CHAPTER 11

ANAESTHETIC AND OPERATIVE DEATHS

Anaesthetic deaths are very rare. Only one in ten thousand persons die totally as a result of anaesthetic. Anaesthetic deaths may be divided into two groups.

(A) DEATHS WHICH OCCUR DURING THE ADMINISTRATION OF AN ANAESTHETIC BUT WHICH ARE NOT DUE TO ANAESTHETIC: (1) The injury or disease which necessiate the operation is sufficiently serious to cause death, though the anaesthetic may have precipitated the death. (2) A patient suffering from a serious disorder, e.g., valvular disease of the heart, may have to undergo an operation for another disease or injury, in which the operation or anaesthetic may have only precipitated death. (3) The patient may be suffering from undiagnosed serious lesion, e.g. coronary artery arteriosclerosis which could have been an important contributory factor in causing death. (4) Surgical shock and exhaustion may be the major factors in causing the death of patient under anaesthesia. This can occur when the pre-operative condition of the patient was poor, or operation has been unduly prolonged. (5) A surgical accident during the administration of anaesthesia, e.g.,damage to a large blood vessel or aneurysm may cause death.

(B) DEATHS WHICH ARE THE DIRECT RESULTS OF THE ADMINISTRATION OF AN ANAESTHETIC: (1) Inexperience: Most deaths occur due to inexperience and failure to adopt precautions when clearly indicated, e.g. mishaps due to intubation (e.g. aspiration of vomit, kinked tubes, etc.), and bronchoscopy. Each may cause vagal inhibition if there is inadequate depth of anaesthesia. Breathing circuit disconnections cause death. (2) TECHNICAL MISHAPS: Equipment failure or mislabelling of oxygen and anaesthetic gases may go undetected and may not be identified as a cause of resulting deaths. Explosions and fires may occur in the operating theatre through the ignition by an electric spark of the inflammable vapour caused by a mixture of air or oxygen with anaesthetic gas. The most dangerous mixtures are cyclopropane-oxygen and ether-oxygen. The ignition may come from the spark of a surgical diathermy electrode, from a faulty electrical appliance, from X-ray apparatus, from static electricity, etc. (3) Death may result from respiratory failure due to an inadequate supply of oxygen: (a) from a depression of the respiratory centre, which may be caused by an overdose of an anaesthetic agent, over-premedication, administration of relaxant drugs, such as curare, which causes paralysis of the respiratory and throat muscles, (b) from obstruction of the respiratory tract from laryngeal spasm (due to pre-existing asthma, hypersensitivity to drugs, aspiration of gastric contents and fluid overload), with progressive hypoxia, bronchiolar spasm, impaction of loose bodies, e.g., swabs or dentures in the larynx, trachea and bronchi, or by reactionary haemorrhages from an operative site in the nasopharynx. The tongue may fall back and obstruct the opening of the larynx. Deaths due to regurgitation of vomited matter are probably caused by hypoxia. Rupture of the lungs may occur from excessive pressure to the airway. Posititve pressure ventilation will rapidly convert a simple pneumothorax into a tension pneumothorax. The use of nitrous oxide will cause a pneumothorax to expand rapidly, leading to death.

(4) The most common cause of sudden death under general anaesthesia is acute neurogenic cardio-vascular failure, which may occur in all types of operation. It usually occurs under light anaesthesia, e.g., when an operation is started before the patient is properly anaesthetised or when traction is exerted on the viscera or peritoneum, or when an instrument is passed into the larynx or trachea of a lightly anaesthetised patient. Severe shortage of oxygen during deep anaesthesia may be due to inadequate ventilation and can result in sudden death due to heart failure.

Deaths due to hypovolaemia may occur due to: (a) failure to recognise or to make adequate provisions for preoperative hypovolaemia, (b) vasodilation converts a compensated hypovolaemia into an uncompensated fatal form, (c) inadequate volume replacement for intraoperative losses may contribute to death from surgically induced haemorrhage, (d) replacement of large quantities of blood lost leads to deficiencies in clotting factors of blood and shock with liberation of fibrinolysins which may cause death from uncotrollable haemorrhage.

Cardiac arrest during the induction of anaesthesia or while the surgical procedure is in progress may be due to inadequate preanaesthetic medication, obstruction of the airway from aspiration of food, vomitus or instruments, insufficient oxygenation, excessive CO_2 in the inspired air, too rapid induction of the anaesthesia, an overdose of the anaesthetic

agent, or hypersensitivity of the individual to the anaesthetic agent emp. yed.

Cardiac arrhythmias during anaesthesia may result from pre-existing disease, abnormal reactions to drugs, unskilful anaesthesia, surgical stimulation, or a combination of these.Increased catecholamine level (from endogenous or exogenous sources) may precipitate arrhythmias especially in combination with hypoxia, hypercarbia and halothane and from injection of adrenaline. Electrolyte disturbances, especially of extracellular potassium and magnesium predispose to dysrhythmias. Myocardial contractility may diminish due to metabolic disorders, electrolyte imbalances, hypoxia, hypothermia, anaesthetic drugs and acute myocardial ischaemia.

COMPLICATIONS OF ANAESTHESIA : A variety of unexplained and untoward anaesthetic events may lead to minor complications to a fatal outcome, or a living death with termination of all conscious, volitional activity, or a paraplegia, or blindness, etc. Common complications are : hypoxaemia, aspiration of foreign material, atelectasis, pneumonia, pulmonary oedema, pneumothorax, bronchospasm, air embolism, oxygen intoxication and neurological sequelae.

CAUSATIVE FACTORS ARE : (1) Physiologic, e.g., insufficient oxygen or inadequate blood supply. (2) Pharmacologic: toxic or untoward effects of anaesthetic drugs and techniques. Some effects are of the minor histaminoid type and others are life-threatening bronchospasm and acute hypotension. Their incidence is about 0.2% of all anaesthetics. (3) Physical: trauma from electricity, heat, explosion, direct pressure or tension. (4) Malfunction or misuse of apparatus and instruments.

MALIGNANT HYPERTHERMIA is a very rare inherited condition seen during general anaesthesia using halothane and succinylcholine, in which the body temperature increases to 40° to 45°C. with muscle rigidity, followed by severe metabolic disturbance and death. It occurs in approximately 1: 14,000 general anaesthetics, with mortality of 60 to 80%. Hepatitis may follow the use of halothane. Nephrotoxicity and even death may occur from methoxyflurane.

All complications are not related to errors. They may result from the patient's disease or the patient's response to the anaesthetic drug or technique or may be unrelated to anaesthesia.

The assessment of responsibility for damage or injury is difficult. Often it is impossible to judge fairly because: (1) All facts are rarely ascertained. Usually no one is fully aware of everything that occurred at the moment of disaster. (2) The time interval between the anaesthesia and the clinical evidence of damage may be long. (3) With some complications, the association with anaesthesia is not clear. (4) With many complications, the nature takes place over an extended time period and the information is disseminated slowly, e.g., malignant hyperthermia.

METHODS OF INVESTIGATIONS, EXAMINATION AND STUDY : The following aspects should be taken into consideration by the pathologist when investigating an operative or anaesthetic death.

(1) HISTORY : The necessary inquiries should cover the period prior to hospitalisation, the hospital stay up to the time of preparation for anaesthesia, the pre-anaesthetic preparation period, the duration of anaesthesia until death. A list of the relevant and potentially toxic chemicals associated with each of these periods should be obtained. A thorough review of the hospital chart and discussions with the surgical and anaesthetic team should be made.

(2) CONDITIONS REQUIRING SURGERY : Some surgical conditions are on high risk, e.g., resection of the aortic aneurysm and repair in which the surgeon may not be able to control the bleeding. Rarely, surgical errors cause death, e.g., ligation of the coronary artery while implanting a heart valve prosthesis.

(3) OTHER PRE-EXISTING CONDITIONS : Some contraindications to operative procedures are not easy to identify, and even if they are identified, their seriousness may not be appreciated, such as symptomless coronary artery disease may prove fatal due to increased anoxia by the anaesthetic agents. Other conditions, e.g., brown atrophy of the heart, anaemia, bronchitis, emphysema, interstitial pulmonary fibrosis, myxoedema, thyrotoxicosis, hypertension, etc., may contribute to death.

(4) PRE-ANAESTHETIC MEDICATIONS : Errors in relation to pre-operative medication are: giving wrong medication, over-medication, or no medication, which may precipitate death.

(5) ANAESTHETIC AGENTS : Inadvertent mixing of the anaesthetic gases may cause death. It is important to get information about the anaesthetic agent used, its quantity and the method of administration. The duration of time the patient remains under anaesthesia and the management of the anaesthetic should be noted.

(6) BURN OR EXPLOSION : Deaths from anaesthetic explosions occur rarely.

(7) SHOCK AND HAEMORRHAGE: Haemorrhage and shock should be evaluated with other findings of the case.

(8) BLOOD TRANSFUSION: Blood transfusion reactions and incompatibilities should be investigated.

(9) RESUSCITATIVE MEASURES : The measures adopted should be noted.

(10) EQUIPMENT: With appropriate qualified

individuals, all the equipment including the valves and containers should be checked to assure the correct mixing of percentages. Devices attached to and inserted into the body should be examined.

Chloroform and halothane are hepatotoxic and chloroform may rarely produce ventricular fibrillation. Halogenated hydrocarbons like cyclopropane, trichloroethylene and haloethane cause cardiac irritability. They sensitize myocardium to the action of adrenaline.

AUTOPSY: In deaths from inhalation anaesthesia, the odour of the anaesthetic agent may be detected at autopsy. Examine *in situ* all the cavities. Measure the contents or fluids and preserve for analysis. Examine sites at surgical intervention *in situ* and describe in detail. Dissect all the organs and inspect every surgical suture. Engorgement of the dependent parts of the viscera is usually seen in cases of prolonged anaesthesia.

Introduction of some surgical and anaesthetic devices like airways, indwelling catheters/needles, intravenous cannulae, wound drains, chest tubes, etc, during and subsequent to surgery are likely to interfere with the findings. Their proper placement and patency should be assessed. Exclude any cardiovascular disorder including occult conditions like myocrditis. Collect specimens for assessing the severity of disease for which the operation was done.

An unsuspected cause of death may be deteced, e.g., pulmonary fat or air embolism or evidence of asphyxia from aspiration of regurgitated material. Venous air embolism can occur during intravenous infusions, and through cerebral venous sinuses when they are opened in sitting posture during neurosurgery. The finding of internal haemorrhage, peritonitis and retained swabs and instruments, or evidence of hypersensitivity reactions are obvious.

Some conditions are not detected at autopsy, e.g., vagal inhibition, fall in blood pressure, arrhythmias of the heart, spasm of the coronary arteries, spasm of the larynx, etc. Blood should be collected for grouping, cross-matching and culture, and exudate for bacteriology . Take samples of all organs for microscopic examinations.

BRAIN: Hippocampal gyrus and the cerebellum show changes of hypoxia. Findings include: diffuse, severe leucoencephalopathy of cerebral hemispheres with sparing of the immediate subcortical connecting fibres. Demyelination and obliteration of axon and sometimes infarction of the basal ganglia is seen. Damage is limited to white matter.

TOXICOLOGICAL EXAMINATION : COLLECT: (1) One lung. A lung is mobilised and the main bronchus tied off with a ligature. The hilum is then divided and immediately the lung is placed in a nylon bag which is sealed. Plastic bags are not suitable. (2) Two gm. of fat from the mesentery. (3) Ten gm. of skeletal muscle. (4) 100 gm. of brain from the cerebral hemispheres. (5) 100 gm. of liver. (6) 100 gm. of kidney. (7) Urine. (8) Blood should be collected under liquid paraffin. Specimens collected in case of inhaled anaesthetic should be kept in containers with as little head space as possible. They should be sealed and immediately refrigerated or frozen. Alveolar air should be collected with a needle and syringe under water by puncturing the lung before the chest is opened. Gaseous or volatile anaesthetics are easily lost if specimens or tissues are collected in routine fashion. To avoid losses due to exposure of tissues to the air, it may be necessary to obtain samples by biopsy techniques prior to autopsy. This may have to include *in situ* encapsulation or freezing, or direct transfer of specimens from the body into hermetically sealed containers, analysing solutions or even directly into the gas liberating module of an analysing instrument. Gases from cavities, heart, and blood vessels should be obtained by filling the body cavity with water and using a rubber dam to trap the gases before cutting the organs.

Extraneous specimens like residual solutions, medication containers, samples of gases used in anaesthesia, samples of the operating room air may have to be collected in some cases.

The analysis helps in: (1) detecting and estimating the quantity of the drug given, (2) estimating overdose of premedications of anaesthetic agents.

The fatal concentration of some of the anaesthetic agents in blood are:

Chloroform: 40 to 60 mg.%
Ethyl chloride: 40 mg.%
Diethyl ether: 180 mg.%
Trichloroethylene: 50 mg%
Divinyl ether: 50mg%
Halothane: 20 mg%

A number of absorbed toxicologically pertinent agents are not actually demonstrated in post-mortem tissues. Failure to find them does not exclude the possibility that they had a bearing on the cause of death.

Finally, the pathologist should carry out retrospective evaluation of the case with appropriate disciplines.

LOCAL ANAESTHETICS: Deaths usually occur from overdosages or allergic reactions, hypersensitivity and idiosyncrasy. The important factors influencing the toxicity are: (1) The susceptibility of the patient. (2) The patient's general condition. (3) The rate of administration of anaesthetic agent. (4) The vascularity of the area injected.(5) Total dose. (6) Accidental

intravascular injection. (7) Adrenaline used along with local anaesthetic agent can cause tachycardia, palpitation, sweating, high blood pressure and ventricular fibrillation.

The incidence of severe reactions to local anaesthesia is about 0.05% of which very few are fatal. The hazards of local anaesthesia are: (1) Overdosage of either the anaesthetic or vasoconstrictive agent. (2) Rapid absorption from highly absorptive areas or due to local vasodilatation. (3) Accidental injection into a vessel. (4) Hypersensitivity reactions.

There may be general effect on the CNS, which is either (1) excitory causing convulsions, or (2) depressive causing respiratory paralysis. Very rarely the heart may be directly affected, or when abnormally high concertration is injected directly into a nerve, permanent loss of function may occur.

Blood, brain, liver and tissue from the site of injection should be preserved for chemical analysis. In some cases hypersensitivity reactions may be obvious.

SPINAL ANAESTHESIA: Hypotension due to paralysis of sympathetic outflow is a common complication. The effects may be very severe in old persons, in those with pre-existing heart disease or in association with haemorrhage. Coronary insuffieiency may be precipitated and there may be either cardiac or respiratory arrest. Death may occur suddenly due to cardiac inhibition following an unnatural stimulation of the vagus nerve. There may be diffusion upwards of the agent beyond the lower cord affecting vital centres. Lumbar puncture head-ache occurs in about a quarter of persons recovering from spinal anaesthesia. Rarely, there may be permanent paralysis of the muscles of one eye. Chronic adhesive arachnoiditis is a common complication and if it involves the cauda equina, dysfunction of the bladder and rectum may appear. Contamination of syringes and ampoules by sterilising and cleaning agents, such as phenols and detergents cause paraplegia. Sepsis may be introduced into the spinal canal.

In the case of local, spinal, caudal or intravenous anaesthetic agents, the concentration of the anaesthetic should be determined and also whether the agents were mixed in the correct proportions.

COMPLICATIONS OF SURGICAL PROCEDURES: All surgical operations, with or without anaesthesia, have some morbidity and mortality. Wound infections, fluid and electrolyte variations, pulmonary and renal problems, and cardiac arrest occur in any and all types of surgery. Severe burns from electrosurgery and explosions from electrocautery of the poorly prepared bowel may occur. Post-operative events, such as delayed haemorrhage, pulmonary emboli, and nosocomial infections are related to surgical care. Surgical complications may be delayed for weeks or months. Artificial plastic or metallic devices implanted in the body may fail to function properly after many years of good service, e.g. artificial heart valve.

Most deaths during or shortly after a surgical operation and general anaesthetic are not due to defects in the surgical technique or the anaesthetic procedure, but are due to other factors. To evaluate a fatality occurring in these circumstances, the answers have to be found out for the following questions. (1) Was the death due to the natural disease for which the operation was being carried out, or was it due to the effects of the surgical procedure or anaesthetic? (2) Would the patient have died, without operation or anaesthetic? (3) Was the operation and anaesthetic essential to save the life of the patient? (4) Was there any defect in the surgical or anaesthetic technique? (5) Did the patient have any predisposing conditions, which made him susceptible to death from the operation or anaesthetic? (6) Was the death due to some natural condition entirely unrelated to the disease for which the operation was being performed and which was unsuspected at the time of operation? (7) Was the patient such a 'poor risk' that only the urgency of the clinical condition made the operation and anaesthetic necessary?

The examination of the operation site may be difficult due to the presence of haemorrhage, adhesions, oedema, sepsis and by surgical sutures and alteration of the anatomy by the surgical procedure. Sometimes, it becomes difficult to distinguish defects due to post-mortem changes from abnormalities present during life, e.g. a sutured stomach or intestine may appear to have broken down, but the defect may be due to post-mortem autolysis. Rarely, ligation of arteries and veins, ureters, bile ducts, perforation of large blood vessels and removal of vital organs or parts of organs may be found.

In most cases, there is no technical defect, and cause of death remains obscure after autopsy. A complete clinical history and consultation with the surgeon is necessary. Most of the operation and anaesthetic deaths are of physiological nature. The opinion must be based on exclusion and reasoning, for functional lapses like fall in blood pressure, cardiac arrhythmia, spasm of the glottis, vagal inhibition, etc. cannot be demonstrated. Pre-existing natural disease, especially heart disease and respiratory insufficiency due to lung disease may be the factors in causing death. In persons already shocked from trauma, haemorrhage, etc. the contribution of this condition must be evaluated.

CHAPTER 12
THERMAL DEATHS

Thermal deaths are those which result from the effects of systemic and/or localised exposure to excessive heat and cold.

COLD

Exposure to cold produces hypothermia which is defined as an oral or axillary temperature of less than 35°C. The body can tolerate dry cold much better than wet cold (immersion). Wetness increases heat loss considerably. The direct effects of cold are prominent in fatty tissue and myelinated nerve fibres. Indirect effects are mostly ischaemic, due to vascular damage. The ability of the hypothalamus to regulate temperature is completely lost below 30°C. Fat persons and women tolerate cold better, than lean persons and men.

Local Effects: The cold produces first a blanching and paleness of the skin, due to vascular spasm. It is followed by erythema, oedema and swelling due to the later vascular dilatation and paralysis and increased capillary permeability. Blister formation is the third more advanced stage which can involve skin, subcutaneous tissues, muscles and nerves. Either the tissues become frozen stiff, hard and necrotic by direct effect of cold, or the necrosis follows vascular occlusion, thrombosis, obliterating endarteritis, secondary inflammation and infection of the damaged tissue.

The localised effects of cold are frost-bite, trench foot and immersion foot. **Trench foot and immersion foot** are the result of prolonged exposure to severe cold (5 to 8°C) and dampness, such as typically seen in soldiers during winter warfare, especially in trenches and in persons exposed to prolonged immersion or exposure at sea. The extremities are affected in those conditions. Blister formation and localised dry gangrene occurs. **Frost-bite** is infarction of the peripheral digits with oedema, redness and later necrosis of the tissue beyond a line of inflammatory demarcation. It may affect only the skin or may extend deeply. It occurs due to exposure to greater extremes of cold (–2.5°C), develops more rapidly and in addition to the extremities, it frequently affects other parts, e.g., nose, ears and the face. In frost-bite, necrosis with blister formation and gangrene occurs. Skin becomes hard and black in about two weeks.

Fig. (12-1) Frostbite foot.

GENERAL EFFECTS : Ill-effects are manifested in three stages which merge imperceptibly, leading to death. In the first stage, the patient feels cold and shivers and the body temperature falls. In the second stage, shivering stops when the temperature is at or below 32°C. The victim is depressed, and with further cooling he becomes lethargic, drowsy and sleepy, which gradually passes into stupor and coma. The muscles stiffen and mobility is impaired. If he tries to walk, he may feel as if drunk. Respiration, circulation, metabolic and enzymatous processes and oxygenation of all cells are slowed down or blocked. In the third stage, the temperature is lowered to 27°C or even less, which if maintained for 24 hours or longer is fatal. Death results from the ultimate failure of the vital centres due to anoxia.

POST-MORTEM APPEARANCES: External: Pink or brown-pink areas with indistinct blurred margins, particularly over and around joints such as knees, elbows and hips is characteristic. Generalised oedema may be seen.

INTERNAL : The appearances are not characteristic. The subcutaneous tissues are relatively avascular. Ice crystals can be found in blood vessels, heart and interstitial tissue spaces. The blood is often of a bright red colour due to the retention of oxygen by haemoglobin at low temperatures. The stomach mucosa is studded with numerous brown-black acute erosions, similar to those seen in many types of pre-death stress. A variable degree of fat necrosis of the pancreas is the most constant finding.

Medico-legal Importance : Most deaths are the result of accidents, especially in drunkenness, mountaineering or persons lost in snow-drifts and those who have been immersed in ice cold waters. Infanticide and homicide in adults, where unconscious persons are left in freezing temperature are rare.

HIDE-AND-DIE SYNDROME: This may occur in

accidental hypothermia. The cause of the condition is not known. It may be due to long exposure to severe cold producing paralysis of the thermal regulatory mechanism. This results in failure of vasoconstriction of arterioles of the skin which results in a flow of blood from the core of the body, thus giving an exaggerated sensation of warmth. Terminal hallucinations occur. Because of the great discomfort, the person may undress himself. In such case, there may be suspicion of sexual offence.

This is a strange condition seen in hypothermia, particularly in old persons. In this persons take off some or all of their clothing (RECIPROCAL UNDRESSING OR PARADOXICAL UNDRESSING), and hide themselves in corners, in cupboard or under piles or furniture or household goods. More commonly a naked or partly clothed old person is found amid a scene of utter confusion with furniture pulled over and drawers and cupboards emptied out, but the disturbance is at a low level and the tops of tables etc. are not disturbed. This may lead to suspicion of crime. The signs of hypothermia are -usually found. The problem arises as to whether the victim became hypothermic first which lead to mental confusion causing strange behaviour, or whether due to some mental aberration, the person began behaving abnormally.

NEONATAL COLD INJURY : It results from a failure of the metabolism to prevent a fall in temperature in a body kept in an unsuitable cold environment. The symptoms appear usually in the first week of life. The rectal temperature is usually below 32°C. The children become increasingly lethargic and drowsy and refuse food. The outstanding feature is swelling of the extremities, with pitting oedema, particularly the hands and the feet, and the eyelids. Localised hardening of the skin and subcutaneous tissue overlying oedematous parts, starts in the distal part of the legs and spreads to involve the trunk. The face, hands and feet are red, which is a striking and constant finding. the heart rate is slow. Pulsation of peripheral arteries is absent. Respirations are shallow, slow and may be irregular. Infants lie still, though conscious. The skin is cold. The haemorrhagic tendency is manifested by gastrointestinal bleeding, petechial haemorrhages and oozing of blood from scratches and injection sites.

DIAGNOSIS : Massive pulmonary haemorrhage without evidence of infection, frothy blood-stained secretion in the nose or mouth, mild ascites and oedema and cyanosis of the extremities is suggestive. It may be mistaken for sclerema or haemorrhagic pneumonia.

Medico-legal Importance : It is a method of killing illegitimate and unwanted infants.

HEAT

Three clinical conditions may result from exposure to high environmental temperature: (1) heat cramps, (2) heat hyperpyrexia, and (3) heat prostration.

(1) HEAT CRAMPS: (miner's cramps, stoker's cramps or fireman's cramps): They are caused by a rapid dehydration of body through the loss of water and salt in the sweat. It is seen in workers in high temperature when sweating has been profuse. The onset is usually sudden. Severe and painful paroxysmal cramps affecting the muscles of the arms, legs and abdomen occur. The face is flushed, the pupils dilated and the patient complains of dizziness, tinnitus, headache and vomiting. Intravenous injection of saline gives rapid relief.

(2) HEAT PROSTRATION (heat exhaustion, heat syncope, or heat collapse): Heat prostration is a condition of collapse without increase in body temperature, which follows exposure to excessive heat. It is precipitated by muscular work and unsuitable clothing. There is extreme exhaustion and peripheral vascular collapse. The patient feels suddenly weak, giddy and sick. He may stagger or fall. The face is pale, the skin cold, the temperature subnormal. The pupils are dilated, the pulse small and thready and the respiration sighing. The patient usually recovers if placed at rest, but death may take place from heart failure.

(3) **Heat Hyperpyrexia or Heat Stroke** : Heat stroke is a condition characterised by rectal temperature greater than 41°C., and neurological disturbances, such as psychosis, delirium, stupor, coma and convulsions. The term **thermic fever** or **"sunstroke"** is used when there has been direct exposure to the sun. High temperature, increased humidity, minor infections, muscular activity and lack of acclimatisation are the principal factors in the initiation. Where there is 100% humidity, a temperature of 32°C in the environment may lead to heat stroke. Other factors are old age, pre-existing disease, alcoholism, use of major tranquilisers, obesity, lack of air movement and unsuitable clothing. Failure of cutaneous blood flow and sweating, the factors which control body temperature, leads to a breakdown of the heat regulating centre of the hypothalamus. **Heat stroke** occurs: (1) in young persons exposed to high temperature while undergoing severe exertion, and (2) in old persons usually over 60 years during heat waves.

CLINICAL FEATURES : The onset is usually sudden, with sudden collapse and loss of consciousness. In some cases, prodromal symptoms of headache, dizziness, nausea, vomiting, weakness, faintness, staggering gait, purposeless movements, mental confusion, muscle cramps, restlessness and excessive thirst occur. The temperature rises to 40°C to 43°C or more. The skin is dry, hot and flushed, with complete absence of sweating. The pupils are contracted. The pulse is rapid (usually more than 130 p.m.) and later becomes irregular. The breathing is rapid, (usually above 30 breaths p.m.) deep and of Kussmaul type. When temperature rises above 42°C. vasodilatation occurs with decrease in blood volume leading to circulatory collapse and cardiac failure. Blood pressure is low. Convulsions occur and the patient becomes delirious or comatose. The fatal period is five minutes to three days.

Post-mortem Appearances : They are not specific. The temperature remains high after death. **C.N.S:** The brain is congested and oedematous and petechial haemorrhages are seen in the white matter. Cerebral hemispheres are increased in weight and show flattening of the convolutions. Cellular changes with pyknotic nuclei, swollen dendrites, chromatolytic changes, degeneration of neurons and diffuse proliferation of microglia are seen. Changes occur in cerebellum rapidly which are more striking and consistent and consist of oedema of the Purkinje layer and swelling, disintegration and reduction of the Purkinje cells. If the person survives for 24 hours, complete degeneration of the Purkinje layer and gliosis are seen. Rarefaction of the granular layer occurs with prolonged survival. Hypothalamus shows oedema of the nuclei. **R.S.**: Trachea and bronchi contain frothy haemorrhagic fluid. The lungs show oedema, congestion and haemorrhages. **Heart** : Dilation of right auricle, flabbiness of muscle, petechial or confluent subepicardial and subendocardial haemorrhages and degeneration of myocardium. **Liver** : Congestion and centrilobular necrosis. **Kidneys** : Congestion, oedema and increase in weight. In case of longer survival, tubular necrosis and haemoglobinuric nephrosis is common. **Adrenals:** Pericapsular haemorrhages, engorgement of sinusoids and cortical degeneration. **General:** Petechial and confluent haemorrhages and disseminated intravascular coagulation are seen in most organs.

Hyperthermic anhydrosis or Desert Syndrome: There is dryness and erythema of face and excessive sweating below the level of neck, and papular rashes over face and neck. It was observed in U.S. soldiers having training in deserts.

BURNS

A burn is an injury which is caused by application of heat or chemical substances to the external or internal surfaces of the body, which causes destruction of tissues. Microscopically, the epithelial cells are elongated and flattened and stain more deeply with haemotoxylin. Small haemorrhages may be seen in the deepest layers of the skin. Vacuolisation in the epidermal and dermal layers is a characteristic feature. The minimum temperature for producing a burn is about 44° C for an exposure of about 5 to 6 hours. At 65°C, two seconds are sufficient to produce burns and full thickness destruction of skin occurs within seconds above 70°C.

Varieties of Burns : The external appearances of burns vary according to the nature of the substance used to produce them. (1) A highly **heated solid body** or a molten metal, when applied to the body for a very short time may produce only a blister and reddening corresponding in size and shape to the material used. It will cause destruction, or even charring of the parts, when kept in contact for some time. The epidermis may be found blackened, dry and wrinkled. The hair may be singed or distorted.

(2) Burns produced by **flame** may or may not produce vesication, but singeing of the hair and blackening of the skin are always present. Hair singed by the flame becomes curled, twisted, blackish, breaks off or is totally destroyed. Roasted patches of skin or deeper parts may be seen.

(3) Burns caused by **kerosene oil, petrol**, etc. are usually severe and produce sooty blackening of the parts and have a characteristic odour.

(4) Burns caused by **explosions** in coal mines or of gunpowder are usually very extensive and produce blackening and tattooing due to driving of the particles of the unexploded powder into the skin.

(5) Burns due to **X-ray and radium** vary from redness of the skin to dermatitis, with shedding of hair and epidermis and pigmentation of the surrounding skin. Severe exposure may produce burns with erythema, blistering or dermatitis, or ulceration with delayed healing and ill-formed scars. Fingernails may show degenerative changes and wart-like growths. Infra-red rays may cause necrosis of the skin.

(6) Burns caused by **ultraviolet rays** (the sun or mercury vapour lamp) produce erythema or acute eczematous dermatitis.

(7) **Radiant-heat burns** are caused by heat waves, a type of electromagnetic wave.

(8) **Microwave burns** are well-demarcated, full thickness burns.

(9) Burns from **corrosive substances** show ulcerated patches and are usually free from blisters; hair is not singed and the red line of demarcation is absent. They show distinct colouration and are usually uniform in character. Strong acids produce dark leathery burns upon the skin. Strong alkalis cause the skin to slough and leave moist, slimy, greyish areas. Hydrofluoric acid and bromine cause necrosis of the skin and tissues.

(10) **Electrical burns.**

Degree of Burns : Dupuytren divided burns into six degrees, but they were merged into three degrees by Wilson. The precise depth of a burn can be measured by a high frequency ultrasound device.

(1) Epidermal : (first and second degree Dupuytren). The affected part is erythematous (red). There is capillary dilatation and transudation of fluid into the tissues causing swelling. A split may occur in the epidermis or at the epidermal-dermal junction to form a blister (vesicle or bulla), which is covered by white, avascular epidermis, bordered by red, hyperaemic skin. Singeing of the hair is present. The blister contains gas and fluid containing protein. When epidermis is lost, the dermis becomes reddened, inflamed and exudes plasma and tissue fluid. These burns are very painful. Repair is complete without scar formation.

(2) Dermo-epidermal : (third and fourth degrees Dupuytren): Whole thickness of skin is destroyed with destruction of dermal appendages. The central zone of necrotic tissue is surrounded by first degree burns, or a zone of hyperaemia or both. These burns appear as shrivelled, depressed areas of coagulated tissue, bordered by reddish blistered skin. The lesions may be brown or black, due to charring and eschar formation. The necrotic tissue separates usually within a week, and leaves an ulcer which heals with scar formation. Contraction of the scar tissue may produce disfigurement or impaired function, according to the site and size of the burns. Pain and shock are greater than in first degree burns.

(3) Deep : (fifth and sixth degrees, Dupuytren):

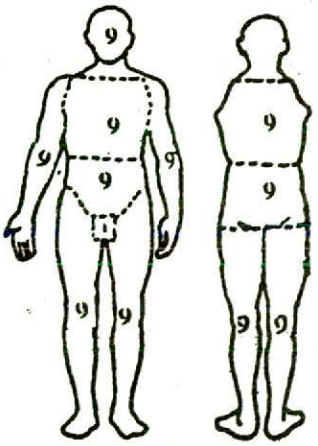

Fig. (12-1) Estimation of the extent of surface burns.

Table (12-2) Estimation of percentage of body surface area burned.

Area of Body	Infant	Child	Adult
Head and neck	20	15	09
Front of trunk	20	20	18
Back of trunk	20	20	18
Upper limb	20	20	18
Lower limb	20	25	36
Genitalia	0	0to1	1

In this, there is a gross destruction not only of the skin and subcutaneous tissue, but also of muscle and even bone. Nerve endings are also destroyed, and as such the burns are relatively painless. The appearances are similar to those of the second degree, but in a more severe form. The burnt part is completely charred.

Clinical classification (1) Superficial, when less than full thickness of skin is involved. (2) Deep.

Effects: The effects depend on: **(1) The degree of heat** : The effects are severe, if the heat applied is very great. The body of an adult does not burn completely in a burnt house, as the temperature usually does not exceed 650°C. For purpose of cremation, a human body has to be incinerated for one-and-half hours at 1000°C. The ashes weigh two to three kg., and contain bone fragments which can be identified as human. **(2) The duration of exposure :** The symptoms are more severe if the heat is applied for a long time. **(3) The extent of the surface :** The estimation of the surface area of the body involved is usually worked out by the **"rule of nine"**, (Wallace), 9% for the head and neck (head 7%, neck 2%); 9% for each upper limb; (arm 4%, forearm 3%, hand 2%), 9% for the

front of each lower limb; 9% for the back of each lower limb; (thigh 10%, leg 5%, foot 3% for each lower limb); 9% for the front of chest; 9% for the back of chest; 9% for the front of the abdomen; and 9% for the back of abdomen, 99% of the body. The remaining one percent is for the external genitalia (Fig.12-1). In child of less than 5 years: head and neck 15%, each lower limb 15%, and for the rest as in adult. Palmar surface of patient's hand is about one percent of body surface area. Involvement of 50 percent of the body surface will prove fatal even when the burns are only of the first degree. Skin surface is about 4.6 sq. metres in an adult. **(4) The site :** Burns of the head and neck, trunk or the anterior abdominal wall are more dangerous. **(5) Age :** Children are more susceptible, old people less. **(6) Sex :** Women are more susceptible.

Local effects of thermal injury include : vascular thrombosis and tissue necrosis, increase evaporation of water from burnt surface and local heat loss.

Causes of Death : (1) Primary (neurogenic) shock due to pain, etc. (2) More than half of deaths from burns occur within the first 48 hours usually from secondary shock, due to fluid loss from burned surface. (3) In smoke inhalation apart from CO, the other factors which contribute to death are oxygen deprivation, cyanide, free radicals (inactivate surfactants, thus preventing oxygen from crossing the alveoli into the blood), and non-specific toxic substances. (4) Toxaemia, due to absorption of various metabolites from the burnt tissue persists up to 3 to 4 days. (5) Sepsis is the most important factor in deaths occurring four to five days or longer after burning. (6) Biochemical disturbances, secondary to the fluid loss and destruction of tissue, e.g., hypokalaemia. (7) Acute renal failure, due to lower nephron nephrosis occurs on the third or fourth day. (8) Gastrointestinal disturbances, such as acute peptic ulceration, dilation of the stomach, haemorrhage into intestines. (9) Oedema of glottis and pulmonary oedema due to inhalation of smoke containing CO and CO_2, if the person dies in a burnt house. (10) Accident occurring in an attempt to escape from a burning house or by injuries due to falling masonry, timber or other structures on the body. (11) Pyaemia, gangrene, tetanus, etc. (12) Fat embolism is rare. (13) Pulmonary embolism from thrombosis of veins of the leg due to tissue damage and immobility. (14) Death may occur years after recovery from malignant transformation of a burn Sacar (Marjolin's ulcer).

In severe burns, respiratory distress may be due to oedema of upper air way, pulmonary oedema and inhibition of respiratory excursions by tight eschar. Delayed deaths in burns may occur from respiratory failure due to ARDS, or pulmonary embolism due to prolonged immobilisation.

Post-mortem Appearances :

External : Cotton fabrics ignite easier and burn faster than other types of fabrics. Nylon, polyester, and wool produce less severe burns. Close fitting garments tend to be safer than long, loose garments. The clothes should be removed and examined for the presence of smell of kerosene, petrol, etc. Any container found should be examined for finger prints. They should be put into airtight bottles or plastic bags and sent for chemical analysis. It is difficult to determine the time of death as body temperature, post-mortem hypostasis and rigor mortis cannot be assessed. The burnt areas will be found reddened and blistered or charred. Blisters may be present either in the main burn or as islands beyond the periphery. The whole of the burned area may form one large blister or be a confluence of blisters. The degree of burning in each area sould be assessed. Microscopically cutaneous erythema characterised by dilated capillaries, occasional necrotic epidermal cells, condensation of nuclear chromatin, swelling of epidermal cell nuclei and oedema of the subepidermal connective tissue is seen. Leucocytic infiltration may be seen after 6 to 8 hours, but may be delayed for 16 hours. Hair is singed, or completely burnt. In lesser degrees of burns, ends are bulbous at intervals. Heat rigor may be observed in the muscles. Portions of the body where clothing is tight, e.g., under the belt, shoes, brassier or buttoned collar are often comparatively unaffected. Sometimes, skin and hair in the armpits and the gums are spared. The colour of light hair changes on exposure to heat. At about 120°C for 10 to 15 minutes, brown hair becomes slightly reddish. There is no change in the colour of the black hair. The face is swollen and distorted. The tongue protrudes and may be burnt due to the contraction of the tissues of the neck and face. Froth may appear at the mouth and nose due to pulmonary oedema caused by heat irritation of the air-passages and lungs. In the hands, the skin detaches as glove, including the fingernails. By removal of the

superficial layers of the skin by wiping or rubbing, tattoo marks become visible. The blisters of a second degree burns cannot be distinguished from blisters seen in CO poisoning, deep coma, antemortem and post-mortem gasoline exposure and peeling of the skin seen in the early stages of putrefaction. When these various types of blisters burst, they leave a pale, moist, raw surface which becomes yellow, tan and finally dark brown and leathery as it dries.

Pugilistic Attitude (boxing, fencing or defence attitude): The posture of a body which has been exposed to great heat is often characteristic. The legs are flexed at the hips and knees, the arms are flexed at elbows and wrists and held out in front of the body, head slightly extended, all fingers are hooked like claws. Contraction of paraspinal muscles often causes a marked opisthotonus, in an attitude commonly adopted by boxers. This stiffening is due to the coagulation of proteins of the muscles and dehydration which cause contraction. The flexor muscles being bulkier than extensors contract more. It occurs whether the person was alive or dead at the time of burning.

Heat Ruptures: In severe burning or charring skin contracts and heat ruptures occur, either before or after death. They are produced by splitting of the soft parts. These splits may be anywhere, but are usually seen over extensor surfaces and joints. These ruptures or splits in the skin may be several centimetres in length, and superficially they may resemble lacerations or even incised wounds. They can be differentiated by: (1) Absence of bleeding in the wound and surrounding tissues, since heat coagulates the blood in the vessels. (2) Intact vessels and nerves are seen in the floor. (3) Irregular margins. (4) Absence of bruising or other signs of vital reaction in the margins. When the skin is completely burnt, the underlying muscle usually shows rupture due to heat.

Sometimes, the charred skin cracks easily when an attempt is made to remove the body from a house destroyed by fire. These tears are commonly seen around joints, especially the elbows, shoulders and knees.

Flash burns: Flash burns are a variant of flame burns. They occur due to sudden ignition or explosion of gases or fine particulate material, e.g. explosions, or ignition of highly inflammable liquids or gases, and produce a uniform first and second degree burns of all of the exposed areas of skin. If clothing is ignited, a combination of flash and flame burns occur. Pure cotton fabrics transmit more thermal energy to skin than polyester-cotton blend fabrics.

Human bodies burn readily, especially when the subcutaneous fatty tissues have ignited. Often, some parts of the body are preserved, if they are protected from the flames. In sitting persons, the buttocks may be spared; if the head falls forward between the knees, the abdomen is spared. The hands and feet may drop off if the burning is sudden and intense, and they may be preserved with slight damage because they fall away from the source of the fire. Flexion of the limbs by heat may cause tumbling of a burnt body from a bed or chair to the floor, if the body was not well balanced. Partial burning of the abdominal wall associated with gas expansion within the intestines may produce rupture of the abdominal wall, in the charred burnt victim. The intestines may protrude through this defect. Flame burns usually have a patchy distribution and vary in size and shape. Sometimes, the body may be covered with a black or brown layer of smoke which does not penetrate into skin creases. On straightening the flexed neck or limb, the paler skin in the crease is exposed which may mimic a ligature mark. In severe burns, the skin may be stiffened, yellow-brown and leathery. Drying after death leaves a stiff, parchment-like surface. Muscles under the burnt area are pale, brownish and part-cooked. This occurs after death due to heated environment. Black, brittle masses are found in the tissues merging into cooked dry muscle beneath. Burnt bone has a gray-white colour, often showing a fine superficial network of heat fractures on its cortical surface. The soft tissue of the face may be completely burnt exposing the skull. When considerable destruction of body occurs, it is difficult to differentiate antemortem from postmortem burns. The outer tables of the exposed cranial vault may show a network of fine criss-crossing heat fractures.Rarely the body cavities may be opened by partial destruction of their walls and hollow organs like stomach and intestines may rupture. If the flame is unchecked, the body will be reduced to a shapeless, coal-like mass and finally to heap of grey and yellow ashes.

Establishment of Identity: In a charred body, the weight and stature are unreliable, as they are greatly altered due to drying of the tissues, skeletal

Table (12–2). Difference between extradural haematoma due to burns and due to blunt force.

Trait	Epidural haematoma due to burns	Epidural haematoma due to blunt force
(1) Cause:	Charring of the skull due to intense heat.	Blunt force to the head.
(2) Situation :	Anywhere. Usually bilateral.	Usually adjacent to sylvian fissure.
(3) Distribution :	Diffuse.	Localised.
(4) Characters :	Thin, granular, soft, friable clot of light chacolate colour, honeycomb appearance: evenly distributed or sickle-shaped.	Discoid shape; localised, more rubbery consistency, reddish–purple.
(5) Skull :	May be fractured.	Associated fracture in temporal area.
(6) CNS :	No injury.	Frequently injured.
(7) Carboxyhaemoglobin:	Present.	Absent.

fractures, and pulverisation of intervertebral discs due to the heat. The stature may be less by several centimetres and weight loss may be up to sixty percent. The features are changed due to contractions of the skin. Moles, scars and tattoo marks are usually destroyed. In a badly charred body cheeks act as insulation and protect posterior teeth for a considerable time, but anterior teeth may be charred and friable. Enamel caps may separate. If a person is killed during the blaze, the teeth are extensively destroyed than when he was killed prior to fire, because the lips behave differently in the two cases. Wen a living person is burnt the teeth become loose in their sockets, whereas in a dead person the teeth are firmly attached. Dental charts should be prepared and X-rays of the jaws taken, which can be compared with previous charts of the suspected person. Post-mortem X-rays can be compared with the previous X-ray of the suspected person. Complete X-rays of the body of the victim are useful to locate possible old fractures, bony abnormalities or foreign bodies. DNA typing is very useful. In a badly charred or incinerated body, the sex can be determined by finding the uterus or prostate which resist fire to a marked degree, and by pelvic bones, and age by teeth and by observing centres of ossification in the bones and the condition of the epiphyses. If the whole body is destroyed, personal effects such as keys, watch, buttons, belt-buckle, cuff-links, etc., may help in identity.

Internal: Heat haematoma occurs when the head has been exposed to intense heat, sufficient to cause charring of the skull. It has the appearance of extradural haemorrhage, but is not accompanied by any signs of injury by blunt force. It consists of a soft, friable clot of light chacolate colour, and may be pink, if the blood contains CO. The clot has a honeycomb appearance. The thickness of the clot varies from one-and-half to fifteen mm., and the volume up to 120 ml (Fig.12-3). The adjacent brain shows hardening and discolouration from the heat. The distribution of the clot follows closely the distribution of the charring of the outer table of the skull. The parietotemporal region is the most common site of such haemorrhage. The mechanism of its development is obscure. It may be due to expansion of blood in the skull diploe and the intracranial venous sinuses, which rupture. The carboxyhaemoglobin level in heat haematoma will be the same as in peripheral blood. Heat haematoma will contain carboxyhaemoglobin, but extradural

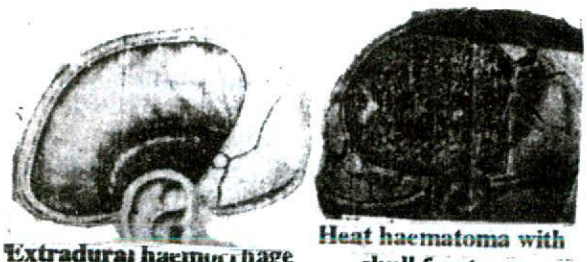

Fig. (12–3). Extradural haemorrhage and heat haematoma.

Fig. (12–4). Fractures in the skull due to burns.

haemorrhage caused by injury before the fire began, will not show carboxyhaemoglobin.

The skull fractures occur most commonly in areas where the skull has been severely burned. There are two types **of thermal fractures of the skull**. (1) Intracranial increase of steam pressure causes separation of ununited sutures or an intracranial explosion occurs, producing fractures with gaping defects and widely separated bony margins. (2) The fracture occurs due to rapid drying of the bone with contraction, and only involves the outer table of the skull. In this type there is no displacement, and the lines of fracture are frequently stellate. Skull fractures are usually seen on either side of the skull above the temples. They consist of several lines which radiate from a common centre and in some cases may fragment (Fig. 12-4). Heat fractures usually do not involve the sutures of the skull even in young persons with un-united sutures. Heat fracture may cross a suture line. Prolonged application of heat to the neck can make the hyoid bone so fragile that it breaks on gentle manipulation. In fire victims fractures of long bones are caused due to excessive shrinkage of the muscles, which exert unduly great pull on the tendons and bones. Peculiar, characteristically curved fractures are often seen in bones of extremities exposed to very high temperatures. Burnt bone has a grey-white colour, usually showing fine superficial network of heat fractures on its cortical surface, which may crumble on handling.

Even in cases of severe external charring, the internal organs are usually well preserved, as the tissues of the body are poor heat conductors. Sometimes, brain, liver, lung, etc. may be cooked, i.e., hardened and discoloured. In death due to burns, the CO levels in the blood will be more than ten percent and may reach 70 to 80%, though children and old persons die at levels of 30 to 40%. The blood is cherry-red, which may change to brownish due to heat. The level of CO saturation of the blood is dependent on concentration of CO in the inhaled air, the duration of exposure, the rate and depth of respiration, the haemoglobin content of the blood and the activity of the victim. CO may be absent in blood due to various reasons, such as rapid death, convection air currents, low production of CO, flash fire (as in the conflagration of a chemical plant), inhalation of superheated air resulting in death by suffocation, in warfare, or in an explosion when death is instantaneous. If death has occurred from suffocation, aspirated blackish coal particles are seen in the nose, mouth, larynx, trachea, bronchi, oesophagus and stomach and blood is cherry-red. Such particles are embedded in frothy mucus which covers the congested mucosa. The presence of carbon particles in the terminal bronchioles on histological examination is absolute proof of life during the fire. The soot is better seen by spreading a thin film of mucus on a clean sheet of white paper. The amount of soot in the air-passages depends on the type of fire, the amount of smoke produced and the duration of survival in the smoke-contaminated atmosphere. Presence of carbon particles and an elevated CO saturation together are absolute proof that the victim was alive when the fire occurred. If the mouth is open, some passive percolation of soot may be found at the back of the pharynx, but it cannot be carried beyond the vocal cords, and also it is not found in the lower oesophagus and the stomach. In absence of CO in blood and soot in the airways, death may result possibly due to poisoning with CO_2 and/or O_2 deficiency. Poisonous gases like cyanide and oxides of nitrogen are produced due to burning of plastic and synthetic material. Burning of nitrogen containing substances, e.g. nitrocellulose film may liberate nitrogen oxide and nitrogen tetroxide. Burning of wool or silk liberate ammonia, hydrogen cyanide, hydrogen sulphide and oxides of sulphur. All these gases contribute to death. Depending on the materials burning in the fire, various levels of cyanide are found in the blood, but the levels are usually less than 0.3 mg.%. Cyanide can be produced in significant concentration by decomposition of the body. If flame or superheated air is inhaled, burns are seen in the interior of the mouth, nasal passages, larynx and air-passages with destruction of vocal cord epithelium and acute oedema of the larynx and lungs. Death may occur rapidly by shock or acute respiratory insufficiency. The interior of the larynx, trachea and main bronchi may be thickened and blanched, or reddened. The mucosa of the air passages is shed into the lumen of the viscus, and smaller peripheral air passages are choked by a mass of desquamated epithelial cells, mucus and carbon particles. Sometimes inhalation of smoke produces vomiting which may be inhaled and found in the smaller bronchi. If the victim survives for a few days, inflammatory changes occur in the larynx,

with sloughing of mucosa, ulceration and secondary infection.

Haemoconcentration is present, and frequently there is some tissue oedema and excess of fluid in the serous cavities. The brain is usually shrunken, firm and yellow to light-brown due to cooking. The dura mater is leathery. The dura may split and the brain tissue may ooze out, forming a mass of frothy paste. The pleurae are congested or inflamed. The lungs are usually congested, and show marked oedema; they may be shrunken and rarely anaemic. The vessels of the lungs may contain a small amount of fat due to a physico-chemical alteration of fat already present in the blood. Visceral congestion is marked in many cases. Petechial haemorrhages are usually found in the pleurae, pericardium and endocardium. The heart is usually filled with clotted blood. There may be inflammation and ulceration of Peyer's patches and solitary glands in the intestines. Occasionally, ulcers are produced in the duodenum (Curling ulcers), in less than 10% cases, about the tenth day in extensive burns of the body. Curling's ulcers are usually sharply punched-out mucosal defects, which may be superficial or deep. Petechiae of stomach and duodenum, often with erosions, occasionally acute ulcers, is a more common finding. The gastric ulcers may occur within a day of burning. There may be bacterial or fungal colonies in the floors of the ulcers. Erosion of large vessels occasionally produce fatal haemorrhage. The large bowel may also be involved. The spleen is enlarged and softened with oedema and necrosis of lymphoid germinal centres. The liver may show cloudy swelling. Fatty liver or necrosis is not due to burns, but due to treatment with tannic acid. Jaundice may occur. The kidneys may show cloudy swelling, capillary thrombosis and infarction. Haeme casts in medullary tubules is common. The adrenals may be enlarged and congested. When more than 30% of the skin surface is burnt, haemoglobinuria occurs.

Laryngeal Oedema : It may be caused by allergic anaphylactic reactions, infections, tumours, inhalation of flame or superheated air, inhalation of irritant gases, etc. The amount of oedema will decrease with post-mortem interval and only wrinkling of mucous membrane may be present. Microscopically, eosinophils may be seen.

Blood should be obtained from the heart or major vessels and placed in a tightly stoppered container. It need not be collected or kept under oil. If blood is clotted, the clot should be preserved. Blood should be preserved by fluorides for analysis of cyanide.

Age of Burns : The ageing of the burns is very inaccurate and depends upon the agent, the extent, and their depth. Redness appears immediately, and vesication in about an hour. The blood vessels in the floor of the blister are dilated. Within 6 hours, inflammatory reaction with polymorphonuclear leucocyte infiltration occurs in the dermis. The epidermis may be coagulated, thinned and deeply staining.The cells in the deeper layers of the epidermis become elongated, with their long axes tending to be oriented more at right angles to the skin surface, closely resembling streaming of epithelial cells as in electric mark. The exudate begins to dry in 12 to 24 hours and forms a dry, brown crust within 2 to 3 days. The red inflammatory zone disappears in 36 to 72 hours, and pus may form under sloughs. Superficial sloughs fall off in four to six days, and deeper sloughs within two weeks. After this, granulation tissue covers the surface and a scar is formed after several weeks.

Untreated or non-healing wounds may lead to chronic ulceration which may undergo malignant transformation, socalled Marjolin's ulcer (squamous cell carcinoma).

Ante-mortem and Post-mortem Burns: In ante-mortem burns, a zone of hyperaemia (line of redness), which varies in width, but is usually five

Table (12–3). Difference between ante-mortem burns and post-mortem burns.

Trait	Ante-mortem burns	Post-mortem burns
(1) Line of redness :	Present.	Absent.
(2) Blister :	Contains serous fluid with proteins and chlorides. Base is red and inflamed .	Contains air and thin clear fluid. Base is dry, hard and yellow.
(3) Vital reaction :	Marked cellular exudation and reactive changes in the tissue cells present.	Absent.
(4) Enzymes :	Peripheral zone of burn shows increase in enzyme reaction.	Peripheral zone does not show increase in enzyme reaction.

to twenty mm. is present at the edge of the burnt area, except in cases of immediate death. It is due to oedema of tissues and capillary dilatation and merges with the edge of the burn which may show blistering or charring. It involves whole thickness of true skin. It is permanent and persists after death. Heat applied up to one hour after death can produce a red line of erythema. If the person is alive, the skin beyond this zone shows erythema, which tend to disappear after death. If the whole body is burnt, line of redness will be absent. The ante-mortem blister appears as a raised dome and contains gas or fluid. The base and periphery show reddening with swollen papillae. Post-mortem blisters are pale yellow, and the contained fluid is thin and clear. The base of the post-mortem blister is dry, hard and yellow. The protein content of serous fluid is not of much value to differentiate ante-mortem and post-mortem burns. Postmortem burns show dried scorching of the skin surface, like burnt paper. In ante-mortem burns, the skin adjacent to burnt area shows an increased reaction for SH groups in all layers, and increase in enzyme reaction. Acid mucopolysaccharides are present in the superficial zone of burnt area. In some cases deep burns may not show inflammatory reaction, due to heat thrombosis of dermal vessels. Burns produced shortly before or after death cannot be distinguished either by naked eye or by microscopic examination. Sometimes blisters with a red rim can be seen in postmortem burns due to contraction of dermal capillaries forcing liquid blood to the periphery of the burn or blister.

In antemortem burns leucocytic infiltration occurs at 6 hours, leucine aminopeptidase at 2 hours, acid phosphatase can be detected at 3 hours, and non-specific esterase at 3 to 4 hours.

CIRCUMSTANCES OF DEATH : The distribution of burns on the clothing may indicate the manner in which it was ignited, the posture of the victim at the time, the path taken by flames and to discover that unburnt cloth was saturated with some inflammable material. Splash patterns burnt into the floor and floor coverings, holes in the floor, particularly holes of the 'tongue and groove' type and the characteristic odour of petroleum fuels and solvents are all useful indicators of the use of inflammable material. Differentiation is mostly a matter for the police investigation . The inhalation of CO often causes severe muscular incoordination, weakness, and confusion due to which the victim is unable to escape and dies of asphyxia, the body being burnt after death.

ACCIDENT : Large number of deaths are accidental. Accidental burning deaths may occur inside the kitchen, in factories, house conflagrations, flaming of highly inflammable fuel, electrical short circuits, manufacture and playing with fireworks, leakage of cooking gas, etc. Infants, children, epileptics, intoxicated or drugged persons or helpless from other causes may fall into a fire. When an intoxicated person goes to bed smoking, and drops a lighted cigarette, he may die due to burns. Lamps or stoves may explode and set fire to the clothes. Clothes of women may catch fire accidentally while cooking. In such cases, burns are usually found on the front of thighs, abdomen, chest and face. There may be severe burning of the hands due to the victim trying to extinguish the fire by beating out the flames. The feet and ankles are usually not burnt. Multiple deaths from burns may result from plane crashes or automobile accidents. In industry, burns may be caused by explosions from inflammable liquids and by flashes from furnaces. If the body is lying on a flat surface, the skin resting on the surface may be well preserved, even though the body as a whole may be severely charred.

SUICIDE: Occasionally, women commit suicide by pouring kerosene on their head and clothes before setting fire to themselves due to domestic worries, disappointment in love or acute or chronic disease. Extensive second and third degree burns more concentrated on the front are seen over the whole of the body; only the skin folds, such as the axillae perineum and soles being spared. Sometimes, a person may keep a piece of cloth in her mouth to suppress her cries. Sometimes, suicidal burning is a mode of public protest. In case kerosene, petrol, etc. is found on the body including head hair in high amounts, it is likely to be either suicide or homicide.

HOMICIDE: Murder by burning is rare. If an inflammable fluid such as kerosene, petrol, etc., is poured on a person lying on his back and then burnt, there will be burning of the sides of the neck, sides of the trunk, between the thighs and other areas, especially if the clothing is absent in those areas, as the fluid runs downwards. Parts of the body which are in contact with ground do not show burning. Sometimes, fire, hot metals, boiling water and corrosive substances are used with criminal intent. A drunken man may push or throw his wife or child on the fire, and sometimes lighted lamps may be used as missiles. Burns may be inflicted on the pudenda of women as a punishment for adultery. Attempts may be made to burn a body after homicide with the object of concealing the crime. In such cases, the body should be examined for marks of violence, e.g., stab wounds,

bullets, strangulation, etc.

Cigarette burns are circular, but if the cigarette has been stubbed out on the skin, a larger and irregular burn is produced contaminated with ash and debris.

Self-inflicted Burns: Burns are sometimes self-inflicted in order to support a false charge.

SCALDS

A scald is an injury which results from the application of liquid above 60°C or from steam. The destruction does not extend as deeply as in burns. Water at 70°C can cause full thickness scalds of the skin in one second of contact. Redness appears at once and blistering will take place within a few minutes. If blistered skin is removed, it will leave a pink raw surface and later the exposed dermis becomes brownish, hard and dry. Scalds show soddening and bleaching but do not singe the hair, and do not blacken or char the skin. Superheated steam soddens the skin which becomes dirty white colour.

Degrees of Scalds: (1) Erythema by vasoparalysis. (2) Blister formation due to increased permeability of the capillaries. (3) Necrosis of the dermis.

The injury is limited to the area of contact and is more severe at the point of the initial contact. Scalding can occur through clothing. Scalded areas are usually large, but may be small if caused by splashing. Streaks of liquid run downwards from the main area causing lines of blisters. Sticky liquids, such as syrup, oils and tar cause more severe scalds than hot water. There is usually a sharply demarcated edge, corresponding to the limits of contact of the fluid. The scalded skin may swell and exude serum. Scars of scalds are much thinner than those of deep burns and cause less contraction and disfigurement.

Blisters have an hyperaemic zone around them. There is a reddening and swelling of the papillae in the floor of the blister. The blister fluid contains white and red cells. A post-mortem blister does not show hyperaemia in the surrounding area and the floor is not red. If inflammable fluids are used, signs of trickling of the burning fluid will be present on some parts of the body, e.g. if kerosene is splashed on a body lying on its back and then ignited, runs of burning liquid will be seen on the sides of the neck, sides of the trunk, between the thighs, etc. Inhalation of steam may cause thermal injury of the respiratory tract, producing death by asphyxia due to obstruction to airway by the oedematous mucous membrane. Death usually occurs from shock, fluid and electrolyte disturbance and secondary infection.

OCCURRENCE: Scalds are usually accidental due to bursting of hot water bottles, bursting of boilers, splashing of fluid from cooking utensils, or pulling over saucepans or kettles by children, etc. Occasionally, children suck the spouts of kettles, which causes severe steam scalds of the mouth and air-passages with oedema of the glottis. Suicide by scalding is rare.

Table (12–4) Difference between burns from dry heat, moist heat and chemicals.

Trait	Dry heat	Moist heat	Chemicals
(1) Cause	: Flame, heated solid body, or X-rays.	Steam or liquid above 60°C.	Corrosive chemicals.
(2) Site	: At and above the site of contact.	At and below the site of contact.	At and below thesite of contact.
(3) Splashing	: Absent.	Present.	Present.
(4) Skin	: Dry and wrinkled, may be charred.	Sodden and bleached.	May be destroyed.
(5) Vesicles	: At the circumference of burnt area.	Over the burnt area.	Very rare.
(6) Red line	: Present.	Present.	Absent.
(7) Colour	: Black.	Bleached.	Distinctive.
(8) Charring	: Present.	Absent.	May be present.
(9) Singeing	: Present.	Absent.	Absent.
(10) Ulceration	: Absent.	Absent.	Present.
(11) Scar	: Thick and contracted.	Thin and less contracted.	Thick and contracted.
(12) Clothes	: Burnt.	Wet;not burnt.	May be burnt; show characteristic stains.

Boiling water may be thrown with intent to injure. Murder by scalding is rare.

Spontaneous Combustion: Spontaneous combustion of the human body does not occur. A body can never be consumed without the application of fire or flame and it cannot be reduced to ashes without the surrounding objects being set on fire.

PRETERNATURAL COMBUSTION: This is very rare. During putrefaction, inflammable gases are produced in abdomen due to the action of microorganisms upon organic matter. These gases are ignited if a flame is nearby, and cause partial burning of the neighbouring soft tissues, but complete combustion of the body does not take place. It is not a valid scientific phenomenon.

It appears that when a person collapses and falls, and part of the body comes in contact with a source of heat, that part is ignited, and adjacent body fat melts and soaks into clothes. The clothing acts as a wick, melts the next zone of adjacent fat, and the process is repeated along the length of the body, till the lower legs are reached. As the lower legs contain less fat and also covered with less layers of the clothes, the burning stops.

During life, inflammable gases, such as hydrogen, hydrogen sulphide and methane may be formed in the alimentary tract. Such gases when belched or let off from the anus, may be ignited on the application of a flame and cause a burn at the site.

ELECTRICAL INJURIES

The injuries caused by contact with electrical conductors depends upon: (1) THE KIND OF CURRENT: Alternating current is 4 to 5 times as dangerous as an equal voltage of direct current. An alternating current is one that reverses its direction at regular intervals. In direct current, current flows in the same direction. (2) THE AMOUNT OF CURRENT: The amount of current that will flow through or over the body may be determined by the formula CV/R, where C is the current in volts and R is the resistance of the body in ohms. The flow of the current through the body is great, if the voltage is high (more than 1000 volts) or if the resistance is low. Electrocution is rare at less than 100 volts, and most deaths occur at more than 200 volts. In India, the voltage of domestic supply is usually 220 to 240 volts, alternating current with 50 cycles per second. Currents of 10mA cause pain and muscle contractions, over 60 mA are dangerous, and 100 mA is fatal. High voltages (more than thousand volts) may cause the victim to be thrown clear, while lower tensions, around 240, cause muscle contraction, due to which the victim holds on to the source of the current. (3) THE PATH OF THE CURRENT: Death is more likely to occur if the brain stem or heart are in the direct path of the current. (4) DURATION OF THE CURRENT FLOW: The severity is directly proportional to the duration of current flow. For an electric shock to occur there must be contact by the body with both a positive and negative pole, or alternatively, the 'earth'. The earth may be any object not insulated from the ground. When earthing of the body is poor, as with dry and rubber shoes, carpets, wooden floors and upstair premises, fatal electrocution is uncommon. The effects of electricity depends on the voltage and the resistance offered by the body. If the body is well insulated, it does not conduct the current and no harm results. Dry skin offers high resistance but the resistance is diminished when the skin is moist or covered with sweat. Blood has a low resistance, and as such within the body, electricity tends to be conducted along blood vessels. Predisposing factors are unexpectedness of shock, anxiety, fear and emotions, exhaustion, cardiovascular and other diseases.

Local Effects : The current passes through the skin producing heat, which causes boiling and electrolysis of tissue fluids. The skin explodes and rolls back from the surface. A well-moistened skin may not show electrical burn, while a thick dry skin may show well-marked electrical burn.

The electric mark (Joule burn): It is specific and diagnostic of contact with electricity and is found at the point of entry of the current. It is endogenous thermal burn due to the heat generated in the body from electricity. These marks are round

Fig. (12–5). Electric mark on the finger.

or oval, shallow craters, one to three cm. in diameter, and have a ridge of skin of about one to three mm. high, around part or the whole of their circumference. The crater floor is lined by pale flattened skin. In some marks, the skin may break within or near the margin of the crater, resembling that of a broken blister. The skin of the mark is pale, but there may be mild hyperaemia of the adjacent intact skin, due to rapid dilatation of pre-capillary vessels (Fig. 12-5). When contact is more prolonged, the skin in the mark becomes brown and with further contact, there may be charring. If the conductor contains copper, the electric mark can have a bright green colour. Occasionally, the mark may have a distinctive pattern, that of the shape of the conductor. An areola of blanched skin is seen at the periphery of the electric mark, which survives death and is pathognomonic of electrical damage. Often there is hyperaemic border outside the blanching. Occassionally, an alternating spectrum of blister-reddening-pallor-reddening is seen Rarely, the mark may be present as a circular hole, penetrating skin, muscle, and even bone, so as to simulate a bullet wound. These electric marks are produced by the conversion of electricity into heat within the tissues. They are commonly found on exposed parts of the body, especially on the palmar aspect of the hands. Histological examination of the electric mark usually shows coagulation of the dermis, with separation of the epidermis in some areas, and in other areas the cells become elongated and arranged in parallel rows at an acute angle, or almost at right angles to the dermis.

(2) Flash or Spark Burns : The intense heat which may result from flash-over produces burns, which resemble thermal burns (exogenous burns). In spark burn, there is an air gap between metal and skin. Here a central nodule of fused keratin, brown or yellow in colour is surrounded by the typical areola of pale skin. The burns may be as small as pinpoints, or deeply seated and contracted if contact is prolonged or very high voltage is applied. If the area of contact is relatively large, e.g. when a hot wire is grasped with a wet hand, or when a person is electrocuted in bath tub, death may occur without any visible skin burning.Burns may also be absent when the area of contact is small in low-voltage electrocutions. Brief contact with a live wire, may not produce burns. In this case, the person may collapse from ventricular fibrillation and fall away from the wire. High voltage burns may be very severe with charring of the body. Multiple individual and confluent areas of third degree burns are seen. 1000 volts will jump several mm and 100 kilovolts about 35 cm. Very high voltage currents produce massive destruction of tissue with loss of extremities and rupture of organs. When bone is involved, periosteum may be elevated or superficial layers of the bone may be destroyed or fracture may occur. Sometimes, multiple lesions are found in the region of flexures of a limb where the current has passed across the joints, instead of passing around it. High tension electrical currents may produce multiple, small, discrete, pitted burns due to arcing from the conductor to the body without direct contact. High amperage has an explosive effect and may produce injuries resembling bullet, stab or incised wounds. Multiple burnt or punched-out lesions are produced due to the arc dancing over the body surface over large areas which present **'crocodile flash burns'**. Flash-over often produce **'arc eye'.** There can be blast effect from very high voltage discharges.

(3) Electric burns or splits : The splits are dry, hard, firm, charred, insensitive, with ragged edges, and their form is round, oval, linear, or of irregular shape. The depth of the lesion is much greater than appears on the surface. Shedding of the superficial layers of the skin is common, and some of this may be found attached to the conductor. Wrinkling of the skin may be found and occasionally localised oedema of a limb. Aseptic necrosis develops, which often extends beyond the burns in area and depth and may lead to sloughing.

Microblisters develop within the squamous epithelium and in the external horny layer, due to the cooking effect on the tissues. They represent defects through which the steam exited. Larger vacuoles are produced within the epidermal cells, the nuclei of which are fusiform, hyperchromatic and show a peculiar distortion with stretching and narrowing of the contour and produce palisade-type appearance. This change is called **streaming of the nuclei.** These flattened cells usually stain darker than the normal cells with haemotoxylin and eosin. The nuclei of the vascular media tend to be twisted to resemble spirals, which may be seen at distant points from the site of contact with the electrode. There may be localised degeneration of the intima. Tearing of elastic fibres and the overlying intima is common and may cause secondary thrombosis.

Fig. (12–6). Electrocution during working on a pole for repairs.

Exit Marks : These are variable in appearance, but they have some of the features of entrance marks. There may be more damage of tissues, and they are often seen as splits in the skin at points where the skin has been raised into ridges by the passage of current; splitting of these ridges may be continuous or interrupted.

Antemortem electric burns cannot be distinguished from postmortem burns.

Post-mortem Appearances : External : The examination of the scene may be much more important than the post-mortem of the body. The face is pale, the eyes are congested and the pupils dilated. Rigor mortis appears early, and post-mortem lividity is well developed. In about 50 to 60% cases there are external marks of electric burning, and contusion or laceration at the point of entrance and exit of the body. In some cases, the lesions may extend through subcutaneous tissues and involve muscles and bone. A number of greyish-white circular spots, which are firm to the touch and free from zone of inflammation may be found at the site of entrance and exit. Severe convulsions caused by electrical discharge may cause fractures of the spine or limbs. Extensive ecchymosis may be found on the skin of the trunk. In some cases, external lesions may be absent and frequently they are so slight as to require careful search. The clothing, including shoes, gloves and headgear should be examined for burns. Occasionally, only the hair is singed. Arcing of the current may produce characteristic pit-like defects on the surface of the hair. Any metallic objects on the body will produce corresponding burns on the skin because it becomes heated by the passage of the current. This metallisation is due to the volatilisation of the metal, particles of which are driven into the skin. Current marks may be hidden inside the oral cavity, from putting live wires into the mouth or from drinking at a water fountain in contact with electric current. They may be found in the urethra due to urination on a high tension wire. In some cases, the entrance and exit marks cannot be determined grossly. Occasionally, the site of entrance may be determined by histochemical methods or by electron microscopy from the deposition of metal particles on the skin. Differentiation between antermortem and postmortem electrical burns is not possible.

Internal : The appearances are usually those of asphyxia. The lungs are congested and oedematous, and the brain, meninges and parenchymatous organs are congested. Petechial haemorrhages may be found along the line of the passage of the current, under the endocardium, pericardium, pleura, brain and the spinal cord. There may be necrosis of the intima, or of the complete wall of the blood vessels. Vascular thromboses may be seen in the vicinity of electrical burns. Skeletal muscle in the path of the current may show Zenker's degeneration. High amperage has an explosive effect and may produce injuries resembling bullet, stab or cut wounds. Small balls of molten metal, derived from the metal of the contacting electrode, so-called **current pearls**, may be carried deep into the tissues. Heat generated by the current may melt the calcium phosphate, which is seen radiologically as typical round density foci **('bone pearls' or "wax drippings")**. There may be bone necrosis, and zigzag microfractures. Focal petechial haemorrhages are found in the brain and spinal cord. In some cases, irregular tears and fissures in the brain tissue and rupture of walls of arteries are seen. A foetus may survive the electrocuted mother or a surviving mother may abort after electric injury. Occasionally, no lesions can be found either externally or internally. Death in these cases may be due to vagal stimulation.

TREATMENT : If the person is in contact with the source of electricity, he should not be pulled with bare hands, but the current should be switched off or

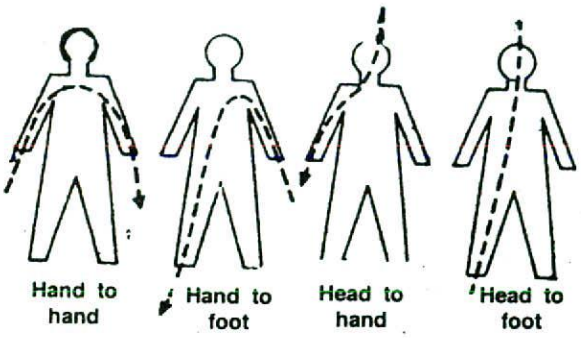

Fig. (12–7). Paths of current.

the victim moved by a stick or the hands should be wrapped in dry cloth or newspaper, or rubber gloves worn. Artificial respiration and closed chest cardiac massage are the principal forms of treatment.

Cause of Death : Circuits from any of the limbs to the head involve the brain stem and upper cervical cord. Arm-to-arm circuit may also involve the upper cervical cord. In these cases, death probably occurs from paralysis of medullary (respiratory) centres. Arm-to-arm or left arm to either leg circuits involve the heart and death occurs either from ventricular fibrillation or cardiac arrest without fibrillation. Death need not be instantaneous. Individuals may be able to walk some distance and talk before the onset of collapse and death. If current is low, but contact time is great (minutes) death occurs by muscle paralysis with secondary asphyxia. Death in high voltage is due to respiratory arrest or electrodermal injuries.

In delayed deaths, unconsciousness occurs, often accompanied by signs of circulatory and respiratory failure. Death may occur after a few days from infection, or from haemorrhage due to damage to blood vessels.

MEDICO-LEGAL ASPECTS : Death by electric currents are usually accidental from defective electric appliances or negligence in the use of equipment, flying kites and short-circuit. Erection of electrified wires to protect property or to attach a live wire to door knobs, gates, railings, etc. against thieves may cause death of intruder. In industry, deaths may result from contact with live overhead cables or from handling of charged lamps, tools or switch gears. Rarely, death may occur during convulsive therapy to mental patients but cases of suicide, and even homicide have occurred. The viscera should be analysed to know whether the victim was impaired at the time of the accident. Suicide is rare. A person usually winds wires round his fingers or wrists, which are then connected to the mains supply by means of a plug and the current is switched on.

Judicial Electrocution : Death penalty is carried out in the electric chair in some states in the U.S.A. The condemned man is strapped to a wooden chair and one cap-like electrode is put on the shaven scalp which is moistened with a conducting paste and the other on the right lower leg, and a current of 2,000 volts and 7 amperes is passed for one minute through the body. After tetanic spasm and loss of consciousness, the same current is passed through the body a second time for one minute. Third degree burns are produced at the site of contact between the electrodes and skin. The brain is heated up to 60°C. and vacuolation occurs around the vessels.

LIGHTNING STROKE

A flash or bolt of lightning is due to an electrical discharge from a cloud to the earth. The electric current is direct with a potential of 1,000 million volts or more. Along the track of the current much energy is liberated, most of which is converted into light. It is attracted by the highest points. It passes normally along the outside of a conductor, and as such, persons in buildings are relatively safe from electrocution. Dry skin and dry clothes are bad conductors, whereas wet skin and wet clothes are good conductors. Lightning or atmospheric electricity differs from ordinary electric current only in degree. A lightning bolt may injure or kill a person by a direct strike, a side-flash, or conduction through another object. In a direct strike or a side-flash strike, the current can spread over the surface of the body, enter it or follow both routes. In a side-flash strike, the flash of lightning hits an object, e.g. a tree, and jumping from it, strikes the person. Rarely a person may be injured while indoors, while in the shower or bathtub, the current travelling along water pipes, or while using the telephone.

POST-MORTEM APPEARANCES : Four factors are involved : (1) Direct effect from electric discharge passing to earth. (2) Surface 'flash' burns from the discharge. (3) Mechanical effect due to force of displaced air around the flash by heat expansion, and (4) Compression effect due to air movement in its return wave.

The clothes are usually burnt or torn at the point of entrance and exit. In some cases, the clothes may be stripped off the body and thrown to some distance. In exceptional cases, clothing is not damaged even though the person is killed by lightning. Conversely, clothing may be burnt without any injury to the person. The expanded, displaced air causes disruptive or blast-like lesions, e.g.,

contusions, lacerations, fractures, ruptures of organs, wounds of almost any variety, burns, etc. Rigor mortis may appear soon and pass off quickly. Intense oedema of the skin develops at points of entry of current in those who survive, probably due to paralysis of local capillary and lymphatic vessels.

The burns may be : (1) Linear : These vary from 3 to 30 cm. or more in length, and 0.3 to 2.5 cm. in width. They are often found in the moist creases and folds of the skin.

(2) Arborescent or Filigree Burns: (Lichtenberg's flowers) : They are superficial, thin, irregular and tortuous markings on the skin. These markings have a general pattern resembling the branches of a tree. This fern-like pattern of erythema in the skin is usually found over the shoulders or the flanks. It is not certain whether it is instananeous, or it develops within few minutes after death. It is not associated with burning. It does not correspond with vascular channels. It may be caused due to the slight staining of the tissues by haemoglobin from lysed red blood cells along the path of the electric current. They are also said to be due to minute depositions of copper in the dermis or from boiling of the intercellular fluid following the fascial planes. They indicate the paths taken by the discharge and disappear in one to two days if the person survives. These marks are seen rarely.

Red streaks following skin creases or sweat-damped tracks are more likely.

(3) Surface Burns : They are true burns and occur beneath metallic objects worn or carried by the person, which are fused by the flash.

Internal findings are those of asphyxia.

Cause of Death : Involvement of the central nervous system with paralysis of the heart or of the respiratory centre or electrothermal injuries cause death.

Medico-legal Importance : Less than half of the persons struck by lightning are killed. Death is always due to accident. Sometimes, the appearances left on the human body closely resemble those produced by criminal violence. Thus a person may be found dead in an open field or on the highway and body may show contusions, lacerations and fractures. In such cases, the diagnosis should be based on the history of a thunderstorm in the locality, evidence of effects of lightning in the vicinity of the body, and fusion or magnetisation of metallic substances.

CHAPTER 13
STARVATION

Starvation may occur from the actual withholding of food or from the administration of unsuitable food. It is of two types: (1) Acute, and (2) Chronic. Acute starvation results from sudden and complete stoppage of food. Chronic starvation results from gradual deficient supply of food. Starvation deaths may be due to (1) famine, (2) being trapped in pits, mines or landslides, (3) neglect on the part of the parents or guardians, (4) wilful withholding of food, and (5) wilful refusal to take food.

Symptoms : In acute starvation, there is a feeling of hunger for the first 30 to 48 hours, which is followed by pain in the epigastrium which is relieved by pressure. After four to five days of starvation, general emaciation and absorption of the subcutaneous fat begins to occur. The eyes are sunken and glistening; the pupils are dilated; the cheeks sink and the bony prominences become visible. The lips are dry and cracked, and the tongue coated and dirty, and thirst is intolerable. The saliva is thick and scanty. The voice is weak and whispering. The skin is dry, rough, thin, inelastic, wrinkled and pigmented. Emaciation may be extreme, the abdomen concave and limbs become thin and flaccid with loss of muscular power. Muscular weakness is progressive and may be severe. Cardiovascular changes are those of progressive insufficiency. The pulse is slow at rest, but on exertion paroxysmal tachycardia supervenes. The temperature is subnormal. Constipation is usual, but towards death diarrhoea and dysentery are common. The urine is scanty, turbid, and highly concentrated and shows evidence of acidosis.The loss of weight is most marked and constant. In the last stage, the body is reduced to an extreme state of emaciation. The ribs are prominent, with concavities in the intercostal spaces and sunken supraclavicular fossae. Before death the body has an offensive odour. Usually, the loss of 40 percent of body weight is fatal. The intellect remains clear till death, though in some cases delusions and hallucinations of sight and hearing occur.

Fig. (13–1) Starvation.

As starvation continues, at first rapid mobilisation of protein stores occur which are converted by the liver to glucose, which is mainly used to supply energy to the brain. This is followed by a reduction in the utilisation of proteins. As complete depletion of fat stores approaches, protein is again rapidly used as a source of energy.

Chronic Starvation : The changes are constant and develop in a constant order. (1) Loss of well-being, hunger and hunger-pains. (2) Mental and physical lethargy and easy fatigue. (3) Progressive loss of weight which is rapid in the first six months. (4) Polyuria. (5) Increasing cachexia, the body weight is reduced by about 40% of the normal. Pigmentation and anaemia. (6) Hypothermia, peripheral vascular stasis in cold and hypotension. (7) Extreme lethargy, gross mental retardation and loss of self-respect. (8) Oedema, first in the feet and lower limbs. (9) Reduced resistance to infection causing diarrhoea, dysentery, tuberculosis, etc.

The blood sugar, chlorides and cholesterol are lowered. Non-protein nitrogen is raised.

Cause of Death : Death occurs from exhaustion, circulatory failure due to brown atrophy of the heart, or intercurrent infection. Dehydration and hypothermia contribute to death.

Fatal Period : If both water and food are completely withdrawn death occurs in 10 to 12 days. If food alone is withdrawn death occurs in 6 to 8 weeks or even more. Death usually occurs when about 70 to 90% of body fat, and 20% of body protein are lost. Newborns may survive for 7 to 10 days without food or water.

Factors Influencing the Fatal Period :

(1) **Age :** The very young and the old suffer the worst.

(2) **Sex :** Females withstand starvation for a longer period.

(3) **Condition of the body :** Fatty, healthy people stand starvation better.

(4) **Temperature :** Exposure to cold or excessive heat hastens death.

(5) **Physical exertion :** Active physical exertion hastens death.

Post-mortem Appearances : All organs and tissues show changes similar to premature senility. There is extreme emaciation and general reduction in size and weight of all the organs except the brain, which is sometimes pale and soft. Muscles are atrophied and darker due to increase in lipochrome. The fibres lose striations and become more uniform from granular degeneration. Fat is almost completely absent in the subcutaneous tissues and also in the omentum, mesentery and about the internal organs, which is never seen in wasting disease. The fat of the female breast and of the orbit is spared till late. Subepicardial fat becomes replaced by a watery gelatinous material. In acute starvation, subcutaneous body fat is not lost completely. In children, the skeleton shows spinal curvature, rickets and dental defects. In adults progressive demineralisation and osteomalacia are seen. Stress fractures may occur. The face is pale, the skin inelastic and pigmented. Sometimes, follicular hyperkeratosis develops. Subcutaneous patches of oedema are seen around the ankles, inside the thighs, under the chin, cheeks and eyelids. Ascites is present in ten percent of cases. Trophic skin changes are common. The hair is dry, lustreless and brittle, and nails are also brittle. The heart is small from brown atrophy and the chambers are empty. The lungs are pale and collapsed, and exude very little blood when cut. Rarely, there may be oedema and hypostatic basal congestion. The stomach and intestines show atrophy of all coats and the mucosa is stained with bile. The walls of intestine appear like tissue paper with atrophy of mucosa. The bowel contains offensive watery fluid and gas. There may be superficial but extensive non-specific ulceration of the bowel like those seen in ulcerative colitis. The liver is atrophied and may show necrosis due to protein deficiency. Spleen is shrunken. The gall bladder is distended with bile. The kidneys show atrophy of the nephron. Blood volume is markedly reduced, and there is marked anaemia. The urinary bladder is empty. There may be evidence of some intercurrent disease.

Medico-legal Aspects : The exclusion of disease likely to cause loss of weight, e.g., malignant disease, progressive muscular atrophy, Addison's disease, diabetes mellitus, tuberculosis, pernicious anaemia, chronic diarrhoea is essential. Sometimes, it may be impossible to determine whether it was the cause or effect of malnutrition, e.g. tuberculosis. If marked loss of weight and especially the absence of fat are found at autopsy, and there is no evidence of disease, a diagnosis of death due to starvation can be made.

Right to life as guaranteed under article 21 of the Constitution of India does not include the right to die, and as such arrest and forcible feeding of persons going on hunger strike is lawful.

Loss of weight and acidosis with ketone bodies in urine are the criteria to advise forced feeding.

SUICIDE : Sometimes, persons fast voluntarily, for the purpose of exhibition. Lunatics and hysterical women may refuse food. Fasting may be undertaken by persons to attract public attention, e.g., fast unto death, for rectification of grievances.

HOMICIDE : The victim is usually an infant, or any other person, e.g., aged or feeble-minded are starved with evil intention. Illegitimate children are frequently starved to death.

ACCIDENT : Accidental starvation may occur during famine, being trapped in pits or mines, landslides, shipwreck, etc. It may be due to ignorance which leads to a failure to provide enough food or to provide food of the right kind. It may also occur in stricture or cancer of the oesophagus or ankylosis of jaw. Signs of neglect and emaciation may be seen in drug addicts, where the desire for the drug is more than the desire for food.

Either due to psychiatric causes, usually of a paranoid schizophrenic nature or due to senile dementia, some persons, usually old, refuse to spend money on food, clothes, etc.

CHAPTER 14
MECHANICAL ASPHYXIA

HANGING

Hanging (self-suspension) is that form of asphyxia which is caused by suspension of the body by a ligature which encircles the neck, the constricting force being the weight of the body. The whole weight of the body is not necessary, and only a comparatively slight force is enough to produce death. In **'partial hanging'** the bodies are partially suspended, the toes or feet touching the ground, or are in a sitting, kneeling, lying down, prone or any other posture, with only the head and chest off the ground. The weight of the head (5 to 6 kg) acts as the constricting force. In **typical hanging**, the ligature runs from the midline above the thyroid cartilage symmetrically upward on both sides of the neck to the occipital region.

Ligature : A suicide will use any article readily available for the purpose, like a rope, metallic chains and wires, leather strap, belt, bed sheet, scarf, *dhotie, saree, turban, sacred thread*, etc. The doctor should note whether the mark on the neck corresponds with the material alleged to have been used in hanging, and if it is strong enough to bear the weight and the jerk of the body. He should also note its texture and length, to know whether it was sufficient to hang. Before removing the ligature from the neck, it should be described as to the nature and composition, width, mode of application, location and type of knot. Sometimes, the rope will break or become detached and the deceased will be found lying on the ground with a ligature around his neck.

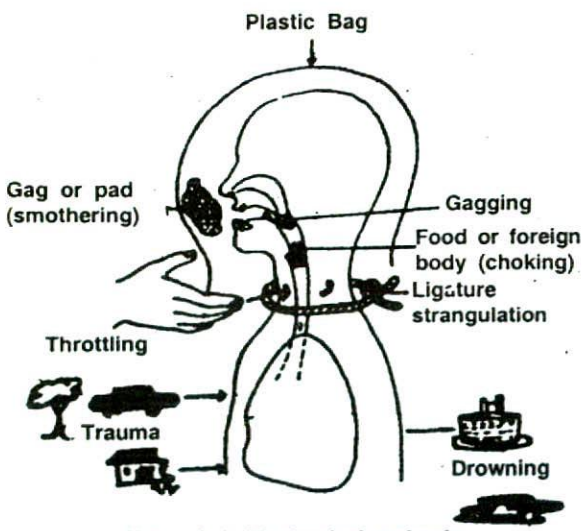

Fig. (14–1) Mechanical asphyxia.

SYMPTOMS : The first symptoms are loss of power and subjective sensations, such as flashes of light and ringing and hissing noises in the ears. There is intense mental confusion, all power of logical thought is lost; the individual can do nothing to help himself even if it were possible. These are followed by loss of consciousness (within 15 seconds when a thin rope is used), and as such it is regarded as a painless form of death. Then follows a stage of convulsions. The face is distorted and livid, eyes prominent, and there is violent struggling. Respiration stops before the heart, which may continue to beat for about 10 to 15 minutes.

Cause of Death : (1) **Asphyxia :** The constricting force of the ligature causes compressive narrowing of laryngeal and tracheal lumina, and forces up the root of the tongue against the posterior wall of the pharynx, and folds the epiglottis over the entrance of the larynx to block the airway. If entry of air into the lungs is completely prevented, death occurs rapidly with marked asphyxial signs. A tension of 15 kg. on ligature blocks the trachea. (2) **Venous congestion** : The jugular veins are blocked by the compression of the ligature which results in stoppage of the cerebral circulation, and a rapid rise in venous pressure in the head and unconsciousness. This occurs if ligature is made up of broad and soft material, which cannot sink into tissue to any depth. The jugular veins are closed by a tension in the rope of 2 kg. (3) **Combined asphyxia and venous congestion** : This is the commonest cause. (4) **Cerebral anaemia**: Pressure on the large arteries on the neck produces cerebral anaemia and immediate coma (10 to 15 seconds). Death will be slow and asphyxial features are less marked. This occurs with ligature made of thin cord, which sinks deeply into tissues. A tension of 4 to 5 kg. on ligature blocks carotid arteries, and 20 kg. the vertebral arteries. (5) **Reflex vagal inhibition** from pressure on the vagal sheath or carotid bodies. (6) **Fracture or dislocation of the cervical vertebrae.**

Delayed Death : Death delayed for several days

is rare. Delayed deaths occur due to (1) aspiration pneumonia, (2) infections, (3) oedema of lungs, (4) oedema of larynx, (5) hypoxic encephalopathy, (6) infarction of brain, (7) abscess of brain, (8) cerebral softening.

The secondary effects of hanging in persons who have recovered are sometimes hemiplegia, epileptiform convulsions, amnesia, dementia, cervical cellulitis, parotitis, retropharyngeal abscess, amnetia, and dementia.

Fatal Period : Death occurs immediately if the cervical vertebrae are fractured, or if the heart is inhibited; rapidly if cause is asphyxia, and least rapidly if coma is responsible. The usual period is 3 to 5 minutes.

TREATMENT : After the ligature is cut to remove the constriction of the neck, artificial respiration and stimulants should be given.

Post-mortem Appearances : External : The ligature mark in the neck is the most important and specific sign of death from hanging. Ligature mark on the neck depends on: **(1) Composition of ligature:** The pattern and texture is produced upon the skin, e.g., if thick rope is used, its texture may be impressed in the form of superficial abrasion (Fig. 14-2). **(2) Width and multiplicity of ligature :** When ligature is narrow, a deep groove is made because much more force per sq. cm. of ligature is directed inwards. A broad ligature will produce only a superficial mark. If the ligature is passed twice round the neck, a double mark, one circular, and the other oblique may be seen. The ligature may have one, two, or more layers. There may be multiple congested areas, where the skin has been caught between the various layers. **(3) The weight of the body suspended and the degree of suspension:** Heavier the body and greater the proportion of the body suspended, the more marked is the ligature impression. **(4) The tightness of encircling ligature :** The ligature impression is deeper opposite the point of suspension, but it may tail off very rapidly if ligature consists of loop rather than a noose. If the noose tightens completely around the neck, the ligature mark will be seen completely encircling the neck. **(5) The length of time body has been suspended** : Longer the suspension, deeper is the groove. Even a soft, broad ligature can cause a clear-cut groove if suspended long. If the ligature is cut down within a short time and a soft broad ligature has been used, there may be no external mark. **(6) Position of the knot:** The main force applied to the neck by ligature is opposite to the point of suspension. If the point of suspension is in occipital region, front of the neck is involved. If in front, the depth of the groove is limited posteriorly by cervical spine. **(7) Slipping of ligature during suspension:** Frequently, only the portion adjacent to the knot moves. There is a tendency for the ligature to move upwards, this being limited by the jaws. The upward movement may produce double impression of ligature. The lower mark is usually very superficial and is connected by fine abrasions, caused by the slipping ligature, to the mark made by ligature in its final position.

Fig. (14–2). Ligature mark of hanging showing pattern of chain.

Knot: It is frequently in the form of a simple slip-knot to produce a running noose or fixed by granny or reef-knot; occasionally a simple loop is used. The knot is usually on the right or left side of the neck, ligature usually rising behind the ear to the point of suspension. Sometimes, the knot is in the occipital region and rarely under the chin. After suspension in hanging, the knot is at higher level than the remainder of ligature, the movement of knot being due to the act of suspension. The involvement of another party may be suggested by certain types of knots and nooses. Removal of the noose from the neck is done by cutting the noose away from the knot and tying the cut ends with string or wire (Fig. 14-3).

Ligature Mark : The description of the ligature mark should include its direction, continuous or interrupted, colour, depth and width, ligature pattern if any, the areas of the neck involved, and its relation to local landmarks. The ligature produces a furrow or a groove in the tissue which is pale in colour,

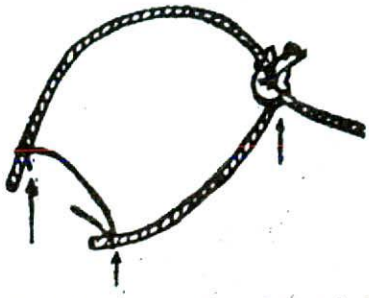

Fig. (14–3). Method of preservation of noose in hanging and strangulation.

but it later becomes yellow-brown or dark-brown and hard like parchment, due to the drying of the slightly abraded skin. The course of the groove depends on whether a fixed or running noose has been used. A fixed noose is one in which the rope is knotted (granny or reef knot). A running noose is one in which the end of rope is passed through

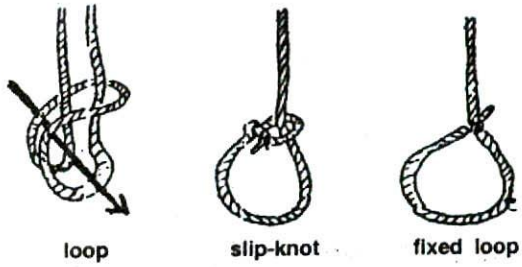

Fig. (14–4). Types of ligature.

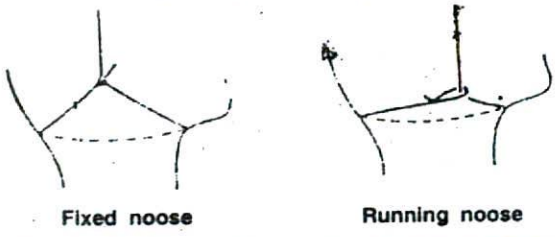

Fig. (14–5). The position of the ligature mark on the neck.

Fig. (14–6). Types of suspension of the body in hanging.

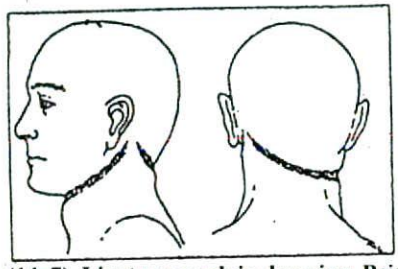

Fig. (14–7). Ligature mark in hanging. Point of suspension is just posterior to the left ear, with the furrow crossing the anterior neck above the larynx, showing inverted V furrow.

the loop (slip knot). (1) When the loop is arranged with a fixed knot, the course of the mark is deepest and nearly horizontal on the side opposite to knot, but as the arms of the ligature approach the knot the mark turns upwards towards it. This produces an inverted 'V' at the site of the knot, the apex of the 'V' corresponding with the site of the knot. An impression from a knot may be found if the ligature is tight on the skin, usually on one or other side of the back and occasionally beneath the chin. (2) In the case of a fixed loop with a single knot in the midline at the back of the head, the mark is seen on both sides of the neck and is directed obliquely upwards towards the position of the knot over the back of the neck. (3) In the case of a fixed loop with a single knot in the midline under the chin, the mark is seen on the back and both sides of the neck, and is directed obliquely forwards towards the position of the knot over the front of the neck. (4) In the case of a fixed loop with the knot in the region of one ear, the mark differs on each side of the neck. On the side of the knot, the mark is directed obliquely upwards to the knot, and on the other side it is directed transversely. If the ligature is in the form of a loop, the mark will be most prominent on the part of the neck to which the head has inclined and less marked over the region of the open angle of the loop. (5) When a running noose is applied, the weight of the body will cause the noose to tighten in a mainly horizontal position. The mark is seen on both sides of the neck, and is usually directed transversely across the front of the neck resembling that of a ligature mark in strangulation, except that it is likely to be seen above the level of thyroid cartilage. (6) If a running noose fails to tighten, the mark may resemble one produced by a fixed loop. If the noose is a belt, a single ligature will produce two parallel ligature marks, as the

upper and lower edges of the belt dig into the skin. (7) In hanging from a low point of suspension, the groove produced by the ligature is less well marked, and may be at about the level of the upper border of the larynx and more horizontal. (8) In partial hanging when the body leans forward, a horizontal ligature mark may be seen.

The junction of the noose and the vertical part of the rope of the noose is pulled upwards and away from the skin and so no mark is left. The apex of the triangle formed in this way is called the suspension peak or point and indicates the position of the junction of the noose and vertical part of rope. This suspension peak is a distinguishing feature from ligature strangulation (Fig. 14.7). The firmer muscular tissues at the back of the neck do not show clear and deep grooves, as are seen at the front or sides of the neck. Along the edges of the depression, a thin line of congestion or haemorrhage will be seen above and below the groove at some point, usually the deepest, if not throughout its course. In some cases, the lower margin of the groove is pale, and upper margin red due to postmortem dilatation and distension of vessels. Ecchymoses and slight abrasions in the groove are rare. Ecchymoses alone have no significance as to whether hanging was caused during life or not, but abrasions with haemorrhage are strongly suggestive of suspension taking place during life.

The mark is situated above the level of thyroid cartilage, between the larynx and the chin in 80 percent of cases. It may be at the level of the cartilage in about fifteen percent, and below the cartilage in about five percent cases, especially in partial suspension. The width of the groove is about, or slightly less than the width of the ligature. Any well-defined pattern in the ligature is likely to be produced in the groove permitting a match of patterns. Ligature pattern may be better appreciated by examining under oblique lighting and using a magnifying lens. Rarely, a narrow wire may be used **("cheese-cutter" method).** When fresh, the ligature mark is less clear, but becomes prominent after drying for several hours. A portion of skin and deeper tissue in relation to ligature should be examined microscopically for evidence of tissue reaction, which if present indicates ante-mortem hanging. The absence of tissue reaction does not exclude ante-mortem hanging (Gordon, et al). However, hanging may occur without visible marks on the victim's neck. If there is a beard, or if a portion of clothing is caught between the ligature and the skin, no ligature mark may be found under it. When a folded cloth has been used, there may be great difference between the appearance of the neck mark and the size of the ligature. When fabric is pulled tight, certain parts of it become raised into ridges, which form the ligating surface, and only these may be reproduced on the skin. When nylon, silk or terylene fabrics are used, they may leave a

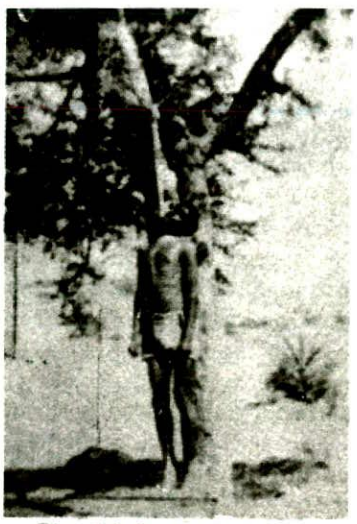

Fig. (14–8). Suicidal hanging.

Fig. (14–9). Partial hanging (sitting position).

Fig. (14–10). Partial hanging (kneeling position).

Fig. (14–11). Partial hanging.

mark only 2 to 3 mm. wide. A loop made of soft material, e.g., towel, scarf, etc. may not produce a ligature mark, but the knot may produce an abrasion due to its firmness. If there is no ligature, the mark should be taped, as it may pick up some fibres by the ligature and facilitate the identification of the material of which the ligature was made. The ligature mark of hanging may be reproduced by dragging a body along the ground with ligature passed round the neck soon after death. Decomposition obliterates the ligature mark. The ligture mark may disappear after several hours following removal of the ligature.

In obese persons or infants, skin folds on the neck may resemble a ligature mark, especially after refrigeration of the body has caused coagulation of the subcutaneous fat. When there is swelling of the neck tissues due to decomposition, marks may be produced by jewellery or clothing.

Partial Hanging : Hanging may occur simply by leaning against the noose secured to a chair or door knob, the leg of a table, a bedpost or rail, or the handrail of a staircase, which is slightly higher than the position of the head, the deceased being in a kneeling position, or fall back or forward and lie prone with only the face and chest off the ground. In these cases, the constricting force is less and congestive changes are more marked, and petechiae are seen, because carotid arteries and jugular veins are occluded, but vertebral arteries continue to supply blood to the head. Bradycardia and fibrillation due to neural or neurohumoral mechanism may cause death when suspension point is very low. Hanging may occur when pressure is applied only at the front of the neck, e.g. by the arm of a chair, rung of a ladder, etc. In such case, the marks on the neck may be indistinct or absent.

Other Signs : The neck is stretched and elongated and the head is always inclined to the side opposite to the knot. The face is usually pale, due to cerebral ischaemia (occlusion of carotids and vertebral arteries and drainage by secondary vertebral venous system) or vagal inhibition, but is sometimes congested and swollen due to leakage of oedema fluid into the soft tissues (swelling often disappears when the body is cut down), if the veins were constricted before the arteries. Occasionally, the congestion drains away from the head, inspite of the ligature being still in position. This probably occurs through the vertebral venous plexus, which is not easily compressed as the jugular veins. The brain is often drained of blood in this way. The petechial haemorrhages in the skin and conjunctivae (25% of cases) remain, as they are extravascular. The signs of asphyxia are most marked in cases in which the noose was placed high up on the throat. Obstruction of the jugular veins, while the arteries remain patent (incomplete suspension), leads to severe engorgement of the head and neck. Face is dusky-purple, congested and often swollen. Slow asphyxia is the exception in hanging and is likely to occur only when the point of suspension is a low one, or ligature exerts pressure below the chin and does not encircle the neck. When suspension is complete or in the standing posture, asphyxial signs are slight, petechial haemorrhages are relatively uncommon due to the complete obstruction of the arterial system, but are usually present when hanging has been from low point. Sometimes, petechiae are so minute and diffuse that the head and neck have a dusky appearance which may be mistaken for congestion, especially when petechiae are in subcutaneous tissues. They may be completely absent. The eyes are frequently protruded and firmer than usual due to congestion. The conjunctivae are usually congested. The eyes are closed or partially open, and the pupils are usually dilated. If the ligature knot presses on cervical sympathetic, the eye on the same side may remain open and its pupil dilated. It indicates ante-mortem hanging **(le facie sympathique)**.

The tongue is usually swollen and blue especially at the base, and usually forced against the teeth when the jaw is shut, or the tip may be found projecting between the lips due to the noose lifting the glossopharyngeal skeleton, compressing the tongue. The protruding part of the tongue is usually dark-brown or even black due to drying. The lips, and the mucous membrane of the mouth are blue. Saliva may be found dribbling from the angle of mouth when the head is drooping forward. This is due to the increased salivation before death due

to the stimulation of the salivary glands by the ligature. Salivation is increased by stimulation of pterygopalatine ganglion. Slight haemorrhage or bloody froth is sometimes seen at the mouth and nostrils, and some blood may be found under the head. This results from rupture of engorged blood vessels, and should not be mistaken for evidence of foul play. Occasionally, haemorrhage into the middle ears is seen due to excessive congestion. The hands are clenched, especially in violent hanging. Engorgement of the penis with blood occurs from hypostasis; it may be semierect, and semen may be found at the tip. Urine and faeces may escape due to relaxation of the sphincters. If the body has been suspended for some time, post-mortem hypostasis is seen in the legs, feet, hands and forearms, while the upper part of the body will be pale. Petechial haemorrhages may be found in the skin of the legs in two to four hours. If the body is removed within four hours after death and is placed in supine position, post-mortem hypostasis in the limbs will fade and new areas of lividity will appear along the back and buttocks.

Internal: The neck should be examined after removal of the brain and viscera from the chest and abdominal cavities. Superficial incision of the groove may show small haemorrhages in the underlying layers of skin, caused by the direct trauma produced by the ligature. The tissues under the mark are dry, white and glistening with occasional ecchymoses in the adjacent muscles. Haemorrhages in strap muscles are present in about 25%, and the platysma and sternomastoid are ruptured (5 to 10%), if violence has been considerable. In some cases (5 to 10%), the intima of the carotid arteries show transverse splits (usually around the region of sinuses) with extravasation of blood in their wall due to stretching and crushing. Several horizontal intimal tears scattered along the carotid arteries at different levels are sometimes found in hanging associated with a long drop. To demonstrate these tears, the carotid arteries should be opened to the level of mandible. The vertebral arteries show rupture, intimal tears, and subintimal haemorrhages in some cases. Injury to the trachea is unusual. Petechial haemorrhages may be found on the epiglottis, in the larynx and trachea. The trachea is usually congested. The lungs are congested, oedematous and exude bloody serum on section in cases of constriction occurring at the end of expiration; but they are pale if constriction occurred at the end of inspiration. Subpleural ecchymoses may be found. The abdominal organs are usually congested. The brain is usually normal, but may be pale or congested according to the mode of the death. Subarachnoid effusions are common.

Opinion varies regarding the frequency of fracture of the hyoid bone. Estimates range from 0 to 60%, but the average is 15 to 20%. Fractures are rare below 40 years because of the elasticity of the cartilage and mobility of the joints. The fracture is common in persons above 40 years and involves the great horns, at the junction of inner two-thirds and outer one-third. The fracture is usually a direct result of the ligature, but it can be a traction or "tua" fracture. The superior horns of the thyrohyoid may be fractured from pressure on the thyrohyoid ligament in about 40% of cases above 40 years.

DIAGNOSIS : (1) Ligature mark around the neck, (2) presence of abrasions, ecchymoses and redness about the ligature mark, (3) trickling of saliva from the mouth, (4) ecchymoses of the larynx or epiglottis, (5) rupture of the intima of the carotid, and (6) post-mortem signs of asphyxia.

THE CIRCUMSTANCES OF DEATH: Scene of Crime: Note the posture of the body, any signs of violence or disorder of furniture, etc., and the condition of the clothing of the deceased. The texture and length of ligature should be noted to know whether it was sufficient to hang. If the ligature had broken and the victim is found on the ground, free ends of the ligature should be compared to know whether they coincide and that a break had occurred.

ACCIDENTAL HANGING: (1) It is seen in children during play while imitating judicial hanging or in athletes who are in the habit of exhibiting hanging. Some padding between ligature and neck suggests accident. (2) Workmen in falling from scaffolding may be hanged by becoming entangled in ropes. (3) When boys climb trees or railings they may loose their foothold and in falling, some garment is caught by branch of tree or bar and is drawn tight round the neck. (4) Infants wearing restraining apparatus may wriggle partly out of it, and become asphyxiated by its tightening around their neck as they try to crawl away or fall over the side of the bed. (5) The ligature need not completely encircle the neck to cause death. It is sufficient if it is applied beneath the chin so as to compress the sides of the neck, e.g., suspension of the chin by the steering wheel of a motor car, the tailboard of a lorry or cart, the edge of a sofa or the arm of chair. (6) A person who slips when

Fig. (14–12). Suicide pact by hanging of a family of five persons.

descending a ladder may be suspended by one of its rungs, or a slip on a staircase may result in suspension on the edge of one of the treads. (7) It may be associated with abnormal sexual behaviour.

SUICIDAL HANGING : Hanging is a common method of committing suicide. A typical method of self-suspension is to attach a rope to a high point, such as a beam, window-casing, ceiling fan, branch of a tree, etc. The lower end is formed into either a fixed loop or a slip-knot which is placed around the neck. The victim stands on a stool, chair or other platform and jumps off or kicks away the support, due to which the body is suspended. The body must be in a position compatible with self-suspension. It is important to examine the point of attachment and the surrounding area. If the point is high, then it is likely that there will be recent disturbance of dust caused while attaching the ligature. The deceased's hands and sometimes part of his clothing may also show the presence of corresponding dust marks. There may also be disturbance of dust from the attached cord or from an abraded area particularly if a beam has been used to attach the ligature . Complete suspension of the body in the absence of any platform is unusual in suicide. The hands and feet are sometimes tied by the victim before hanging himself, to prevent a change of mind. The position of the ligature with reference to the knot and the manner in which it is attached to the support must be compatible with self-suspension. Determination of purpose will often compensate bodily infirmity. Blindness or age is no bar to hanging. The victim might pull away the ligature to free himself from the constriction and if he had long nails, nail marks may be inflicted on the neck. Sometimes, the upward movement of the rope at the time of suspension may scratch the skin. In an attempted resuscitation, scratches or nail marks on the neck may be produced by another person. Superficial abrasions and sometimes small contusions overlying bony prominences of the limbs and trunk may be found in suicidal hangings due to contact of the body against nearby objects during voluntary or early involuntary movement. Sometimes, a person may hang himself after other forms of suicide, e.g., cutting the throat or wrists, stabs, firearm wounds, ingestion of poison, etc., have failed to produce death. Unusual positions, e.g., where the parts of the body touched the ground, kneeling or reclining, are almost diagnostic of suicide. Suicide pacts effected by hanging are rare.

MULTIPLE METHODS OF SUICIDE: CASE: (1) A man was found hanging. The examination of the scene and information obtained by the police were consistent with suicide. However, the body had a bullet wound on the right side of face and another in the palm of the left hand; five cut wounds of the throat; cuts over the left wrist, dividing the muscle tendons but not blood vessels. Apparently he had attempted to shoot himself, to cut his throat, and the blood vessels in the wrist, all of which failed. In desperation, he hanged himself.

(2) A highly pessimistic person determined to commit suicide, and decided to hang himself. He selected a tree with a stout branch overhanging a cliff, the sea being 16 metres below. He procured a dose of opium to prevent any pain in the process of hanging. To make certain that death occurs he decided also to shoot himself. The noose adjusted, opium swallowed, and the revolver cocked, he stepped over the cliff, and as he did so fired. His aim was altered by the jerk of the rope, and the bullet missed his head but partly cut through the rope. The rope broke due to the jerk of the body, and he fell into the sea 16 metres below. He swallowed sea water, vomited the poison, and swam ashore a wiser man.

HOMICIDAL HANGING: It is extremely rare. It is difficult for a single assailant to carry it out unless the victim becomes unconscious by injury or by a drug, or is taken unawares, or is a child or a very weak person. Homicide should be suspected (1) where there are signs of violence or disorder of furniture or other objects, (2) where the clothing of the deceased is torn or disarranged, (3) where there are injuries, either offensive or defensive. In all doubtful cases, circumstantial evidence is important.

LYNCHING : The name is derived from captain William Lynch, who used to order hanging on the spot without trial in USA. It is homicidal hanging. Sometimes a suspect, accused or enemy is hanged by a rope from a tree, etc., by the mob.

Post-mortem Hanging: A person may be murdered, and the dead body suspended to simulate suicide. A ligature applied to the neck within two hours of death will produce a ligature mark. Look for signs of dragging to the place of suspension. When a dead body is suspended, the rope is usually tied first around the neck, and then around the beam, branch of a tree, etc. The beam shows evidence of the rope having moved from below upwards as the body has been pulled up. In true suicidal hanging, the rope moves from above downwards. Further, fibres from the rope may be found on the hands of the victim in suicidal hanging, but not in case of post-mortem hanging. The rope should be examined for presence or absence of any paint similar to one on the beam. In most cases, the internal signs are clearly not those of hanging, although in most cases ligature mark cannot be distinguished. Rarely, for motives of revenge, fraud or for some other reason, a victim arranges his suicide to appear to have been a murder.

JUDICIAL HANGING : In Indial legal death sentence is carried out by hanging the criminal. The face of the person is covered with a dark mask, and he is made to stand on a platform above trapdoors which open downwards when a bolt is drawn. A rope to allow a drop of five to sven metres according to the weight, build and age of the person, is looped round the neck, with the knot under the angle of the jaw. The placement of the knot beneath the chin, in the submental position is said to be more effective. On drawing the bolt, the person drops to the length of the rope. The sudden stoppage of the moving body associated with the position of the knot causes the head to be jerked violently. This causes fracture-dislocation usually at the level of the second and third, or third and fourth cervical vertebrae. Bilateral fractures of either the pedicles or laminae of the arch of the second, third or fourth cervical vertebrae occur. Less commonly, dislocation of the atlanto-occipital joint or odontoid process of the axis vertebra occurs causing pulping of the spinal cord and transection of the cervical spine, causing the neck to be lengthened considerably. The upper cervical cord is stretched or torn across. With proper judicial hanging, there is a rupture of the brain stem between the pons and the medulla. This results in instantaneous and irreversible loss of consciousness (due to destruction of reticular formation) and in irreversible apnoea (due to destruction of the region of respiratory centre). It results in immediate unconsciousness, but heart beats and respiratory movements may continue up to 10 to 15 minutes and spasmodic muscular jerking may occur for a considerable time. The pharynx is usually injured and the carotid arteries may be torn transversely, either partly or completely.

STRANGULATION

Strangulation is that form of asphyxia which is caused from constriction of the neck by a ligature without suspending the body. Pulling a U-shaped ligature against the front and sides of the neck while standing at the back can cause death. It is of two types : (1) strangulation by a ligature, and (2) manual strangulation or throttling.

SYMPTOMS : Sudden and violent compression of the windpipe causes almost immediate insensibility and death. If the windpipe is partially closed, buzzing in ears, congestion and cyanosis in head, vertigo, tingling, muscle weakness, bleeding from the mouth, nose and ears, clenching of the hands and convulsions occur before death.

Cause of Death : Death may be due to: (1) Asphyxia, due to elevation of the larynx and tongue, closing the airway at pharyngeal level. It is difficult to occlude the airway at laryngeal or tracheal level, due to the rigidity of the strong carilages except when extreme pressure is applied. (2) Cerebral anoxia or venous congestion. (3) Combined asphyxia and venous congestion. (4) Vagal inhibition, and (5) Fracture-dislocation of cervical vertebrae (rare).

Post-mortem Appearances : (A) External: The ligature mark : It is usually a well-defined and slightly depressed mark at any level on the neck, but usually about the middle or below the thyroid cartilage. The mark completely encircles the neck transversely, but is more prominent at the front and sides than at the back. The skin of the front of the neck is more likely to be damaged by a ligature than the thicker, tougher skin at the back of the neck. Sometimes, the ligature mark is seen only at the front. The mark may be absent on the back due to the presence of clothing or long hair between the ligature and the skin. A ligature mark may be interrupted at the front by the presence of the clothing or by the victim's fingers in an attempt to pull the ligature away. If a knot has been applied, there may be a wider area of bruising at the site of the knot. If the ligature has been tightened pulling on the crossed ends, the mark is likely to be more

prominent at the site of cross-over, and the marks produced by the two ends will be at different levels. The mark of cross-over may be at the front, back or side according to the position of the assailant. The mark may be oblique as in hanging, if the victim has been dragged by a cord, after he has been strangled in a recumbent posture. Multiple turns produce a complex mark in which it may be possible to trace the number of turns, but a complex ligature composed of several pieces knotted together may produce a mark which simulates multiple turns, though there was only one. In rare cases, a soft and yielding ligature may produce only a slight depression or flushing of the skin.Occasionally, a ligature mark may be seen only across the front of the neck, if the assailant presses from the front, or pulls from the back, using a cord stretched between two hands.

Twisted cords with a rough surface, if tied around the neck several times in parallel, may squeeze a skin fold and compress the capillaries inside leading to haemorrhage into the fold. Vesicles containing fluid may also form in these folds.

When narrow ligature, e.g., a cord, wire or thin rope has been tightly forced into the skin, the skin may stretch and after the ligature is removed, the elastic recoil may make the ligature mark slightly narrower than the actual diameter of the ligature itself. When the ligature is still in position when the body is examined, it may appear to be deeply embedded in the skin, and on removal a deep groove may be seen in the skin. This embedding may be increased by oedema of the tissues, especially above the ligature, which initially may not have been applied so tightly. The swelling can continue to develop to some extent even after death, increasing the depth of the groove, possibly due to some passive transudation of tissue fluid even after stoppage of circulation.

Rarely, a narrow wire may be used, the so-called **"cheese-cutter" method.** Strong pressure may lacerate the skin or cut into the deeper tissues and cartilages. When a folded cloth has been used, there may be great difference between the appearance of the neck mark and the size of the ligature. If the ligature used is broad, soft and yielding, e.g. a towel, scarf, etc. one or more linear marks may be produced on the skin, often discontinuous. These marks may fade if the neck is not examined soon after death, and if there was no abrasion. When nylon, silk or terylene fabrics are used, they may leave a sharply defined mark only two to three mm. wide, resembling a mark caused by a narrow cord or wire. The reason for this is, that when a broad piece of cloth is tightly stretched by pulling, certain parts of it become raised into ridges which form the ligating surface and only these may be reproduced on the skin. The neck should be examined under ultraviolet light to visualise a suspected mark made by soft material. The base of the mark is usually red, especially if the ligature was of soft material, but cords, ropes and wires tend to abrade the surface, which on drying becomes hard, yellow or brown and parchment-like. There may be exudation of tissue fluid which later dries, forming a stiff film. Petechial haemorrhages are usually found immediately adjacent to the ligature mark, which is a confirmation that the mark was made during life. A narrow zone of reddening and congestion is also common immediately above and below the groove, due to lateral displacement of blood from the squeezed area. This does not necessarily indicate that the ligature was applied during life. Scratches may be found on the skin of the neck near the ligature. They are usually vertical, but may be irregular or crescentic. The fingernails of the deceased should be examined for fragments of skin and blood. In cases of homicide also, fingernails should be clipped and examined. A body which is wet, may not reveal fingernail marks until drying of the skin. The pattern of the ligature may point to the agent, e.g, a woven belt, plaited electric wires, links of chains, spiral rope patterns, etc. If a rough ligature, e.g., a rope is used, and if there is some movement of the rope on the skin during a struggle, the skin may show marked abrasions and haemorrhages, and the deep muscles of the neck are grossly bruised. The ligature mark of strangulation is not obliterated by putrefaction, but is better preserved than the skin beyond it, because of compression of the underlying blood vessels, and preventing the access of bacteria. Even if the mark is obscured, subcutaneous haemorrhages in relation to the mark may be found.

Pseduo-Strongulation: (1) Occasionally marks are seen on the dead bodies of infants and children. In whom the neck is short. These depressed marks are produced from folds in the skin due to bending of the head. (2) A similar mark of depression is found in short-necked persons after death, across front of the neck. (3) It can also be seen in decomposing bodies with tight collars, buttoned shirt

at the neck or other clothing round the neck. In these cases, a deep groove simulating ligature mark of strangulation is produced due to the swelling of the tissues around the tight-fitting garment, as the body decomposes.

If at autopsy, the ligature is still in place around the neck, it should be removed by dividing it away from the knot, so that the knot may be preserved. The knot should be secured by tying the component parts with strings so that they do not fall apart as the ligature is removed. Photographs (at close range)should be taken before the ligature is removed. The ligature should always be examined for the presence of blood, fragments of epidermis, hair or other suspicious substances. If the nature of ligature is in doubt, before disturbing the neck, a search should be made for fibres or other material from the ligature, on the skin and adjacent clothing. This can be done by sticking five cm. lengths of transparent adhesive tape to the suspected area and stripping them off. This is then transferred to microscope slides and examined. The pattern produced by the ligature can be made out by examining the neck with oblique light or by ultraviolet light.

If there has been a struggle, abrasions and contusions may be seen on the face and other parts of the body. If the assailant kneels on the chest or abdomen of the victim, fractures of the ribs and injuries to the internal organs may be present. If a stick or foot is used, a bruise is seen in the centre of the neck, across the windpipe, corresponding in width to the substance used. If two sticks are used, a similar mark will be seen on the back of the neck.

Signs of Asphyxia : A sudden compression of the windpipe often makes a person powerless to call for help, and causes almost immediate unconsciousness and death. If there is slight vagal effect and some venous obstruction, there will be slight congestion of head and neck and occasional petechial haemorrhages. With moderate venous constriction and some respiratory obstruction asphyxial signs are moderate. When constricting force is great, asphyxial signs are marked. Intense congestion and deep cyanosis of the head and neck is seen, because the vertebral arteries continue to supply blood to the head and venous drainage is very less. The face is puffy, oedematous, congested and cyanotic. The eyes are wide open, bulging and suffused, with confluent scleral haemorrhage; the pupils dilated, the tongue swollen and often bruised, dark-coloured and protruded. Petechial haemorrhages are common in the skin of the eyelids, conjunctivae,

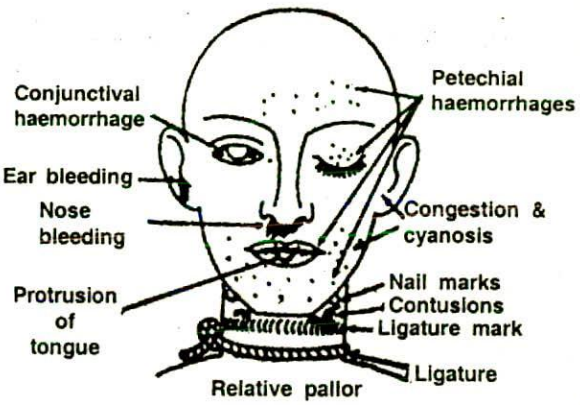

Fig. (14–13). Signs of strangulation.

face, forehead, behind the ears and scalp. Bloody froth may escape from the mouth and nostrils, and there may be bleeding from the nose and ears. The hands are usually clenched. The genital organs may be congested and there may be discharge of urine, faeces and seminal fluid. These asphyxial signs may be absent if death occurs quickly from vagal inhibition, due to pressure on carotid sheath.

Internal : The neck and its structures should be examined after removal of brain and chest organs, to allow blood to drain from the neck blood vessels. There may be superficial haemorrhage under the ligature mark, though this is often minimal. There is severe engorgement and haemorrhage into the tissues in and above the area compressed. The adjacent muscles of the neck are usually lacerated. The deep muscles of the neck show little or no bruising, if the ligature used is soft and yielding. In some cases, no external mark is seen on the surface of the neck, but extensive bruising of the deeper tissues may be found. The extent of the bruising depends upon the degree of pressure used. A ligature which is tightly applied on the neck until death occurs, may fail to produce any bruising. Subcapsular and interstitial thyroid haemorrhages are common. The mucous membrane of the pharynx, pyriform sinuses, epiglottis and larynx usually show areas of haemorrhagic infiltration. Lymphoid follicles at the base of the tongue and the palatine tonsils are congested; the posterior lingual mucous membrane, submaxillary and parotid glands may be studded with petechiae. The intima of the carotid arteries are not usually damaged, but a deeply sunken narrow ligature applied with force may damage the carotid arteries.

Injury to the hyoid bone is not common, because the level of constriction is usually below the bone. If ligature is wide, sometimes fracture may occur. Hyoid bone may be fractured in older persons in 10 to 15% of cases. Fracture can be caused by (1) direct lateral compression from the sides of the neck, by pressure applied high up under the angles of the jaw. (2) indirect violence, in which the bone is drawn upwards and immobilised by the various muscles which are attached to its upper surface when the neck muscles are contracted, as in attempt to resist strangulation. Fracture of the thyroid cartilage is more common, especially of one or both superior horns. Fracture of thyroid laminae and cricoid cartilage is less common and occurs only when considerable force is used, or if some solid object is included in the ligature and applied over the front of the neck. Trachea is rarely broken.

Bruising of the root of tongue and floor of the mouth may occur. Haemorrhage may be seen under the mucosa of the larynx, especially beneath the vocal cords as a direct result of compression and due to stasis of blood rather than asphyxia. These haemorrhages are larger than petechial haemorrhages of asphxia. The larynx, trachea and bronchi are congested and contain frothy, often blood-stained mucus. False haemorrhages may be present in the back of the oesophagus and on the anterior spinal ligaments. The lungs are markedly congested and show ecchymoses and large subpleural haemorrhages. Silvery-looking spots under pleural surface due to rupture of the air cells which disappear on pricking, are seen in more than 50% cases. Bullae due to putrefactive gas formation will slip under the fingers if it is smoothened being subpleural, while emphysematous bullae will not. Pulmonary oedema may be present. Microscopically, there is usually intense interalveolar congestion with haemorrhages of varying size, fluid in the alveoli, areas of collapse and intervening areas of ruptured alveoli. The air-passages often contain large areas of desquamated respiratory type epithelium, red blood cells and fluid. The parenchymatous organs show intense venous congestion, and in young persons ecchymoses are usually seen on the heart and kidneys. The brain is congested and shows petechial haemorrhages.

MEDICO-LEGAL QUESTIONS : (1) WHETHER DEATH WAS CAUSED BY STRANGULATION ? In death due to strangling, the general features of asphyxial death are present. Their local distribution in the head and neck is strongly presumptive of strangulation. This is confirmed by the ligature mark on the neck. Evidence of violent compression or constriction of the neck during life is obtained from the presence of bruising or ecchymoses about the marks on the neck, haemorrhages in the strap muscles, under the skin, in the sides of the tissues around the trachea and larynx, in the larynx and in the laryngeal structures themselves. The ligature mark alone is not diagnostic, for it may be indistinct or absent, if a soft ligature material is used. The ligature mark may be produced by the application of a ligature to the neck even after death. Certain marks on the neck produced after death may simulate ligature mark.

The possibility of other causes of suboxic or asphyxial death should be excluded. In the absence of ligature mark in the neck or deeper injury, it will be difficult to form an opinion, except from circumstantial evidence. In cases of putrefaction, a medical opinion about strangulation can be given fairly, if there are signs of mechanical violence applied to the neck, e.g., fracture of the larynx or hyoid bone, bruising of the muscles and visible skin impressions. Indistinct marks on the neck, patches of discolouration or signs of asphyxia cannot be relied upon as evidence of strangulation in a putrefied body.

A medical opinion should be based on all the facts connected with the position of the body, the nature and direction of the ligature and the effects produced on the neck and structures below the skin. The mere presence of a cord or ligature around the neck of a dead body does not confirm the diagnosis, for it may be put around the neck for a malicious purpose. All marks of violence on the body of a supposedly strangled person should be carefully examined, to determine whether they could cause death, or whether they can be explained on other grounds. Strangulation by ligature has to be differentiated from hanging.

(2) WHETHER THE STRANGULATION WAS SUICIDAL, HOMICIDAL OR ACCIDENTAL ?

SUICIDAL STRANGULATION : Suicide by strangulation is rare. Various methods of tightening the ligature are employed by the victims. The number of knots, tightness and method of knotting should be considered. (1) The ligature is tightened like a tourniquet, but the person can apply a single or double knot, before consciousness is lost . In most cases, some mechanical device is always made to keep the ligature tight after insensibility develops. (2) Several turns of rope are tied round the neck with a knot which is usually single and in front, or at the side or back of the neck. (3) A cord may be tied around the

neck and twisted tightly by means of a stick or some other solid material used as a lever. When consciousness is lost, although grip on stick is released, the ligature will not become loose as it gets arrested against the shoulder or chin. (Spanish Windlass Technique). (4) A running noose is applied to the neck, and the free end of the rope to which a weight is attached, is thrown over the end of the bed on which the victim lies. (5) A person may strangle himself by leaning with the whole weight of his body on a cord passed round the neck and attached to a fixed point.

In suicidal strangulation, the signs of venous congestion are very well developed above the ligature, and are especially prominent at the root of the tongue. This severe congestion probably results by the slow tightening of the ligature, and also because it is usually so secured that it remains in place after death, preventing post-mortem drainage of blood. Injuries are usually less marked because less force is used. In all cases of suicidal strangulation, the ligature should be found *in situ*, and the body should not show signs of violence or marks of struggle. If ligature is still present, the number of turns and type of the knots require detailed study. The application of ligature with several turns, whether closed with a half-knot or even a complete knot, is consistent with suicide. A single turn of a broad ligature of rough cloth, closed with a half-knot indicates suicide. A correct medical opinion may be usually formed from the course and direction of the tie, the way in which it was secured or fixed to produce effective pressure on the windpipe, and the amount of injury to the muscles and parts beneath.

HOMICIDAL STRANGULATION : Strangulation is a common form of murder. Many of the victims are adult women and frequently strangulation is then associated with sexual assault. Usually there is a single turn of ligature round the neck, with one or more knots (granny or reef knots) at the front or side of the neck. When there are two or more firm knots, each on separate turns of the ligature, homicide is almost certain. There may be more than one ligature mark, each of varying intensity and crossing each other, in parallel or at an angle to each other. Abrasions are usually seen due to movement of the ligature across the neck. Fingernail marks may be seen, either from the victim attempting to remove the ligature, or from the assailant attempting to secure the ligature, and/or restrain the neck from moving, or even attempting manual strangulation. The victim's clothing may sometimes be caught in the ligature during a struggle and produce marks, which require careful evaluation. The mark may either completely encircle the neck or may be seen only at the front, when the ligature is pulled tightly from behind. The mark may also be sloping if the ligature is pulled upwards from behind, and the position is high up at the level of the hyoid bone. Sometimes, a ligature is passed over the body, and then tied to the hands and feet to simulate suicide. In such cases, the manner of tying should be examined. The presence of a complex type of knotting in the cord, e.g., the presence of reef knot, suggests homicidal strangulation. Infanticide by strangulation may be caused by winding the umbilical cord round the infant's neck. In such cases, the cord will show appearances indicative of rough handling with displacement of Wharton's jelly, and other signs of violence are present on the body. Sometimes, homicidal strangulation is feigned by an individual to bring a false charge against his enemy. Hysterical women sometimes feign it without any obvious motive.

Evidences of struggle are usually found, but if the person is taken unawares, and the ligature is suddenly placed around the neck and pulled tightly, the person loses consciousness quickly and is unable to offer much resistance. If the person is weak and infirm, or made unconscious by blows on the head or by intoxicating drugs and in children, there may be few or no signs of struggle. If the clothing of the deceased is torn or disarranged, it indicates that a struggle has taken place. If there is a struggle, both assailant and victim may show abrasions and contusions. Entanglement of hair or clothing with the ligature should be regarded as suspicious of homicide.

Strangulation should be assumed to be homicidal until the contrary is shown. As a rule, the murderer uses far more force than is necessary, and as such, injuries to the deeper structures are well marked. If the ligature is around the neck with two or three knots at the back of the neck, it is presumptive of homicide. The ownership of the ligature may sometimes become an important clue, e.g., if the ligature found around the dead body may be proved to correspond with parts of the same material found in the possession of suspected assailant. Unusual ligatures may narrow the search for the assailant, since they may be material of the kind used in a particular occupation. If the ligature is removed or lies loose, unless explained, are presumptive of homicide. If the ligature mark in the neck does not accurately correspond with the ligature found, it is presumptive of homicide. Sometimes, circumstantial evidence, such as time, place, locked doors and windows, motive, etc., is almost the only evidence for a suggestion either of suicide or homicide.

Ligature marks produced after death do not show bruising. Either a grooved impression is seen on the skin which is not injured, or yellow or brown abrasion without signs of vital reaction. There may be ligatures or other marks around the limbs especially wrists and ankles, which may be placed either before or after death.

Table. (14–1). Difference between hanging and strangulation.

Trait	Hanging	Strangulation by ligature
(1) Ligature mark :	It is oblique, does not completely encircle the neck; usually seen high up in the neck between the chin and larynx. The base is pale, hard and parchment-like.	It is transverse, completely encircling the neck below the thyroid cartilage. The base is soft and reddish.
(2) Abrasions and ecchymoses :	About the edges of ligature mark not common.	About the edges of the ligature mark are common.
(3) Bruising :	Of the neck muscles less common.	Of the neck muscles more common.
(4) Neck :	Stretched and elongated.	Not stretched or elongated.
(5) Subcutaneous tissues :	White, hard and glistening under the mark.	Ecchymosed under the mark.
(6) Hyoid bone :	Fracture may occur.	Fracture is uncommon.
(7) Thyroid cartilage :	Fracture is less common.	Fracture is more common.
(8) Larynx and trachea :	Fracture rare.	Fracture may be found.
(9) Emphysematous bullae :	Not present on the surface of the lungs.	Very common on the surface of the lungs.
(10) Carotid arteries :	Damage may be seen.	Damage is rare.
(11) Face :	Usually pale and petechiae are not common.	Congested, livid and marked with petechiae.
(12) Signs of asphyxia :	External signs less marked.	External signs well-marked.
(13) Tongue :	Swelling and protrusion is less marked.	Swelling and protrusion is more marked.
(14) Saliva :	Often runs out of mouth.	Absent.
(15) Bleeding :	From the nose, mouth and ears not common.	From the nose, mouth and ears common.
(16) Involuntary discharge :	Of faeces and urine less common.	Of faeces and urine more common.
(17) Seminal fluid :	At glans is more common.	At glans is less common.

BOSTON STRANGLER: Albert Desalvo strangled to death 13 women aged between 19 to 68 years, between June 1962 to October 1964 in Boston and Lawrence in USA. He would press the buzzer of an apartment, and the woman who opened the door became his victim. The women were found with a nylon stocking or other article of clothing tied around the neck, nude or partially undressed with evidence of rape or sexual molestation. Some victims had been gagged and tied and two were stabbed. In October, 1964, he attacked a young woman in her apartment, gagged, tied her to bed and molested sexually and left after extracting a promise from her that she would not tell anyone. She informed the police, who arranged for an artist's sketch of the man based on her description. The sketch resembled 32 year old Albert Desalvo. Desalvo was arrested three years earlier for housebreaking, who admitted at that time that he had been measuring women for their suitability for employment as models. He was diagnosed as sociopathic personality marked by sexual deviation with prominent schizoid features and depressed trends.

Desalvo was committed to hospital for pretrial psychiatric examination. He made a detailed confession of 13 homicides and claimed that he had sexually assaulted beween 800 to 1,000 women. He was sentenced to life imprisonment.

The common methods of homicidal strangulation are : (1) strangulation by ligature, (2) throttling, (3) bansdola, (4) garrotting, and (5) mugging.

BANSDOLA : One strong bamboo or stick is placed across the back of the neck and another across the front. Both the ends are tied with a rope due to which the victim is squeezed to death. Sometimes, a stick is placed across the front of the neck, and the assailant stands with a foot on each end of the stick. If a stick or foot is used, a bruise is seen in the centre of the neck across the windpipe corresponding in width to the substance used. If two sticks are used, a similar mark will be seen on the back of the neck. Sometimes, the chest may be squeezed forcibly between two sticks placed across the back and front of the upper part of the chest.

This interferes with respiration and causes laceration of the muscles and fractures of the ribs.

GARROTTING : The victim is attacked from behind without warning. The throat may be grasped, or a ligature is thrown over the neck and quickly tightened, by twisting it with a lever (rod, stick, ruler, etc.), which results in sudden loss of consciousness and collapse. The assailant is then able to tie the ligature with one or more turns. In this way, a single assailant can kill a healthy adult male. This method is usually used in lonely places to kill travellers and to rob them. This method had a refinement in which the neck was forced against a sharp spike which penetrated the spinal cord. Garrotting as a mode of execution was once employed in Spain. An iron collar around the neck is tightened by a screw for strangling (Spanish Windlass).

MUGGING : Strangulation is caused by holding the neck of the victim in the bend of the elbow. Pressure is exerted either on front of the larynx, or at one or both sides of the neck by the forearm and upper arm. The attack is usually made from behind. The post-mortem appearances are those of ligature strangulation with a broad object, i.e. the signs are minimal. Sometimes, a diffuse abrasion may be seen along the margin of the jaw due to the friction of the forearm. Internally, there may be diffuse bruising, but this may be slight or absent. There may be bruising behind the larynx and in the strap muscles of the neck. Fracture of superior horn of thyroid or hyoid is rare. In some cases, the neck may be pressed by the foot or knee. When the neck is stamped on repeatedly, there will be crushing of the larynx and trachea, and bleeding in the soft tissues with swelling.

Accidental Strangulation : (1) Children may get entangled in ropes during play, or the neck may be caught in window cords, etc. (2) Infants are sometimes strangled in their cots when the neck is caught inside bars, in restrainers, braces, etc. (3) Occasionally, an infant is strangled with a string attached to a toy tied to the crib. (4) Persons under the influence of alcohol, epileptics, and imbeciles may be strangled either by a tight scarf or collar and neck tie. (5) It may occur if an intoxicated person rests the neck against a bar or other hard object. (6) It may occur when a string used in suspending a weight on back, slips from across the forehead and compresses the neck. (7) In industry, belts, ropes or parts of clothing may be caught in the rollers or other parts of the moving machinery and cause accidental strangulation. (8) Accidental strangling may occur in uterus when the movement of the foetus causes the umbilical cord to encircle the neck. In such case, there is relatively slight cervical tissue injury. Wharton's jelly is not damaged and lungs are usually incompletely expanded.

In a charge of murder, it may be suggested that the deceased might have been accidentally strangled in a state of intoxication, either by a tight scarf or collar and tie. When there is pressure on the windpipe, the victim attempts to pull the ligature, and scratches may be found on the neck, which may arouse a suspicion of throttling. If the relations of the body to surrounding objects and the constricting agent have not been disturbed, cases of accidental strangulation present no difficulty. If the body has been removed from the place in which it was first discovered, or the ligature has been removed, the presumption of accident can only be established from the description given.

THROTTLING OR MANUAL STRANGULATION

Asphyxia produced by compression of the neck by human hands is called throttling. Death occurs due to occlusion of carotid arteries. Occlusion of airway plays minor role.

Post-mortem Appearances : External : The situation and extent of the bruised areas on the neck will depend upon the relative positions of the assailant and victim, the manner of grasping neck, and the degree of pressure exerted upon the throat. The bruises are produced by the tips or the pads of the fingers. Their shape may be oval or round and of the size of the digits (1.5 to 2 cm.), but continued bleeding into the contused area usually increases the size. If the fingers skid across the skin surface, longer, irregular marks may occur, especially along the jaw margins. Usually, more force is used than is necessary to kill the victim. (1) A grip from right hand from the front produces a thumb impression on the right side of the victim's neck, which is usually under the lower jaw over the cornu of thyroid. Several finger marks are seen on the left side of the neck obliquely downwards and outwards and one below the other, but sometimes are grouped together and cannot be distinguished separately. (2) In a grip from behind the victim, the pressure is applied all round the neck, but some areas of bruising are more prominent due to the

pressure of the fingertips. (3) When both hands are used to compress the throat, the thumb mark of one hand, and the finger marks of other hand, are usually found on either side of the throat. Sometimes, both thumb marks are found on one side, and several finger marks on the opposite side. (4) A grip from both hands, one being applied to the front and the other to the back, produces bruises on the front and back of the neck. In the case of children, or where the victim's neck is small, or the assailant's hand large, the bruises may be towards the back. Due to the shifting of the grip and sometimes the frank struggle of victim,bruises may be seen anywhere, even at the posterolateral sides of the neck and on the upper chest and collar bones. Bruises may be seen over the prominence of the larynx and at the level of the cricoid. They may also be seen in the grooves on either side of the larynx. As such, it cannot be definitely determined which hand was applied from which side. In such cases, it is not possible to tell whether an assailant seized the victim from front or behind. Sometimes movement of fingers may cause large irregular bruises. When fresh, the bruises are soft and red, but after several hours they appear brown, dry and parchment-like. If a soft material is kept between the hand and throat, bruising may not be seen. If the pressure upon the neck is maintained until after the death of the victim, bruising may be absent, because there has been no blood flowing to extravasate from the damaged vessels. Rarely, in throttling there are no external or internal injuries. This occurs if the victim is unconscious and amount of pressure to the neck is minimal.

If the finger-tips are pressed deeply, the pressure of the nails produce crescentic marks on the skin. They are more likely to be seen at the site of the thumb than the fingers, because when throat is gripped, the thumb exerts more localised pressure, and is less likely to move than the fingers during the struggle of the victim. Fingernail abrasions are of two types. (1) When the pressure is static, regularly curved, comma-like, dash-like or straight, up to 1.5 cm. in length and a few millimetres in width. (2) When the nails skid down the skin, parallel, linear lines, several centimetres in length may be seen. Many scratches may be several millimetres wide and placed a centimetre or so apart are produced by the victim herself, while trying to pull away the assailant's hand. As most victims are females, the nails may be long and the scratches more severe than those caused by the assailant. These defence scratches are seen in parallel lines in a vertical direction in the long axis of the neck, but are often random. Victim's fingernail scrapings may contain fragments of skin, blood, hair and fibres. Irregularity of the nails may leave signature on the victim's skin. If one hand only is used, there may be more extensive abrasions on the side of the neck to which the fingers were applied, the thumb making few scratches. If numerous scratches are found on the left side of the victim's neck, the inference will be that the throtttling was by the right hand of the assailant and vice versa. Haemorrhage in the subcutaneous tissues and the muscles underlying nail marks is usually scanty when compared with external injuries. In some cases, linear impression is produced. It is commonly assumed that the concavities of the crescentic abrasions follow the anatomical shape of the nail margin. But the results may be completely contrary. According to Gordon and Shapiro, the shape of the fingernail, largely determines the result. Nails with straight border give unpredictable results. As the nails become more pointed towards the centre of the free border, paradoxical results are more common. This results due to the anchoring of the skin of the victim by the central portion of the assailant's fingernail thus displacing the skin so as to produce the reversed crescent. In some cases, the injuries are indefinite abrasions, which may not be noticed unless examined carefully. A wet body may not show fingernail marks until drying of the skin has occurred. Marks of struggle and external appearances of asphyxia are similar to those found in strangulation. The tongue may or may not be bitten, but is usually protruded. Congestive-asphyxial signs appear in 15 to 30 seconds of pressure on the neck, but if a change in grip occurs and fingers impinge on carotid structures reflex cardiac arrest occurs, so that the intensity of congestive changes may be of any degree in any given death.

DISSECTION OF THE NECK : The neck structures should be dissected *in situ* and in a bloodless field. The block removal of the neck structures (as in routine autopsies), may produce artefacts in the neck tissues which resemble bruises. When the tongue and neck structures are firmly grasped and pulled upon, the hyoid bone may be fractured. Bruising invariably occurs in throttling, and is very important in the absence of external marks and

fracture of the neck structures. To obtain a bloodless field in the neck, the head should be opened, and the brain removed as in routine autopsy. The abdominal and thoracic organs should be removed as in routine autopsy. The head is then moved slowly up and down and allowed to drain of blood. Then an incision should be made from the chin to the manubrium sterni, or a V-shaped incision made on the neck and the platysma dissected laterally on both sides. If the veins are damaged, they should be ligated to prevent bleeding, as otherwise the blood will infiltrate into the tissues and may be mistaken for contusions. The sternomastoid muscles are cut from their attachments.

The common carotid artery is cut longitudinally, looking for any bruising around the bifurcation. Tears of the intima of the carotid artery are usually seen half to one cm. below the bifurcation of the vessels. Toothed dissecting forceps should not be used as it may damage the intima which resembles a tear. The hyoid bone is identified and the suprahyoid and infrahyoid muscles are reflected, noting for any contusions. The hyoid bone is grasped at the body in one hand and each greater horn is tested with the other hand by bending it outwards and inwards to note the presence of a fracture. The hyoid bone is removed from the neck and any fracture if present is confirmed. The fracture appears as an irregular break in the continuity of the bone and is usually associated with haemorrhage at the site of fracture. The thyroid cartilage is exposed by dissecting the thyroid gland through the isthmus and the middle constrictor muscle. The larynx and trachea are examined for the presence of any fractures.

Usually injuries of the cervical vertebral column and spinal cord are missed. The neck organs should be removed, the anterior longitudinal ligament of the vertebral column is exposed and examined. Incise posterior side of the neck and dissect down to the spinous process and the ligaments surrounding the foramen magnum, and odontoid process is cut. Expose the spinal cord.

POST-MORTEM DISSECTION ARTEFACTS OF THE NECK : During routine post-mortem examination, the holding of organs and the incision of vessels often produces extravasation of blood into the tissue spaces. These are dissection artefacts. When the structures of the neck are removed *en masse* by downward traction from the floor of the mouth, blood will extravasate in the deep connective tissues. All the structures of the neck should be examined *in situ* to ensure that post-mortem artefacts are not mistaken for ante-mortem bruises.

Internal : The soft tissues of the neck are compressed and forced upwards and backwards

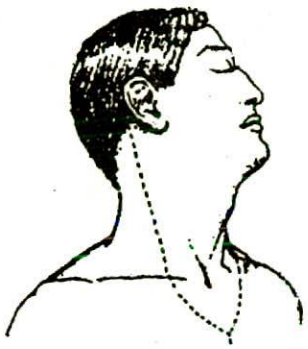

Fig. (14–14). Incision for dissection of neck.

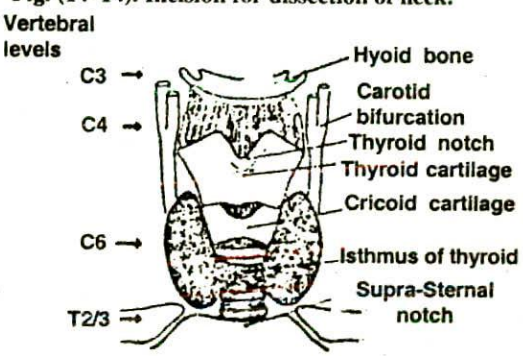

Fig. (14–15). Structures on the front of the neck.

against the cervical vertebrae. Bruises may be found in the dermis, in the superficial fascia, in the deep fascia, on the sheaths of the muscles, in the substance of the thyroid gland, and sometimes under the capsules and in the substance of the submandibular glands. Bruises are usually separate, and usually the muscles are involved. In some cases, bruising may be absent externally, although the deeper tissues may show fairly extensive bruising. Rarely, there are no external or internal injuries, if the victim is unconscious and amount of pressure to the neck is minimal. The mark on the surface of the neck may not exactly correspond with the internal bruising, because of the mobility of the skin which may alter the relationship which normally exists between it and underlying structures. The extent of bruising depends upon the degree of pressure used. In some cases, a small area of bruising on either side of the midline and usually over the thyroid cartilage or the hyoid bone may be the only finding. Sometimes, the bruising of the muscles is very slight, and as such the muscles of the neck should be dissected individually *in situ*. Tissues at the back of the neck may show bruising when counterpressure has been exerted. Muscles,

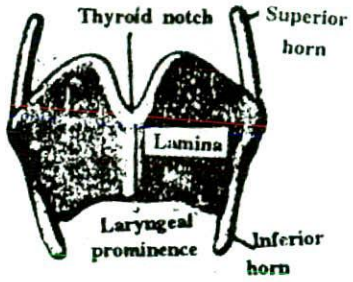

Fig (14–16). Thyroid cartilage

especially the sternomastoid, may be torn. The muscles surrounding the larynx, both anteriorly and posteriorly frequently show well marked bruising. There may be deep haemorrhage in the neck tissues surrounding or adjacent to the bifurcation of the common carotid artery. Carotid arteries show intimal tears in 10 to 15 % of cases at or near the carotid sinus.

Haemorrhages may occur in pharynx, tonsils, base of the tongue, the larynx immediately below the vocal cords and also beneath the capsule of the thyroid, submaxillary and parotid glands and lymphatic glands of the anterior triangle of the neck. The larynx is usually squeezed, as the pressure is bilateral. Lateral pressure of the fingers can displace any of the four horns inwards, either by direct pressure or by pressure on the thyrohyoid membrane, which then drags the horns medially. Fractures are common especially in old persons with calcified cartilages. To demonstrate the fractures of laryngeal cartilages, it is essential to strip the larynx of its attached muscles and ligaments. Bruises of the laryngeal mucous membrane is frequent, sometimes accompanied by severe laryngeal swelling which may or may not be accompanied by fracture of the hyoid bone and laryngeal cartilages. The surface of the epiglottis may show a shower of petechial haemorrhages or frank haemorrhage. Deep haemorrhages may be present in the base of the tongue.

Spurious collections of blood are commonly found behind the pharynx, larynx and on the front of the cervical spine. In most cases it is an artefact produced by overdistension and rupture of the venous sinuses, forming the pharyngo-laryngeal plexus, which can occur in natural deaths and may be either peri- or early postmortem in origin. They can be mistaken for evidence of throttling. Similarly, there can be small collection of blood around the hyoid and thyroid cartilages which can be mistaken for strangulation. Banding of the oesophagus is another artefact, especially when the tissues are congested. These bands are pale areas in the mucosa caused by post-mortem hypostasis being prevented from settling by the external pressure of larynx, trachea and aortic arch.

The superior horn of thyroid is much more fragile and more vulnerable than greater horn of hyoid bone. Fracture of the superior cornu of the thyroid at its base is common due to the local pressure, but the extent of damage varies. Often only the right horn may be broken to which the thumb was applied. Fracture of a horn even with slight bleeding can be produced after death by rough handling of the body, e.g., by hyperextension of the neck, and as such it is not proof of injury during life. Fracture of the ala of the thyroid cartilage occurs often either in the midline or obliquely or spirally across the left or right lamina, if pressure is much greater. This injury is more common in blows to the front of the neck, either by the fist or the edge of the hand, punching, kicking, arm-locks or fall on to a ridged object, such as gate or chair-back. They are usually vertical and near the junction of the laminae in the midline, and are the result of a direct blow upon the laryngeal prominence. The body of the thyroid cartilage can be broken by a **Karate blow** to the front of the neck or by contact with the handlebar of a bicycle or the edge of a chair or any projecting object. Sudden death may be caused through vagal inhibition of the heart or laryngo-spasm. In **"commando punch"**, the edge of the hand is brought forcibly across the side of the neck or the front of the larynx. Blows directly to the larynx indirectly stimulate the sinus region, or the laryngeal sensory nerve endings may trigger the cardio-inhibitory reflex. Fractures of the hyoid bone with inward driving of its distal fragments occur in 30 to 50% of cases, either due to direct lateral compression or due to indirect violence. In direct violence, the hyoid is drawn up and held rigid by the powerful muscles attached to its upper and anterior surface. Violent downward or lateral movement of the thyroid cartilage or pressure between the hyoid bone and the thyroid cartilage will exert traction through the thyrohyoid ligament and produce fractures of the hyoid bone. Fractures of the thyroid cartilage and also of hyoid bone are usually found in old people with calcified thyroid

cartilages and rigidly ossified hyoid bones, but are very rare in young children. Fracture of the cricoid cartilage (shaped like a signet ring with the signet part at the back) occurs almost exclusively due to the anteroposterior compression of it against the spine, e.g., by the thumbs or the forearm of the assailant. It tends to break either across the front midline or laterally. Focal haemorrhage is always seen around fracture caused during life. If bleeding is not seen by the naked eye, but histology of the fracture site shows some red cell extravasation, this can be accepted as ante-mortem in the presence of surface bruises, scratches, muscle bleeding, intralaryngeal and tongue haemorrhages. Minor fractures of the larynx may not be fatal. Fractures of the thyroid cartilage are more serious than those of the hyoid bone. Fractures of the cricoid cartilage is seen only in fatal cases. Severe injury to the internal cervical structures, e.g. bilateral comminuted fracture of the larynx, is usually caused by a blow to the neck or a fall on the neck rather than throttling. Larynx composed of nine cartilages is situated opposite to 3 to 6 cervical vertebrae in adult males and little higher in females. In these conditions, the fractured margins are driven inward, whereas in throttling squeezing of the sides of the hyoid bone and larynx causes the fractured margins to point outwards. The lungs show congestion with subpleural petechial haemorrhages. Pulmonary oedema may be present. A fine froth, often blood-stained is seen in the bronchi. Microscopically, haemorrhages are seen in the interstices under the pleurae and through rupture of the alveolar walls. Some areas are overdistended with ruptured alveoli and other areas are collapsed. The brain is usually congested and may show petechial haemorrhages in the white matter. Subarachnoid haemorrhages and rarely areas of small haemorrhages in the brain may be present. Haemorrhages may be found over the brain. Other internal features are similar to that of strangulation.

PALMAR STRANGULATION: The palm of one hand is placed horizontally across the mouth and nostrils without using the fingertips, its pressure being reinforced by placing the other palm on the top of it at right angles, the heel of the upper palm pressing upon the front of the neck. In such case the face is congested with petechiae. Diffuse bruising with fracture of thyroid may be seen. In most cases the victim is intoxicated.

Other Injuries: Bruises and abrasions may be found on other parts of the body. In cases where the victim has been forced to the ground and has been held down, bruising may be found: (1) in the scalp tissues over the back of the head, (2) in the tissues overlying the spinous processes of the lower cervical and upper dorsal vertebrae, (3) in the tissues overlying the posterior surface of the scapulae. If the assailant kneels on the victim, bruising of the muscles of the front of the chest and abdominal wall may be found. If the force is considerable, fracture ribs and contusions and lacerations of the abdominal organs may occur. Fingernail marks and fingertip bruising of the face are quite common. There may be an attempt to obstruct mouth.

CAUSE OF DEATH: Pure asphyxia from strangulation is rare, as considerable pressure is necessary to obstruct the trachea which will also block the jugular and carotid systems. Occlusion of the airway probably plays a minor role in causing death. The carotid arteries lie over the transverse processes of fourth, fifth and sixth cervical vertebrae and any anterolateral impact in this position can compress them against the underlyig bone. The usual mechanism of death is occlusion of carotid arteries. A shifting grip may suddenly impinge upon the carotid vessels causing sudden death. Thus, there may be a period of partial asphyxia terminated suddenly by the onset of cardiac arrest. About half of the deaths are due to vagal inhibition, in which the amount of force need not produce any damage either to skin, deep tissues or the arteries. Rapid or instantaneous death can occur due to sudden cardiac arrest, when a pale face with no signs of asphyxia are seen. This is commonly seen in throttling, often in hanging and less often in ligature strangulation. If a victim of throttling survives, amnesia and neck pain are common.

Hyoid Bone Fractures: They can be classified into three groups. (1) Inward compression fractures. (2) Anteroposterior compression fractures. (3) Avulsion fractures. Lacerations of the pharynx may occur following fracture of the hyoid bone.

Inward Compression Fractures: This is seen in case of throttling, where the main force is an inward compression acting on the hyoid bone. The fingers of the grasping hand squeeze the greater horns towards each other, due to which the bone may be fractured and the posterior fragment is displaced inwards. The periosteum is torn on the outer side of the bone, but not on the inner side. In such cases, if the body of the bone is grasped

in one hand, and the distal fragment between the finger and thumb of the other hand, the distal fragment can be easily bent in an inward direction, but outward movement is limited to the normal position only. The greater horn lies behind the front part of sternomastoid, 3 cm. below angle of mandible and 1.5 cm. from the midine. At the joint between the greater horn and body of hyoid, a similar fracture may be seen. In some cases, bilateral inward fractures may occur. In cases of putrefaction and maceration, if the soft tissues are not attached to the bone, it is difficult to say whether the small fragment was fractured inwards or outwards. The bone should be preserved with the soft tissues attached, if it has to be kept as an exhibit.

In some cases of bilateral fracture of hyoid bone in hanging, one greater horn is fractured outwards and the other inwards (fig14-17). This may be explained as follows : The hyoid bone is pressed backwards, as well as moves from side to side in hanging, due to which posterior end of the greater horn may be caught against a bony ridge or sides of the vertebrae. An inward fracture of the imprisoned greater horn occurs because of the continued side to side movement and counter-pressure. An outward fracture of the other greater horn occurs due to the further compression of the vertebral column.

Anteroposterior Compression Fractures: In cases of hanging, the hyoid bone is forced directly backwards, due to which the divergence of greater horns is increased which may fracture with outward displacement of the posterior small fragment. In such case, the periosteum is torn on the inner side of the fracture only, due to which the fragment can be easily moved outwards, but inward movement is limited to the normal position only. Like the inward compression fracture, anteroposterior compression fracture may occur either in the greater horn or at its junction with body, and it may be bilateral. When compression is severe, the small fragment may be completely detached from the bone and may lie either medially or laterally to the rest of the bone. In such cases, *in situ* examination of the hyoid bone in the neck only will decide whether the fracture was inward or outward. Outward fractures of the greater horn of hyoid bone are seen in ligature strangulations, run over motor vehicle accidents, blows on the front of the neck, etc. In these cases, the hyoid bone is grossly fractured with outward displacement of the fragments and multiple fractures of other structures are also found.

Inward compression or anteroposterior compression fractures are not of much practical value.

Avulsion Fractures : They occur due to muscular overactivity, without there being direct injury to the hyoid bone. They are also called "tug" or "traction" fractures.

The cartilaginous separations between the greater horns and the body, and the joints between the lesser horns and the body, or the presence of incomplete bony union of the hyoid parts should not be mistaken for fractures. Improper dissection of the neck may produce post-mortem fracture. A hyoid fracture should not be diagnosed as ante-mortem in origin, if there is no recent haemorrhage at the alleged traumatised site. The neck should be X-rayed in lateral oblique views to demonstrate fracture of the hyoid and cricoid.

MEDICO-LEGAL QUESTIONS

(1) WHETHER DEATH WAS CAUSED BY THROTTLING ?

The usual diagnostic signs of death due to manual strangulation are: (1) Cutaneous bruising and abrasions. (2) Extensive bruising with or without rupture of the neck muscles. (3) Engorgement of the tissues at and above the level of compression. (4) Fracture of the larynx, thyroid cartilage and hyoid bone. (5) Cricoid cartilage is almost exclusively fractured in throttling. (6) General signs of asphyxia.

When all the signs are present, the diagnosis is easy. In the absence of external signs , or when they are equivocal, care is necessary. The pressure must be applied for two minutes or more to cause death. Fingernail abrasions are often produced due to the victim trying to free himself from the throttling grip. The examination of the nails of the victim and assailant may indicate their origin. When a suspended body shows extensive injuries to the neck structures, there is a strong probability that the victim was first throttled and then suspended after death. In such case, signs of violence on the body, and sometimes of rape, if present are helpful. The discolourations produced in decomposing bruises are usually localised, but similar areas of decomposition may be found when

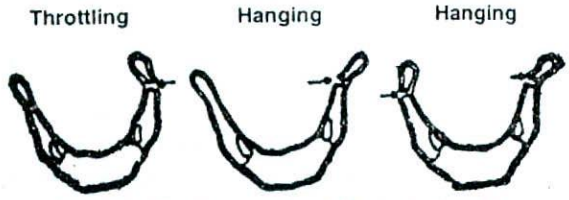

Fig (14–17). Fracture hyoid bone in throttling and hanging.

decomposition affects localised ante-mortem intravascular collections of blood in the cervical tissues, or localised patches of post-mortem lividity. Hyoid bone fracture is strongly suggestive of throttling.

When throttling has been attempted at about the moment of death, one cannot be certain whether the deceased was alive or dead at the time. Nail marks will appear much the same whether produced just before or just after death, but contusions are only produced during life.

(2) WHETHER THE THROTTLING WAS SUICIDAL, HOMICIDAL OR ACCIDENTAL ?

SUICIDAL THROTTLING : Suicide by throttling is not possible, because the compression of the windpipe produces rapid unconsciousness and the fingers are relaxed. Sometimes, a person might try to strangle himself with his hand, and upon failure might use a ligature. In such case, the degree to which the impressions exist will usually clear the doubt.

HOMICIDAL THROTTLING : Throttling is a common mode of homicide because the hand is immediately available. It is a method of choice in infants. The victims are usually infants, children or women. Adults can be throttled when under the influence of drugs or drink, or stunned or taken unawares. In an adult, signs of struggle are usually present, but if the throat is forcibly grasped and firmly compressed, the victim cannot struggle. The assailant may also sustain injury, especially scratches and bruising of the face and arms, or his hands and fingers may be bitten. The alleged assailant should be examined to correlate any injuries that may have been inflicted on him by the fingernails of the victim, such as scratches, which are found mostly on the back of the hand and face. The fingernail scrapings of the assailant should be taken to compare any debris found and the tissue types of the victim. Sometimes, it is preceded by rape or attempted rape. The victim may have been held down by the throat during intercourse or throttled to stop her cries. If contusions and fingernail abrasions are present on the neck, the presumption must be of homicide. The defence may allege that such marks have been produced due to fall by the deceased while his hand was passively applied to his neck, the marks being produced accidentally by the pressure of his own fingers. This is highly improbable.

ACCIDENTAL THROTTLING : A sudden application of one or both hands on other person's throat as a demonstration of affection, in joke, as a part of physiological experiment, etc., may cause death from cardiac inhibition. The victim cannot have died instantaneously if there is bruising, for bruising requires a beating heart.

(3) How much force could have been used by an assailant ? If there is severe damage to neck structures, it indicates use of considerable force, and is indicative of intent to injure, if not to kill. If there is fracture of hyoid bone or larynx, it indicates the use of appreciable force and is homicidal in nature, for it cannot be an accidental touch or momentary grip. A brief and minor contact with the neck would be consistent with restraint, without intention of injuring and causing death. Minor damage or absence of damage to the neck structures is presumptive of innocence, but sometimes deliberate interference with the neck structures can kill without producing much damage, e.g., the karate blow. If only slight changes are seen in the neck structures, a guarded opinion should be given about the probable degree of force used.

COMPRESSION OF THE NECK: This is a broad term used for non-specific causes of neck pressure which may be sudden. In hard compression, such as kicking or stamping or jumping on the neck, or karate chops, and flying kicks, soft tissues are grossly damaged. There may be vertical fracture of the laminae of thyroid cartilage, cricoid or upper tracheal rings. Hyoid bone and thyroid cartilage tend to be flattened and broken outwards. Death may be rapid with crush injury, and seepage of blood into the tissues, or it may be asphyxial due to swelling or obstruction of the airway. Surgical emphysema may be present. Soft, prolonged neck compression occurs in wrestling, carotid sleeper hold and choke hold.

SUFFOCATION

Suffocation is a general term to indicate that form of asphyxia, which is caused by deprivation of oxygen, either due to lack of oxygen in the environment or from obstruction of the air-passages at the level of the nose and mouth.

SMOTHERING: This is a form of asphyxia which is caused by closing the external respiratory orifices either by the hand or by other means, or blocking up the cavities of the nose and mouth by the introduction of a foreign substance, such as mud, paper, cloth, etc. Smothering has been used synonymously with suffocation by some authors.

Suicide by Smothering : (1) Suicidal smothering by the hand is impossible. (2) Suicide is possible by burying the face in a mattress or lying against the bed clothing to obstruct the nose and the mouth. It is usually seen in the mental patients or prisoners. (3) Sometimes, in cut-throat wounds, the trachea may be completely cut and the soft parts may

obstruct the trachea and the victim is smothered. (4) Suicidal suffocation can be effected by tying a polythene or similar bag over the head.

Accidental Smothering : Most fatal smotherings are accidental. (1) Infants covered with heavy blankets or bedding will not die of smothering. (2) Suffocation rarely occurs when an infant 3 months or less, turns on its face and buries it in soft pillow or mattress. It is not necessary that the mouth and nostrils should be completely closed at the start, for as obstruction increases and congestion develops, saliva, mucus, oedema fluid and traces of blood will pour out into the mouth and cause obstruction to breathing. (3) An epileptic or intoxicated person may smother himself accidentally by burying his face in a pillow or covering with bed clothes. (4) A person may accidentally fall into a large quantity of semisolid or finely divided material like mud, ashes, grain, sand, coal dust, etc., so that his mouth and nose are covered by the substance. The victim may struggle, inhale some of the material into his air-passges, and swallow some into his stomach in an effort to breathe. (5) Children may be suffocated accidentally while playing with plastic bags. Death may occur even if the open end of the bag is not tied around the neck due to cardiac inhibition due to CO_2 narcosis. Even a flat plastic sheet may adhere to the face in some way and block the nose and mouth which is exaggerated by attempts to breathe. Face is pale. Signs of asphyxia are faint or lacking in case of plastic bag suffocation. Moisture usually collects in the bag. (6) Smothering from plastic bags may occur due to the addictive habit of "glue-sniffing", in which the organic solvents of certain glues is used as an intoxicant, by putting some into a plastic bag and inserting the head to obtain a high concentration of vapour. In such cases, chemical analysis is essential. (7) Plastic bags may be applied to the head for experiment or auto-erotic exercise, as partial asphyxia is believed to increase sexual sensation. (8) It also occurs if the membranes remain round the head of the newborn after delivery.

Homicidal Smothering : Homicide is possible where the victim is incapacitated from drink or drugs, very weak, child or old person, in ill-health and when the victim is stunned by a blow. Usually, the mouth and nose are closed by a hand or cloth, or the face may be pressed into a pillow. Smothering can be caused by pinching the nose, with child in one hand, while the other hand is used to push the jaw to close mouth.

Environmental Suffocation : Death from hypoxic hypoxia may usually result from breathing in a vitiated atmosphere. A vitiated atmosphere is deficient in oxygen which is caused by displacement of oxygen from the atmosphere by inert gases or by gases generated in the atmosphere. CO, CO_2, methane, sulphuretted hydrogen and sulphur dioxide are commonly found in vitiated atmosphere. CO displaces oxygen from the atmosphere, and sulphur dioxide prevents haemoglobin from combining with oxygen. Deaths are almost always accidental. The concentration of oxygen in air is about 21% and CO_2 is 0.033%. An oxygen concentration of 16% or less is dangerous, and with 5% concentration, consciousness is lost rapidly and death occurs within a few minutes. (1) Smothering occurs in airtight place or one in which ventilation is negligible. This may occur when children become locked in old disused refrigerators or when they lock themselves into large boxes or trunks during play. (2) Suffocation due to lack of oxygen in the atmosphere may occur in the vicinity of lime kilns and wells or excavations in chalk rock, where the oxygen is displaced by CO_2. (3) In a confined space, such as tanks, grain-bins, silos, deep tanks of a ship, fermenters, tanning vats, unused wells, sewers, etc., hazardous gases, vapour, dust or fumes may accumulate or the oxygen may be deficient. A person may be suffocated on entering such a confined space. (4) Inhalation of irrespirable gases, such as CO_2, CO, hydrogen sulphide or smoke from a bruning house , or entering into disused wells produce suffocation. CO_2 and methane are the most commonly encountered suffocating gases. (5) Suffocation may occur in decompression, such as cabin failure of aircraft at high altitudes. (6) It also occurs in ship's tanks or other industrial metal chambers, in which oxygen is replaced by nitrogen. (7) In deaths associated with replacement of oxygen with an inert gas, rapid death is common before hypoxia had any physiological effect. In hypoxic death petechial haemorrhages are absent. Congestion and cyanosis may or may not be present.

Autopsy : Obstruction by bed clothing, a pillow, a cushion, etc., applied with skill, may not leave any external signs of violence, especially in the young and the old. When the face is pressed into a pillow, the skin around the nose and mouth may appear pale or white due to pressure. Petechiae and congestion are rarely seen unless the victim struggles

and fights for breath. Saliva, blood and tissue cells may be found on the pillow. If the orifices are closed by the hand, there may be scratches, distinct nail marks, or laceration of the soft parts of the victim's face. The lips, gums and tongue may show bruising or laceration. Slight bruising may be found in the mouth and nose, which should be confirmed by microscopy. The asphyxial signs and symptoms are severe, because death usually results due to slow asphyxia and often the fatal period is three to five minutes. The head and face may show intense congestion and cyanosis with numerous petechial haemorrhages in the skin of the face and beneath the conjunctivae. Blood may ooze out from the mouth and nose. The tongue may be protruded and may have been bitten. The air-passages contain bloodstained frothy fluid, with red blood cells and desquamated respiratory epithelial cells. The lungs are congested, oedematous and show areas of haemorrhage and collapse with areas of emphysema. Petechiae are usually present, even in cases where hypoxic changes are slight. Often, the head and face enclosed in a plastic bag are pale, with few petechial haemorrhages in the eyelids and pericardium. In some cases, death is rapid due to reflex cardiac arrest, and asphyxial signs are absent.

Internal : Blood-stained frothy fluid is present in air-passages. Mucus may be found at the back of the mouth. Slight acute emphysema and oedema of the lungs with scattered areas of atelectasis, petechiae and congestion are the major findings. The internal organs are deeply congested and sometimes show small haemorrhages. In the absence of localising signs at autopsy, the background to the death and the circumstances in which the body was found are of help. The finding of the material from the victim such as mucus, squamous epithelium on the smothering material is also of help. If a person is buried alive, earth and sand will be found in the respiratory tract.

Homicidal smothering is extremely difficult to detect. The autopsy may reveal asphyxia, but there may not be any corroborative medical evidence to prove foul play. The pathological changes must be interpreted keeping in view the medical history of the deceased, the scene of death, and the specific circumstances surrounding the death.

GAGGING: This is a form of asphyxia which results from forcing a cloth into the mouth, or the closure of mouth and nose by a cloth or similar material, which is tied around the head. A gag (such as rolled up cloth) pushed into the mouth sufficiently deep to block the pharynx will cause asphyxia. Initially, the airway may be patent through the nose; collections of saliva, excessive mucus with oedema of the pharynx and nasal mucosa, progressively causes complete obstruction. There may be congestion of the face and fine petechiae of the face, sclerae and conjunctivae. In adults, false dentures may impact in the throat sometimes during anaesthesia. In injuries to the nose and mouth, blood may seep into the back of the throat and clot. It is almost always homicidal and the victim is usually an infant. It is not possible for one person to gag and bind another. Sudden death due to reflex vagal inhibition may occur.

Gagging is usually resorted to prevent the victim's shouting for help, and death is usually not intended. The victim's hands are tied behind to prevent their removing the gag, and the legs are tied together to prevent walking or running for help. It should be noted, as to how the cloth piece is wrapped round the nose and mouth, how it is tied, and how far the mouth gag is stuffed inside the mouth.

OVERLAYING: Overlaying or compression suffocation results due to compression of the chest, so as to prevent breathing. It occurs when the mother or other person shares a bed with an infant. During sleep, the older person rolls on to or crushes the infant. The thoracic movements are limited and respiratory exchange is either reduced or completely prevented. In many such cases, the mother or older person goes to the bed under the influence of alcohol. It is very rare. Flattening of the nose and face (smothering) may or may not be seen. These parts are pale. The nostrils are often filled with froth, which may be blood-stained and this may stain the pillow or garment. The usual findings are those of asphyxia.

Traumatic asphyxia and smothering: When a person is buried in loose earth or sand or in grain silos, he may die due to occlusion of the nose and mouth and immobilisation of the chest and abdomen by external pressure sufficient to prevent respiratory movement.

BURKING: Burking is a method of homicidal smothering and traumatic asphyxia. William Burke and William Hare, made their living by digging up bodies from graveyards and supplying them to the

medical schools for dissection. Later they killed 16 persons in Edinburgh during the years 1927 and 1928, and sold their bodies to Dr. Robert Knox for use as specimens in his anatomy classes. A victim was invited to their house and given alcohol. Then the victim was thrown to the ground and Burke used to kneel or sit on the chest and close the nose and mouth with his hands, and Hare used to pull him round the room by the feet. Hare turned approver.

CHOKING: Choking is a form of asphyxia caused by an obstruction within the air-passages.

Accidental Choking : Choking is almost always accidental. (1) Choking from objects being lodged in the throat is commonly seen in the very young, elderly, psychiatric patients or in the infirm, particularly where the ability to swallow or masticate is severely impaired. (2) Choking commonly occurs during a meal when food is accidentally inhaled, especially when the victim is laughing or crying. (3) Vomited matter may be inhaled by a person under the influence of drink or of an anaesthetic, during a fit of epilepsy, or while in a state of insensibility from other causes. (4) Infants usually regurgitate clotted milk after a meal, and this may fall into the larynx. (5) Choking may occur due to inhalation of blood from facial injuries, such as a broken nose, or dislodged teeth, and laceration of the lips and gums inflicted during fight, if the victim becomes unconscious and lies on his back. (6) Impaction of solid bodies, such as a large bolus of food, piece of meat, fruitstone, onion, potato, corn, button, coin, rag, rubber teat, seeds, live fish, mud, leaves, cotton, or a set of false teeth, extracted teeth in dentistry, blood and cloth after ENT operation, such as tonsillectomy may cause asphyxia. (7) Gauze packs inserted during an operation can be inhaled and cause death. (8) Children often place objects like marbles or coins in their mouths, which may pass into, larynx or trachea during a sudden deep inspiration. (9) Objects like rubber balloons may be inhaled by children during play. (10) Choking due to regurgitation of food may occur during rape or violent sexual intercourse. (11) In head injury, irritation of the brain causes vomiting, which may be inhaled. (12) Food aspiration following suppression of the gag reflex by tranquilizing drugs is sometimes seen in lunatic asylums. The foreign body becomes arrested at, or just below the vocal cords and may produce an inflammatory reaction with oedema. (13) Insect bites especially those of bees, wasps and hornets, and drug reaction from penicillin, etc., can cause swelling of the lining membranes of the larynx and death within a few minutes due to an allergic reaction. (14) A blow to the front of the neck may cause severe swelling of the mucosa of the airway due to oedema and haemorrhage. Death may occur due to reflex vagal inhibition.

Microscopically, lungs show intense interalveolar oedema and collection of desquamated respiratory type epithelium. If there is struggle to breathe and attempts to remove the occluding object are unsuccessful, asphyxial changes are well marked. When a foreign body is inhaled, there is immediate acute respiratory distress, but once this has passed, the victim has little subsequent distress. Complications may develop after a latent interval.

Very rarely pins, safety pins, small bone pieces may be lodged in the air passages for relatively long periods without causing serious trouble.

Suffocation may occur from diseases, such as diphtheria, infectious mononucleosis, H. influenzae infection in children, rupture of aortic aneurysm in air-passages, haemoptysis in pulmonary tuberculosis, a tuberculous gland eroding into a bronchus and prolapsing into its lumen, acute oedema of the larynx due to inhalation of steam or ingestion of irritant substances, pharyngeal abscess, epiglottitis, laryngeal and bronchial growths, haemorrhage into the trachea, etc., and from the effects of certain poisons.

Choking from external causes may occur from impaction of a relatively large foreign body, a bolus of food, or a denture in the oesophagus, compressing the trachea.

Suicidal Choking : It is rare. The victims are usually mental patients (dementia or psychoses) or prisoners. For this a foreign body is thrust into the throat.

Homicidal Choking : Choking as a mode of infanticide may be caused by stuffing a wad of paper or cloth into the pharynx or larynx. It is very rare and is practicable only when the victim is suffering from disability or disease.

Cause of Death : (1) Cardiac inhibition is the common cause. (2) Asphyxia. (3) Laryngeal spasm. (4) Delayed death may result from pneumonia, lung abscess or bronchiectasis.

MECHANISM OF DEATH : Large foreign bodies may be impacted in the pharynx and cover

the opening of the larynx. By completely obstructing the airway, such impacted bodies may cause death from hypoxic hypoxia or anoxic anoxia. A small object partially blocking the lumen of larynx may cause death by laryngeal spasm. Usually laryngeal spasm passes off before the hypoxia becomes fatal. Sudden reflex neurogenic cardiovascular failure is probably produced by reflex parasympathetic cardiac inhibition. Impaction of a foreign body at the bifurcation of the trachea may cause death by asphyxia, but irritation in this region usually causes parasympathetic cardiac inhibition. A foreign body impacted in a bronchus may produce reflex cardiac inhibition.

CAFE CORONARY : This is a condition in which a healthy but grossly intoxicated person (restaurant patron), who begins a meal, suddenly turns blue, coughs violently, then collapses and dies, without much fuss. Death appears to be due to sudden heart attack. At autopsy, a large piece of poorly chewed food (bolus or a piece of meat) may be found obstructing the larynx. The clinical signs of choking are absent, because of the high blood alcohol content which anaesthetises the gag reflex.

TREATMENT : A blow on the back or on the sternum may cause coughing and expel the foreign body. If this is not successful, the foreign body should be removed from the hypopharynx with the middle and index fingers or with forceps.

Autopsy : The foreign body which caused the occlusion of air passages will be found in the mouth, larynx or trachea. When food or vomited matter has been inhaled, particles of food material may be observed embedded in thick mucus in the trachea and bronchi, and particles may be drawn into the bronchioles which distinguishes the condition from those cases in which food is forced up the oesophagus and falls into the larynx after death. Other signs of asphyxia will be seen.

TRAUMATIC ASPHYXIA: Traumatic asphyxia results from respiratory arrest due to mechanical fixation of the chest, so that the normal movements of the chest wall are prevented. Fatal cases are only due to accident. Usually, there is a gross compression of the chest by a powerful force.

Causes: (1) Multiple deaths are likely to occur when there is an outbreak of fire in a theater or whenever large crowds gather in an enclosed place. Some are crushed by the weight of the crowd, the chest being pressed violently, or may even get trampled on and crushed under feet (riot crush or human pile deaths). (2) Another common cause is crushing by falls of earth or stone usually in a coal mine or during tunnelling or in a building collapse. (3) Sometimes, the victim is pressed to the ground by some heavy weight as by a motor vehicle or other machinery. (4) A person repairing a car may be crushed when the jack slips and the vehicle falls on top of him. (5) It may occur in assault cases, where the victim is jumped or stamped upon and crushed by one or more assailants. (6) It occurs in industrial disasters, earthquakes and landslips. (7) Occassionally, it results from indirect compression, when the body is subjected to force in such a manner that his thighs and the knees are driven against his chest, th so-called "jack-knife" position

Post-mortem Appearances : An intense congestion, petechial and confluent haemorrhages and cyanosis of deep purple or purple-red colour of the head, neck, and upper chest above the level of compression is the prominent feature. The purple-red colour is due to haemorrhage into the tissues around the dilated blood vessels. Below this level, the skin is pale or mildly cyanosed. Areas of pallor seen at the level of the collar of the shirt, folds or creases in the garments, buttons, braces, etc., are another characteristic feature. The face, lips and scalp may be swollen and congested. Fractures of the ribs, and other bones may occur. If the patient recovers, the purple colour gradually disappears in ten to fourteen days, without the colour changes seen in bruises. Retrograde displacement of blood from the superior vena cava into the subclavian veins and the veins of the head and neck results from sudden compression of the chest or abdomen. The spread of the hydrostatic force to the veins of the upper limbs is prevented by valves in the subclavian veins. The displacement of the blood into the valveless veins of the head and neck causes the rupture of distal venules and capillaries. These ruptures produce numerous petechial haemorrhages into the skin, eyelids, conjunctivae, mucous membrane of the mouth and usually bleeding from the nose and ears. The bleeding in the eyes may form blood blisters which bulge through the eyelids and may occupy the whole of the sclera. Petechial haemorrhages may be seen over the surface of the cerebral hemispheres. The lungs are usually dark, heavy and have subpleural petechial haemorrhages. The right heart and all the veins above the aorta are markedly distended. Internal organs are congested.

POSTURAL OR POSITIONAL ASPHYXIA: It arises in special circumstances. (1) When cough reflex is impaired due to intoxication by drink or drugs, natural disease or unconsciousness from trauma or stroke. (2) Ability to breathe is impaired mechanically, usually by virtue of a posture that compresses the chest so that lungs cannot fill and empty freely. The individuals become trapped in restricted spaces, where because of the position of their bodies, they cannot move out of that area or position. This results in restriction of their ability to breathe, followed by death. It is always accidental.

Causes: It occurs. (1) When a person falls in a well and wedged between the walls. (2) An intoxicated person may slide out of bed so that his head and adjoining region hang down from the edge and the remaining body rests at an upper level. (3) From forcible flexion of the neck on the chest. (4) Occassionally, it results from indirect compression, when the body is subjected to force in such a manner that his thighs and the knees are driven against his chest, the so-called "jack-knife" position. There is usually marked congestion, cyanosis and petechiae in the face and neck.

DROWNING

Drowning is a form of asphyxia due to aspiration of fluid into air-passages, caused by submersion in water or other fluid. Complete submersion is not necessary, for submersion of the nose and mouth alone for a sufficient period can cause death from drowning. About 150,000 person die from drowning each year around the world.

Duration of Submersion in Fatal Cases : When a person falls into water, he sinks partly due to the force of the fall, and partly to the specific gravity of the body which is 1.08. The specific gravity of fat is 0.92; bone 2.01, muscle 1.08, soft organs 1.05, and brain 1.04. Shortly afterwards, he rises to the surface due to the natural buoyancy of the body. In sudden immersion into cold water, the victim may take a deep inhalation of water due to reflex from stimulation of the skin. He may hold his breath for varying periods until the CO_2 in his blood and tissues reaches sufficient levels to stimulate the respiratory centre. At that time, an inevitable inhalation of water may occur. When he cries for help and struggles, he is likely to inhale water, which produces coughing and drives out large volume of air out of lungs, and leads to disturbance of the rhythm of the breathing. He may vomit and aspirate some gastric contents. His struggle increases and again he sinks. If this occurs during inspiration, he will inhale more water. The cerebral hypoxia will continue until it is irreversible and death occurs. With warm water, cerebral anoxia becomes irreversible between three to ten minutes. Consciousness is usually lost within three minutes of submersion. The struggle for life with rising and sinking of the body goes on for a variable period, depending on the vitality of a person, until he remains submerged. Convulsive movements then occur, followed by coma or suspended animation and death.

THE MECHANISM OF DROWNING : Brouardel carried out experiments with dogs as follows. The four limbs of the dog were fixed to a wooden board, and a weight of lead was fixed to the lower end. A cannula was introduced into the femoral artery to record the blood pressure and heart beats, and a pneumograph attached to the epigastrium for recording respiratory movements. The dog was then lowered into a tub filled with water. The dog's head was kept about 30 cm. below the surface throughout. The process was divided into five stages. (1) The stage of surprise lasting for 5 to 10 seconds. The animal inspired once or twice but inactive. (2) The first stage of respiratory arrest, lasting for about one minute. The dog was violently agitated, fighting against its bonds and obviously trying to reach the surface. The mouth was shut and respiration arrested. (3) The stage of deep respiration, lasting for about one minute. The dog made some deep inspirations and expelled white foam to the surface. The agitation stopped. The eyes and mouth were open. A few swallowing movements were noted. (4) The second stage of respiratory arrest, lasting for about one minute. Thoracic movements were not observed. The corneal reflex was lost and pupils were widely dilated. (5) The stage of terminal gasps, lasting for about 30 seconds. The dog made 3 or 4 respiratory movements. The lips and jaw muscles showed fibrillary contractions. The whole process of drowning of these dogs in fresh water took 3 to 4 minutes. Under identical conditions, sea water is approximately twice as lethal as fresh water. In man, probably the course is similar except rising to the surface once or more. Hypoxic convulsions may occur in the fourth stage.

Kylestra (1965) reported that mice submerged in suitably oxygenated physiological saline solution, could survive for 18 hours. If this medium was replaced by sea water or tap water, the mice succumbed in less than twelve minutes. The volume inhaled is also important. Modell (1966) showed that in dogs, if the volume inhaled exceeded 44 ml. per kg. body weight,

the chance of survival was very small. The critical volume of sea water was twnety-two ml. per kg. In humans, it is believed, similar phenomenon occur in drowning.

Types : Drowning is of four types : (1) **Wet drowning** : In this, water is inhaled into lungs and the victim has severe chest pain. This is also known as **primary drowning,** in which death occurs within minutes of submersion secondary to cardiac arrest or ventricular fibrillation. Hyperkalaemia is only a relatively minor factor. (2) **Dry drowning:** In this type, water does not enter the lungs, but death results from immediate sustained laryngeal spasm due to inrush of water into the nasopharynx or larynx. Thick mucus, foam and froth may develop, producing a plug. This is seen in 10 to 20% cases of immersion and is commonly seen in children and adults under the influence of alcohol or sedative hypnotics. Resuscitated victims have panoramic views of past life and pleasant dreams without distress. (3) **Secondary drowning** (post- immersion syndrome or near drowning): **Near drowning** refers to a submersion victim who is resuscitated and survives for 24 hours. The person may or may not be conscious. These persons may develop hypoxaemia resulting in brain damage, electrolyte disturbances, pulmonary oedema, haemoglobinuria, pneumonitis, fever, sepsis, metabolic acidosis, chemical pneumonitis, cerebral oedema, cardiac arrhythmias and myocardial anoxia. Death may occur from half to several hours after resuscitation in about 20% of cases. In survivors, about 5 to 10% develop most serious neurologic damage. (4) **Immersion syndrome** (hydrocution or submersion inhibition): Death results from cardiac arrest due to vagal inhibition as a result of (a) cold water stimulating the nerve endings of the surface of the body, (b) water striking the epigastrium, (c) cold water entering ear drums, nasal passages, and the pharynx and larynx which cause stimulation of nerve endings of the mucosa. Falling or diving into the water, feet first, or "duck-diving" by the inexperienced, or diving involving horizontal entry into the water with a consequent blow on the abdomen cause such accident. Alcohol increases such effects, due to the general vasodilation of skin vessels, and possibly by some central effects on the vasomotor centre. This type of very rapid death on immersion is also said to occur in emotionally tense individuals, such as intending suicides, in whom the nervous reflex arcs seem more active. This is seen in one to two percent of cases of drowning. Deprivation of oxygen caused by obstruction of alveolar spaces is a factor in all types of drowning, especially as the time of immersion lengthens.

The Pathophysiology of Drowning : The pulmonary alveolar lining is semi-permeable. If water enters the alveoli, an exchange of water takes place through the alveolar lining. The extent and direction of this exchange depends on the difference between the osmotic pressure of the blood and the water.

(1) Drowning in Fresh Water or Brackish Water : In drowning in fresh water (0.6% NaCl), two-and-half litres or more of water may be inhaled and absorbed in three minutes; blood volume may increase by 50% causing a great strain on the heart due to hypervolaemia. Fresh water alters or denatures the protective surfactant which lines the alveolar wall, while sea water dilutes or washes it away. The denaturing of surfactant can continue even after a person is successfully resuscitated. Loss or inactivation of pulmonary surfactant (lipoprotein) and alveolar collapse decrease lung compliance, resulting in severe ventilation perfusion mismatch, with up to seventy-five percent of the blood perfusing non-ventilated areas. The defective functioning of surfactant leads to pulmonary oedema. When water is inhaled, vagal reflexes cause increased peripheral airway resistance with pulmonary vasoconstriction, development of pulmonary hypertension, decreased lung compliance and fall of ventilation perfusion ratios. The concentration of serum electrolytes (sodium and calcium) decreases considerably. Proteins and haemoglobin are also reduced. The serum potassium increases (a powerful myocardial toxin). This increased load causes rapid overburdening of the heart and produces pulmonary oedema. The oedema fluid contains serum proteins. The heart is subjected to hypoxia, overfilling, sodium deficit and potassium excess. Cardiac arrhythmias leading to ventricular tachycardia and fibrillation occur, probably due to hypoxia and haemodilution. Haemodilution leads to haemolysis, haemoglobinaemia, and haemoglobinuria, marked hyponatraemia and hyperkalaemia. Calcium levels may fall to two mEq/L.

(2) Drowning in Sea Water : Due to the high salinity of sea water (usually over three percent NaCl), water is drawn from the blood into the lung tissue, and produces severe pulmonary oedema, and

hypenatraemia. This causes haemoconcentration. Simultaneously, in an attempt to re-establish osmotic balance, salts from the water in the lungs pass into the blood stream. A marked bradycardia occurs, probably due to the raised plasma sodium level. Slow death occurs from asphyxia.

Causes of Death: (1) **Asphyxia:** Inhalation of fluid causes obstruction to the air-passages. Circulatory and respiratory failure occur simultaneously, due to anoxia of both the myocardium and the respiratory centre. (2) **Ventricular fibrillation:** In fresh water drowning death may occur in three to five minutes from a combination of anoxia, and a disturbed sodium-potasium ratio producing arrhythmias of the heart beat, ventricular tachycardia and fibrillation. Severe hyperkalaemia is only a relatively minor factor. (3) **Laryngeal spasm** may result from inrush of water into the nasopharynx or larynx. (4) **Vagal inhibition** is due to icy cold water, drunkenness, high emotion or excitement (intending suicides) and unexpected immersion. (5) **Exhaustion.** (6) **Injuries** : Fracture of skull and fracture-dislocation of cervical vertebrae may occur due to the head striking forcibly against some solid object. Concussion may occur due to striking the head against some hard substance, or the water itself while falling from a height.

Fatal Period : Death usually occurs in four to eight minutes of complete submersion.

TREATMENT : Artificial respiration and closed-chest cardiac compression should be started immediately. In fresh water drowning an external defibrillator should be applied to the chest and the electrolyte balance should be restored. In sea water drowning administration of oxygen and correction of haemoconcentration by infusion of hypotonic fluids should be carried out. The mouth and nostrils should be cleaned and air-passages kept clear by repeated suction. The body should be wrapped in warm blankets and stimulants given.

Direct mouth-to-mouth or direct mouth-to-nose breathing are the best methods of artificial respiration. The patient is made to lie on his back, and the head is hyperextended. The operator takes a deep breath and then breathes directly mouth-to-mouth or mouth-to-nose, or through a specially designed tube. The patient is allowed to exhale passively. This is repeated about fifteen to twenty times per minute. This should be continued for about an hour or till natural respirations are restored.

CLOSED-CHEST CARDIAC MASSAGE : The patient is made to lie on the back. The operator places his hands one on top of the other, on the lower end of the patient's sternum. Forcible rhythmic compressions are made 60 to 80 per minute to empty the blood from the ventricles. The force of compression must be sufficient to produce pulsation in the carotid and femoral arteries.

Post-mortem Appearances : External: The post-mortem signs are variable and none of them is pathognomonic. If the body is removed from the water shortly after death, the clothing is wet and the skin is wet, cold, moist and pale because of vascular contraction on the surface. Mud, silt, sand, sea-weed, water weed, algae, etc. may be present on or in the body, such as mouth, nostrils, ears, etc. The post-mortem lividity is light-pink in colour (simulating the colour in CO poisoning) due to oxygenation, but in some cases it is dusky and cyanotic, or it may be a mixture of the two. Post-mortem staining is usually found on the face, the upper part of the chest, hands, lower arms, feet and the calves, as the body usually floats face down, buttocks up, with legs and arms hanging down in front of the body. The face may or may not be cyanotic, the conjunctivae are sometimes congested and few petechial haemorrhages are seen beneath the conjunctivae, especially in the lower eyelids. The pupils are dilated. The tongue may be swollen and protruded. Petechial haemorrhages are rarely seen in the skin. Rigor mortis appears early, especially when a violent struggle takes place before death. Vomiting, micturition, defaecation and seminal emissions may occur agonally.

A fine, white, lathery **froth or foam** is seen at the mouth and nostrils, which is one of the most characteristic external signs of drowning. The inhalation of water irritates the mucous membrane of the air-passages due to which the tracheal and bronchial glands secrete large quantities of tenacious mucus, and the alveolar lining cell irritation produces oedema fluid. Vigorous agitation of the seromucoid secretion, and the surfactant with aspirated water and retained air by the violent respiratory efforts converts the mixture of endogenous secretions and drowning medium into froth. The froth consists of protein and water and the fine bubbles do not readily collapse when touched with the point of a knife. The froth may project as a small balloon or mushroom-like mass, from the mouth and nostrils for a distance of several centimetres. Froth is more common in drowning in sea water. Froth is usually white, but may be blood-stained, because of slight

admixture with blood from intrapulmonary bleeding. If wiped away, it gradually reappears, especially if pressure is applied on the chest. Froth is seen in death due to strangulation, acute pulmonary oedema, electrical shock, during an epileptic fit, in opium poisoning and putrefaction, but in all these cases it is not of such a large quantity as in drowning, and the bubbles are also much larger. Putrefaction converts froth into bubbly, reddish, foul-smelling fluid.

Cutis anserina or goose-skin or goose-flesh, in which the skin has granular and puckered appearance may be seen. It is produced by the spasm of the erector pilae muscles, attached to each hair follicle, and can occur in living when the skin comes in contact with cold water. It may occur on submersion of the body in cold water immediately after death, while the muscles were still warm and irritable. It is also produced by rigor mortis of the erector muscles. Agonal contraction of erector pilae is common. It is rarely seen in India, as the water is usually warm. Retraction of the scrotum and penis is due to the same cause, and has the same value. These changes have been designated "reaction phenomenon".

Weeds, gravel, grass, sticks, twigs, leaves, etc. present in the water may be firmly grasped in the hands due to **cadaveric spasm**. This strongly suggests that the person was alive when he drowned, because it indicates the struggle of the person for his life. This is seen rarely. The old adage about a "drowning man clutching a straw" contains a large amount of scientific truth. Damaged nails and abraded fingers showing sand, mud, or other materials under the nails due to struggle has the same significance.

Soddening of the skin occurs due to absorption of water into its outer layer. It is first seen on the fingertips in two to four hours and spreads to the palm and the backs of the fingers, and the back of the hand, in that order in about twenty-four hours. The accuracy of timing is not possible due to variations in environmental conditions. Similar progress and changes are seen in the skin of the foot, but when shoes are worn, it takes almost twice as long. Wrinkling of the skin begins to appear shortly after immersion, bleaching of epidermis in four to eight hours, and the bleached, wrinkled and sodden appearance is seen in twenty hours. The skin becomes sodden, thickened, wrinkled, and white in colour, known as **"washerwoman's hands"**. This is seen early in warm water. Similar changes are seen on the feet.

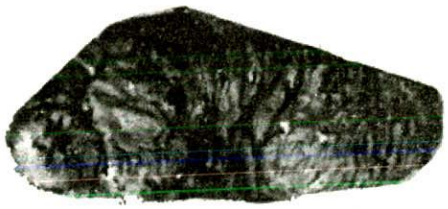

Fig. (14–18). Washerwoman's foot.

Contusions and abrasions produced during life may not be seen after removal from water, but are seen after the drying of the skin. In a few hours after removal from the water, the face may be bloated, either livid or black, later changing to a deep green. The discolouration is usually not found on surfaces which have been in close contact, as in the armpits and upper limbs if they are in close contact with the body, and the lower limbs if they are close together. The stains are usually not seen on the parts which have been closely wrapped in clothing due to pressure which prevents accumulation of fluids.

Internal : The lungs are voluminous, may completely cover the pericardial sac, and bulge out of chest when the sternum is removed. This is known as ballooning and is due to presence of fluid

Table (14–2) Difference in lungs between fresh water and sea water drowning.

	Trait	Fresh water drowning	Sea water drowning
(1)	Size and weight:	Ballooned but light.	Ballooned and heavy; weight up to 2 kg.
(2)	Colour :	Pale pink.	Purplish or bluish.
(3)	Consistency:	Emphysematous.	Soft and jelly-like.
(4)	Shape after removal from the body:	Retained; do not collapse.	Not retained; tend to flatten out.
(5)	Sectioning:	Crepitus is heard. Little froth and no fluid.	No crepitus. Copious fluid and froth.

and air in the bronchi. The lungs are overdistended, and the alveolar walls are torn. Peripheral displacement of air by water distends the air spaces and the medial aspects of each lung approach the midline. The oedema fluid in the bronchi blocks the passive collapse that normally occurs at death, holding the lungs in the inspiratory position. On section, an oedematous condition due to the presence of a large amount of watery, frothy, blood-stained fluid is seen. Drowning fluid actually penetrates alveolar walls to enter the tissues and the blood vessels. This has been described as **emphysema aquosum.** It is present in about 80% of cases and is presumptive evidence of death from drowning. If the victim is unconscious at the time of drowning, mere flooding of the lungs with water, but without formation of columns of froth occurs, which is known as **oedema aquosum**. The foam acts as a valve which permits air entry to the lungs but obstructs air exit from them. Usually the lungs are congested moderately, but may be pale due to the forcing out of blood from the lungs, and compressing of the vessels in the internal alveolar septa by the air and water trapped in the alveoli. The impression of ribs (grooves) are often seen on the lungs; the lungs feel doughy and readily pit on pressure. The alveolar walls may rupture due to increased pressure during forced expirations, and produce haemorrhages, which when present subpleurally are called **"Paltauf's haemorrhages"**. Paltauf's haemorrhages are shining, pale bluish-red, and may be minute or 3 to 5 cm. in diameter. They are usually present in about 50 percent of cases in the lower lobes of the lungs, but may be seen on the anterior surfaces of lungs, and the interlobar surfaces. Red and grey patches may be seen on the surface, due to Paltauf's haemorrhages and to patchy interstitial emphysema, respectively. The degree of ballooning is reduced in cases of pulmonary fibrosis and when extensive pleural adhesions are present. Petechial haemorrhages on the surfaces of the lungs are absent (or very rare), due to compression of the blood vessels in the interalveolar septa by the water.

In fresh water drowning, the lungs are ballooned but light in weight. They are pale-pink and appear uniformly emphysematous. They retain their normal shape and do not collapse when they are removed from the chest. A crepitus is heard on sectioning and each portion retains its normal shape. On compression, little froth is squeezed out, and there is no fluid in the tissue unless there is oedema. In salt water drowning, the lungs are ballooned and heavy, weighing up to 2 kg. They are purplish or bluish in colour, sodden and jelly-like in consistency and pit on pressure. When removed and placed on a flat surface, they tend to flatten out. On sectioning of the lung, crepitus is not heard. Copious amounts of fluid pour out of the cut sections even without compression. The shape of the sectioned portion is not retained. When squeezed the tissue is found to be filled with fluid in most parts of the lungs, i.e., they are wet and sodden. Occasionally, small intra-alveolar haemorrhages are seen in both fresh water and sea water drowning which causes the red staining of the foam in the respiratory tract. If the body remains in water for several hours, these changes become less marked, and the difference in appearance between the fresh water and sea water drowning lungs are not clear.

The most important histological findings in the lungs are interstitial congestion, oedema, alveolar macrophages, alveolar haemorrhages and alveolar wall disruption **(emphysema aquosum)**. Acute dilatation of the alveoli with extension, elongation and thinning of the septa and compression of the alveolar capillaries are significant.

In death due to laryngeal spasm, very little water may enter the lungs but asphyxial signs are present. In laryngeal spasm, there is no anatomic evidence. It is a diagnosis of inference and exclusion. In many cases of drowning, relatively dry lungs **(dry lung drowning)** are observed. This may occur if circulation continues for a short time after removal of the victim from the water or if resuscitative measures are carried out. In such cases, most of the water in the lungs is absorbed into the hypertonic plasma while the lungs remain distended. It has been suggested that this is likely to occur if laryngeal spasm supervenes to prevent further water entry, so that continued circulatory function can remove intra-alveolar fluid into the plasma. Microscopic examination of lungs from freshly drowned persons shows distension of alveoli, alveolar ducts and bronchioles, with extension, elongation and thinning of the septa and compression of the alveolar capillaries. Some alveolar walls may have been ruptured. Capillary congestion, intra-alveolar haemorrhages and protein-rich oedema fluid are often present. Intra-alveolar and intra-capillary red cells may not contain haemoglobin.

Froth appears within two minutes of drowning, and its quantity varies depending on the length of the submersion, and the violent respiratory efforts. The mucosa of the air-passages is congested. Froth in the air- passages varies from body to body. They may be completely filled by it, but usually the froth is seen in secondary bronchi and beyond. This is one of the characteristic signs of drowning, but if artificial respiration has been performed, especially by means of a respirator, the amount of froth and fluid in the air-passages may be greatly reduced. If there has been delay between death and examination, froth in the lungs and air-passages and over-distension of the lungs is not seen in most cases of drowning.

The fluid in the respiratory passages is of the same nature as the medium in which the body was found and substances like fine silt, grit, sand, weeds, diatoms, or various forms of algae can be found. If the matter has penetrated deeply into the lung it is useful evidence, but its presence in the trachea may be due to passive entry after death. Occasionally, the individual vomits during the unconscious gasping phase of drowning, and stomach contents may be found in the air-passages. The pleurae may be discoloured by haemorrhages, but petechial haemorrhages of asphyxial type are not found. Petechial haemorrhages may be present in the subepicardial region of the heart posteriorly.

If a dead body is thrown into water, due to the hydrostatic pressure water passes into the lungs. This **"hydrostatic lung"** will simulate the "drowning lung". According to Eisele, a "drowning lung" may be produced in a body remaining at the depth of 2 metres for 20 hours. A drowning lung together with the frothy fluid is diagnostic. Inhalation of water causes obstruction of the pulmonary circulation. This results in dilation of the right side of the heart and the large veins, which contain dark fluid blood. The blood is fluid due to the dilution by inhaled fluid and release of plasminogen activator from the damaged endothelium of pulmonary capillaries. The intima of the aorta is stained red.

The stomach contains water in 70% of cases. If the chemical and microscopic nature of the water is same as that of the medium of submersion, it is a valuable confirmatory evidence of drowning, but it is possible that the victim might have drunk the same water shortly before death. When a disagreeable liquid which would not be swallowed voluntarily and which corresponds to the drowning medium, e.g., liquid manure, or muddy water containing debris is found in the stomach, it is a valuable indication of drowning. The amount should be measured and examined for foreign substances. Water is also not found in the stomach, if the person died from syncope or shock and in putrefaction. Gastric mucosa is often soft and heavy. The small intestine may contain water in about 20% cases. This sign is regarded as positive evidence of death by drowning as it depends on peristaltic movement which is a vital act.

The brain is swollen with flattening of the gyri. The other organs are congested. When the struggle is violent, the victim may bruise or rupture muscles, especially those of the shoulder-girdle. Violent respiratory efforts may force some water into the middle ear through the Eustachian tubes. Haemorrhages are found in the middle ear in about half the cases of drowning. Haemorrhage in temporal bone or in the mastoid air cells, is seen in large number of cases. The increased pressure transmitted from the surrounding water to the body and tending to be uniformly distributed, more easily compresses air in closed cavities than the body tissues. The lining of those cavities absorbs fluid and swell up followed by vascular engorgement and haemorrhages into the chambers. **Temporal bone haemorrhages** are also seen in deaths due to hanging, head injury and CO poisoning. Fluidity of the blood is due to fibrinolysis resulting from release of plasminogen activator from the damaged endothelial system.

Cutis anserina, washerwoman appearance of the palms and soles, pulmonary oedema, and haemorrhage into the petrous and mastoid bones can be found in a victim of drug overdose thrown in water, and the victim of heart attack collapsing into water.

ALTERATIONS IN BLOOD (GETTLER TEST): Normally, the chloride content is almost equal in the right and left chambers of the heart, and is about 600 mg. per 100 ml. When drowning occurs in fresh water, water tends to pass from the lungs to the blood and the blood gets diluted by as much as 72% in 3 minutes, and the blood in the left side of the heart will show chloride content up to 50% lower than usual. In drowning in sea water, water is absorbed from the pulmonary circulation into the alveolar spaces which may be up to 42% and due to the haemoconcentration, the chloride content in the left side of the heart shows an increase up to 30 to 40%. A 25% difference in

chloride is significant. The test is of doubtful value.

Haemodilution is far more dangerous than haemoconcentration. The red cells are crenated in sea water drowning and lysed in fresh water drowning, and potassium sodium ratio is greatly increased.

DIATOMS : They are microscopic unicellular or colonial algae. They have a complex structure of their cell-walls which are usually strongly impregnated with silica and contain chlorophyll and diatomin, a brown pigment. Diatoms belong to class Bacillariophyceae. Diatom secretes hard siliceous outer box-like skeleton called a frustule (fig.14-19). They resist heat and acid. There are about 25,000 species. They vary considerably in size from 2 microns to one mm. in length or diameter. Most species are from 10 to 80 microns in length and if elongated, up to 10 microns in width. Diatoms measuring up to 60 microns in diameter are said to enter the pulmonary circulation during drowning. The diatom skeletons are readily recognisable as radially or axially symmetrical structures. They vary from place to place, and there are seasonal variations at the same place. They occur in cultivated soils and on surface of moist rocks and in the atmosphere. Large numbers of free floating diatoms are found in both fresh water and sea water. Their shape may be circular, triangular, oval, rectangular, linear, crescentic, boat-shaped, etc. They may be demonstrated in human organs by: (1) direct digestion of the material with nitric acid and sulphuric acid, (2) incineration in electrical oven and then dissolving the ashes with nitric acid, (3) direct microscopic examination of the lungs. Water is squeezed out from the lungs, centrifuged and sediment examined, (4) microscopic examination of tissue section, whereby optically empty sections are produced.

Fig. (14–19). Diatoms and planktons.

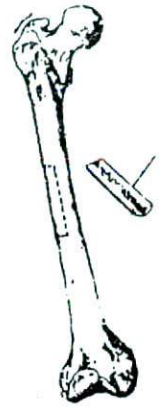

Fig. (14–20). Method of securing a specimen of bone marrow.

The drowning fluid and the particles in it, e.g., diatoms and planktons, pass from the ruptured alveolar wall into lymph channels and pulmonary veins and thus enter the left heart. Only a live body with a circulation could transport diatoms from the lungs to the brain, bone marrow, liver and other viscera, and skeletal muscle (fig. 14-21). They are also found in the bile and urine. The bone marrow is highly suitable and reliable. The bone marrow of long bones, such as the femur, tibia and humerus or sternum is examined for diatoms. The sternum is washed in distilled water. The periosteum is removed from the posterior surface. A piece of rectangular bone is removed with a sharp and clean knife and the marrow is curretted out from the gutter. Kidney, lung, liver or brain is also washed and 1x1 cm. pieces cut from the deeper tissue.

Technique : Five grams of bone marrow or liver, kidney, brain, etc. is put in a separate test tube and covered with five times the volume of concentrated nitric acid, and left at room temperature for one to two days to allow digestion. Alternatively, they can be heated in a water-bath overnight. This process chars, blackens, and destroys organic matter. Diatoms have silica shells and as such are not destroyed. The tube is centrifuged, the supernatant acid poured off and replaced with distilled water. This process is repeated 2 or 3 times to dilute the acid. The deposit is examined under phase-contrast or dark-ground illumination. The number of diatoms

Fig (14–21). Diatoms in drowning.

found in the tissues is relatively small.

It is claimed by some Japanese workers that using detergent or enzyme digestion instead of destructive acid, even soft-bodied algae and protozoa can be recovered from the tissues in drowning. Strong acid digestion markedly reduces the yield.

Control samples of about 2 litres water should be obtained from the site of accident for comparison. About 15 ml. of iodine solution is added to this to kill microorganisms, and allowed to settle overnight. The bulk of the water is poured off and the remainder centrifuged to recover diatoms. The finding of similar diatoms in the water and in the body tissues is in favour of drowning. Diatom test is often negative in undoubted cases of drowning in water full of diatoms. Recent evidence indicates that diatoms from the alimentary canal may enter the circulatory system and reach the various organs in the body, and occasionally may be found in cases other than drowning.

Plasma Specific Gravity : In drowning, the specific gravity of plasma from the left side of the heart is less than that of the plasma in the right side. In non-drowning cases the reverse is the case.

Magnesium: The magnesium content of the blood on the left side of heart is more than 1.25 mg/1000 ml than on the right side in salt water drowning.

Serum Strontium: Abdallah, et al (1985) reported raised serum strontium levels in deaths due to drowning, which was reciprocally related to the volume of the water aspirated.This will differentiate death due to drowning from post-mortem immersion of a body. Differences in the strontium concentration of blood from left and right heart are always greater than 75 µg/1 in sea water drowning (Azparren,et al., 1994).

Dead bodies are commonly found immersed in water and other fluids in all manner of places and circumstances. Such cases prove the most difficult medico-legal problems. The circumstances surrounding each individual case are important. It should be remembered that drowning is not limited to deep water situations like sea, tanks, rivers, lakes, wells, etc., but persons under the influence of drugs or drink, infants, epileptics can fall face down in a puddle or ditch and die of immersion.

DIAGNOSIS : The autopsy diagnosis of drowning can pose problems, because the findings are often minimal, obscure or completely absent. Drowning is one of the most difficult modes of death to prove at postmortem, especially when the body is not examined in a fresh condition. The diagnosis is basically one of exclusion based largely on the history and investigative reports of the case. When the findings are negative, cause of death may be given as "consistent with drowning" or even to admit that the cause of death is "undetermined". The reliable signs of drowning at autopsy are: (1) Fine, white froth at the mouth and nose. (2)The presence of weeds, stones, etc., firmly grasped in the hands. (3) The presence of fine froth in the lungs and air-passages. (4) The voluminous water-logged lungs. (5) The presence of water in the stomach and intestines, and (6) Findings of diatoms in the tissues.

The above signs will not be found, if death occurs due to vagal inhibition. In death from syncope, or when a person is in a state of helplessness from drink or other cause, or when a person receives an injury during fall into the water which prevents him from struggle, the signs will be slight. In dry drowning, the post-mortem appearances are those of asphyxia. A body removed from water undergoes rapid decomposition. If the post-mortem is delayed for a few hours, or if any appreciable delay has occurred before recovery of the body from water, the signs of drowning will not be found to a great extent.

If the body remains in water, lividity appears in the head, neck and chest, and putrefaction begins in the same place and produces the appearance of diffuse scalp haemorrhage. The blood becomes more fluid and water is found in gradually increasing quantity in the pleural cavities. In moderately advanced

putrefaction the diagnosis is difficult, the only evidence being the presence of water in the pleural cavities due to diffusion of water from the lungs, which finally collapse, and froth in bronchi. In advanced putrefaction the signs are completely absent. Algae get attached to exposed portions of drowned bodies, multiply and form a layer over the skin, which may be seen in 3 to 4 days in summer. Scraping off the algae will remove the superficial layers of the skin, due to which small abrasions may disappear.

THE CIRCUMSTANCES OF DROWNING : Bodies recovered from water may have died of: (1) natural disease before falling into the water, (2) natural disease while already in the water, (3) injuries before being thrown into water, (4) injury while in water, (5) drowning. The manner of death cannot be interpreted from an autopsy alone. The findings have to be viewed together with the circumstances.

ACCIDENTAL DROWNING : (1) DEATH IN THE DOMESTIC BATH : A sudden collapse from coronary or cerebrovascular disease may cause loss of consciousness, leading to immersion of head and death. Similarly, epilepsy or a fall producing a disabling head injury may also cause death. Other causes include CO poisoning, alcohol or drug intoxication and electrocution. In such cases, it should be established whether the head was really in the water and if so, whether the water was inhaled. A sample of the bath and tap water should be collected. Bruising of the head is usually seen from falling or being struck. Grip marks (finger-tip bruises) on legs or arms indicate forcible immersion. Natural disease should be excluded at autopsy and the viscera preserved for chemical analysis.

CASE: BRIDES OF THE BATH: John Lloyd took an insurance policy in the name of his wife. A few days later, she was found dead in the bathtub. At inquest, a verdict of accidental death was recorded. Lloyd collected insurance money. Earlier he married Burnham's daughter under an assumed name of George Joseph Smith. Mrs Smith was found dead in the bathtub, and a verdict of accidental death was recorded. Smith collected insurance money. Burnham complained to the police. It was further revealed that Smith has married Munday a year earlier who also died under similar circumstances, the insurance money having been collected by Smith. All were drowned in boarding houses with the women lying supine with their heads under the water at the sloping end of the bath tub, with their legs sticking out of the other end. The bodies did not show any signs of violence. No shouting was heard in any case.

Inspector Neil experimented with a bathing suit-clad police woman who got into a bathtub identical to those used by Smith. He tried to force her under water. Water was splashed everywhere. Neil could not hold the girl under the water for more than a few seconds at a time, though he was strong. Then he picked up her legs and pulled, when the body was supine. As her head slid under water, she became unconscious immediately. She recovered after 30 minutes resuscitation. Smith confessed his guilt and was hanged in 1915.

(2) DEATH OF NEWBORN INFANTS : In precipitate labour, the baby may fall into lavatory pan or bucket and die. Microscopy of the lungs and examination of the fluid in air-passages may be helpful. Foreign material inhaled into the lung parenchyma or passages may be seen and compared with a sample of fluid from bucket or lavatory pan. Chemical analysis of fluid in the air-passages, e.g., for soap or disinfectant agents present in the fluid in the lavatory or bucket is helpful.

(3) Occasionally, swimmers, fishermen and dock workers may be drowned accidentally, but it is common in non-swimmers. (4) It also occurs while bathing in tanks, rivers or sea. (5) Women may fall accidentally into a well while drawing water from it. (6) Children may fall in ponds or lakes while playing near their banks. (7) Usually, children die from drowning in shallow water, but adults usually epileptics, or under the influence of drink or drugs, or collapse due to coronary artery disease or dizziness due to hypertension may fall face down into shallow water and die. Drowning and neardrowning are major causes of morbidity and mortality in children. (8) Accidental drowning in the swimming pool sometimes results from jumping off the diving board. Impact of the forehead on the floor of the pool may cause hyperextension of the head and loss of consciousness with subsequent inhalation of water. In such cases, haemorrhages are seen in the deep neck muscles in the region of C_1 and C_2 with or without vertebral fractures.

Accidental drowning is very common.

HYPERVENTILATION DEATHS: For swimming for a longer time than normal under the water, the swimmer may hyperventilate before jumping into the water, due to which CO_2 tension is very much lowered. While swimming under the water, oxygen is utilised and CO_2 is produced, but the CO_2 tension does not rise sufficiently to irritate the respiratory centre and cause air-hunger, due to its abnormally low starting point. He may suddenly lose consciousness and drown.

DROWNING IN SKIN AND SCUBA DIVING : In skin diving simple mask and fins are used. The hazards are similar to those of swimming. SCUBA (self-contained underwater breathing apparatus) diving

enables prolonged independent stay under the water. Serious accidents are caused by equipment failure, environmental factors, or human factors, e.g., exhaustion, panic, pre-existing disease, improper use of equipment. Hazards of scuba diving are drowning, barotrauma (pressure changes associated with descent or ascent), bends (Caisson's disease), acute pulmonary oedema, emphysema, pneumothorax, air embolism, etc. In scuba diving, frequently there is entrapment of air within the lungs on rising from the depths, producing fatal or non-fatal extra-alveolar air syndrome. Air escapes from the alveoli and may result in interstitial emphysema, pneumothorax or air embolism. This is caused by disproportionate expansion of air-containing alveoli, as compared to the adjacent fluid-filled vascular changes during too rapid an ascent.

SUICIDAL DROWNING : In India, drowning is a common method of committing suicide especially amongst women, and more particularly in localities nearby the sea or river or canal. In case of a woman, the body is usually fully dressed. Suicides usually remove some of their outer clothing or shoes before leaping into the water. In a non-swimmer, a naked body suggests suicide. Suicides may drown themselves in very shallow water, or even by putting the head in a pail or cistern. If a body is found with heavy weights attached to it, it must be either homicide or suicide, and with children homicide alone. The nature of the weights, whether they are tied by ligature or fixed in clothing or found in the pockets are important. Sometimes, suicides tie their hands or legs together, and in such cases the manner of tying, and the knot of the rope or ligature should be examined to determine whether they could have been made by the suicide himself. Suicidal drowning may be preceded by the swallowing of the poison, cutting the throat or other suicidal attempts. Injuries may be caused during fall, especially if the bodies are found in the wells.

HOMICIDAL DROWNING : Murder by drowning is very rare, except in the case of infants and children. A person may be pushed into a river or into the sea. Marks of strangulation or throttling or severe violence applied to the head are presumptive of homicide. Bruises are strongly suspicious. Homicidal drowning in shallow water is possible, if the assailants hold the victim's head in such a position as to cover the nostrils and mouth. Signs of struggle or marks of violence on the body are likely to be found in such cases. If a person is taken unawares or rendered senseless and defenseless by alcohol or hypnotic drugs, and head is submerged in water for 5 to 10 minutes, no marks of violence will be found on the body.

INJURIES ON DROWNED PERSONS : Wounds may be produced before, at the time of, or after immersion. Before immersion, they may be of accidental, suicidal or homicidal origin. At the time of immersion, they may be produced by the deceased striking hard objects, such as rocks or stone. After immersion, injuries may be produeed from the striking of the body into rocks, coral or marine structures. As the body floats along the bottom, abrasions may occur on the head, face, backs of the hands, knees and the toes. The body may be hit by ship's propeller, which may produce often parallel, long and deep cuts and amputation. Aquatic life (fish, crabs, lobsters, eels, crustaceans, etc.) attack and destroy soft parts of the face, i.e., eyelids, lips, nose, ears, penis, scrotum, and also anus. The lesions are circular or oval and punched-out.

Probable Duration of Submersion : Body heat is lost about twice as rapidly in water than in air, and the temperature of the medium is reached in about fourteen hours. The time of floatation of body varies greatly. In salt water, bodies float earlier than in fresh water. Very obese persons and infants float more readily than thin or heavily-framed persons. The body floats in about 12 to 18 hours in summer, and 18 to 36 hours in winter in India. In cold countries the body floats in about two days to one week or more, depending on temperature of the water. The epidermis and nails are loosened and the skin of the hands and feet may be peeled off like glove or stocking in two to four days. The body usually floats with the spine uppermost, though obese persons and some women may float face up due to fat and gas in the breast and abdomen. In advanced decomposition, the body usually floats belly up. A drowned body will not move more than a few hundred metres from the initial position, unless there are strong currents. After floating it may drift a considerable distance from the site of death.

SEXUAL ASPHYXIAS

Sexual asphyxias (autoerotic asphyxia; autoerotic deaths) are very rare. Partial asphyxia caused by pressure on carotid vessels, or partial obstruction of air-passages causes cerebral disturbances and may lead to hallucinations of an erotic nature in some men. The degree of asphyxia produced by mechanical means is controlled, but in some cases death occurs accidentally. These cases are associated with some form of abnormal sexual behaviour, usually masochism and transvestism. The victims are always males, and usually young. The scene is usually the victim's own house; the bedroom, bathroom, basement

or attic are usually selected, and the door is locked from the inside. Adult males with homosexual preferences tend to carry out the procedure in pairs as a means of protection from accidental death.

Methods: Hanging is the most frequent form seen in sexual asphyxias. The neck is protected by a padding between the neck and the ligature.The ligature is passed around the neck in the form of a running noose, the free end of which is tied to a limb, or to a fixed object. The weight of the body is used to control the pressure. The free end of the ligature may be tied to the wrists or ankles, which are usually tied together. The noose can be tightened by extending the arms or legs, and when consciousness is lost, the relaxation of the limbs release the pressure on the neck. In some cases, a running noose may be passed upwards to some fixed point. There are indications that death is unintentional, for the individual is often found incompletely suspended with his feet on the ground or close to an object, such as a chair or stool, that would have allowed him to release the constriction. Evidence of previous episodes of similar activity may be found on the neck, such as old scars. Such persons are usually found naked, partly naked, or may be wearing women's dress. There may be padding of the brassiers to simulate breasts; female undergarments, and even sanitary pads, wigs and make-up may be worn. Frequently, they tie their arms, legs and sometimes waist and genitalia (bondage) with a rope, string, wire, padlocks, chain, etc. In addition to bonds and restraints, there is frequent evidence of self-mutilation, such as puncture wounds, cuts or burns, or one may find weights, clamps, or pincers attached to the genitalia or breasts. Erotic or pornographic literature or attractive female nude photographs are spread out within view, and there may be evidence of recent emission of semen. The person may blindfold himself or may arrange a mirror to watch the events or camera to make a photographic record. Many of these cases are misdiagnosed as suicidal hangings, and rarely as homicides. (2) Sexual gratification may be obtained by electrical stimulation. For this, electrodes are applied to the genitals or on abdominal wall, usually with a low voltage supply from a battery or transformer. (3) Other methods include, covering the head in a plastic or some impervious bag, which may be secured around the neck by an elastic band or a ligature to achieve partial anoxia. This ligature may form part of a system of bondage, which is also attached to the genitalia. In addition, lengths of chain with padlocks are often applied. It is sometimes combined with the inhalation of sniffing substances such as glue, ether, amyl nitrate, etc., and soaked pads with one of the sniffing substances are found with the bag. In these cases the head and face are pale, with few petechial haemorrhages in the eyelids. The interior of the bag contains abundant droplets of moisture. (4) Carbontetrachloride, trichloroethylene, paint thinners, petrol, ethylene chloride, amyl acetate, etc. are inhaled either directly from the container or by re-breathing after placing in a plastic bag.

The scene should be examined for: (1) Evidence of abnormal sexual behaviour, e.g., masochism, transvestism. (2) Evidence that the act had been practiced previously, such as grooves in the rafter or door from ropes, or verbal communications with others regarding the nature of activities, diaries, etc. (3) Evidence of attempts to conceal the act by some method to prevent a ligature from leaving marks around the neck. (4) No evidence to suggest a suicidal act.

CHAPTER 15
IMPOTENCE AND STERILITY

Impotence is the inability of a person to perform sexual intercourse. Sterility is the inability of the male to beget children, and in the female the inability to conceive children. About 10 to 15% of all married couples are involuntarily sterile. A person can be sterile without being impotent, or he can be impotent without being sterile, or both may co-exist. **Frigidity** is the inability to initiate or maintain the sexual arousal pattern in the female. Ejaculation which occurs immediately before or immediately after penetration is termed **premature ejaculation. Sexual dysfunction** is an impairment either in the desire for sexual gratification or in the ability to achieve it.

The question of impotence and sterility may arise in: (A) **Civil:** (1) Nullity of marriage, (2) divorce (S.12, Hindu Marriage Act, 1955; S.24, Special Marriage Act, 1954), (3) adultery, (4) disputed paternity, and legitimacy, (5) suits of adoption, and (6) claim for damages where loss of the sexual function is claimed as the result of an assault or accident. (B) **Criminal :** (1) adultery, (2) rape, and (3) unnatural offences, where impotency is pleaded as a defence.

Examination : The examination should be undertaken only when asked by the Court or the police. Before examining a male alleged to be impotent, a complete history of the previous illness, especially with reference to nervous and mental condition, and his sexual history should be obtained. A complete medical examination, including central nervous system should be carried out. The condition of the testes, epididymis, cord and penis should be noted and the private parts tested for sensation. The penis is supplied by nerves from the second, third and fourth sacral segments through the pudendal nerve and pelvic plexus. The length of the penis is measured from mons to the tip of glans, and circumference about middle of the shaft. When erect, the length is 15 cm. The penis varies greatly in size. The size of the penis has less constant relation to general physical development than that of any other organ of the body. The axis of the erect penis averages 26 degrees to the horizontal ranging from 16 to 36 degrees. The prostate and seminal vesicles are palpated per rectum. Pressure should be made on the vesicles, and matter expressed is brought to the meatus by pressing the finger along the urethra and examined for spermatozoa. In cases of sterility in the male, examination of the seminal fluid is essential.

Opinion : An opinion regarding potency must depend upon a man being like, or unlike other men. An opinion of diminished potency or impotency cannot be given, unless there is marked deviation from normal. If the male external genitals are normal, it cannot be said that the person is impotent. In such cases, **the opinion should be given in the negative form, stating that from the examination of the male, he finds nothing to suggest that the person is incapable of sexual intercourse.** Proof of potency or impotency is largely inferential. In the case of the female, the defect usually of the vagina is likely to be clearly seen.

THE CAUSES OF IMPOTENCE AND STERILITY IN THE MALE

(1) Age : The power of erection and therefore of coitus, may be present at a much earlier age than puberty. Poor physical development of the penis is a common cause of impotence, and therefore the medical examiner should depend more on the development of the private parts of the person than on his age. In cases of precocious development, as in gonadal or adrenal tumours, Mc Cune Albright syndrome, the sexual organs may show advance development as compared to the body as a whole. In advanced age, the power of erection and the ability to perform the coitus may diminish or disappear, but there is no specific age at which such loss of power occurs. Spermatozoa are not usually found before the age of puberty, but may be found in the semen of very old men. As long as live spermatozoa are present in the seminal fluid, the individual must be presumed to be fertile. Boys of 9 years and old people of 94 having children have been recorded.

(2) Defects of Development and Acquired Abnormalities : Absence of penis excludes coitus and non-development of penis may prevent the sexual act. In case of partial amputation, sexual act may not be possible. Certain malformations of external genitals, e.g., intersexuality, hypospadiasis

and epispadiasis may prevent intercourse, and even when intercourse is possible, the seminal fluid may not reach the vagina, because of the abnormal position of the urethral orifice, but such individuals are not necessarily sterile. Double penis and the penis adherent to the scrotum may cause difficulty in sexual intercourse. Loss of both testicles cause complete sterility after a certain time, but may not produce impotence. If the testes are removed before puberty impotence is the rule, but if the testes are removed after puberty, potency is retained. The removal of one testis does not affect either potency or fertility. Cryptorchids are not necessarily either sterile or impotent, but sterility is common. With both testes present a man may be sterile due to azoospermia.

(3) Local Diseases : Temporary impotency may be caused by acute disease of the penis, such as gonorrhoea, sores on the glans, etc. Large hernias, elephantiasis or large hydroceles, phimosis, paraphimosis and adherent prepuce may cause temporary impotence by mechanical obstruction to sexual intercourse. Diseases of the testicles, epididymis or penis, such as cancer, sarcoma, tuberculosis, syphilis, truma, etc., may cause sterility, impotence or both. Fracture pelvis with injury to parasympathetics, fracture spine at L-1 level with injury to sacral segments of spinal cord (eriginitus nerve, genital branch of genito-urinary nerve) can result in impotence. Tumours or injury of cauda equina, and spina bifida produce impotence. Lithotomy operation may damage ejaculatory ducts and produce sterility. Exposure to X-rays causes temporary azoospermia. When spermatic cords are blocked due to operation or disease, ligated or cut, sterility results.

(4) General Diseases : Impotence is common during the course of any acute illness; in convalescence, normal function is rapidly regained. General diseases causing anaemia and debility, e.g., diabetes, pulmonary tuberculosis, chronic nephritis, etc., may cause temporary impotence. General ill-health may be associated with diminished fertility. Endocrine disease may produce sexual infantalism and impotence. Certain conditions of the central nervous system, such as hemiplegia, paraplegia, syringomyelia, locomotor ataxia, disseminated sclerosis, may cause impotence, but this is not always so. Lack of sexual power is common in those suffering from paranoia, tabes dorsalis and general paralysis of the insane. Occasionally, the reverse effect, i.e. **satyriasis** or exessive sexual desire is seen. Impotence may also be produced by excessive masturbation and the excessive and continued use of some drugs, e.g. alcohol, opium, cannabis indica, tobacco, cocaine and bromides while the habit lasts. Impotence and failure to ejaculate may occur due to excessive tranquilisation. Temporary impotence is found in neurasthenia. Occupational exposure to lead may lead to sterility. Orchitis following mumps especially in adolescence may cause atrophy of the testes and may occasionally lead to sterility rather than impotence.

(5) Psychic Causes : Emotional disturbances are a common cause of temporary impotence. Fear of impotence or fear or inability to complete the act are common causes of temporary impotence but usually they are soon overcome. Disgust of the sexual act or dislike of the partner may cause temporary or permanent impotence. Anxiety, guilt sense, timidity, depression, excessive passion and sexual overindulgence produce temporary impotence. **Quoad hanc** (as far as this) is an individual who may be impotent with one particular woman but not with others. Until recently it was thought that psychological factors accounted for most cases of impotence. Nocturnal penile tumescence have revealed that a majority of cases of impotence have organic causes (Shabsigh, R. etal, Mueller, S.C., etal and Chiu, R.C, etal). Vasculogenic impotence is one of the most frequent causes of erectile failure (about 40%). Vasculogenic impotence may be due to poor arterial inflow into the penis (arteriogenic impotence), or excessive venous leakage of blood from the penis (venogenic impotence) or both. Other causes are diabetes mellitus (20%), psychogenic (12%), neurogenic (7%), malignancy, testosterone deficiency, trauma, etc. accounting for (20%).

Diagnostic procedures: For the functional testing of erectile capability papaverine is injected i.v. which induces vascular changes similar to those which occur after stimulation of cavernous nerves, i.e. increased arterial flow, decreased venous flow, and sinusoidal relaxation. The techniques to assess the arterial and venous systems before and after injection of pharmacologic agents include, evaluation of the penile arteries with duplex ultrasonography during papaverine-induced erection, pudendal arteriography, pharmacocavernosometry, and cavernosonography.

CAUSES OF IMPOTENCE AND STERILITY IN THE FEMALE

(1) **Age** : As the woman is the passive agent in the sexual act, the age has no effect on potency. Sexual desire is not completely lost in old age. A woman is usually fertile from puberty to the menopause.

CASE : A girl of 6 years and 6 months delivering full term baby has been reported. Kennedy records a case in which a woman gave birth to her twenty-second child when she was 63 years old after which she still continued to menstruate.

(2) **Defects of Development and Acquired Abnormalities** : The vagina is sometimes absent in malformed females and Turner type intersexuals which makes a female completely and permanently impotent and sterile. Impotence may result from some organic defects of the genitals, e.g., total occlusion of the vagina, adhesion of the labia, and the tough imperforate hymen, which can be cured by surgery. Vaginal injury or severe infection may lead to stricture, and kraurosis vulva in old women may cause narrowing of the vagina. The conical cervix and absence of uterus, ovaries or Fallopian tubes produce sterility but not impotence. Occlusion of the vagina does not indicate sterility as long as the internal organs are healthy.

(3) **Local Diseases** : Diseases of the genital organs do not cause impotence but may produce sterility, e.g., gonorrhoea involving the cervix, uterus, ovaries and Fallopian tubes. Hyperaesthesia of vagina, prolapse of the uterus or bladder, and vulval or vaginal tumours produce temporary impotence. Sterility may result from disease of the ovaries, obstruction of the Fallopian tubes or neck of the uterus, rectovaginal fistula, rupture perineum, disorder of menstruation, leucorrhoea, acid discharges from the vagina, etc.

(4) **General Diseases** : As the woman is the passive agent in sexual act, general diseases do not cause impotence. Occupational exposure to lead or exposure to X-rays lead to sterility. Drug dependence may also lead to sterility.

(5) **Psychic Causes** : Psychic factors may lead to impotence as in males. In males, the impotence is passive leading to non-erection, but in females it is of an active nature, leading to vaginismus. **Vaginismus** is a classical example of a psychosomatic illness. Anatomically, it may affect the perineal muscles exclusively, or may be felt as a varying constriction of the levator ani, right up to the vaginal fornices. There is usually a definite cramps-like spasm of the adductor muscles. Physiologically, these muscle groups contract spastically instead of their rhythmic contractual response to orgasmic experience. Hysterical hyperaesthesia co-exists with this condition, which in some cases may be more prominent than the spasm itself. The hyperaesthesia starts at the vaginal introitus, but in extreme cases it may be present all over the vulva and even over adjacent part of the abdomen and thighs. The spastic contraction of the vaginal outlet is completely involuntary reflex, stimulated by imagined, anticipated, or real attempts at vaginal penetration. In a fully developed state, constriction of the vaginal outlet is so severe that penetration by the penis is impossible. If an attempt is made to examine the hymen by passing a glass rod through hymenal orifice, sphincter muscles of the vagina contract due to which the rod is tightly grasped, and such severe pain is caused that she may scream. In a severe case, the legs cannot be separated sufficiently for the examination of the vulva and occasionally she may rise in a bow-shape, so that she rests only on her head and heels. It can occur with equal severity in the woman who has borne children as in the virgin. The aetiological factors are : (1) Male sexual dysfunction (wife's high levels of sexual frustration developing secondary to husband's impotence). (2) Psychosexually inhibiting influence of excessively severe control of social conduct due to religious orthodoxy. (3) Specific incidents of prior sexual trauma. (4) Stimulus derived from attempted heterosexual function by a woman with prior homosexual practice. (5) Secondary to dyspareunia. Severe laceration of the broad ligament, pelvic endometriosis, ulceration or fissures in the vagina, if untreated may lead to increasingly painful coitus and vaginismus. (6) Rarely, personal dislike or a general feeling of disgust at the idea of coitus. Psychotherapy is beneficial. Psychological causes affect fertility adversely. A woman may be sterile or impotent with a particular man but not with another. Both environment and nutrition have some influence upon conception.

STERILISATION

Sterilisation is a procedure to make a male or female person sterile, without any interference with potency. It is direct when it is intended to make the person operated upon sterile. It is indirect when it

is the unintended result of an operation for some other purpose such as for preserving the life or health.

TYPES : (1) COMPULSORY : It is performed on a person compulsorily, by an order of the State. It may be carried out on mental defectives and others from a strictly eugenic point of view or as a punishment for sexual criminals. It is not done in India.

(2) VOLUNTARY : It is performed on married persons with the consent of both the husband and wife. It is performed for (a) therapeutic, (b) eugenic, and (c) contraceptive purposes.

(A) THERAPEUTIC STERILISATION : This is performed to prevent danger to the health or life of the woman due to a future pregnancy. (B) EUGENIC STERILISATION: Sterilisation performed to prevent the conception of children who are likely to be physically or mentally defective is called eugenic sterilisation. The object is to improve the race by preventing the tansmission of disease and hereditable defects. (C) CONTRACEPTIVE STERILISATION: It is performed to limit the size of the family, i.e., for family planning.

METHODS : Sterilisation may be: (1) surgical. (2) radiological. (3) chemical, and (4) mechanical.

The methods of permanent sterilisation are (1) vasectomy in male, (2) tubectomy in female, and (3) exposure to deep X-rays in both sexes. The methods of temporary sterilisation are: (1) coitus interruptus, (2) loop, (3) oral hormonal pills, (4) foam tablets, (5) diaphragm, spermicidal jellies, and condom.

GUIDING PRINCIPLES : To avoid legal complications, the following precautions should be taken. (1) The written consent of both wife and husband should be obtained for contraceptive sterilisation. (2) It is not unlawful if perfomed on therapeutic or eugenic grounds after obtaining true and valid consent. (3) It is preferable to have a check up after vasectomy. The person should be advised to abstain from sexual intercourse for about three months or until the seminal examination shows absence of spermatozoa on two successive occasions. (4) The pills containing hormonal substances may be harmful rarely, and so necessary precautions have to be taken to avoid any complications.

ARTIFICIAL INSEMINATION

The artificial introduction of semen into the vagina, cervix or uterus to produce pregnancy is called artificial insemination. About five percent of males are infertile.

Types : (1) If the semen of the woman's husband is used, it is known as 'artificial insemination homologous' or "artificial insemination husband" (A.I.H). (2) If the semen of some person other than the husband is used, it is known as "artificial insemination donor" (A.I.D). (3) 'Pooled' donor semen is composed of donor semen to which semen from the husband has been added (A.I.H.D.).

Biological Aspects: Semen is obtained by masturbation and one ml. is deposited by means of a syringe in or near the cervix. The timing of insemination is important as the life span of the spermatozoa in the female reproductive tract is short. The time of maximum fertility coincides with ovulation. The ovum can survive in a fertilised form for 8 to 12 hours after it leaves ovary. The usual time taken by sperms to travel from vagina to tubes is 6 to 24 hours. The power of sperms to fertilise is usually retained for about 48 hours. Because of the problem of timing, insemination on several successive days in the month increases the chances of pregnancy. The success rate is 70 to 75% pregnancies within three to four months of the start of treatment. The use of frozen semen for AI.D. is becoming increasingly common. This is done by addition of glycerol, slow cooling, rapid freezing and storage below minus 79°C.

Indications : (1) When the husband is impotent. (2) When the husband is unable to deposit the semen in vagina due to hypospadiasis, epispadiasis, etc. (3) When the husband is sterile. (4) When there is Rh incompatibility between the husband and wife. (5) When the husband is suffering from hereditary disease.

Precautions : Certain recommendations have been made when a donor is used. They are : (1) Consent of the donor and his wife is essential. (2) The identity of the donor must remain secret. (3) The donor should not know to whom the semen is donated and the result of insemination. (4) The donor must be mentally and physically healthy and should not be suffering from any hereditary or familial disease. He should be screened for chromosomal studies for possible genetic defects. (5) The donor must not be a relative of either spouse, he should have had children of his own. (6) The race and characteristics of the donor should resemble those of the husband of the woman as closely as possible. (7) The donor should be of the same blood group as that of the husband. (8) There should not be any Rh incompatibility between the donor nd recipient. (9) The couple should be psychologically fit and emotionally stable. (10) The woman to be inseminated and her husband must give consent in

writing that an unknown donor should be used. (11) A witness must be present, when insemination is done. (12) It is usually wise to use "pooled" semen. When husband's semen is mixed with that of a donor, there is the technical possibility that the husband may, in fact be the father of the child. (13) The physician should have permission to use his own best judgement in selecting the donor, and he should screen the donor with all available tests, including chromosome studies, for possible genetic defects. (14) The physician who administers the artificial insemination should avoid delivering the child. This will avoid the necessity of either falsifying the birth records or disclosing the true paternity in those records.

Legal Problems : There is no statutory law in India for artificial insemination. Artificial insemination with the semen of the husband is justifiable and unobjectionable, since the child is actually the biologic product of both husband and wife, but it does not constitute evidence of proper consummation of marriage. The following are the legal apects of A.I.D. as applicable to India.

(1) **Adultery** : The donor and recipient cannot be held guilty of adultery in India, as S. 497, I.P.C. requires sexual intercourse as necessary part of adultery. Adultery is punishable with imprisonment up to five years.

(2) **Legitimacy** : The husband is not the actual father of the child, and as such, the child is illegitimate and cannot inherit property.

(3) **Nullity of Marriage and Divorce** : Mere A.I. is not a ground for nullity of marriage or divorce, because sterility is not a ground for it. However, if A.I. is due to impotence, it is a ground. Consent of husband has no bearing on this. When A.I. was done due to the impotence of the husband, the wife may ask for nullity or divorce, even if a child was born out of A.I. If A.I. is done without the consent of the husband, he can sue his wife for divorce and the doctor for damages.

(4) Natural Birth: If a child is born naturally some time after the birth of a child by A.I., the status of the child born after A.I. remains illegitimate unless it is adopted, and the status of the natural born child remains legitimate. But, if the parents do not declare A.I., the child remains to be a natural child for practical purposes.

(5) Unmarried Woman or Widow : An unmarried woman or widow may have a child from A.I. but that child would be illegitimate.

(6) Incest : There is risk of incest between the children born by A.I and children of the donor, but this is not an offence in India.

COMPLICATIONS: The husband may feel humiliation of his deficiency from the presence of the child of some one else and may develop psychiatric symptoms. If the child is mentally retarded or physically deformed, the father may develop bitter feelings, for he may be held responsible for this deformity by other persons. A neurosis may develop in the mother, based on the fact that the child belongs to her alone. She may also develop an obsession to know the donor, and to have a second child from the same donor. The child may suffer mental trauma if he learns his past history.

Conception is possible without penetration of the vagina by the penis due to deposition of semen on the thighs, or on the vulva which leads to "***fecundation ab extra***", the insemination occurring due to passage of spermatozoa from the external genitalia to the uterus.

THE DELHI ARTIFICIAL INSEMINATION (HUMAN) BILL, 1995: The main purposes of this legislation are: (1) to allow the issueless couples to have a child through A.I. and give it a legal status, (2) to control spread of HIV through A.I., (3) to regulate the donation, sale or supply of human semen/ovum for A.I., (4) to make obligatory on the part of the medical practitioners: (a) not to indulge in segregating the XX or XY chromosomes, (b) not to disclose the identity of the donor/recipient, (c) to prohibit to carry on semen bank without registration.

ASSISTED REPRODUCTIVE TECHNIQUE (ART): In india, there is no law on issues relating to ART. The following is the code of conduct for ART as formulated by Indian Council of Medical Research (ICMR). (1) ART clinic has to get approval from the appropriate accreditation authority. (2) The ART clinic is not commercial party in donor programme or surrogacy. (3) No ART procedure can be done without the spouses consent. (4) The sperm donor and surrogate should not be a relative or a friend of the couple. (5) Sex selection is not permitted. There should be pre-implantation diagnostic testing of parents for genetic abnormalities. (6) The consent of the couples for the use of embryos is a must. (7) Biological parents must adopt a child born through surrogacy. (8) The sale or transfer of human embryos outside the country is prohibited. (9) Donors should be screened for HIV and hepatitis B and C infections (10) The records have to be maintained and regularly chequed to guard against tampering.

TEST TUBE BABIES (in vitro fertilisation; I.V.F): The techniques available are : (1) The ovum is removed from the ovary through the abdominal wall and is fertilised by the sperm of her own husband in a small laboratory dish in an artificial medium. At the stage of blastocyst, the embryo is returned to the uterus through the uterine cervix, which gets implanted in the endometrium. (2) Similar re-implantation of one of her own ova fertilised externally by donor sperm. (3) Implantation in an infertile woman of another woman's ovum fertilised by the sperm of the first woman's husband. (4) Implantation in an infertile woman's uterus, of a donor ovum fertilised by donor sperm.

SURROGATE MOTHERHOOD: A surrogate mother is a woman who by contract agrees to bear a child for someone else. It is intended to help a couple, of whom the woman is infertile, but the male has not reproductive deficiency. Artificial insemination with the semen of the barren woman's husband is carried out in a hired woman (womb leasing). After surrogate birth, the baby is returned to its biological father and his wife. Another method is to remove a mature healthy ovum from the wife and fertilise it in 'vitro' with the husband's semen, and implant the embryo in the womb of a hired woman. The legal problems of surrogate motherhood are those of artificial insemination donor.