MODERN MORPHOLOGICAL CRITERIA FOR DETERMINING VITAL SIGNS IN THERMAL INJURIES

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Abstract. *This article analyzes modern morphological criteria for determining vital signs in cases of thermal injuries. In forensic medical practice, it is of great importance to establish whether thermal injuries occurred during life or after death, as this is essential for the accurate assessment of the cause and mechanism of death. The article examines macroscopic and microscopic changes, tissue reactions, signs of inflammation, and modern methods of morphological diagnosis. In addition, the difficulties encountered in distinguishing vital signs from postmortem changes are analyzed, and scientific approaches to resolving these issues are discussed. The results of the study may contribute to improving the accuracy and reliability of forensic examinations of thermal injuries.*

Keywords: *thermal injuries, vital signs, morphological criteria, forensic medicine, differential diagnosis, tissue reaction, inflammation, microscopic examination, postmortem changes, forensic expertise.*

Relevance of the Problem: Thermal injuries are among the most severe pathological conditions resulting from exposure of the human body to high temperatures and occupy an important place in forensic medical practice. Nowadays, deaths associated with thermal exposure are frequently encountered in fires, domestic and industrial accidents, traffic incidents, and criminal cases. In such situations, one of the primary tasks of a forensic medical expert is to determine whether the injuries occurred during life or after death. Establishing the vitality of thermal injuries is important not only for determining the cause of death but also for reconstructing the actual circumstances of the incident, providing a legal assessment of criminal actions, and ensuring the reliability of expert conclusions. The study of the morphology, pathogenesis, and forensic diagnosis of thermal injuries plays a significant role in improving forensic medical expertise. It also contributes to the development of key morphological criteria used to differentiate between vital and postmortem thermal changes. In thermal injuries, coagulative necrosis develops in the epidermis and dermis. Histological examination reveals destruction of the epidermal layer, homogenization of collagen fibers, and nuclear changes such as pyknosis, karyorrhexis, and karyolysis. As the intensity of thermal exposure increases, these changes become more profound and may extend to the subcutaneous fat tissue, muscles, and even bone tissue. Researchers emphasize that the severity of thermal injuries directly depends on the temperature level, duration of exposure, and environmental conditions. As the duration of thermal exposure increases, both the area and depth of necrosis progressively enlarge.

Research objective: To analyze modern morphological criteria for determining signs of vitality in thermal injuries, evaluate their diagnostic significance in forensic medical practice, and improve reliable methods for the differential diagnosis of thermal injuries occurring during life and after death.

Materials and Methods: The study analyzed a total of 200 forensic medical examination cases. All cases involved thermal injuries (burns) and were investigated based on archival records of the local forensic medical bureau and postmortem examination reports. The following methods were employed: macroscopic examination, microscopic (histological) examination, hemodynamic assessment, biochemical methods, immunohistochemical (IHC) studies, and statistical analysis.

Results of the Study: The causes of death resulting from thermal injuries manifest differently in clinical and forensic medical practice, and their frequencies vary within certain ranges. Burn shock constitutes the highest proportion, occurring in approximately 30–40% of cases. It develops as a

severe systemic response of the body to extensive thermal damage. Circulatory disturbances, hemodynamic changes, and severe impairment of vital functions play a leading role in its pathogenesis.

Carbon monoxide poisoning is also a significant cause of death in thermal injury cases. It occurs in 15–25% of cases and primarily develops when individuals inhale combustion products during fires. In such cases, the oxygen-carrying capacity of hemoglobin is impaired, resulting in tissue hypoxia. Acute respiratory failure is observed in approximately 10–15% of cases. It may result from thermal injury to the airways, airway edema, or obstruction caused by combustion products. Toxemia also occurs in 10–15% of cases and is associated with the absorption of toxic substances into the body and their systemic toxic effects. Sepsis and septic toxemia are recorded as complications of thermal injuries in 15–20% of cases. These conditions usually develop following extensive burns complicated by infection and are characterized by a systemic inflammatory response and infectious-toxic syndrome. Finally, multiple organ failure is another important cause of death, occurring in 10–20% of cases. This condition involves simultaneous dysfunction of several vital organs and is commonly associated with severe burns, shock, and infectious complications.

Approximate frequency of causes of death in thermal burns

Cause of Death	Frequency (%)
Burn shock	30–40
Carbon monoxide poisoning	15–25
Acute respiratory failure	10–15
Toxemia	10–15
Sepsis and septic toxemia	15–20
Multiple organ failure	10–20

Tissue changes developing as a result of thermal exposure are associated with the direct effect of high temperatures on cellular and tissue structures. According to numerous authors, the primary processes observed in thermal injuries are protein denaturation and coagulation. These processes are accompanied by damage to cell membranes, disruption of enzyme system activity, and impairment of cellular metabolism.

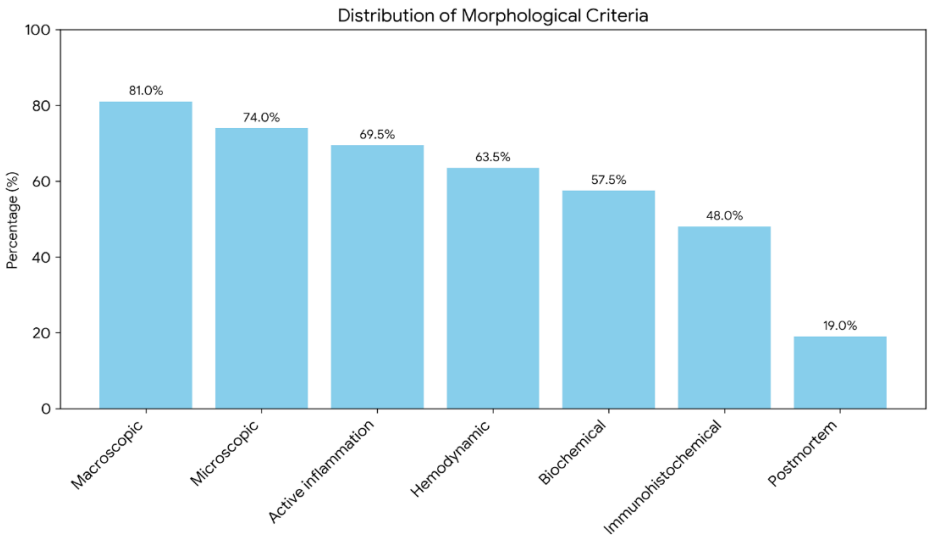


Figure 1. **Frequency (%) of Morphological Criteria**

The results of the forensic examination of 200 cases of thermal injuries clearly demonstrated the comprehensive significance of modern morphological criteria in determining signs of vitality. The findings made it possible to assess both the frequency of occurrence and the diagnostic value of each criterion. The highest frequency was observed for macroscopic changes, which were identified in 162 of the 200 cases (81%). These changes included skin redness (hyperemia), blisters, localized edema, and hemorrhages. Such findings usually develop as a response of a living organism to thermal injury. Hyperemia is associated with vasodilation and increased blood flow to the affected tissues, whereas blisters result from fluid accumulation beneath the epidermis and are characteristic of intravital injuries. Therefore, macroscopic changes represent one of the earliest and most readily detectable indicators of vitality in thermal injuries. Microscopic examination revealed significant alterations in 148 cases (74%). These included epidermal destruction, leukocyte infiltration into the injury site, and dilation of capillary vessels. Such changes indicate active biological reactions occurring at the tissue level. In particular, leukocyte infiltration confirms the response of the immune system to injury and can only occur in a living organism. Active inflammatory reactions were detected in 139 cases (69.5%) and were characterized by neutrophil migration, exudate formation, and tissue edema. These processes reflect the active phase of the body's protective and adaptive response. In forensic practice, the presence of an inflammatory reaction is considered one of the most reliable morphological indicators that an injury was sustained during life, since such active cellular responses do not occur after death. Hemodynamic alterations were recorded in 127 cases (63.5%) and included disturbances of microcirculation, hemorrhages, and, in some cases, thrombus formation within small blood vessels. These findings indicate that the circulatory system responded to the injury. Hemorrhage and thrombosis are regarded as physiological protective mechanisms aimed at limiting blood loss and protecting damaged tissues. Biochemical analyses demonstrated elevated levels of histamine, serotonin, and various cytokines in 115 cases (57.5%). These mediators increase vascular permeability, enhance pain sensitivity, and activate inflammatory processes. Since they appear shortly after thermal injury, they represent important early biological indicators with high diagnostic value. Immunohistochemical studies revealed the expression of markers such as IL-1, TNF-α, and COX-2 in 96 cases (48%). These markers indicate molecular activation of inflammatory pathways. Although detected less frequently than other criteria, they are among the most accurate and advanced confirmatory methods because they directly reflect the immune response occurring within the tissue. Comparative analysis showed that postmortem changes were present in 38 cases (19%). This included necrosis, tissue dehydration, and the complete absence of inflammatory reactions. Such findings indicate that the injury occurred after death or that the organism did not survive long enough for vitality reactions to develop. Therefore, postmortem changes represent important diagnostic criteria confirming the absence of vital reactions. Overall, the results demonstrated that the highest diagnostic value in determining vitality in thermal injuries belongs to macroscopic and microscopic changes, as well as active inflammatory responses. However, biochemical and immunohistochemical methods significantly expand modern diagnostic capabilities and are particularly useful in complex or doubtful cases for distinguishing intravital from postmortem injuries with a high degree of accuracy. Consequently, forensic medical practice should rely not on a single criterion but on a comprehensive combination of morphological and laboratory approaches to achieve the most accurate and reliable conclusions.

Morphological Criteria for the Assessment of Injuries and Tissue Changes. Morphological criteria play a crucial role in the assessment of injuries and tissue alterations, allowing forensic experts to determine whether an injury occurred during life or after death. These criteria include macroscopic, microscopic, inflammatory, hemodynamic, biochemical, and immunohistochemical changes, as well as postmortem findings. Macroscopic signs are external changes visible to the naked eye. These include skin redness (hyperemia), hemorrhages (hematomas), blister formation, and localized swelling. Such findings develop as a response of the living organism to injury. For example, redness

results from vasodilation and increased blood flow to the affected tissue, while edema occurs due to increased vascular permeability and fluid leakage into surrounding tissues. Microscopic changes can only be detected through laboratory examination. These include destruction of the epidermis, leukocyte infiltration into tissues, and dilation of capillary vessels. Such findings indicate that active biological processes are taking place and that the body's defense mechanisms are functioning. Inflammation represents one of the primary protective responses of the body to injury. During this process, neutrophils rapidly migrate to the site of damage, tissue swelling develops, and inflammatory exudate is produced. Exudate contains proteins and immune cells that help protect the injured area. The presence of inflammation is considered one of the most reliable indicators that an injury occurred during life. Hemodynamic changes refer to alterations in blood circulation. These include hemorrhages, thrombosis within small blood vessels, and disturbances of microcirculation. Such findings indicate that the circulatory system responded to injury while the organism was alive. For example, thrombosis serves as a protective mechanism that limits blood loss and confines tissue damage. Biochemical changes are associated with alterations in tissue metabolism and the release of inflammatory mediators following injury. Increased levels of histamine, serotonin, and cytokines are commonly observed. These substances increase vascular permeability, intensify pain perception, and activate immune responses. Consequently, they serve as important indicators of early vital reactions. Immunohistochemical markers represent one of the most advanced diagnostic tools available. The expression of markers such as IL-1, TNF-α, and COX-2 confirms the presence of active inflammatory processes at the molecular level. These markers allow a precise assessment of tissue immune responses and are of great importance in forensic medical practice. Finally, postmortem changes differ significantly from vital reactions. They are characterized by necrosis, tissue dehydration, and the absence of inflammatory responses. After death, no active immune or circulatory reactions occur. Therefore, these findings are essential for distinguishing whether an injury was sustained before or after death.

Signs of vitality in thermal injuries

Morphological Criteria	Observed Changes	Diagnostic Significance
Macroscopic Signs	Skin redness (hyperemia), hemorrhages, blisters, edema	May indicate that the injury occurred during life
Microscopic Changes	Epidermal destruction, leukocyte infiltration, capillary dilation	Confirms the presence of an inflammatory response
Inflammatory Response	Neutrophil migration, tissue edema, exudate formation	One of the most important indicators of vitality
Hemodynamic Changes	Hemorrhages, thrombosis, microcirculatory disturbances	Reflects the response of a living organism
Biochemical Changes	Increased levels of histamine, serotonin, and cytokines	Indicates early vital reactions
Immunohistochemical Markers	Expression of IL-1, TNF-α, and COX-2	Molecular-level confirmation of the inflammatory process
Differentiation from Postmortem Changes	Necrosis, dehydration, absence of inflammatory response	Helps distinguish between antemortem and postmortem injuries

Conclusion: Determining signs of vitality in thermal injuries is one of the most important and relevant tasks in forensic medical examination. Coagulative necrosis, denaturation of collagen fibers, and microcirculatory disturbances resulting from thermal exposure constitute the general

morphological basis of thermal injuries. However, vascular reactions, plasmorrhagia, tissue edema, leukocytic infiltration, and inflammatory processes are recognized as the principal criteria confirming that thermal exposure occurred during life. The absence of these reactions in postmortem thermal injuries makes it possible to differentiate them from antemortem burns. The introduction of modern forensic histological, immunohistochemical, and molecular biological research methods has significantly increased the sensitivity and reliability of detecting signs of vitality.In the future, the integrated application of morphological and molecular markers will contribute to the further improvement of the forensic diagnosis of thermal injuries, enhancing the accuracy and evidential value of forensic medical examinations.

REFERENCES

1. Akhmedov Yu.M., Ergashev T.A. Forensic medical changes resulting from thermal effects // Uzbekistan Forensic Medicine Bulletin, 2022.
2. Betz P. Vital reactions: A review // Forensic Science International, 2023.
3. Busuttil A. et al. Forensic Medicine: Clinical and Pathological Aspects. — 2018.
4. Dolinak D. et al. Forensic Pathology: Principles and Practice. — 2020.
5. Fetisov V.A. Forensic Medical Diagnostics of Injuries. - M., 2018.
6. Fracasso T. et al. Immunohistochemistry in forensic pathology // Forensic Science, 2021.
7. Grellner W. et al. Vitality and time since infliction of burn injuries // Forensic Science International, 2022.
8. Grinenko O.A. Immunohistochemical markers in forensic medical examination of burns. - Moscow, 2019.
9. Henssge C. et al. The estimation of time since death in burn cases // Forensic Science, 2021.
10. Karger B. et al. Immunohistochemical detection of cytokines in burn wounds // International Journal of Legal Medicine, 2019.
11. Kondo T. Vital reaction in burn wounds // Forensic Science International, 2020.
12. Kozlov S.V., Levchenko T.V. Morphological features of thermal skin lesions. - M.: Medicine, 2020.
13. Maiese A. et al. The role of immunohistochemistry in the estimation of wound vitality: A systematic review // Forensic Science, Medicine and Pathology, 2021.
14. Matyshev A.A. Examination of injuries from high temperature. - T.: 2020.
15. Nesterov A.M. Modern methods for investigating the lifetime of burn wounds // Forensic Medical Examination, 2023.
16. Pavlov A.L., Zakharov S.N. Forensic medical diagnostics of thermal trauma during life. - Тошкент, 2021.
17. Pigolkin Yu.I. Forensic Medicine: A Textbook. - M.: GEOTAR-Media, 2020.
18. Pollak S. et al. Histological study of thermal injuries // International Journal of Legal Medicine, 2019.
19. Schmidt U. et al. Postmortem changes in burn wounds // Journal of Forensic Medicine, 2020.
20. Simonsen J. The forensic diagnosis of burn injuries // Forensic Science, 2020.
21. Takamiya M. et al. Immunohistochemical study of heat shock proteins in burn wounds // Forensic Science International, 2021.
22. Turillazzi E. et al. Immunohistochemical assessment of burn vitality // Journal of Forensic Sciences, 2020.
23. Vavilov A.Yu. Forensic Medical Examination of Thermal Trauma. - Тошкент, 2018.
24. Vermel I.G. Forensic Medical Examination of Thermal Trauma. - M., 2017.
25. Yusupov N.A. Differential diagnosis of causes of death in thermal injuries. - T., 2023.