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REVIEW ARTICLE

From Death to Decay : An Overview of Postmortem Changes

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ABSTRACT

Background: The normal course of the body's disintegration after death, starting at the cellular level, is known as postmortem changes. The changes that start right after death last for a long time to different organs at varying speeds. Many internal and external factors influence the start and severity of these changes. The rates are imprecise, vary across different geographic regions, and fluctuate seasonally within a single geographic location. One of the main goals of the forensic autopsy is to estimate the postmortem interval (PMI), or time since death, and understanding postmortem changes is crucial for this purpose.

Aim: The current review provides a view of understanding postmortem changes,their classifications, their time of onset, their rate, and the factors influencing them.

Conclusions: In summary, researchers have classified postmortem changes according to their order of appearance and they emphasize the value of understanding postmortem changes in the forensic field.

Keywords: Postmortem Changes, postmortem interval, death.

INTRODUCTION

Death is the termination of the physiological mechanisms that keep cells intact and functional. The body goes through a series of progressive and permanent physical and chemical changes almost immediately after death **[1].**

Post-mortem change is the term for the natural disintegration of the body that occurs following death, at the cellular level. The procedure involves complex cellular and biochemical processes. The immediate post-mortem alterations persist for a significant duration, with varying rates for different organs. Numerous internal and external factors affect the onset and degree of these changes. These alterations could be important for establishing or verifying the time of death, providing a clue to the method or cause of death, or suggesting that a body might have been moved after it passed away **[2].**

Two crucial pieces of information must be given to forensic pathologists before they can estimate the PMI. The initial time, referred to as time A for clarity, is when the deceased was last confirmed to be alive. The deceased was discovered to be dead during the second instance (time B). When estimating the time of death, the pathologist can only definitively state that the deceased passed away between time A and time B **[3].**

Before the commencement of noticeable, gross decomposition modifications, the body goes through several early stages that occur over the course of death and lead to a distinct change in the physical nature and/or appearance of the body. These modifications may cause confusion if they are not

acknowledged because they have historically been utilized when estimating the PMI **[4].**

Broad Classification of Postmortem Changes: -

Postmortem alterations are categorized into immediate, early, and late postmortem alterations according to when they occur **[5].**

I- Immediate Postmortem Changes:

The immediate alterations following death are linked to "somatic death" or "systemic death." Somatic death is the irreversible loss of vital functions such as heart, brain, and lungs. Accordingly, the term immediate postmortem alterations are referred to as the "signs or indicators of death" **[6].**

Among the immediate changes include loss of sensitivity, absence of voluntary movements, halt of breathing, stoppage of blood flow, and halt of nervous system activities. Primary muscle relaxation occurs at this time. Although insensibility and loss of voluntary movement are believed to be among the first signs of death, they can also happen in trance states, fainting episodes, narcosis, catalepsy, electrocution, etc**[2].**

Placing a stethoscope over the upper areas of the lungs allows one to detect even the tiniest sound of breathing, if present, in order to confirm whether or not breathing has stopped. It is important to remember that respiratory cessation can occur in premature infants, drowning, electrocution, and Cheyne-Stokes breathing. Listening to the heartbeats with a stethoscope over the precordial region is used to monitor the stoppage of blood circulation. **[7].**

An ECG is another tool that can be used instead of a stethoscope. When the ECG is flat, it signifies a halt in blood flow. An EEG is used to identify the halt of nervous system activity. It is also essential to assess brain stem reflexes **[6].**

II- Early postmortem changes:

The early post-mortem stage is perhaps the most important time frame for PMI calculation because this is when the majority of medico-legal cases are investigated. This timeframe is when determining the time elapsed since death is crucial for determining the sequence of events and forming a hypothesis about the cause of death. This time frame starts from 3 hours to 72 hours postmortem. The early post-mortem period is typically estimated using the traditional triad of post-mortem changes: rigor mortis, livor mortis, and algor mortis **[8].**

A- livor Mortis

Livor mortis is a passive process that causes pooling of blood because of gravity in the blood vessels in the body's dependent parts. It is also known as postmortem hypostasis or postmortem lividity. Resulting in skin discoloration from pink to dark purplish. It appears an hour after death, takes three to four hours to form completely, and takes six to eight hours to fix **[5].**

Blood is pulled by gravity into the capillaries in the dermis of the body's dependent areas once the cardiovascular system has stopped working. Therefore, when a patient passes away while prone, the livor mortis will cover the front of the body, and when they pass away while supine, it will cover the back of the body **(Fig. 1)[9].**

Pattern:

When someone applies pressure to body parts that are dependent, it stops the blood from filling the cutaneous capillaries, resulting in the patterning of livor. In Caucasians, the skin appears pale and white when compressed, creating a stark contrast with the nearby red-purple congested skin, as shown on the decedent's back in Figure 2.A. By pressing an object against the skin, a clear outline may be left behind, as shown in Fig. 2.B on the outer thigh where fingers were placed **[11].**

Fixation is believed to result from hemoconcentration followed by red blood cell lysis, which leaves the surrounding tissues permanently stained, much like putrefactive hemolysis does to the blood vessel lining **[12].**

Movement of the body results in blood settling into dependent areas, known as 'postmortem lividity shifting.' Nevertheless, repositioning may not be feasible after 6 to 8 hours since blood in the dependent parts of the body may have already coagulated postmortem. The term used for this phenomenon is 'fixation of postmortem

staining.' The blanching test decides if lividity is permanent. The observer's thumb exerts pressure on the livid area for approximately one minute before being released. If the skin under the thumb turns pale when pressure is released, the lividity is considered unfixed; however, if the area remains stained after pressure is removed, the lividity is considered fixed **[13].**

Differential Diagnoses

It's critical to distinguish bruises from livor since the latter suggests blunt force trauma. During the initial postmortem phase, bruises will not blanch when pressure is applied, but livor will. A small incision will show that there is normal yellow subcutaneous fat in livor, which is typical, in contrast to red interstitial hemorrhage in bruises **[11].**

Discoloration:

The colour of livid skin can be either red or purple blue, based on the amount of deoxygenated blood present. If the body is cool, red livor is seen. This is identical to some poisoning deaths (such those caused by carbon monoxide poisoning). It's hard to be seen if someone has dark skin. Livid areas change to green or brown due to decomposition [**14].**

Livor Mortis in Internal Organs

Like how it develops and is distributed on the exterior of the body, livor can also be present in dependent parts of internal organs including the kidneys, liver, lungs, and heart. Blood and transudate build up in the lungs, with the latter being caused by localized hypostasis, which could sometimes be mistaken for edema or pneumonia **[9].**

Internal livor in the heart can simulate a recent infarction, as evidenced by a red zone of discoloration within the heart's muscle. The exact location of the livor in the myocardium is determined by the corpse's postmortem position. Contact blanching from the ribs may be detected if livor has developed in the liver while the body has remained on its right side **[15].**

Significance:

Only an approximate time of death can be determined by evaluating the degree of lividity. At a death scene, the existence of livor, particularly permanent livor, in a body's independent components suggests that the corpse's position has altered**[14].**

B- Algor Mortis

"Cold death" (algor mortis) is the Latin phrase used to describe the change in temperature that happens when a person dies. After death, the body's natural cooling and heating mechanisms stop working, and the deceased's temperature gradually reaches the surrounding temperature. This variable assumes that the body temperature at the time of death was within the normal range of 34.2-37.6 °C, encompassing temperatures both higher and lower than the normal living body temperature of 36.9 °C. Rectal temperatures are frequently employed as the benchmark for assessing the deceased's temperature and algor mortis **[16].**

The body cools and acclimates to the surrounding temperature after death since it can no longer sustain his temperature. In general, Throughout the first twelve hours, the body cools at a rate of roughly 1.5°F (0.8°C) each hour; however, the rate at which this cooling happens is dependent upon the temperature difference between the body and the environment (cool ambient temperatures and elevated body temperatures will accelerate this process) **[17].**

Byard [18] noted that there is a great deal of variation, which could risk techniques that use 37 as a basis for estimating the time of death. The variables influencing the core temperature are enumerated in **(Table 1)**.

The term "postmortem temperature plateau" refers to the period of time immediately following death or when cardiorespiratory activity stops during which the body's temperature does not change. In cool to moderate temperatures, this plateau is expected to last for one to three hours. After that, the temperature will drop linearly over the next 10 to 16 hours, by 0.5 to 1.5°C every hour. As the body temperature approaches that of the surrounding air, this rate decreases. Many methods have been tried because it is uncertain how long the temperature plateau lasts for each individual and the initial body

temperature is unknown, all attempts to estimate the time since death based on the presumed predictable fall in body core temperature (measured in the rectum, brain, and tympanic membrane) are inaccurate, the accuracy decreases as the body temperature approaches the ambient temperature **[11].**

Medicolegal Aspects

Chief experts in the field take temperature-based nomogram approaches into consideration, which are based on three key components to estimate the time since death: (1) body weight determination; (2) rectal temperature and mean ambient temperature measurements at the death scene; and (3) the use of an empirical corrective factor, to be the most reliable **[19].**

These temperature-based techniques and the formulas that go along with them are most helpful in industrialised nations with temperate and cool climates, where the majority of deaths occur indoors with heating; they are frequently ineffective in regions with warm or tropical temperatures or when deaths occur outside **[20].**

Rigor Mortis

Following death, a phase known as primary relaxation or flaccidity occurs in which the muscles entirely relax. This condition is followed by rigor mortis, which is characterized by the muscles shortening and stiffening, and eventually return to full relaxation (secondary relaxation or flaccidity). Rigor mortis, which means "stiffness of death" in Latin, is a brief stiffening of the muscles that follows a death. There is very little fiber shortening in these muscles. At this point, individual cells begin to die. It's one of the obvious indicators of death **[21].**

The Order of Appearance and resolution of Rigor:

Every muscle in the bodyis affected. Rigor does not begin in every muscle at the same time, according to Nysten's rule **[22].**

The eyelid and jaw muscles start showing signs of rigor mortis about 20 minutes after death, causing the jaw to become tight due to the stiffening of the chewing muscles. Subsequently, bigger muscle groups are affected by postmortem rigidity, resulting in stiffness in the elbow and knee joints 4-6 hours after death. Nevertheless, the speed at which rigor mortis sets in and reaches its full extent can vary greatly and, like all postmortem changes, largely depend on the temperature of the surrounding environment (higher temperatures speed up the onset and strength of rigor mortis, but very cold temperatures can also lead to a quick onset of rigor mortis) **[23].**

Rigor mortis is usually followed by resolution in identical pattern. Male humans often exhibit more significant rigor mortis than female humans because rigor mortis is generally more evident in bodies with larger muscle bulk, while newborns and old people may not exhibit much detectable rigor **[13].**

Mechanism of rigor mortis:

Contraction hypothesis or sliding filament theory:

The process of generating adenosine triphosphate (ATP) from adenosine diphosphate (ADP) is necessary for muscle contraction. Following death, the respiratory function ceases, which causes an increase in lactic and pyruvic acid production, an accumulation of CO2, and a lack of oxygen, all of which lower intracellular pH. Therefore, the utilization of glycogen through anaerobic metabolism in muscles results in glycogen depletion, decreasing ATP levels together with leakage of calcium into the sarcomere influences the beginning of rigor mortis **[24].**

Actin and myosin protein filaments alternate in attaching to each other. Calcium binds to the filaments, creating a cross-link that causes the filaments to pull against one another, becoming shorter and stiffer and ultimately producing muscle contraction. The breakdown of these cross-links between filaments in the living organism is facilitated by ATP, which causes the muscles to relax **[25].**

The reverse of this rigidity cannot be done after death as ATP synthesis is halted but is still consumed until depletion; hence, postmortem body position eventually becomes fixed. When ATP degradation exceeds the rate of resynthesis, rigor mortis occurs. Rigor mortis starts when the ATP

amount drops to 85% of its normal level and maximum rigor mortis occurs when the amount of ATP drops to 15% of its normal level **[24].**

Certain conditions simulate rigor mortis:

Conditions that imitate rigor mortis include heat stiffening, cold stiffening, gas stiffening, and cadaveric spasm. People who are exposed to hot liquids, high voltage electrocution, or high temperatures may develop a condition known as heat stiffening. It is characterized by tissue protein denaturation and coagulation, which causes the body to become rigid. People's subcutaneous fat and biological fluids freeze in below-zero temperatures, causing the body to stiffen. We call this state "cold stiffening." The rigidity caused by gas stiffening is a result of the build-up of putrefactive gases throughout the body. **[6].**

When evaluating the degree of rigor mortis in forensic pathology, is determined subjectively by examining if joints can be flexed or extended and if there is resistance when trying to move muscles **(Fig.3)**. Because of this, different investigators determine the condition of rigor mortis in very different ways. Furthermore, rigor mortis is influenced by a wide range of internal and external circumstances, therefore utilizing it as a tool to determine time since death has little practical relevance **[26].**

Rigor Mortis in Internal Organs

Postmortem rigidity is not limited to the skeletal muscles; it also affects the cardiac and internal organs such the bladder, gallbladder, and uterus. Similar to skeletal muscle, initial relaxation of all internal organ muscles occurs before rigor mortis. The sudden relaxation of muscles following death accounts for the seminal fluid or urine leaking from the urethral opening, which is caused by the pelvic diaphragm's and the bladder's flaccidity, respectively **[27].**

Medicolegal Aspects

Sometimes rigor mortis is useful in figuring out if a body has been moved after it has died. It is implied that if a body is found in a strange position-for instance, one that could not have been held due to gravity during the initial muscle relaxation after death-it suggests the body has been moved after acquiring rigor mortis. **[25].**

III- Late postmortem changes:

Decomposition

Decomposition includes two mechanisms: putrefaction and autolysis. While autolysis initiates the process shortly after death, the visible macroscopic changes resulting from decomposition are not evident until putrefaction takes place **[5].**

(A) Autolysis:

When cells die and their membranes are disrupted, lysosomal enzymes are released during "autodigestion," which results in the sterile disintegration of tissues and organs. This process is known as autolysis. There is a significant loss of tissue structure as a result of this endogenous enzyme activity **[11].**

Within cells, pH changes as a result of the body's decreased oxygen concentrations, increased carbon dioxide levels, and other waste products. Enzymes are released as a result, denaturing the remaining membrane molecules, and causing a further reduction in the integrity of the cellular membranes. At this point, many of these chemical and microscopic alterations are not readily visible without histological testing. This offers proof of cell necrosis and validates the deterioration of the cell structure. External observations of more macroscopic features, like clouding of the cornea, body cooling, or other visible characteristics, are frequently possible **[28].**

During postmortem examination, autolytic alterations are observed as the pancreatic parenchyma's doughy consistency and loss of its typical macroscopic architecture on exposed surfaces. Another early autolysis condition that can be mistaken for splenic softening as a result of acute splenitis is liquefaction of the splenic pulp (septic spleen). Numerous macrophages in the lung parenchyma emit hydrolytic enzymes from their lysosomes, which causes a loss of cellular structure outlines when viewed under a microscope. **[29].**

The adrenal glands typically maintain their macroscopic look but seem soft with loss of medulla cohesiveness. The stomach's lining epithelium is attacked by gastric acid since

the mucosa is no longer protected and mucus secretion has stopped after death. Rarely, autolytic self-digestion leading to postmortem gastric juice leaking from the peritoneal cavity might happen. Hemolysis of the blood is the result of erythrocyte membranes breaking down. The term "imbibition" refers to the darkening of the intima of both larger and smaller vessels to a light brown colour**[12].**

(B) Putrefaction:

The term "putrefaction" describes the microbial breakdown of soft tissues and organs. Anaerobic bacteria, primarily Clostridium and Proteus species, travel from the gut into blood vessels and tissues after death when homeostasis is disrupted. From there, they reproduce and distribute throughout the body. Because autolysis destroys the gut mucosa's cell integrity, bacteria are able to proliferate throughout the body. Putrefaction and "decomposition" are terms that are frequently used interchangeably. In many situations, the cause and mode of death can still be ascertained despite obvious putrefaction **[9].**

The prostate gland and non-gravid human uterus decompose last during internal organ degradation **[30].**

The first visible sign of putrefaction is a greenish discoloration of the skin in the right iliac fossa area. Considering that the caecum is relatively shallow and has semi-solid intestinal debris and commensal gut bacteria in it. This discoloration of the skin in the right iliac fossa area appears about eighteen hours after death. This green color could initially develop two to three days after death in moderate temperature **[5].**

The bacteria create hydrogen sulphide through a process of reductive catalysis. Sulphahemoglobin is produced when haemoglobin and hydrogen sulphide mix, leaving a green color in the nearby area. Microbes travel throughout the body via the blood vessels. The putrefaction of erythrocytes within the superficial blood vessels results in a greenish-blue discoloration that is apparent throughout the skin. The term 'marbling' refers to the visible superficial blood vesselson skin surface **(Fig.4) [6].**

Factors affecting decomposition:

The duration of these processes varies greatly because of both internal and external influences, the impacts of which build up over time in a frequently non-uniform manner. Factors relating to the human remains itself, such as body weight, injuries or trauma, and cause of death, are known as intrinsic factors **[31].**

Open wounds provide a way for bacteria and fungi to enter, while infections before death suggest a higher level of bacteria present. On the other hand, bacterial development and, thus, the rate of decomposition, may be slowed by antibiotic exposure or a significant blood loss just before death. Regarding ante-mortem intoxication,excessive consumption of substances like paracetamol would result in the deterioration and necrosis of the liver before to death. The rate of decomposition can also be changed by treating a disease before death **[32].**

The ambient temperature is the most important element influencing the rate of decomposition; a greater temperature accelerates the beginning of bacterial growth, post-mortem tissue changes, and enzymatic activity. Clothes can accelerate the body's natural breakdown process and slow down its natural cooling process. Ventilation and humidity: While humid climates speed up decomposition, dry places with continuous air movement rapidly dehydrate a dead body, inhibiting bacterial development and causing mummification **[33].**

Medicolegal Aspects

Putrefaction's signs can make it difficult to interpret autopsy results, which makes deaths appear suspicious. Any injuries someone may have experienced prior to death may be covered up by putrefaction. Moreover, the clearing of decaying liquid from the mouth and nostrils is often mistaken for blood coming from facial injuries that occurred before death by those who are not familiar with the situation. Putrefactive tissue alterations can also make visual identification challenging, requiring the use of additional

criteria (such as the recognition of specific tattoos) or orthopaedic implants on radiological screening **[34].**

When drug or alcohol intoxication is suspected, putrefactive changes and bacterial activity can alter drug levels, making accurate interpretation difficult **[35].**

Conditions replacing putrefaction:

1) Maceration:

Maceration is a particularly specific type of postmortem changes that usually occurs solely in cases of intrauterine death (IUD). Putrefaction does not occur in the normal uterine cavity since it is sterile (unless an infection is present). Instead, autolysis is the only process that leads to decomposition. After 48 hours of IUD, skin slip starts to show **[36].**

Intrauterine infection may hasten the maceration process. It is possible to estimate the period of fetal death prior to delivery roughly, always accounting for potentially changing environmental conditions and the amount of time between delivery and autopsy. **(Table 2)** offers a general maceration guide **[37].**

2) Adipocere formation:

A variant of putrefaction known as saponification or adipocere formation entails the fatty tissues are hydrolyzed and hydrogenated to create an adipocere, a wax-like, greasy, yellowish material. This adipocere primarily comprises of stearic, oleic, and palmitic fatty acids with trace levels of glycerol. Typically, adipocere development appears in adipose tissues such the cheeks, chin, abdomen, and buttocks. Since water is necessary for the hydrolysis of fats, the body must break down in a warm, humid, and moist environment in order to generate adipocere. Though it typically takes three months to form, it can happen as early as three weeks **[6].**

3) Mummification:

Mummification is a type of putrefaction in which the cadaveric tissues are dried up or desiccated. The most significant observation during mummification is that the skin becomes rough, leathery, and parchment-like, turning dark brown. Similar to adipocere development, the body shrinks and shrivels, but the injuries and features of the face remain intact **[38].**

Mummification requires an environment that is continually hot, dry, and arid. The body requires more time for mummification than for adipocere formation. Partial mummification has been observed to coexist with other putrefactive modifications in specific parts of the same body because features are preserved in bodies during adipocere formation or mummification, identification of the individual and injuries are still possible **[39].**

Table 1: Factors that may alter body temperature [18]

Elevated rectal temperature
Physical exertion
Infections/fever
Emotional stress
Organic conditions e.g., malignant hyperthermia, hyperthyroidism Decreased fluid intake.
Neuroleptic medications
Illicit drugs e.g., amphetamines, cocaine
Reduced rectal temperature.
Hypothermia
Hypothyroidism
Frailty syndrome

Table 2: Approximate Guide to Maceration Timing **[37].**

0-6 hours	**Little change, clear corneas**
6 h-1 day	Skin peeling on periphery and bony prominences.
1-2 days	Widespread skin peeling, abdomen discoloration
2-3 days	Diffuse reddening, hemolytic changes in cord, serosanguinous fluid in body cavities, uniform coloration of organs
4-7 days	Overlapping skull bones, sunken eyes, mobile mandible suture, periosteum and dura lifts from skull bones
>7 days	Brown discoloration
10-12 days	Increased loss of fluid. After many weeks fetuspapyraceous

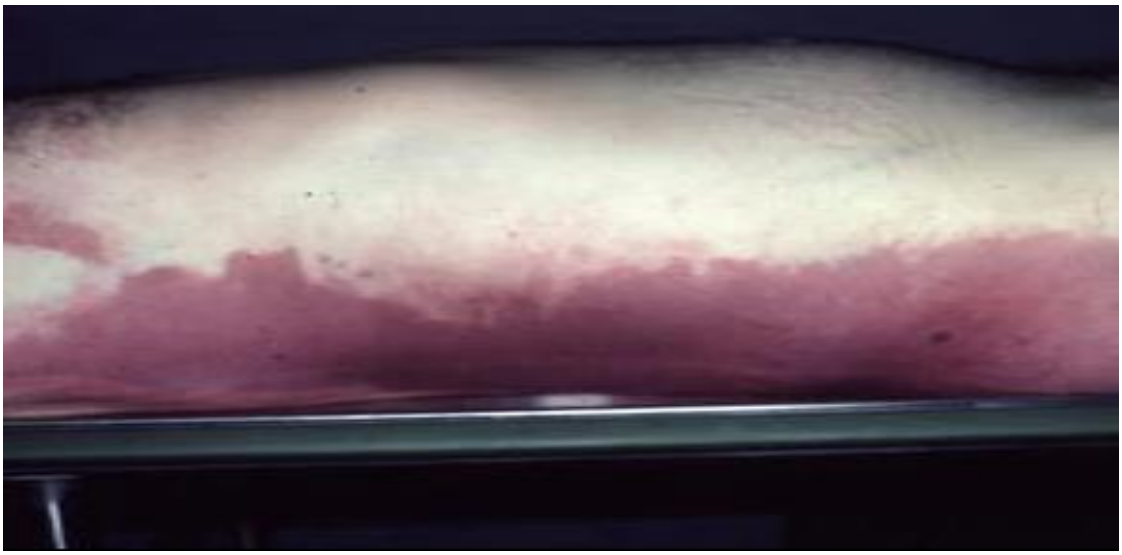

Fig.1: Livor mortis with body lying in supine position showing settling of blood to lower portions **[10].**

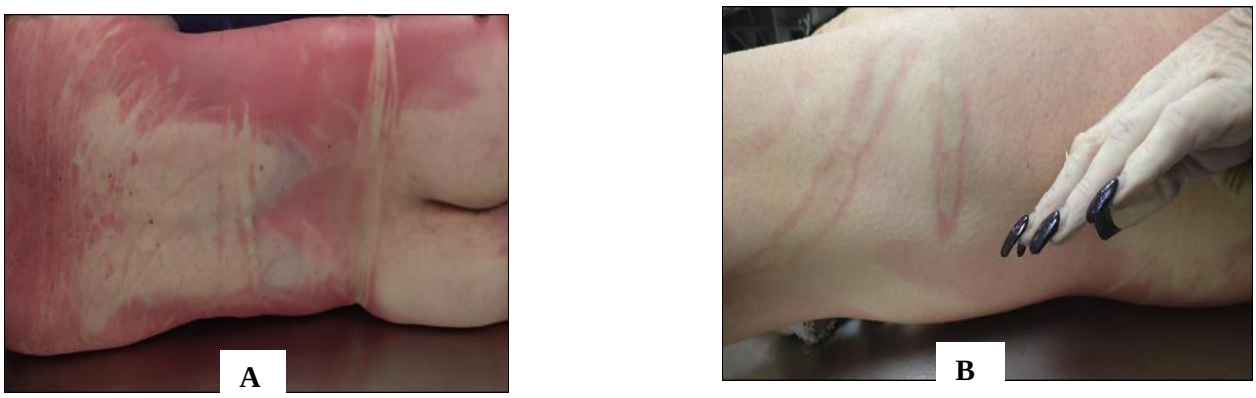

Fig.2: A. Pink dependent lividity over the back of a recently deceased individual with prominent pressure blanching over the buttocks and center of the back. Linear blanching can also be seen around the waist from clothing; **B.** The original position of the fingers over the left side of the body can be seen due to pressure blanching

Fig. 3: a. Due to rigor mortis the lower leg is fixed against gravity; **b.** Objects in the hand such as branches must not be mixed-up with instantaneous rigor mortis or cadaveric spasm **[26]**

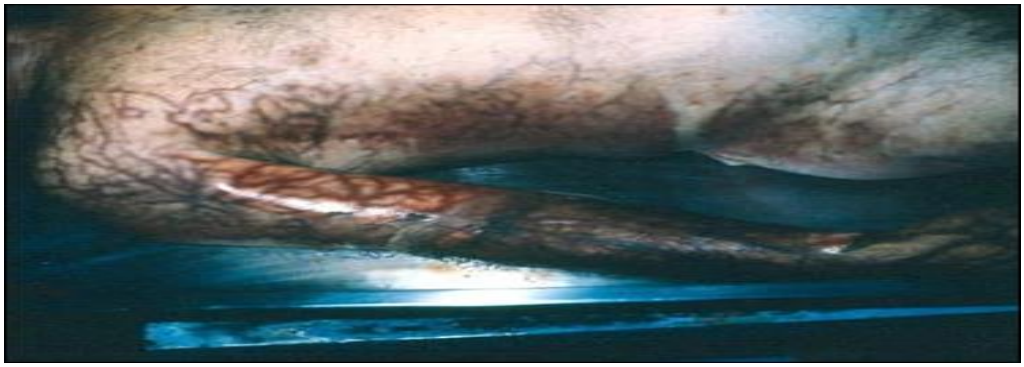

Fig.4: Post-mortem marbling of body **[10]**

CONCLUSIONS

In summary, researchers have classified postmortem changes according to their order of appearance and they emphasize the value of understanding postmortem changes in the forensic field.

Declaration of interest

The authors report no conflicts of interest.

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