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EMBALMING

Principles and Legal Aspects



SECOND EDITION

Editor
ML Ajmani

JAYPEE

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Chapter 3

Death and Postmortem Changes

TD Dogra, A Sinha, ML Ajmani

INTRODUCTION

Conventionally, death means complete cessation of the activities of the three vital and interdependent systems of the body:

1. Circulatory
2. Nervous
3. Respiratory.

Death occurs when one or more of these systems completely fail. Many medicolegal experts classify the mode of death on the basis of these three systemic failures:

1. Syncope—failure of function of the circulatory system.
2. Asphyxia—failure of function of the respiratory system.
3. Coma—failure of function of the nervous system.

According to Spitz and Fisher, after a person is legally dead, the individual muscle fibers and other cells may continue to live for varying amount of time. Because of this phenomenon, the death of the person as a whole has come to be referred to as somatic death and the ultimate death of all of the cells of the body is described as cellular death.

There are two types of death: (1) somatic and (2) molecular death. Somatic death means the death of the whole organism. It progresses in orderly form from clinical death to brain death, then to biological death, and finally, to molecular death.

Somatic death means permanent and irreversible cessation of the following three organs that constitute "Tripod of Life":

1. Brain
2. Lung
3. Heart.

Failure of any one of these organs will result in loss of integration of the body systems.

However with the invent of cardiorespiratory resuscitative measures and in view of organ transplantation, it has become difficult to establish progression of the stages of death. Moreover with recent medical advances, it is now possible to keep the body alive by artificial supportive measures.

In clinical death, there is spontaneous cessation of respiration and heartbeat. If resuscitative measures are taken at this stage, life may be fully restored otherwise death will be established within a maximum of 5–6 minutes after the failure of respiration or circulation. This is a reversible stage of somatic death.

Brain death occurs in steps, so as the body. The cells die because of oxygen starvation (anoxia). The first part of the brain to die is the cerebral cortex (after 5 or 6 minutes), followed by midbrain and brainstem. Therefore, brain death can be:

- Cortical or cerebral death with an intact brainstem
- Brainstem death with the cerebrum intact and functionally cut-off
- Whole brain death.

Therefore, it is possible to have death of higher center, i.e. cerebrum without damaging the brainstem. In this condition, the patient remains unconscious but the respiratory system and heart may function for years. After brain death, biological death occurs. Now, the death of individual cells begins and results in cessation of the life processes of the various organs and tissues of the body. It is an irreversible phase of the somatic death.

Molecular death varies depending upon metabolic activity of the cells. It continues till there is a complete biodegradation of total tissue mass. The process of molecular death occurs in "bits and fragments" because more highly specialized and more active cells of the body react faster to a decrease in oxygen and nutrient contents, whereas less-specialized cells continue to live in the body for hours after somatic death are given in Table 3.1.

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Table 3.1: Lifespan of less-specialized cells after somatic death.

Cells	*Lifespan*
Cells in brain and nervous system	5 minutes
Muscle cells	3 hours
Blood cells	6 hours

AGONAL PERIOD

This is the period just prior to commencement of somatic death. This period has been greatly prolonged by medical science. Long-agonal period provides more time to disease process and secondary infections to act upon the body organs. Two types of thermal changes occur during the agonal period:

1. *Agonal fever*: It is an increase of body temperature just prior to death. It hastens the onset of rigor mortis and decomposition process after death. It is more often seen in infectious bodies.
2. *Agonal algor*: It is a cooling or lowering of the body temperature just prior to death. This is because metabolism and circulatory system have slowed down. It slows the onset of rigor mortis and decomposition and is good for the embalming procedures.

POSTMORTEM CHANGES

The postmortem changes occur in a sequential manner, which depends upon many factors like environmental conditions (temperature, humidity, weather, land, and water), manner of death, and time passed since death. After death, the body undergoes a number of physical and chemical changes. The longer the time between death and embalming, the more changes will occur and embalming process may not be successful. On the other hand, embalming conceals the postmortem changes. The postmortem changes can be divided into three groups:

1. *Immediate (somatic death):*
   - Insensibility and loss of voluntary power
   - Cessation of respiration
   - Cessation of circulation.
2. *Early changes (cellular death)*:
   - Pallor and loss of elasticity of skin
   - Changes in the eye
   - Cooling of the body (Algor mortis)
   - Postmortem lividity
   - Primary flaccidity of muscles
   - Rigor mortis
3. *Late changes (decomposition, autolysis, and decay)*:
   - Putrefaction and autolysis
   - *Modified putrefaction*:
     - Adipocere formation
     - Mummification.

Immediate Changes

Insensibility and Loss of Voluntary Power

Early signs of death can be found in cases of prolonged vagal inhibition, epilepsy, catalepsy, narcosis, electrocution, etc.

Cessation of Respiration

Complete stoppage of respiration for more than 5 minutes usually causes death. It may stop for short period as in Yoga, Cheyne–Stokes breathing, drowning, and newborn infants.

Cessation of Circulation

Stoppage of heart for more than 3–5 minutes is irrecoverable and is considered as evidence of death.

Early Changes

Changes in Skin

It becomes pale and there is loss of elasticity.

Changes in Eye

Loss of corneal reflex, opacity of the cornea, flaccidity of eyeball, pupillary changes (pupil dilation and no response to light), changes in blood vessels, and chemical changes.

Algor Mortis

It is a postmortem cooling of the body. Normal pathways of heat loss are circulation, respiration, and excretion. After death, these are no longer functioning and there may be slight rise in body temperature. It takes time for the body to cool to the temperature of the surrounding environment. In the first few hours after death, the body usually cools faster and thereafter, cooling slows as the body assumes the temperature of the surrounding environment. Normally, the dead body cools to temperature of the surrounding environment within 12–14 hours. The internal organs cool much slower than the surface tissues of the body and contribute to the putrefaction and autolytic changes at a rapid rate. The fall of temperature is further influenced by the following factors:

- Temperature difference between body and environment
- Individual physique—larger persons cool slowly; thin persons cool faster.

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- Age of the individual—younger body cools much faster than an adult.
- Body coverings—the amount of clothing on the body also affects algor mortis.

Postmortem Caloricity

In this condition, there is a rise of body temperature after death in first few hours. Cellular metabolism continues in the body after somatic death and releases heat and energy. This reaction continues until the entire oxygen present in the tissues is used; the heat released is trapped in the tissues because the normal pathways of heat loss circulation, respiration, and excretion are no longer functioning. This results in a slight rise in temperature. The heat loss is slowed, if the body is clothed or environment is warm.

Cadaveric Lividity, Hypostasis, and Suggillation for Postmortem Staining

It is a discoloration of skin due to the accumulation of the fluid blood into the capillaries and small veins of the rete mucosum in the most dependent parts of the body. Postmortem staining begins to form within an hour after death and is well marked in 4–12 hours. It starts as patchy mottling of the skin, which fuses to produce the discoloration of dependent parts. In the first few hours after death, these patches will disappear and new ones will form on the dependent parts on changing the position of body. Later on, fading is slow and incomplete due to its inability to flow in well-marked lividity. The coagulation of blood commences in 6–12 hours after death when the postmortem staining is fixed and pressure does not blanch the area. The color of hypostasis may depict the cause of death.

- Cherry red in carbon monoxide and sometimes in burns cases.
- In hydrocyanic acid poisoning and sometimes in burns, the color is bright red.
- Poisoning by nitrates, potassium chlorate, or potassium bicarbonate, color is reddish brown or deep blue.
- In phosphorus poisoning, color is dark brown.
- In asphyxia, the color may be bluish violet or purple.
- Dead body exposed to cold in refrigeration may become pink in color.
- In septic abortion due to *Clostridium welchii* the color may be grayish brown. Internal hypostasis may occur on the dependent part of the internal organs. It is likely to be confused with antemortem congestion and is required to be differentiated from contusion/bruise.

Primary Flaccidity of Muscles

This stage occurs in somatic death period immediately after death, all muscles are relaxed. This is called primary flaccidity. This is the best period for embalming the body because the body proteins will react best with formalin and produce firm tissues.

Rigor Mortis

Rigor mortis is a postmortem stiffening of all body muscles (voluntary and involuntary) with slight shortening. Individual cell death (muscle cell) takes place at this stage. Rigidity is well established in smooth muscles before it is apparent in the skeletal muscles.

After death, during primary flaccidity phase, the body tissue pH is slightly alkaline or neutral. In rigor mortis, tissues gradually become acidic with pH 5.5. As rigor passes the tissues again become alkaline because of decomposition of muscle proteins and formation of alkaline product (Table 3.2).

Table 3.2: Postmortem staining and contusion of body.

Postmortem staining	*Bruise/contusion*
• Occurs on extensive area of most dependent part	• Can occur anywhere on body
• Involves superficial layers	• Involves deeper tissues
• Sharply defined edges of skins	• Edges not sharply defined
• Does not appear elevated above surface	• Appear raised above surface
• Cuticle intact	• Cuticle may be abraded
• Uniform color, may become green on putrefaction	• Exhibits changes of color
• Pressure prevents postmortem staining color	• Pressure gives it a lighter color
• On cut section, no effusion of coagulated or liquid blood in subcutaneous tissues	• On cut section, infiltration of the tissues with coagulated or liquid blood

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During life, the pliability of the muscles depends on the union between the muscle protein, actin and myosin, and adenotriphosphate (ATP). ATP stores and releases energy for use in cellular processes. Dephosphorylation of ATP by the action of ATPase produces adenodiphosphate (ADP) and phosphate, and the ATP is replaced by resynthesis. After death, oxygen is no longer available to the cells, as a result ATP is depleted and there is no resynthesis of ATP. When the ATP is reduced to critical position, actin and myosin filaments combine as rigid link of actomyosin, which is viscous and inextensible producing rigidity of muscles. During life, glycogen stored in the muscles and liver is broken down to produce ATP, energy, and pyruvic acid. In the absence of oxygen, the pyruvic acid is reduced to lactic acid.

Therefore, there is rise in lactic acid and fall in hydrogen ion concentration due to glycolysis. After cellular death, the lactic acid content of muscle becomes very high. Thus rigor mortis marks the end of muscle cell life.

The time of onset of rigor mortis is variable depending on the local temperature and humidity. The rigor mortis is also affected by age, nature of death, muscular state, etc. It is likely to be apparent within 1–2 hours after death and takes 1–2 hours to develop. In temperate countries, the onset is within 3–6 hours and takes further 2–3 hours to develop. In India, usually it lasts 24–48 hours in winter and 18–36 hours in summer. It lasts for 2–3 days in temperate region. When rigor sets in early, it passes off quickly. In rigor, stiffness of the muscle mass is stronger than in normal muscle contraction. This is because in rigor all the muscle fibers contract and contraction is stronger than the normal muscle. The acid present in rigor inhibits bacterial activity thus preventing decomposition.

Rigor mortis appears first in eye then progresses to the face, lower jaw, upper limbs, trunk, and lower limbs affecting lastly the legs and feet. It passes off from the body in the same order as it appears, i.e. firstly from the face and lastly from the legs and feet. Refrigeration or cold may delay the onset. Heat will hasten the onset.

Rigor mortis is required to be differentiated from heat stiffening (muscles are shortened causing flexion of the joints), cold stiffening (in cold body fats solidify, giving the tissues rigor like firmness), cadaveric spasm (as in violent death—the position of the body remains as it is at the time of death and the rigor may not affect all the muscles of the body), gas stiffening, etc.

Secondary Flaccidity

When the rigor passes off in the unembalmed body, the muscles become soft and flaccid. Autolysis occurs and muscle protein starts breaking down and shows evidence of decomposition. The reaction of the muscle becomes alkaline.

Late Changes

Putrefaction

The putrefaction commences immediately after death at the cellular level, which is not evident to the naked eye. It is defined as decomposition of proteins. It is an anaerobic process brought about by the action of enzymes and results in the formation of foul smelling products. The proteolytic enzymes produced by bacteria break down complex proteins. The changes are brought by microorganisms and fungi such as *Penicillium*, *Aspergillus*, *Streptococci*, *Staphylococci*, *Balantidium proteus*, *Balantidium coli*, *Balantidium aerogenes capsulatus*, etc. These bacteria produce enzymes causing break down of body tissues. Lecithinase produced by *C. welchii* most important as it hydrolyses the lecithin, which is present in all cells including blood cells and is responsible for the postmortem hemolysis of blood. Putrefaction may appear after disappearance of rigor mortis but during summer, it may commence prior to the disappearance of rigor.

Autolysis

The process of self-digestion or self-destruction of the body cells and tissues by enzymes produced within the cells when living is called autolysis. In dead human body, the enzymes of decomposition have two sources—(1) saprophytic bacteria and (2) lysosomes. The saprophytic bacteria are normal inhabitants of the gastrointestinal tract. After death, they translocate and increase in number. They thrive on dead organic material. During life, lysosome, a cell organelle contains the digestive enzymes of a cell. As the pH changes from alkaline to acidic, the membrane surrounding the lysosome ruptures or is destroyed and their enzymes are released, which digest the surrounding cellular material, thus autolysis occurs. In this process, the proteins break down into peptones and amino acids, which reverse the pH to alkaline and stop the enzyme activity. Alkaline nature of the embalming fluid further weakens the action of the enzymes. The proteolytic, glycolytic, and lipolytic action of enzymes causing autodigestion and disintegration of various organs without bacterial effect is seen in parenchymatous and glandular tissues and brain. Autolytic fermentation results in maceration of dead fetus in uterus. Autodigestion of gastric mucosa by gastric juice

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may be seen resulting in softening and rupture of the stomach.

Putrefactive Changes

Putrefaction occurs at different rates in various body tissues and depends upon their moisture content. Three main changes are noticed during putrefaction:

1. Changes in color
2. Liberation of gases
3. Liquefaction of tissues.

Color changes: The color change is due to hemolysis of red blood cells. The liberated hemoglobin of blood is converted into sulfmethemoglobin by the combination of hydrogen sulfide formed in large intestine. The color change appears in 6–12 hours in summer and in a period of 1–2 days in winter. The pigment stains the tissue greenish. In unembalmed body, the first greenish discoloration appears over the right lower quadrant of the abdomen, i.e. the area of the cecum. Slowly the discoloration spreads to the entire trunk, genitalia, chest, neck, face, arms and legs, and then these patches become green, later coalesce and the whole skin of the body is discolored. The blood present in the superficial veins gradually breaks down and stains the surrounding tissues. The outline of the veins on the surface of the skin can be easily marked. The superficial veins especially over the shoulder, upper chest, neck, groin, and lower abdomen are stained greenish brown or purplish red due to hemolysis of red blood cells, which stain the wall of vessels and infiltrate into the tissues giving a "marbled" appearance. This occurs early but is more prominent in 36–48 hours. The early discoloration that occurs due to hemolysis of red blood cells is the "postmortem stain". This staining of the tissues is extravascular and cannot be removed by arterial injection and blood drainage.

Liberation of foul-smelling gases: As decomposition progresses, gases are formed in the viscera, firstly in the stomach and intestine and later in the body tissues. This is due to reduction of the complicated proteins and carbohydrates, which split into simple compounds like amino acid, ammonia, carbon dioxide, hydrogen sulfide, methane, and mercaptans. The gases have characteristic smell of their own; hydrogen sulfide smells like a rotten egg; hydrogen phosphate like garlic and ammonia smells urinous. Gases collected in the gastrointestinal tract in 6–12 hours in summer and the abdomen becomes tense and distended. On opening the abdomen, at times gases may escape with explosive noise. As a result of the pressure from the gas, the contents of the stomach and the lungs are compressed and forced through the oral and nasal cavities. Such an evacuation is called "purge". The purge material from stomach is a foul-smelling liquid and contains acid and is described as coffee ground in color. Purge from the lungs is generally frothy. The gases are noninflammable in the early stages, but later on, there is enough collection of hydrogen sulfide, which can be ignited to burn with a blue flame.

The eyeballs become soft and yielding. Cornea becomes white, flattened, and later it collapses, 18–36 hours after death, the gases collect in body tissues and cavities causing considerable pressure and the features become bloated. The subcutaneous tissues become emphysematous giving an appearance of corpulence to a thin body. Certain areas such as breast, scrotum, and eyelids easily distend with gases. Eyeballs bulge out of sockets, tongue is forced out between the swollen lips, the sphincters relax and urine and feces may escape. Gases may accumulate in tissues, giving crepitant sponge like feeling on touch and spread to inflate the body. The gas formation in the blood vessels may force fluid, air, and liquid fat between epidermis and dermis developing small blisters. Blisters contain blood-stained fluid. These gradually enlarge, coalesce, and rupture causing large area to be denuded of the cuticle. The break down of vessel wall and cell membranes lead to water logging of tissues, which further facilitates to the spread of bacteria. The anus and uterus may prolapse in 48–72 hours. Postmortem delivery of a fetus has been known to take place.

Hypostasis stain may get displaced in any direction after 3 days. The face is so discolored and bloated that identification becomes very difficult.

Hair become loose and are easily pulled out in 48–72 hours, the nails are also loose. In 3–5 days or more, the sutures of skull especially in children are separated and brain gets liquefied. The skin of the hand and feet shows slippage and may come out in the glove in stocking fashion.

Luminescence of dead body may occur due to contamination of bacteria like photobacterium fischeri, luminescent fungi, armillaria mellea, etc.

Small military plaque consisting of calcium fat endothelial cells and bacteria, which may be mistaken for inflammatory lesion 1–3-mm size are seen on endothelial surface of pleura, peritoneum, pericardium, and endocardium in advanced stage of decomposition. Colliquative putrefaction begins after 5–10 days of death and skeletonization may occur depending upon circumstances of the dead body.

Internal Phenomenon

The order of decomposition of the various organs and tissues of the body varies depending upon their moisture

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content. The organs containing muscular and fiber tissue resist putrefaction longer than the parenchymatous organs with the exception of intestine and stomach, which may get decomposed rapidly. The order of tissue decomposition is given below:

- Soft tissue
- Firm tissue
- Hard tissue.

The blood-rich organs and organs close to source of bacterial infection putrefy rapidly. Vascular system is one of the last systems to decompose. The common sequence of decomposition changes is as follows:

- Larynx and trachea—infant brain—stomach—small intestine
- Large intestine—spleen—mesentery and omentum—liver
- Adult brain—heart—lungs—kidneys—urinary bladder—esophagus
- Pancreas—diaphragm—veins—arteries—prostate nonpregnant uterus.

Factors Affecting the Rate of Putrefaction

External factors: Temperature—putrefaction commences at 10°C and is optimum between 21°C and 38°C. It is arrested below 0°C and above 48°C. Other factors are moisture, air, clothing, etc.

Internal factors: Age, sex, condition of the body, cause of death, and mutilation.

Putrefaction in Water

It is rapid in warm water and slow in cold and salted water. In buried bodies, it is slower than in bodies exposed to air and water due to the anaerobic conditions. If buried immediately after death, the rate of putrefaction is slow; if buried after putrefaction has set in, it is rapid. As a general rule, body decomposes in air twice as rapidly as in water and eight times as rapidly as in earth. Putrefaction is slow in old and aged bodies due to more fibrosis and less of moisture content. It is rapid in women and obese persons because of more fat and moisture.

Modified Putrefaction

Adipocere (saponification/grave wax): It is soft, whitish, greasy material consisting mainly of fatty acids formed by the hydrolysis and hydrogenation of body fats. Ultimately, fat is converted into palmitic, stearic, and hydroxystearic acid and mixture of these substances forms adipocere. It first begins in the subcutaneous fat in the buttock, breast, cheek, lower abdomen, and thigh. The presence of moisture is necessary for the formation of adipocere. Warmth enhances the formation of adipocere. Once the adipocere starts to form putrefaction is retarded because of the acid formed, which inhibits the bacterial activity. Its medicolegal importance is that the surface features are preserved and body can be identified years after burial. Adipocere formation starts within days of death and take 3–6 months to become visible. Time required for adipocere formation in India observed is within 3 days. In temperate climate, it is about 3 weeks.

Mummification: It is the complete dehydration, desiccation, and shriveling of the dead body due to evaporation of moisture. Mummification begins in the exposed parts such as hands, feet, and the face and then extends toward the trunk. It resists decomposition due to lack of moisture. This occurs in hot and dry atmosphere. Embalmed body can become mummified by the simple process of dehydration, if left uncared.

DISPOSAL OF THE DEAD

The methods of the disposal of the dead vary with the religion and social and economic status of the deceased. Most of the bodies are disposed off unpreserved. The most commonly practiced method of disposal in India is either burial or cremation. The body is wrapped in cloth and buried in the soil in a particular community. In the large cities, incineration is done in the welt designed electricity operated crematorium. The cremator maintains a high degree of temperature around 600–700°C for total combustion of the body. It takes about 1–2 hours to fully consume an average adult body. In towns and villages, the incineration is done in an open place by burning the body. The energy for heating is obtained from burning the dry wood.

In India embalming is not necessary for burial or cremation. People prefer the traditional way of quick method of disposal of the dead within the shortest possible time after doing the last rites. Preservation is required only when the body has to be transported or when the preservation is desired pending the arrival of the next of kin. Embalming is done solely by anatomy departments of the medical schools in India. Medical schools are located only in big cities.

With the improvement in educational standard and change in the social pattern, people are becoming more and more aware about the science of embalming and possibility of preserving the cadaver for variable length of times after death.

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EMBALMING

Principles and Legal Aspects

Embalming has a very long and *cross-cultural* history, with many cultures giving the embalming processes a greater religious meaning. Modern embalming techniques are not the result of a single practitioner, but rather the accumulation of many decades, even centuries of research, trial–error and invention. A standardized version and variation on techniques are included in the book.

It is important to know more about the process of embalming, its history, whether or not it is necessary, and how it may affect the environment, in order to know if it is something you would want for yourself or for you loved one.

Viewing the deceased prior to the funeral is a common practice and embalming is recommended to prevent any natural deterioration of the remains, which would cause further distress to family and friends. Embalming is also a general legal requirement for international repatriation of human remains and is required by a variety of laws depending on locality, such as for extended time between death and final disposition.

The first edition of the book *Embalming: Principles and Legal Aspects* was published in 1998. It was based on his practical experience in the subject at AIIMS, New Delhi, and outcome of the National Workshop on Embalming and AIDS where need for detailed information on embalming was realized. Care has been taken in the text to provide all the necessary information conforming to the Indian environment and availability of resources in any medical school in the country.

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