with the acceptable range being 0.5 – 2 ml/kg/h.

When extra fluid is needed, boluses of 5 to 10 ml/kg can safely be given quite rapidly. Additional fluid can also be given by increasing the next hour's fluid to 150% of the calculated volume. Both methods may be needed if the patient's fluid status has become seriously depleted. Frequent re-assessment at periods of 15 to 30 minutes is needed to decide whether another bolus should be given. Remember, over resuscitation is also dangerous. Fluids may need to be reduced if urine output persistently high and patient well hydrated.

4. Intravenous Cannulae

As in adults, the first choice of route of administration is percutaneous cannulation of veins through unburned skin. If the expertise is available, percutaneous insertion of larger catheters into major veins such as the femoral is useful. In inexperienced hands in children these techniques are hazardous. Percutaneous cannulation of peripheral veins through burned skin is perfectly acceptable although more difficult to accomplish and dressings to secure these will be difficult. Cut-downs on veins requires expertise, is slow and obliterates the vein so is not recommended but intra-osseous cannulation can be very useful in shocked children. Intra-osseous administration of fluids is relatively safe and several devices to aid placement are now widely available. It is increasingly being used in adult practice too.
Any cannulae inserted must be well secured.

5. Maintenance Fluids

In children maintenance requirements are significant in relation to the amount of resuscitation fluid. Maintenance requirements should be calculated as follows:

100ml/kg for the first 10kg of body weight **plus**
50ml/kg for each kg over 10kg & less than 20kg body weight **plus**
20ml/kg for each kg over 20kg of body weight

Fluid: 5% Glucose in 0.45% (1/2 normal) saline.

This maintenance fluid should contain glucose. It should be added to the volume of resuscitation fluid of all children whose total body weight is up to 30kg. The addition of glucose is necessary because of the decreased glycogen stores in children and the speed with which hypoglycaemia can occur, particularly in association with hypothermia. Regular blood sugar estimations are necessary during initial stabilisation and transport.

Airway

Occult upper airway obstruction in children is common. Enlargement of adenoids and tonsils and laryngomalacia may pre-exist the burn injury and are detected historically by evidence of sleep apnoea such as snoring or waking at night, somnolence during the day, or noisy breathing. Narcosis may not only depress respiration but also may relax pharyngeal muscles and thus increase obstruction. Any swelling on top of occult obstruction may cause problems early.

The lower airway is narrower in absolute diameters in children than in adults. Therefore swelling of the bronchial mucosa or accumulation of secretions within the bronchi causes a comparatively larger reduction in cross-sectional area and so interferes with gas flow. For these reasons an uncuffed tube is commonly used up to the age of 10 years although cuffed tubes are increasingly used in children requiring intensive care in the U.K.

Bronchial hyper-reactivity (asthma) is extremely common in children and is indicated by a history of nocturnal cough or for weeks following viral respiratory infection. Smoke inhalation will frequently lead to bronchospasm in children prone to this reaction.

Endotracheal intubation technique is slightly different in children than in adults. The larynx is more cephalad compared with adults. Because narrow tubes are used, frequent gentle suction is necessary to clear secretions. Stabilising tubes is more difficult particularly when the face is burned, and two woven cotton tapes, one above and one below the ear, which can be lengthened if swelling increases, are useful in this regard. The position of the tip of the tube should be checked by auscultation before fixing the tube in position and subsequently followed by chest x-ray to confirm satisfactory position of the tube tip. Endotracheal intubation should only be attempted by a suitably trained and experienced practitioner.

If airway obstruction occurs and endotracheal intubation is not possible, a large bore (14 gauge) needle passed through the cricothyroid membrane should be used instead of surgical cricothyroidotomy. This is only a temporising solution and urgent tracheostomy may be required.

Escharotomies

Limb escharotomies are needed in children as they are in adults. Trunk escharotomies, however, are necessary more often in children than in adults. The reason is that breathing by diaphragmatic movement is more important in children and this means that abdominal wall rigidity is more likely to restrict tidal volume. For this reason interference with gas movement may occur with trunk burns that are not circumferential. Therefore, if a burn involves the anterior and lateral aspects of the chest and the upper half of the abdomen, trunk escharotomies should be considered. In this situation in addition to the procedures outlined in Chapter 7 under Escharotomy, an incision should also be made across the upper abdomen and parallel with the costal margins, to allow abdominal wall movement separate from chest wall movement.

Gut

Children are more prone to gastric dilatation than adults and tend to swallow air when crying. A nasogastric tube on free drainage is therefore necessary in the initial assessment phase and during transport particularly if aerial evacuation is needed. However, children's high metabolic rate and their nutritional needs for growth mean that they have less tolerance of nutritional deprivation. Very early enteral feeding should be established as soon as they arrive at the definitive treatment centre, as it prevents loss of gut function and maintains nutrition.

Progressive Assessment of Burn Wound

Assessment of the depth of the burn wound, particularly scald injuries, can remain difficult in children up to seven to ten days after the injury. However, a burn wound that is unhealed in a child at Day 10 should be considered as needing skin grafting.

Emotional Aspects

Pre-existing psychosocial pathology is common in paediatric burns as well as in adults, but the type of pathology is different. The cycle of deprivation, lack of societal and parental skills causing impoverishment and further deprivation is common because the parents of such families lack satisfactory parenting techniques to protect children, often themselves indulging in risk-taking behaviour. They are frequently pre-occupied by their own emotional and social problems. Teenage children of such families are frequently involved in risk-taking behaviour and are frequently without any parental influence.

The emotional and social needs of children are very different from adults. Play is an essential part of a child's normal daily activities and the frivolous connotation that adults give to the word is not appropriate in children. Socialisation in their peer group and minimisation of separation are important aspects of a child's emotional life. Person-to-person interaction is different and language used should be appropriate for the age of the child. The importance children place on trust in their relationships demands that adults be truthful with their paediatric patients at all times but stark or brittle phraseology should be avoided as it can frighten a child unnecessarily.

After a child is burned the whole family suffers from major emotional disturbance of which guilt and blame are prominent features. Siblings are often severely affected. The wider peer group (e.g. the child's school class) is also often affected. All these aspects of a paediatric burn need to be addressed eventually, and appreciated from the outset.

Finally, the long-term emotional outcome after a paediatric burn is more dependent on the whole family's emotional care than in adult burns where the concentration is on the patient. Therefore early and adequate care of the family is essential, and this starts from the moment of burn injury.

Non-Accidental Injury

The emotional factors, which often contribute to the causation of a child's, burn form a spectrum that varies from momentary lack of supervision through more overt, long-term psychopathology to the other extreme of deliberate abuse. The point on the spectrum at which "Non-accidental Injury" begins is often difficult to define. The decision as to which children may be "at risk" in future is often easier. Any member of the multidisciplinary team has an obligation to report suspicious or deliberate injury or a child that is in need, whether they are from the referral or receiving unit.

Suspicion of child abuse requires transferring the child to a specialised burn service, and during this transfer process such suspicions should be passed on and clearly documented. Each hospital should have its own protocol to follow with the key emphasis being placed on good inter agency communication to protect the child in need.

Suspicion of non-accidental injury may be raised by:

- delay in presentation
- vague or inconsistent history from different observers
- history not compatible with pattern of injury
- presence of other signs of trauma
- certain patterns of injury (e.g. cigarette marks or bilateral "shoes and socks" scalds

Remember that false diagnosis and accusation of non-accidental injury is extremely damaging to the family. Unusual and bizarre distribution of burns can be caused by accidental injury and should not automatically be assumed to be deliberate trauma. These children should be transferred to a paediatric burns service so that experts in safeguarding children and burns can assess the situation and act appropriately.

In practice the distinction between accidental and non-accidental is less important medically than socially because all of these families will need considerable help over a prolonged period so that the patient's long-term functional result is as good as possible.

Transfer Criteria

In children the need to transfer occurs at a lower threshold than in adults. A child with more than 2% deep burns should be considered for transfer. Some children may need to be transferred simply for pain relief if techniques, such as continuous opioid infusion, are not available locally. Finally, the possibility of non-accidental injury should prompt transfer. Other criteria applicable to adults, such as burns of special areas (hands, face, feet, perineum), and known or suspected respiratory burn, burns with associated major trauma, or burns in patients with significant pre-existing disease, are also valid criteria for transfer in children.

Summary

1. The **principles** of burn care are as valid in children as in adults.

2. Factors that modify the care of children are:
   - different body proportions
   - different fluid dynamics
   - thinner skin
   - different psychosocial needs

3. Major physical differences in care are:

   - tendency to hypothermia
   - increased depth of burning for a given insult
   - increased fluid needs

4. The psychosocial background and emotional needs of the burned child and its family are very different to those of adult burn patients.

CHAPTER 10

Electrical Injuries

Introduction

Electrical injuries are divided into three groups: low voltage, high voltage and lightning strike. Each group has its own particular features that are worthy of separate consideration. The common feature of each is heat generation resulting in a thermal burn.

Low Voltage is considered to be anything below 1000 volts. This includes standard single-phase household electrical supply in the U.K. that is 240 volts alternating current (AC) at 50 cycles per second. Industrial power supplies are often three phase and commonly 415 volts.

Other low voltage electrical accidents can occur with direct current (DC) that is used in the electroplating industry, electrolyte purification and some transport systems.

The common car battery is capable of producing a current of sufficient amperage at only 12 volts to cause a significant thermal burn when a short circuit occurs through such articles as metallic watch bands, wedding rings and jewellery. Surgical diathermy is a commonly encountered direct current in operating theatres.

High Voltage includes anything above 1000 volts but is often 11000 or 33000 volts, which are the currents commonly encountered in high tension transmission cables. Even higher voltages occur in power stations and substations.

Lightning is an extremely high voltage, high amperage, DC electrical discharge of ultra-short duration, which produces its own peculiar injury pattern.

Pathophysiology

Tissue damage from electrical injury results from the generation of heat, which is a function of

- the resistance of the tissue
- the duration of the contact
- the square of the current.

Different tissues exhibit characteristic electrical resistance according to their electrolyte content. In order of decreasing resistance, the various tissues may be listed:

- Bone
- Skin
- Fat
- Nerve
- Muscle
- Blood and body fluids

Skin resistance varies according to whether it is thick and callused like the sole of the foot, or thin skin. It also depends on whether the skin is wet or dry, dry skin having a higher resistance than moist or sweaty skin.

The rise in temperature produced by a conductor depends on the heat produced and the rate at which heat can escape from the conductor by conduction, convection and radiation.

Electricity conducted through bone therefore may cause a substantial rise in temperature. The increase in bone temperature continues even after the current flow has ceased causing secondary thermal damage. This phenomenon is known as the Joule effect. Due to the depth of the bone, heat escape is slow and considerable periosteal, muscle and nerve damage close to the heated bone may occur.

The high concentration of current at the contact points and the high resistance of the skin cause intense heat and charring occurs. Once the skin has been breached increased current is permitted to flow. In high voltage injuries arcing may occur across such joints as the wrist and elbow causing charring and penetration wounds. Similar charring and exit wounds occur on the feet and hands because of the thick skin and resistance to flow resulting in intense heat and blowout type injuries.

Types of Burn Injury

Low voltage current will cause significant local contact wounds (traditionally called entrance and exit wounds) and may cause cardiac arrest but no deep tissue damage. The 50 cycles per second alternating household current can cause muscle spasm or tetany and prevent the victim from releasing the source of discharge.

High voltage current causes injury in two ways; flash burns and current transmission. A cutaneous burn without deep tissue damage results when there is a high-tension discharge or “flash over”, the current not passing through the victim. The arc ignites clothing and can cause deep dermal burns without the formation of contact sites or entrance and exit wounds.

High voltage current transmission generally results in both cutaneous and deep tissue damage and the entrance, exit and contact areas are always full thickness defects. Less commonly there may be internal organ damage, though this is more likely to occur as a result of an associated injury such as a fall from a pole or tower.

Deep muscle damage, which occurs under apparently normal skin and subcutaneous tissue, may be very extensive and involve whole compartments of the limbs.

Swelling within the limbs as a result of the muscle damage may produce a situation similar to the “crush” syndrome where fasciotomy may be required. The limb becomes very swollen and tense to palpation. The symptoms are severe deep pain and tenderness. It eventually causes decrease in peripheral circulation and loss of pulses. If fasciotomy is required it should be done as an open procedure and will probably require a general anaesthetic.

Muscle injury and necrosis result in release of myoglobin from the muscle cells into the circulation. This pigment along with haemoglobin from haemolysis of red cells may lead to renal impairment. As both these haemochromogens precipitate in the renal tubules, they can cause rapid onset of acute kidney injury.

Lightning injuries result from an ultra high tension, high amperage short duration electrical discharge of direct current. This form of injury is not particularly common in the U.K. 2-5 people in U.K., 5 to 10 Australians, 90 Americans, and 10,000 people worldwide die from lightning strikes each year.

The pattern of injury is variable. A direct strike is where the discharge occurs directly through the victim and this, as expected, has a very high mortality. More commonly a side flash or splash occurs, when lightning strikes an object of high resistance such as a tree and the current is then deflected through a victim on its way to the ground. Stride potential may occur as the discharge flowing through the ground may pass up one leg and down the other. Typically the current flows over the surface of the victim causing superficial or partial thickness burns. However, there may be significant exit burns on the feet.

The short duration of lightning strike is not commonly associated with significant internal tissue damage but respiratory arrest is common and this is followed by cardiac arrest. The initial respiratory arrest occurs as a result of the discharge affecting the medullary respiratory centre. This is usually reversible so prolonged efforts at resuscitation are justified.

Another organ that can be damaged is the ear. The tympanic membrane may be perforated due to the blast and should be checked at the time of the strike. Corneal damage has also been recorded and this may be acute, or a long-term sequel of the injury.

Lightning may also be responsible for unusual skin damage which has an arborescent or splashed on appearance. These are known as Lichtenberg flowers. These lesions are pathognomonic of lightning strike.

Management

Initial rescue of the victim of an electrical accident may place the rescuer at risk of succumbing to the same fate.

First switch off the power source or remove the live wire from the victim. If this is not possible, remove the victim from the power source with a non-conductor.

Remember that high voltage electricity will discharge through air; 1,000 volts will only jump a few millimetres, 5,000 volts will bridge one centimetre, and 40,000 volts, 13 centimetres.

Once clear of the power source the **primary survey** begins as with any burn injury.

The airway must be cleared and the cervical spine protected. Breathing may be arrested as a result of the discharge affecting the medulla and cardiac arrest may also have occurred due to the effect of the current on the myocardium. Cardio-pulmonary resuscitation (C.P.R.) is therefore vital to the resuscitation of victims of electrical injury. Endotracheal intubation may be indicated to maintain airway patency.

Protection of the cervical spine is of importance because trauma may be associated with the electrical injury. Violent muscular spasms may occur with alternating household current, which can produce fractures. Electrical workers may suffer from falls from poles, towers or elevated equipment.

Cervical spine fracture should be excluded with satisfactory cross table cervical spine x-rays or CT before abandoning immobilisation with hard collar, sand bag or simply holding the head immobilised. A spine board or sandbags should be used to protect the thoracic and lumbar spines until fractures of these areas have been excluded.

History of the Event

Having completed the **primary survey**, a full history of the circumstances of the electrical injury should be obtained either from the patient, bystanders, or paramedics.

- How did the accident occur?
- How long ago did the accident occur?
- Was there loss of consciousness and for how long?
- Is there amnesia for the event?
- Was there any associated trauma?

- Did cardiac arrest occur or was any dysrhythmia recorded?

Secondary Survey

- First remove all clothing and in particular any watches and jewellery.
- Examine for sites of entry or contact wounds with particular attention to scalp, hands and feet.
- Estimate the total area of burn wound and the burn depth.
- Undertake neurological examination with particular reference to the peripheral and spinal nerves.
- Thoroughly document all clinical findings.

Resuscitation

If, on completion of the secondary survey, the extent of the injury is sufficient to require fluid resuscitation, use two large bore intravenous cannulae as for other major burns.

Fluid requirements in electrical injuries are likely to be greater in volume than would be anticipated in a pure cutaneous burn. Concealed muscle damage in the limbs will be responsible for fluid loss which is not accounted for by the standard formula.

In those patients with deep tissue damage, haemochromogenuria is to be anticipated. A urinary catheter should be inserted both to detect the earliest sign of urine discolouration, and to monitor urine output. If pigments appear in the urine, the infusion rate of fluids must be increased to maintain a urine output of 75-100 ml/h for adults and 2 ml/kg/h for children.

Alkalisation of the urine by the addition of sodium bicarbonate has traditionally been used to increase the solubility of haemochromogens in the urine, but its efficacy has been brought into doubt by more recent work. If more than simple fluid replacement is required to clear the urine pigment it is suggested that the advice of the receiving burn service be obtained.

On clearing the haemochromogens from the urine the rate of fluid replacement should be reduced to a level which will maintain the urine output of 30 - 50 ml/h or in children < 30kg, an output of 1 ml/kg/h.

Dysrhythmias

An ECG should be obtained on admission of all patients with electrical injury. In those patients who have suffered a cardiac arrest or in who it is thought that the passage of current has been through the thorax, there is a risk of serious dysrhythmias. Such patients should be monitored after injury as deterioration may occur even after an initial stable cardiac rhythm.

Low voltage injuries may cause chest pain and dyspnoea that will generally abate after a few hours, leaving the patient with a normal ECG. More significant currents may cause damage to the conducting system or the myocardium resulting in marked ECG change even after an initial normal trace.

Assessment of Peripheral Circulation

Hourly assessment of the peripheral circulation must be made:

- Skin colour
- Oedema
- Capillary refill
- Peripheral pulses
- Skin sensation

Where there is evidence of an entrance or exit wound on an extremity, the possibility of sub-fascial oedema must be anticipated. This oedema may cause an increase in muscle compartment pressure sufficient to obstruct the circulation. This increase in muscle compartment pressure causes severe deep-seated pain. The limb becomes stony-hard to palpation and there is progressive loss of peripheral sensation and loss of pulses. Under these circumstances fasciotomy is required.

Fasciotomy

It is important to have the patient well resuscitated prior to fasciotomy so that haemochromogens released from the newly perfused muscle are flushed rapidly through the kidneys. The burn service should be contacted regarding prophylactic mannitol prior to fasciotomy.

1. **Upper Limb**

The forearm muscles are very susceptible to ischaemia and the development of a compartment syndrome. This is relieved by performing a longitudinal incision along the mid-medial and mid-lateral lines of the forearm, extending from just above the elbow down to the wrist. The incision is made through skin and subcutaneous fat to expose the deep fascia which is then incised. Particular care must be taken to protect the ulnar nerve at the elbow. Bleeding may be brisk and require control with diathermy or ligature.

If the patient is hypotensive at the time of the procedure then delayed haemorrhage may occur. Carpal tunnel release may be necessary for burns to the hands. Before proceeding with this measure, consultation with the receiving burn service is advised.

2. **Lower Limb**

There are four compartments of the lower limb that may be affected by sub-fascial oedema resulting in a compartment syndrome. Each of these compartments requires incision. The four incisions can be made through two cutaneous incisions. The lateral incision is made over the fibula, extending from the head down three quarters of its length, care being taken not to damage the peroneal nerve, which passes around the neck of the fibula. The intermuscular septum separating the anterior and lateral compartments is incised over the full length of the skin incision.

The medial incision begins proximally, commencing one finger breadth below the subcutaneous border of the tibia, and extends down to the medial malleolus. The incision is made through the skin, subcutaneous fat and the investing fascia with care being taken not to injure the saphenous nerve and vein. Carefully retracting this incision the deep posterior compartment can be identified and decompressed over the full length of the incision.

As in the forearm, fasciotomy of the leg is best done under a general anaesthetic and in a sterile environment. Blood loss may be considerable and facilities for diathermy and ligature haemostasis should be available. Again, delayed haemorrhage may be considerable after resuscitation. The fasciotomy incisions should be dressed with vaseline gauze or kaltostat and a lightly applied gauze dressing.

Be aware of the difference between a fasciotomy (releasing fascia around swelling muscle) and escharotomy (cutting through a deep skin burn, Chapter 7)

Wound Care

The general principles of burn wound care apply to electrical burns and are described elsewhere.

Meticulous wound management and infection prevention is mandatory due to the presence of large amounts of dead muscle. This may include topical antimicrobials of antimicrobial dressings.

Paediatric Electrical Injury

The majority of electrical burn injuries in children are low voltage accidents that occur at home. Discharge from faulty insulation of electrical appliances and cords, or placing metal objects in power points is responsible for most paediatric injuries. The very young who are prone to picking up and sucking electrical cords sustain deep burns around the mouth when the saliva soaks into the faulty or frayed insulation resulting in a discharge. Finger and hand injuries are seen in older children, handymen and electricians while playing with or working on radio or TV sets or household appliances that are still turned on. Many of these accidents could be avoided by the use of earth leakage circuit breakers.

Most of these low voltage discharges will result in small full thickness defects which require excision and closure, skin grafting or even small flap repairs and should be referred to a burns service for definitive care. Low voltage household accidents do not usually result in deep muscle damage in the limbs, however cardiac monitoring may be required as previously described because of cardiac arrest or arrhythmias.

Summary

1. Avoid injury to those rendering assistance. Treat cardiac and respiratory arrest. Assess and manage associated trauma.

2. Continuous cardiac monitoring is indicated for 24hrs for significant injuries.

3. Patterns of injury are specific to high voltage, low voltage and lightning strike.

4. Standard burns resuscitation formula may be inadequate. Haemochromogenuria is common in high voltage injury and requires maintenance of a urine output 75-100ml/h until urine clears.

5. High voltage injury involving limbs may require fasciotomy.

6. According to referral criteria, all electrical burns should be admitted to a burns service for definitive treatment.

CHAPTER 11

Chemical Burns

Introduction

More than 25,000 products capable of producing chemical burns are now marketed for use in industry, agriculture, military science and the home. In the USA more than 3,000 deaths directly related to cutaneous or gastrointestinal chemical injury are documented each year with an estimated 60,000 patients requiring medical care for chemical burns.

As an exposed part of the body and the part handling these noxious materials, the hands and upper limbs are the most frequently injured sites and, indeed, suffer chemical burns as often as all other sites combined.

Protection

It is vital that all carers and first aid workers are aware of the need to protect themselves from the contaminant e.g. wearing gloves, aprons and protective face mask and overalls. All clothes should be removed as soon as possible if contaminated and stored in a protective container for disposal later.

Aetiology and Classification

Laboratory accidents, civilian assaults, industrial mishap and inexpert application of agents used for medical purposes account for most of the chemical burns in the civilian population.

Commonly used chemicals capable of producing burns are:

1. Industry

- Alkalis - sodium, potassium, ammonium, lithium, barium and calcium hydroxide (washing powders, drain cleaners, paint removers).
- Acids - picric, sulfasalicylic, tannic, trichloroacetic, cresylic, acetic, formic, hydrochloric and hydrofluoric (etching glass and electronics).

2. Household

- Alkalis - drain cleaners, paint removers, urine sugar reagent test tablets.
- Phenols - deodorants, sanitizers, disinfectants.
- Sodium hypochlorite - disinfectants, bleaches, deodorants.

- Sulphuric acid - toilet bowl cleaners
- Phosphorous - fireworks, insecticides, fertilizers.

3. Military

- Phosphorous red or white.
- Vesicants.

Pathophysiology

Tissue damage as a direct result of exposure to any chemical is dependent upon:

- strength or concentration of agent
- quantity of agent
- manner and duration of skin/mucosa contact
- extent of penetration into tissue
- mechanism of action

The principal difference between thermal and chemical burns is the length of time during which tissue destruction continues since the chemical agent causes progressive damage until it is inactivated by a neutralising agent or by dilution with water.

The estimation of burn depth by clinical examination following chemical injury may be difficult during the first few days after injury.

The above agents all cause cell injury but by means of different types of chemical reactions. Generally speaking:

- Acids produce a coagulative necrosis.
- Alkalis produce a liquefactive necrosis.
- Vesicants cause ischaemic and anoxic necrosis (liberates tissue amines and cause blistering).
- All produce coagulation of protein by oxidising, corrosive or salt forming effects on protein.

An important feature of some chemicals is their systemic toxicity.

- Hypocalcaemia - oxalic, hydrofluoric acid and phosphorous burns.
- Liver and/or kidney damage - tannic, formic and picric acid, phosphorous injury and petroleum
- Inhalation injuries - strong acids or ammonia.
- Methaemoglobinaemia and massive haemolysis - cresol
- Perforation nasal septum - chromic acid

First Aid

Remove contaminated clothing and dry chemicals.

Constant water flow is the most important treatment of most chemical burns (except elemental sodium, potassium or lithium). For best affect it should be started within 10 minutes of contact.

Specific Agents: Some non-specific chemical treatments such as Diphoterine are now available and are useful for most chemical injuries.

Acid Burns

- Very painful
- Appearance varies from erythema (superficial) to black eschar (deep)
- Irrigate with water
- Surgical treatment as for thermal burn

Hydrofluoric Acid

- Very corrosive, inorganic acid of elemental fluorine: 2% body surface area can prove fatal.
- **Mechanisms of injury**
  a) Hydrogen ions cause typical acid skin injury that is minimised by irrigation with water.
  b) Soluble free fluoride ions penetrate damaged skin and bind calcium ions. This causes necrosis of soft tissue and hypocalcaemia that is so severe that mobilisation of calcium ions from the bones is inadequate to overcome it. Extent of injury depends on concentration of acid and extent and duration of contact.
- Arrhythmias, secondary to hypocalcaemia and hypomagnesaemia, may occur.

- **Treatment**
  Prompt water irrigation
  Trim fingernails
  Inactivate toxic free fluoride ions and change to insoluble salt with:
  a) Topical calcium gluconate burn gel (10% with Dimethylsulfoxide DMSO).
  b) Local injection with 10% calcium gluconate (multiple injections 0.1 - 0.2 ml through 30G needle into burn wound). Number and frequency of injections required monitored by pain response.
  c) Intra-arterial infusion of calcium gluconate.
  d) Intravenous ischaemic retrograde infusion (Biers block) of calcium gluconate.
  e) Early excision sometimes required.

Alkali Burns

- Most common around house
- Less immediate damage than acid but more long-term tissue destruction as they liquefy tissue and so penetrate more deeply.
- Irrigate for longer than acid (at least 1 hour)
- Surgical treatment required for deep burns

Cement Burns

- Wet cement caustic with a pH up to 12.9
- Pain and burning occur late (after several hours)
- Prolonged irrigation is important

Phosphorous Burns

- More common in military personnel
- White phosphorus ignites spontaneously when exposed to air
- Oxidises to phosphorous pentoxide
- Is extinguished by water
- Particles of phosphorous embedded in the skin continue to burn
- Treatment:

  a) Copious water irrigation
  b) Debride visible particles
  c) Apply copper sulphate (this forms black cupric phosphide and facilitates removal of phosphorous particles) but toxic. Woods light better as phosphorus luminous.

- Mortality is related to the systemic effects of hypotension and acute tubular necrosis.

Petrol (Gasoline)

- Complex mixture of alkanes, cycloalkanes and hydrocarbons.
- Hydrocarbon component is incriminated in endothelial cell damage which is the common pathway of injury to the lungs, liver, spleen and kidneys in immersion or extensive skin contact.
- Petrol dissolves lipid compounds readily, causing increased membrane permeability and fluid loss.
- There are two types of petrol burn:

  a) Ignition - fluid requirements frequently higher than other thermal burns. Burns tend to be larger, require more surgery and have longer hospital stays.

  b) Immersion or extensive skin contact without ignition results in partial thickness skin injury, sometimes with systemic and inhalation lung damage.

Bitumen

- A product of petroleum refining.
- Miscible with other petroleum products (kerosene, medicinal paraffin, paraffin wax) and vegetable oil.
- Transported and used at temperatures up to 190^{0}C (150^{0}C is the norm).
- Liquid at 150^{0}C, but forms semisolid at atmospheric temperatures.
- Burns are due to the hot liquid, not the toxic effects of bitumen.
- Treat by cooling bitumen with copious amounts of water.
- Remove loose clothing but do not attempt to physically remove bitumen.
- Remove bitumen with peanut or paraffin oil.

Tar

- By-product of coal gas industry.
- Contains complex chemicals including phenols, hydrocarbons etc, thus some toxicity.
- Burns by heat and phenol toxicity.
- Soluble only in highly aromatic liquids (e.g. benzene, toluene, xylene) **NOT** petrol or vegetable oils.
- Treat by cooling and remove with toluene.

Special Anatomic Complications

Gastrointestinal

- Accidental ingestion of corrosive agents utilised in household are more common in children.
- 1/3 of all patients with intra-oral burns eventually prove to have associated oesophageal injury.
- Symptoms are unreliable and definitive diagnosis requires endoscopic evaluation.
- Panendoscopy past the initial site of injury is desirable to ascertain the extent of the injury.
- X-ray chest and abdomen; CT scan of chest/abdomen may show extraluminal damage.
- Surgical exploration and debridement of necrotic tissue may be necessary.
- Steroids are of **no** proven benefit.
- Stricture formation of the oesophagus is common.
- Endoscopic and surgical treatment of stricture may be necessary.

Eye

- Chemical burns of eyes are associated with a high incidence of residual ocular impairment.
- Physical signs include blepharospasm, tearing, conjunctivitis and uncontrolled forceful rubbing of the eye.
- Rapid swelling of corneal epithelium, clouding of the anterior layers of stroma and cells floating within the anterior chamber occur.
- Treat with copious irrigation of water. Diphoterine is very useful.
- Prolonged period of time (48 hours) in hospital.
- Topical antibiotics prevent secondary infection.
- Corneal ulceration and perforation, cataract formation, secondary glaucoma, iridocyclytis and symblepharon are possible late complications.

Tracheobronchial Tract

- Direct injury to trachea and bronchi rare, but occurs occasionally after ingestion of caustic agents or exposure to chemical gases (e.g. ammonia).
- Respiratory distress or hypoxia calls for prompt treatment and investigation by fibreoptic bronchoscopy.
- Bronchodilators and inhaled steroids minimise bronchospasm and inflammation.
- Temporary mechanical ventilation may be necessary.
- Bronchiectasis may occur as a late complication.
- Follow up pulmonary function studies and chest x-ray are necessary.

Summary

1. Agents capable of causing chemical burns are common in the environment.

2. All chemical burns require copious irrigation with water.

3. Hydrofluoric acid burns require neutralisation with calcium gluconate. Systemic toxicity is common after exposure to hydrofluoric acid, petrol, or cresol.

4. Bitumen and alkali burns require irrigation with water for an even longer period than other chemical burns.

5. Chemical injuries to the eye also require copious irrigation, and then referral.

CHAPTER 12

Management of the Burn Patient after the First 24 Hours

Introduction

In the U.K. there are rare times when a burn patient cannot be transferred immediately to a burns service due to difficulties of transport and access. This chapter is designed to help doctors and nurses who are placed in the situation of having to continue the care of a patient who fits the criteria for transfer, but for whom it is impossible to arrange evacuation within 24 hours. It may be necessary to continue care of the patient for longer than 24 hours, but it should be emphasised that failure to transfer a patient to a burn service early will adversely affect the outcome.

It is important to heal the patient's burn wound as quickly as possible following burning. In the deep dermal and full thickness burn this is accomplished by early tangential excision and split thickness skin grafting. The optimal time to undertake this is between days three and five post burn. Any delay in undertaking this surgery usually allows infection to supervene and morbidity and mortality rate rises.

Even though it may not be possible to evacuate a patient to a burns service within 24 hours after injury it is emphasised that every effort must be made to transfer the patient as soon as possible after that time. The principles described in this chapter are not seen as a means of justifying the treatment of severely burned patients in outlying centres. These guidelines are designed to assist you in keeping the severely burned patient in an optimal condition, so that when the transfer is possible, definitive management of the patient can proceed as part of the normal course of events. These guidelines are designed to supplement telephone and fax contact with the burn service.

Many of the principles in this chapter are guidelines and are designed to complement the assistance and further advice that may be available to remote centres either locally or from a distance. Personnel with intensive care, anaesthesia or trauma management backgrounds may be more directly available than staff of the burns service and their expertise can be drawn upon in an emergency.

Respiratory Support

Severely burned patients should continue to breathe high flow oxygen at 15 litres per minute until their COHb levels are normal and then titrated to maintain a PaO_2 sufficient to maximise oxygenation of burned tissues. Oxygen should ideally be humidified.

Repeated reassessment of the patient should be undertaken, particularly when there are burns to the head and neck or a history or suspicion of inhalation injury because, as is pointed out in Chapter 2, endotracheal intubation may be required at this stage. Clinicians may also be in the position of having to continue care of the patient who has been intubated and whose transfer for logistic reasons was not possible. It is likely in the U.K. that these patients will be cared for in a critical care unit with access to investigations, including blood gas estimation and chest X-ray, useful to help monitor treatment.

1. Endotracheal Intubation

A correctly placed endotracheal tube guarantees a patent and protected airway, allows high concentrations of oxygen to be delivered reliably, provides airway access for secretion clearance, may allow large doses of analgesia and sedation to be given safely and enables mechanical ventilation to be carried out. In the presence of an upper airway burn or smoke inhalation, intubation may become progressively more difficult as airway swelling or hypoxia worsens and therefore should be considered early.

On the other hand, endotracheal intubation may be technically difficult, especially in an upper airway burn with severe swelling already present or facial injuries. The most important complication is technical failure and this is often lethal for the patient. Other short-term problems include endobronchial tube misplacement, upper airway trauma and tube obstruction by secretions or mechanical kinking.

Any burn patient requiring intubation needs definitive care by a specialist intensivist in a major hospital, preferably one that also has a specialised burns service.

2. Indications and Techniques

Intubation and ventilation should be considered in patients with clinically apparent respiratory distress, severe or worsening hypoxia or hypercarbia, an obtunded neurological state with impaired airway reflexes or respiratory drive, severe chest injuries, or upper airway obstruction from swelling due to an airway burn. Occasionally mechanical ventilation may be indicated for “logistical” reasons, such as safe transport or to facilitate some therapeutic or diagnostic procedure.

The orotracheal route is usually the simplest, but nasotracheal intubation may occasionally be successful where oral intubation is impossible. If neither can be performed quickly in a patient with complete or near complete airway obstruction, surgical cricothyroidotomy is the only alternative. It is usually straightforward and should be performed without hesitation.

Anaesthetic induction agents or muscle relaxants may make intubation easier, but should only be used by those with appropriate training and experience. All these agents have significant side effects of their own and there is the potential to convert a patient with impaired but acceptable airway, and adequate ventilation, to one that is apnoeic and unable to be intubated or ventilated.

Following intubation the tube position should be checked both clinically and by x-ray.

3. Physiology

Oxygen transport from inspired gas to alveolar capillary blood occurs predominantly by diffusion and continuous removal of oxygenated blood from the lungs depends on pulmonary blood flow (i.e. cardiac output). By contrast CO_2 diffusing into the alveoli from capillary blood is removed from the airways by ventilation, which is necessary to provide a “downhill” gradient for CO_2. Thus oxygenation depends mainly on inspired oxygen concentration, diffusing capacity of the lungs and the cardiac output, whereas the main determinant of arterial PCO_2 is alveolar ventilation.

The alveolar ventilation can be delivered in a variety of patterns. A small tidal volume with a rapid rate would minimise the adverse effects of a high intrathoracic pressure (see below), but a substantial proportion of each breath would be wasted, ventilating dead space (which is increased by endotracheal tube and ventilator circuitry as well as by a number of patient factors), and there would be a greater tendency to atelectasis. Conversely large volumes at a slow rate minimise atelectasis and waste the least possible ventilation on dead space, but problems due to high pressure and volume are maximised. Clinical practice is always a compromise between these extremes.

4. Benefits and Disadvantages of Mechanical Ventilation

In addition to replacing or supplementing inadequate spontaneous breathing, mechanical ventilation allows fairly precise control of arterial $PO_2$and PCO_2. It also eliminates the work of breathing and hence saves the oxygen used in this process. However, positive pressure breathing reduces venous return and may result in hypotension, especially in a hypovolaemic patient. Matching ventilation and perfusion is generally less efficient than with spontaneous breathing.

Over distension may occur if pathology (including respiratory burns and smoke inhalation) makes the lungs stiff (non-compliant), excessive tidal volumes are used, or the presence of lower airway obstruction (asthma or chronic obstructive lung disease) causes hyperinflation. This can produce life-threatening complications such as tension pneumothorax.

Finally, mechanical ventilation almost always requires sedation and possibly muscle relaxation introducing still further potential for complications and side effects.

5. Specific Respiratory Problems in Burns

(i) Carbon Monoxide (CO) Poisoning

Where hyperbaric facilities are immediately available, most authorities would recommend their use. However, the elimination of CO when the patient breathes 100% oxygen is rapid and the early use of oxygen is mandatory when there is reasonable suspicion of CO poisoning. A decision regarding hyperbaric oxygen should be made electively in consultation with the burns service and the National Poisons Information Service.

(ii) Respiratory Burns and Smoke Inhalation

These injuries affect both the gas exchange function of the lung and its mechanical stiffness (compliance). Presentation is usually with otherwise unexplained worsening respiratory distress and hypoxaemia. A cough productive of soot particles may be present and the chest X-ray may show a diffuse interstitial/alveolar opacity consistent with other forms of acute respiratory distress syndrome (ARDS). This situation mandates definitive management by a specialist intensivist in a major hospital with sophisticated facilities.

(iii) Chest Injuries

Pulmonary contusion may result in significant hypoxia or haemoptysis and a large flail segment will render spontaneous breathing inefficient. The presence of these injuries in a burn patient increases the likelihood that mechanical ventilation will be required.

Chest injuries increase the likelihood of lung injury during mechanical ventilation. The possibility of tension pneumothorax, in particular, should be carefully considered. If a severe injury with multiple fractured ribs is present and mechanical ventilation is required prophylactic intercostal drainage may be appropriate.

Once again such cases should be discussed with a specialist intensivist.

(iv) Chest Wall Burns

The presence of a circumferential deep chest wall burn may markedly affect chest wall compliance. This situation should be distinguished from that of poor lung compliance and the use of higher inspiratory pressures to achieve the required tidal volumes is probably less dangerous. Chest escharotomies may, however, be needed.

6. Optimal Ventilator Patterns/Settings

A tidal volume of 5-7ml/kg body weight with a rate of 12 breaths /min and an inspired oxygen concentration of 50% is commonly used initially in adults. This is reasonably safe provided adequate oxygen saturation can be maintained, plateau pressures do not rise above 35cm H_2O, and there is cardiovascular stability. Rates of 15-20 may be more appropriate in children.

Arterial blood gases should be checked as soon as practicable after ventilation is initiated and appropriate adjustments made. These should be repeated frequently until the patient is stable.

If lung compliance is poor or cardiovascular instability occurs, the tidal volume should be reduced, even if normocarbia cannot be attained. This will not be harmful in the short term unless severe head injury is present. If there is suspicion of CO poisoning or continuing cardiovascular instability 100% oxygen should be used. Progressive deterioration in lung compliance suggests the development of a tension pneumothorax or some other mechanical problem and a chest X-ray should be obtained as soon as possible.

Modern intensive care ventilators allow a wide variety of settings, allowing the patient to breathe spontaneously but with variable degree of assistance from the machine. These modes of ventilation offer substantial benefits for difficult problems, long-term management and ventilator weaning, but they require more expertise and sophisticated equipment. For the occasional practitioner using simple equipment, full control of ventilation assisted by heavy sedation and where necessary, muscle relaxation may be the simplest short-term option. However, extremely close monitoring and one to one nursing is essential to ensure safety under these circumstances.

7. Sedation/Muscle Relaxation During Ventilation

Sedation during mechanical ventilation is usually provided by a combination of opioids and benzodiazepines. Morphine and midazolam are most commonly used by continuous infusion, titrated to achieve the desired effect (0-10 mg/h of each in adults), with occasional supplementary boluses as required.

If adequate control of ventilation cannot be achieved by this means a non-depolarising muscle relaxant may be added. Rocuronium or atracurium are the most commonly used and are usually given by intermittent IV boluses. It must be stressed that heavy sedation or paralysis renders the patient completely helpless in the event of ventilator malfunction or disconnection and constant vigilance is required.

8. Simple Monitoring of Ventilation

Pulse oximetry, heart rate, blood pressure, end tidal CO_2 and pressure-disconnect alarms should be regarded as an absolute minimum requirement for any such mechanically ventilated patient. Pressure disconnect alarms are built into all but the simplest portable ventilators but are also available as stand-alone units. Some monitoring of tidal and minute volumes are also highly desirable and may also be built-in but is most simply provided by a Wright's respirator. The ability to perform blood gases and serial x-rays is desirable if ventilation is undertaken.

The use of monitors is no substitute for the continuous presence of a trained and attentive nurse at the bedside performing frequent clinical observations. This is mandatory for any ventilated patient.

9. Ventilation during Transport

Transport of a ventilated patient involves a level of risk substantially greater than in a hospital environment. In addition to the increased potential for accidental extubation, dislodgment of lines and equipment malfunction, movement and vibration may contribute to further cardio-respiratory deterioration. Those attending to the patient must often work in cramped, dimly lit, unstable environment and may themselves be affected by problems such as motion sickness. The transport team must be fully self-contained with respect to portable equipment, power, oxygen, supplies and consumables and must be capable of dealing with unforeseen problems arising en route.

Altitude results in reduced inspired oxygen tension, especially if non-pressurised aircraft are used an increase in the volume of any gas collections (such as a pneumothorax, the air in an endotracheal tube cuff or the dead space in an IV flask) and may alter the performance of some ventilators.

All these issues must be carefully considered when planning to transport any seriously ill patient. Before such a patient is moved there should be discussion between the transferring and receiving institutions.

Reliable vascular access and monitoring should be secured and every effort should be made to stabilise the patient’s condition as far as practicable. If experienced critical care transport teams are available it is almost always preferable to use them even if this further delays definitive care. No ventilated patient should be transported without medical and nursing escorts of appropriate seniority and skill.

Circulatory Support

Patients with major burns continue to remain haemodynamically unstable in the second 24 hours. Fluid requirements often do not follow standard rules and continuing reassessment using the general criteria of clinical appearance, pulse, urine output and blood pressure is necessary to ensure that the correct amount of fluid is given.

The following laboratory investigations will help guide the fluid treatment:-

- Haemoglobin and Haematocrit
- Urea and Electrolytes
- Arterial blood gases (as appropriate)
- Blood glucose

1. Composition of Fluid

As capillary permeability gradually returns to normal during the end of the first post-burn day, colloid containing fluids can be used to keep the intravascular space expanded. The amount of overall volume is adjusted to keep urine output of 0.5ml/Kg/hr (30-50 ml/hr) in the adult and children less than 30 kg 0.5 to 1.0 ml/kg/h.

The fluids given during the second 24 hours may include 0.3 to 1 ml of colloid per kg body weight per percentage body surface area burn. One suggested colloid is 5% normal serum albumin (50g per litre).

In the adult crystalloid solutions can be added to maintain an adequate urinary output. In children half normal saline with glucose added as necessary is used to maintain an adequate urine output. Electrolytes should be monitored to select the correct fluid composition.

2. Oral Fluids

Patients who are able to tolerate oral fluids can take small amounts in addition to the intravenous regime, or oral fluids can be substituted for the dextrose/saline component. Patients with severe burns should receive high protein fluid supplements either freely by mouth if tolerated or by nasogastric tube if there is no evidence of ileus. This will be further discussed in the section on nutrition but care must be taken not to overload the patient.

3. Fluid Balance

During the second 24 hours the fluid requirements are less than in the first 24 hours and it is important not to overload the patients with fluid, particularly those with pre-existing pulmonary and cardiac abnormalities. A fluid regime that produces an excessive urinary output is not appropriate and it is possible to produce pulmonary oedema during this time by giving the patient too much fluid.

Abdominal Compartment Syndrome can develop as serious secondary complication if excessive fluid volumes have been given to maintain or achieve adequate urine output and hemodynamic stability. Bladder pressure monitoring can give valuable information about intra-abdominal pressures.

During the second 24 hours a natural diuresis should begin and urinary output may increase above the levels expected from the amount of fluid infused. In addition any haemochromogenuria will begin to settle from 24 to 48 hours post burn. Estimation of the haemoglobin and haematocrit at this stage may demonstrate falling haemoglobin due to haemolysis and whole blood may need to be introduced at this stage. Consequently the haematocrit becomes an increasingly unreliable guide to fluid requirement.

Wound Care

The wound should be frequently reassessed to obtain a more accurate diagnosis of the extent and depth of burning. Areas of the burn which during the first 24 hours were thought to have been erythema only may progress in depth and in the second 24 hours be diagnosed as a significant partial thickness burn. Formal reassessment of the area of the burn will enable a recalculation of fluid replacement for the second 24 hours.

Burns which were judged to be superficial to mid dermal may well have been treated with a biologically compatible dressing (Biobrane, Opsite, Duoderm, Suprethel or similar) and if these dressings are in a satisfactory condition during the second 24 hours then they do not need to be changed.

Any areas of burn judged to be deep dermal or full thickness should be treated with the topical antimicrobial, silver sulphadiazine (SSD with 0.1% chlorhexidine) in all patients for whom evacuation has been abnormally delayed. Contact the burn service for advice on the most appropriate choice.

Continuing care of the burn dressed with SSD consists of daily removal of the cream and re-application. This is best achieved by washing, either in a bath, or if the patient will tolerate it, by showering. Old cream and sloughing skin should be removed and loose pieces of skin debrided with sterile forceps and scissors. After drying the patient digital images should be taken for monitoring of the wound. A clean dressing should then be applied and the patient left comfortable.

Care should be taken to ensure that bandages are not too tight and that on completion of the dressing the underlying limbs have appropriate sensation and circulation distally. In the initial 24-48 hours dressings should be applied to leave the tips of fingers and toes exposed so that the colour and circulation can be frequently checked.

Upper and lower limbs should be elevated on pillows or foam wedges to encourage resolution of dependant oedema. If available a doppler may be used to assist in the monitoring of circulation of swollen limbs.

Escharotomy and Haemorrhage

Regular capillary refill and limb observations should indicate the possible need for an escharotomy. Post burn swelling may continue during the second 24 hours post burn, so an escharotomy may be necessary to ensure adequate circulation.

As peripheral circulation returns to normal during this stage there will be a gradual opening up of peripheral vessels and so bleeding may occur from previously performed escharotomy sites. Bipolar diathermy or simple application of an artery forceps with ligature may be necessary to control this bleeding. It is not appropriate to attempt to control bleeding by application of firm bandages as this may restore the peripheral constriction released by the escharotomy.

Pain Relief

During the second 24 hours the simplest, safest, way of providing adequate analgesia is with small incremental doses of intravenous opioids. The dose should be titrated against the patient’s response including the respiratory rate, and no sophisticated facilities are required for administration or monitoring.

However, if facilities for morphine infusions are available a 20-30 microgram per kg per hour dose (after the loading dose) may be the most flexible form of pain relief. Higher doses may be needed and it may be necessary to top up this intravenous infusion with small incremental intravenous doses as it takes many hours for the infusion alone to provide a blood level that will give satisfactory analgesia. There are no concerns regarding addiction to opioids at this stage. When pain is genuinely present appropriate analgesia should be given.

Pain will be most severe during dressing changes, episodes of mobilisation, and physiotherapy. Adequate levels of opioids should be provided to cover the patient during these painful episodes using intravenous, intranasal, oral or buccal routes as appropriate.

Patient controlled analgesia (PCA) is extremely effective in burns and if PCA is available it is the method of choice. PCA can be used in quite small children with care. An acute pain expert or anaesthetist may be necessary to assist with the regime.

Nitrous oxide administered by a device which prevents inadequate oxygen delivery is a useful supplement, particularly when procedures are being undertaken but it should be supervised by an anaesthetist or other experienced staff member.

Nutrition

It is important to establish normal gastric feeding as soon as possible after burn injury. The presence of food passing through the intestine protects the small bowel mucosa from damage that occurs following trauma and starvation. This damage to the mucosal cells allows bacteria from the bowel to move into the blood stream and it is this translocation of intestinal bacteria that is responsible for the severe secondary gram-negative sepsis that is often fatal in severe burns. Early introduction of food helps prevent this.

Patients with severe burns (> 10% in children, >20% in adults) frequently have intestinal ileus, particularly if their intravenous fluid resuscitation is delayed and they suffer significant shock. A nasogastric tube must be passed to empty the stomach to avoid vomiting and aspiration but as soon as bowel sounds are present or if present at the time of admission then feeding should begin.

Approximately twice the usual amount of energy is required per day in severely burned patient and this can be given using a number of propriety dietary supplements. If these are not available milk based foods are most useful.

Patients may be able to eat a normal diet. This should be rich in eggs and dairy products so that sufficient protein and calories are provided. The addition of skimmed milk powder to ordinary milk (200 g per litre) significantly increases the protein level. In addition, high protein high calorie milkshakes can be made by adding ice-cream, eggs and glucose based flavouring agents to milk. These are often well tolerated.

Patients with large burns are often unable to consume adequate amounts of nutrients. In these patients a fine bore silastic nasogastric or post-pyloric feeding tube 8 or 10 French should be inserted for supplemental feeding. The head of the bed should be elevated 30^0 whilst the feed is being given. Gradual increase in rate often overcomes the problem of troublesome diarrhoea.

The patient should be weighed regularly according to unit protocols (at least weekly), bowel movements should be recorded to document any change and if the patients are eating spontaneously extra time should be allowed for them to complete their meals. Extra food can be provided as small snacks between meals if patients are not able to eat a full meal at regular times. Patients with hand burns may need assistance with their eating.

Because the risk of acute gastric ulceration following severe burns is so high, an H_2 antagonist should be given. Ranitidine given daily will help protect against acute gastric ulceration.

Physiotherapy

Because deep burn wounds contract, it is important to maintain all joints in an appropriate position. Prevention of contractures starts early (first few days). Patients should not be allowed to adopt positions that are those of contracture. **The position of comfort is the position of contracture.**

The precise position depends on the aspect of the joint involved. Usually the correct positions are:

- neck - extension
- axilla - abduction
- elbows - extension
- wrists - neutral or extension
- metacarpophalangeal joints - flexion
- interphalangeal joints of fingers - extension
- knees - extension
- ankles - 90^{o} dorsiflexion

A splinting regime may be required and at least once a day all joints should be put through a passive range of movement as far as pain will allow. Those patients with respiratory burns who are conscious, or who have chest wall burns should have supervised breathing or coughing exercises to ensure adequate pulmonary expansion.

As part of the splinting regime it is particularly important to avoid tight bandages and splints that press on nerves surrounding joints. Particularly at risk is the ulnar nerve at the elbow which may be easily damaged from splints or from resting on the edge of a bed or operating table. Also, the common peroneal nerve around the head of the fibula is frequently damaged in elderly people by bandages or incorrectly applied splints and often results in permanent foot drop.

During ICU admission the severely burned patient is usually immobile so meticulous care of pressure areas is essential. In the elderly sacral, occipital and calcaneal pressure sores are very common. Other pressure sores may also occur at less usual sites. Patients should be turned every two hours around the clock utilising pillows for comfort. Pressure relieving beds and mattress may be used but care should be taken to prevent the patient getting into the position of contracture.

Infection Prevention

All equipment should be kept separate for each patient. Hand washing between patients is the most effective means of preventing cross infection.
When undertaking direct patient care, a different isolation gown and gloves should be worn for each patient. The patient's mattress and beside area should be wiped down daily with an antiseptic.

Summary

1. Patients should be transferred to a burns service within 24 hours of burn injury to maximise survival. If this is not possible intensive care management is required to keep the patient in the best state for transfer.

2. Attention to respiratory and circulatory support, careful wound care, pain relief, nutrition, physiotherapy, and infection control will present the patient to the burns service in the optimal condition.

3. Frequent telephone contact with the receiving burn service or receiving ICU is essential.

CHAPTER 13

The Outpatient Management of the Minor Burn

Introduction

Approximately 130,000 people with burn injuries visit emergency departments in England and Wales each year (source: Hospital Episode Statistics, 2004-2009). Of these only a very small proportion, around 500patients, are admitted to hospital with very severe burn injuries which require fluid resuscitation (this does not account for all hospital admissions as a result of burn injury). About half of these are children under 16 years of age (source: IBID).There are approximately 300 deaths in hospital after burn injuries each year in Britain.

Many patients receiving acute burns will attend the emergency department of a district general hospital or a minor injuries unit. Patients may also present to and receive primary care from their general practitioner.

Burn Assessment

1. History

The history of the incident is essential. A history of what the causative agent was and any first aid received will give clues as to whether the burn is likely to be superficial or deep.

Scald burns are less likely to be deep than flame burns, but in a child, as in the elderly, scald burns are frequently deeper than first assessed. An idea of how hot the scalding liquid was should be obtained. Flame burns are usually deep, particularly where flammable solvents were involved, or the clothing has caught fire.

Suspicion of non-accidental injury in a child or assault in an adult can often be guided by an inconsistency noted between the appearance of the visible injury and the history of occurrence. Any suspicion of non-accidental injury or assault should prompt referral to a burn service for further investigation.

2. Examination

The burn should be carefully examined and the appearance recorded.
Note:

- the colour of the burn
- the presence or absence of blistering

- the presence or absence of sensation to fine pin prick (with a hypodermic needle)
- the presence or absence of capillary return following digital pressure
- the level of pain caused by the burn (superficial burns are more painful than deep burns)
- the nature of any exudate on the burn wound (which can indicate possible infection in a burn presenting after a delayed period)
- the presence or absence of surrounding inflammation suggesting invasive sepsis

It is usually possible to diagnose the depth of burning with reference to the above findings. This is set out in more detail in Chapter 7 “Wound Management”. The small burn can be referred to a burn facility with an expertise in excision and skin grafting if it is not appropriate for these patients to be referred to a burns unit (refer to criteria in Appendix 1). If there is any doubt about the depth or treatment required for a burn, contact the burn service for advice.

3. Assessment of the Area of Burn

Use of the Wallace “Rule of Nines”, as discussed in Chapter 5, should enable accurate assessment of the area of burning. Alternatively, the palmar surface of the patient’s hand (from fingertips to wrist) is approximately 1% of body surface area and this can be used as a guide to assess the extent of small or patchy burns.

Superficial to mid-dermal burns less than 10% TBSA for adults and 5% for children may be suited to outpatient management, and with the advent of the newer biologically compatible dressings it is possible to treat these burns with dressings that protect the wound and facilitate normal healing.

However larger superficial burns approaching 10% consume considerable dressing resources and may be outside the scope of frequent redressing in the primary care setting. For this reason they may be better off treated at an outpatient department and all burn services have associated outpatient clinics where these burns can be readily managed in conjunction with care provided by the General Practitioner.

Pain Relief

Small burns when appropriately dressed are well suited to oral administration of paracetamol with codeine in various concentrations. Oral opioids e.g. Oramorph or intranasal e.g. Diamorphine may be used in the outpatient setting with appropriate protocols but if this is not sufficient or available to provide appropriate analgesia you should consider admission of the patient for interim treatment until the pain of the burn wound has decreased. Subsequently, it may be appropriate for outpatient management to recommence.

Dressing of burns in children may be difficult and produce considerable pain. Oral sedatives and analgesics can be given 30 to 45 minutes before dressings are undertaken to enable these burns to be treated as outpatients. Intranasal opioids have a quicker onset and duration of action which are suited to the outpatient environment. Again, if it is not possible to provide adequate analgesia in the outpatient or primary care setting, then hospital admission should be sought.

Wound Management

Following first aid, management of the burn should be based on the same principles that apply to treatment of any wound. Aseptic technique should be used to minimise the risk of contamination, and care should be taken to prevent further tissue damage.

The burn wound should be washed using a dilute antibacterial agent. Dilute aqueous chlorhexidine 0.1 or 0.2% is often used, but if this is not available it is appropriate to wash the area with saline or soap and water and to remove any loose skin with sterile scissors. Small blisters can be left intact. In cases where there are large areas of blisters which have ruptured and the skin has rolled up, the loose skin should be removed.

Once the area has been cleaned and debrided, further examination will help assess the depth of the burn.

Epidermal Burns

Burns that are bright pink to red, very tender without blistering are likely to be epidermal only. The typical examples are sunburn or a minor flash from a gas explosion. These burns do not need specific treatment, but may be very painful and require pain relief. Moisturising cream may be all that is needed.

Dermal Burns

Burns that have blistered are usually dermal burns. The base below the blistered skin should have capillary return and sensation if the burn is only superficial dermal, and should heal spontaneously. After the blistered superficial dermis and epidermis have been removed, the papillary dermis will be exposed. If this is allowed to dry out or become infected, the contained epidermal elements that should heal the burn by epithelialisation will die and the burn wound will become deeper. As a consequence it may not heal spontaneously and may require skin grafting.

The appropriate treatment for these wounds is a biologically compatible dressing such as one of the silicone dressings (e.g. Mepitel), a hydrocolloid (e.g. Duoderm or Comfeel), silver dressing (e.g. Acticoat, Mepilex Ag or Acquacel Ag) or a film (e.g. Opsite or Tegaderm). Dressings & skin substitutes such as Biobrane, Suprathel, Matriderm, pig skin or preserved human cadaver skin are also ideal but are generally only applied in a burn service.

The superficial dermal burn will continue to exude serum secondary to the inflammatory reaction. Some dressings may become saturated with blister fluid and require more frequent dressing changes. Hydrocolloid dressings will need to be changed approximately every 3-5 days or more frequently if there is excess exudate or a foul odour. Dressings that adhere to the wound such as Biobrane, pig skin or various forms of preserved human skin should gradually peel off at the edges as epithelialisation proceeds.

In most burns a repeat wound inspection after approximately 3 days is advised to make sure that the initial assessment of burn depth was correct and that complications of the burn (particularly infection) have not occurred. A change in management may be required if repeat assessment suggests that the burn is full thickness or that the burn is infected.

Infected Burns

Acute burns infrequently require antibiotics on initially if no delay in presentation and treatment.
Burn wound sepsis may occur in those burns contaminated at the time of injury, or where the wound has been treated with a dressing lacking antibacterial properties.

A topical anti-microbial agent should be used for burns which appear infected at the time of initial presentation, or are judged likely to have been contaminated at the time of injury. The most appropriate products in the U.K. are either a slow-release silver dressing or silver sulphadiazine (SSD) with or without chlorhexidine digluconate but this should only be applied after discussion with the burns service.

SSD (Flamazine) will convert the burn wound into a moist wound with a khaki coloured exudate that makes inspection of the base of the burn difficult.

Any evidence of surrounding inflammation or systemic signs of infection are suggestive of invasive burn wound sepsis. At this stage it is appropriate for a referral to occur because invasive burn wound sepsis in a mid-dermal burn usually produces a deep dermal or full thickness injury.

Exposure allows desiccation that produces deepening of the wound so exposure treatment of the minor burn, except for epidermal burns, is not appropriate. If at re-examination of the burn, the initial diagnosis of superficial burn appears incorrect, then referral for surgery should occur.

Follow Up

Depending on the primary dressing applied follow up is usually at 2-3 days following initial dressing then at 3-7 day intervals. On these occasions, it is important to determine whether the patient's home circumstances are satisfactory for continuing outpatient management. In situations where the patient may not be able to cope, hospital admission may be needed, e.g. the elderly, the patient who lives alone, or the child with working parents whose on going outpatient care may be compromised by lack of family support. Patient's co-morbidities can also effect possible outpatient management. Those with incontinence or mental impairment may require more frequent wound management and dressing changes.

Home nursing services may be useful in extending the role of the primary care outpatient service and can assist in provision of repeated dressings of the minor burn, particularly when it is difficult for the patient to come to the outpatient clinic or surgery.

1. Physiotherapy

Minor burns to the hands, limbs and around joints that do not fit the criteria for admission to a burn service may need physiotherapy. In burns that take longer than 2 weeks to heal, hypertrophic scarring may occur so they should be referred to a burns service. Physiotherapists and occupational therapists might be required for scar management using elasticised garments, contact media or adhesive tape.

2. Education Post Healing

It is important to protect the recently healed burn and to provide appropriate protection from sunburn by use of 30+ sunscreens and appropriate clothing. Recently healed burns may not stand up to the rigours required during work, and some time off may be needed to allow normal thickening of the healed area. Frequent application of moisturising creams to overcome the problem of lack of natural skin moisture due to the damage of sebaceous glands might also be needed for some time after the burn has healed.

Itching may be a problem in the recently healed minor burn and is helped by moisturising creams and massage. Pressure also helps. Prescription of antihistamines and application of cold compresses may help relieve itch.

3. **Post Burn Functional Impairment**

Some small burns that take slightly longer than 14 days to heal and produce hypertrophic scar tissue may leave a primary skin shortage. If this occurs around joints there might be secondary loss of function. Burns with loss of function that do not respond to scar management and physiotherapy may require referral to a burn service for secondary reconstruction to overcome this functional problem. Many minor degrees of skin shortage and contracture are well treated by therapists and the majority of these patients with good therapy do not need secondary surgical treatment.

4. Post Burn Cosmetic Disability

Small burns may produce considerable cosmetic disability either due to colour match defects following spontaneous healing of the partial thickness burn or as a result of post burn hypertrophic scarring. Some patients will not be concerned, but occasionally a patient will be abnormally distressed by the appearance of what is otherwise a minor burn.

The secondary body image disturbance that may occur following a minor burn is sometimes quite out of proportion to the size of the burn itself. Counselling at the primary care facility or by a psychiatrist skilled in body image problems may assist in the management at this stage. Skin camouflage can mask many colour mismatches. There may be unreasonable requests for cosmetic correction of these minor defects. Revision surgery by excision of scar and skin grafting might leave a blemish that is no better than the original appearance. In these cases, supportive psychotherapy with repeated counselling sessions is the appropriate management.

In addition to the cosmetic defect, many patients and relatives may have unresolved anger or guilt relating to the circumstances of burning and this may need to be dealt with as part of treatment.

Summary

1. Many minor burns can be satisfactorily treated at the primary care level. As the great majority of burns in the U.K. fall into this category, it is appropriate for local practitioners to develop expertise in the management of these minor burns and for burns services to remain available to provide advice or treatment as necessary.

2. Management of the burn wound includes meticulous attention to the burn wound to facilitate normal healing and prevent complications. Many products are not mentioned in this chapter that are just as effective. The list of products mentioned is not intended to be all-inclusive.

3. Secondary referral of the patient with healed minor burn may be required for reconstructive surgery, scar management, physiotherapy or psychotherapy.

APPENDIX 1

National Burn Care Referral Guidance

Version 1, Approved February 2012

National Network for Burn Care (NNBC) National Burn Care Referral Guidance

1. Introduction

This guidance describes the most clinically appropriate level of Specialised Burn Service for treating burn injuries of varying severities. It answers the question of "What types of burn injuries need referral to which level of Specialised Burn Service."

Following the recommendations of the National Burn Care Review 2001, Specialised Burn Services were stratified into three levels of service:

Burn Centres – This level of in-patient burn care is for the highest level of injury complexity and offers a separately staffed, geographically discrete ward. The service is skilled to the highest level of critical care and has immediate operating theatre access.

Burn Units – This level of in-patient care is for the moderate level of injury complexity and offers a separately staffed, discrete ward.

Burn Facilities – This level of in-patient care equates to a standard plastic surgical ward for the care of non- complex burn injuries

However, these definitions lacked specificity and so this Guidance has been developed through the National Network for Burn Care, an NHS body that includes representation from the 4 regional Burn Care Networks for England and Wales, NHS Specialised Commissioners, Patient Representatives and the British Burn Association. The development of the guidance was informed by an expert multidisciplinary group. The guidance is based on the general principals outlined in the National Burn Care Review (2001) but now replaces the referral guidance contained within it.

This guidance aims to ensure that patients are referred to a burn care service which has the relevant level of expertise and specialised resources to optimise their treatment and recovery

The most up to date version of these guidelines can be found at:
www.specialisedservices.nhs.uk/burncare

2. Using this Guidance

The guidance uses 5 criteria to guide referral decisions:

• TBSA - Total Body Surface Area

• Depth - The depth of burn injury

• Site - Anatomical site of the burn injury

• Mechanism - The aetiology of the burn injury

• Other Factors - Parameters that may impact on the severity/complexity of burn injury

Thresholds for the above criteria are listed as either

"Refer:" It is recommended that the patient be referred to the level of specialised burn service described

Or

"Discuss:" It is recommended that the patient be referred to the level of specialised burn service described. In such cases a discussion should take place with a Consultant within the appropriate service and consideration given to referring / transferring the patient to the appropriate service level.

- For Thresholds listed as "Refer", it is acceptable (in extenuating circumstances) for patients not to be transferred according to these criteria if discussed with and agreed at Consultant level with the appropriate specialised burn care service (i.e. the next service level up). Such agreement should be recorded in the patient notes and all such cases should be subject to formal audit.

- For the purpose of these guidelines a child is defined as being under 16 years of age.

- For the purpose of these guidelines a neonate is defined as: If born at term (37-42 weeks) then up to 4 weeks after birth. If born pre-term (before 37 weeks) then up to 44 weeks post conception.

- For Adult patients, the implementation of End of Life Care as a result of burn injury should only be made following assessment by at least two Consultants, one of whom should be a Specialised Burn Care Surgeon.

3. Specific Advice to Emergency Departments, General Practitioners and other non-specialised providers:

- The suggested minimum threshold for referral into specialised burn care services can be summarised as:
    - All burns ≥ 2% TBSA in children or ≥ 3%□ □in adults
    - All full thickness burns
    - All circumferential burns
    - Any burn not healed in 2 weeks
    - Any burn with suspicion of non-accidental injury should be referred to a Burn Unit/Centre for expert assessment within 24 hours

- In addition, the following factors should prompt a discussion with a Consultant in a specialised burn care service and consideration given to referral:
    - All burns to hands, feet, face, perineum or genitalia
    - Any chemical, electrical or friction burn
    - Any cold injury
    - Any unwell/febrile child with a burn
    - Any concerns regarding burn injuries and co-morbidities that may affect treatment or healing of the burn

- If the above criteria/threshold is not met then continue with local care and dressings as required

- If burn wound changes in appearance / signs of infection or there are concerns regarding healing then discuss with a specialised burn service

- If there is any suspicion of Toxic shock syndrome (TSS) then refer early
  If non-specialised practitioners require advice regarding the assessment, care or treatment of any type of burn injury they can contact their nearest specialised burn service at any time.

A list of the specialised burn services in England and Wales is available at:
http://www.specialisedservices.nhs.uk/burncare/key-documents/specialised-burn-care-services-england- wales-1

Thresholds for Referral to Paediatric Burn Services (1)

Criteria		Facility Threshold	Unit Threshhold	Centre Threshold	Note
TBSA	**Refer**	≥2% <5%	≥5% <30% ≥5% <15% if under 1 year old	≥30% ≥15% if under 1 year old	
	Discuss			≥ 20% ≥ 10% if less than 1 Year Old	
Depth	**Refer**	All full thickness burns.	≥2% full thickness if under 10 yrs old ≥1% full thickness if under 6 months old	≥ 20% TBSA if Full Thickness	*All burns that are not blanching should be referred to a specialised burn service*
Site	**Refer**		Any significant burn to special areas (hands, feet, face perineum or genitalia) Any circumferential burn		*"Significant" can mean any injuries where the referrer feels that greater MDT expertise is required*
	Discuss	Any burn to special areas (hands, feet, face, perineum, genitalia)			
Mechanism	**Discuss**	Any chemical, electrical, friction burn. Any cold injury.			
Other Factors	**Refer**	Any burn not healed in 2 weeks.	Any predicted or actual need for HDU / PICU (including those predicted to require support for reasons other than the burn injury – e.g. smoke inhalation)	All those predicted to require assisted ventilation specifically for their burn injury for more than 24 Hours.	*Any child requiring assisted ventilation for >24 Hours must be within a Paediatric Intensive Care Unit.* *It is recommended that all children with smoke inhalation (irrespective of the presence of burn injury) are referred to a PICU with a specialised burn care service on site.*

Version 1, Approved February 2012

Thresholds for Referral to Paediatric Burn Services (2)

Criteria		Facility Threshold	Unit Threshold	Centre Threshold	Note
Other Factors	**Refer**		Any significant deterioration in physiology. Any burn with suspicion of non- accidental injury should be referred to a Burn Unit/Centre for expert assessment within 24 hours	Any child who is physiologically unstable as a result of burn injury	*Suggested parameters for physiologically unstable are:* *Requirement for Inotropic support* *Requirement for renal support or with deteriorating renal function* *A base deficit >5 and deteriorating* *An oxygen requirement >Fi02 of 50% and increasing, especially with abnormal C02 / respiratory rate*
	Discuss	Unwell/febrile child with a burn Any concern regarding burn injury any co-morbidities that may affect treatment or healing of the burn	All children with Major Trauma + Burn Injury (post treatment within Major Trauma Centre) where the burn injury meets unit level thresholds **Any** burn injury in a neonate should be discussed with a Burn Unit or Centre	All children requiring respiratory support All children with Major Trauma + Burn Injury (post treatment within Major Trauma Centres) where the burn injury meets centre level thresholds **Any** burn injury in a neonate should be discussed with a Burn Unit or Centre	*The treatment of children with Major Trauma + Burn Injury should be agreed between the Trauma service and the appropriate specialised burn service* *Neonates should only be admitted to burn services with an onsite NICU*

Version 1, Approved February 2012

Thresholds for Referral to Adult Burn Services (1)

Criteria		Facility Threshold	Unit Threshhold	Centre Threshold	Note
TBSA	**Refer**	≥3%<10% (including those with inhalation injury)	≥10%<40% ≥10%<25% with inhalation injury	≥40% ≥25% with inhalation injury	*The minimum indication for Inhalation Injury is defined as – Visual evidence of suspected upper airway smoke inhalation, laryngoscopic and/or bronchscopic evidence of tracheal or more distal contamination/injury or unconscious at scene with suspicion of inhalation or raised COHb.* *If there are any concerns regarding inhalation injury with a patient with any size burn then it should be discussed with a Burn Care Centre*
	Discuss			≥25%	*Special Consideration should be given to referring patients >65 yrs with ≥25% TBSA (especially where there are co-morbidities) to the Burn Care Centre*
Depth	**Refer**	Any full thickness burns	≥5%<40% if non-blanching		*All burns that are not blanching should be referred to a specialised burn service*
Site	**Refer**		Any significant burn to special areas (hands, feet, face, perineum, genitalia) Any non-blanching circumferential burn		*"Significant" can mean any injuries where the referrer feels that greater MDT expertise is required*
	Discuss	Any burn to special areas (hands, feet, face, perineum, genitalia)			
Mechanism	**Discuss**	Any chemical, electrical, friction burn. Any cold injury			
Other Factors	**Refer**	Any burn not healed in 2 weeks.	Any predicted or actual need for HDU or ITU level care Any burn with suspicion of non-accidental injury should be referred to a Burn Unit / Centre for expert assessment within 24 hours		

Version 1, Approved February 2012

Thresholds for Referral to Adult Burn Services (2)

Criteria		Facility Threshold	Unit Threshold	Centre Threshold	Note
Other Factors	**Discuss**	Any concern regarding burn injury and co- morbidities including any co-morbidities that may affect treatment or healing of the burn.	Patients who are pregnant All patients with Major Trauma + Burn Injury (post treatment within Major Trauma Centre) where the burn injury meets unit level thresholds.	All patients with Major Trauma + Burn Injury (post treatment within Major Trauma Centre) where the burn injury meets centre level thresholds. Patients assessed as requiring end of life care should be discussed with a Consultant Burn Specialist at a Burn Centre (to discuss the appropriateness of local palliative care versus transfer to a centre).	*The treatment of patients with Major Trauma + Burn Injury should be agreed between the Trauma service and the appropriate specialised burn service (in accordance with the TBSA,Depth, Site and Mechanism criteria listed above)*

Version 1, Approved February 2012

Glossary

TBSA Total Body Surface Area
Ventilation Mechanical support for patients who cannot breathe by themselves
Circumferential burn An injury that goes all the way around the surface of a limb or the body
HDU High Dependency Unit
ICU Intensive Care Unit
PICU Paediatric Intensive Care Unit
Inotropic Support Drugs administered to support the heart or circulation
Renal Kidneys and their functioning

The most up to date version of these guidelines can be found at:
www.specialisedservices.nhs.uk/burncare

Please note that since publication some of the Burn Networks across the U.K. have published updated region/network- specific guidelines for referral. These can be viewed via their websites:

Midland Burn Care Network: http://www.midlandsburnnetwork.nhs.uk
Northern Burn Care Network: http://www.nbcn.nhs.uk
London & South East Burn Care Network: http://www.lsebn.nhs.uk
South West UK Burn Network: http://www.swscg.nhs.uk
Care of Burns in Scotland (COBIS): http://www.cobis.scot.nhs.uk/clinical.shtm

APPENDIX 2

Tetanus Protocol

Table 3.21.1: Guide to tetanus prophylaxis in wound

Immunisation status	Clean wound	Tetanus prone wound	
	Vaccine	**Vaccine**	**Human Tetanus Immunoglobulin**
Fully immunised, i.e. has received a total of five doses of vaccine at appropriate intervals	None required	None required	Only if high risk
Primary immunisation complete, boosters incomplete but up to date	None required (unless next dose due soon and convenient to give now	None required (unless next dose due soon and convenient to give now)	Only if high risk
Primary immunisation incomplete or boosters not up to date	A reinforcing dose of vaccine and further doses as required to complete the recommended schedule (to ensure future immunity)	A reinforcing dose of vaccine and further doses as required to complete the recommended schedule (to ensure future immunity)	Yes: one dose of human tetanus immunoglobulin in a different site
Not immunised or immunisation status not known or uncertain	An immediate dose of vaccine followed, if records confirm the need, by completion of a full five-dose course to ensure future immunity	An immediate dose of vaccine followed, if records confirm the need, by completion of a full five-dose course to ensure future immunity	Yes: one dose of human tetanus immunoglobulin in a different site

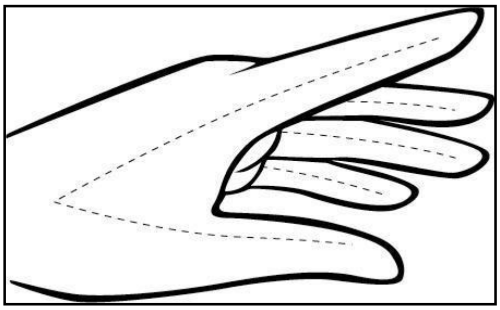
Notes:
A tetanus prone wound is: more than 6 hours old *or* any wound with:

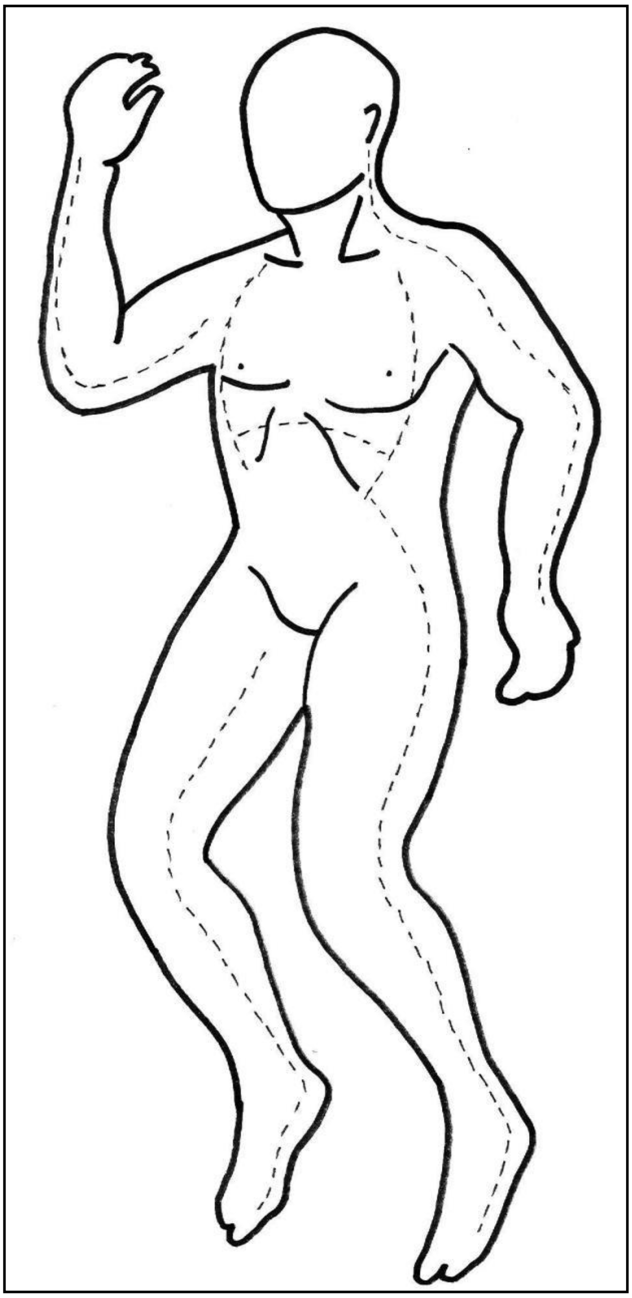
- significant degree of devitalised tissue
- puncture-type wound
- contact with soil or manure
- clinical evidence of sepsis
- foreign bodies
- compound fractures

Full information in: Immunisation against infectious disease 2006
Department of Health, Welsh Assembly Government, Scottish Executive
DHSSPS (Northern Ireland), published by TSO
http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_079917

APPENDIX 3

Escharotomy





APPENDIX 4

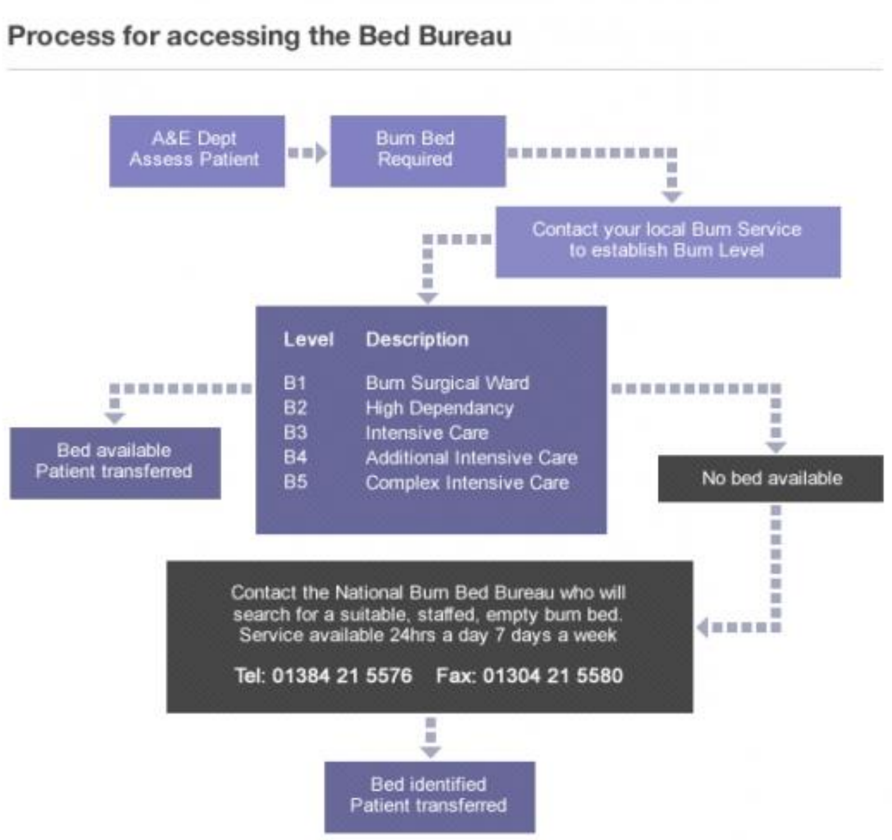
National Burn Bed Bureau

The National Burn Bed Bureau responds to requests from local emergency services for specialist burn beds. It provides:

- 24/7 coverage of availability in response to requests for patient transfers to specialist burn services across the British Isles.
- Twice-daily establishment of bed capacity and availability.
- NBBB is now part of the nationwide response to a major incident involving burn injuries

NBBB is managed by the Capacity Management Team at West Midlands Ambulance Service NHS Trust. They can be contacted on 01384 215576.

The first point of contact from a local A&E should always be to the nearest local specialist centre. If a bed cannot be found – then the National Burn Bed Bureau should be contacted.



http://www.specialisedservices.nhs.uk/burncare/national-burn-bed-bureau

British Burn Association

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