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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგ-ლისურენოვან ტექსტებში - **Times New Roman** (**Кириллица**), ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენ-ტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემა-ჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტო-სურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სუ-რათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხო-ური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანე-ლის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შე-ჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

FEATURES OF DIAGNOSTICS OF FATAL KIDNEY INJURY IN MEDICAL PRACTICE

Olena Babkina[1,2]*, Svitlana Danylchenko[3], Ihor Korobko[4], Oleksandr Yanchevskyi[4], Artem Kravchenko[5].

[1]*Department of Pathophysiology, O.O. Bohomolets National Medical University, Kyiv, Ukraine.*

[2]*Kyiv City Clinical Bureau of Forensic Medical Examination, Kyiv, Ukraine.*

[3]*Department of Physical Therapy and Occupational Therapy, Kherson State University, Kherson, Ukraine.*

[4]*Department of Biology, Histology, Pathomorphology, and Forensic Medicine, State Institution "Luhansk State Medical University", Rivne, Ukraine.*

[5]*Department of gynecology and reconstructive urology, CNE "Vinnytsia regional clinical Hospital Named After M.I. Pirogov Vinnytsia Regional Council", Vinnytsia, Ukraine.*

Abstract.

Aim: To examine how temperature changes over time in injured and uninjured kidney tissues, based on the time elapsed since trauma and death. Additionally, develop a regression model to estimate the time of death using temperature measurements from the abdominal organs.

Material and Methods: The study included data from 256 individuals (both males and females aged 20–60 years) who died from mechanical trauma. Tissue temperatures were measured using infrared thermometry at various times within 24 hours after death. The analysis covered temperature measurements of the liver, spleen, pancreas, kidneys, skin, and the thickness of subcutaneous fat tissue.

Results: Determining the exact time of death remains a complex aspect of forensic practice, especially in cases involving traumatic injuries. Often, the moment of injury does not match the time of death: the person may die immediately at the scene or after some delay—during transport or at a medical facility. Therefore, distinguishing between the "time of injury" and the "time of death" is crucial for accurate forensic evaluation. A statistically significant decrease in temperature was observed in both injured and uninjured kidney tissues. The temperature in the injured areas stayed consistently higher by 2–3 °C (±0.28) compared to uninjured regions. The temperature difference between the right and left kidneys was 1.5–2 °C (±0.14), likely due to anatomical factors that offer greater protection to the right kidney. The sex of the deceased did not affect temperature indicators. A regression model was created to estimate the time of death with high accuracy ($R^2 = 0.86$), including temperatures of several parenchymal organs, skin temperature, subcutaneous fat thickness, and ambient temperature. All predictors in the model were statistically significant ($p < 0.05$).

Conclusions: The developed multivariate regression model, which considers temperature parameters of injured and uninjured parenchymal organs, serves as a promising tool for forensic estimation of the time of death. Our study's findings emphasize the potential of infrared thermometry in forensic practice as a quantitative method for determining the post-injury interval and the time of death.

Key words. Injury, kidneys, fatal, diagnostics, thermometry.

Introduction.

Accurate diagnosis of injuries to the abdominal and retroperitoneal organs, as well as reliable estimation of the time of injury and death, remains a crucial issue in both clinical and forensic medicine. These injuries are associated with high mortality rates, reaching 5–10% in cases of isolated abdominal trauma and up to 20–30% in polytrauma cases [1-3]. A study by Wiik Larsen J. et al. involving 7,202 patients with abdominal trauma revealed that injuries to the abdominal cavity accounted for 6.2% of trauma-related admissions, with 44% of these cases involving multiple injuries. The overall 30-day mortality rate was 12.5% [1]. According to Mirzamohamadi S. et al., abdominal trauma ranks as the third most common injury after head and limb trauma, with hospital mortality in polytrauma cases ranging from 3% to 10%, depending on the injury mechanism. Over 80% of affected individuals were between 20 and 40 years old [2]. In a cohort of over 25,000 patients, abdominal injuries made up 7–10% of all hospital trauma cases, with mortality rates increasing significantly in combined injuries, especially among younger patients under 45 years old [3]. This topic is particularly important since victims of such injuries are often working-age individuals, and mechanical trauma remains the leading cause of death among people under 40.

Despite extensive clinical experience, diagnosing the timing of injury and death remains a challenging task. Notably, there is a lack of standardized quantitative criteria that could enhance the objectivity of forensic assessments in cases involving damage to parenchymal organs, including the kidneys. Various authors report that renal injuries are diagnosed in 6–18% of all abdominal organ trauma cases [3-6]. For instance, a retrospective study by Khoschnau S. et al. involving 152 patients found the frequency of kidney injuries in abdominal trauma to be 8–10%, with a mortality rate of around 11% [3]. Modern reviews and clinical guidelines confirm that renal trauma accounts for up to 3% of all trauma cases and approximately 8–10% of abdominal trauma cases, with about 80–95% of these resulting from blunt trauma [4,5]. A meta- analysis of over 44, 000 patients reported a renal trauma prevalence of roughly 6. 4% (95% CI: 4. 4.8–8. 8.4%), highlighting trends related to age, male predominance, and typical injury mechanisms, mainly blunt force [6].

Literature reviews indicate that several studies have sought to use morphological and histochemical features of kidney injuries to reconstruct the trauma mechanism, identify the nature of the injurious force, and estimate injury timing [7-9]. For example, reactive changes in the glomerular apparatus, tubules, and renal interstitium have been described, showing potential for assessing the timing of mechanical impact [7]. However, other authors stress that morphological changes are highly variable, depend on individual physiological characteristics, and do not always enable clear temporal correlations [8]. A systematic review of current methods for diagnosing kidney trauma confirms that, although morphological signs are actively studied, reliable techniques for determining injury chronology based on temperature indicators are virtually absent from the existing literature [9].

This study aims to fill this gap. It proposes an innovative approach using infrared thermometry data from kidney tissues to determine injury and death timing, along with a mathematical regression model that could become an additional, objective tool in forensic practice. The results may be valuable for comprehensive forensic evaluations of blunt abdominal trauma, including fatal cases.

Aim.

The study aimed to investigate the dynamics of temperature changes in injured kidney tissues caused by different types of mechanical trauma, depending on the time since injury and the time of death.

Materials and Methods.

Study design and participants:

The research material includes right and left kidney tissues from 256 individuals of both genders, aged 20 to 60, who died with a known time of injury and death, with or without alcohol in the blood. These individuals were examined at the anatomical department of the Bureau of Forensic Medical Examination in Luhansk region, Ukraine. The terms “time of injury” and “time of death” are used to differentiate between the moment of injury and the moment of death. Often, injured people did not die immediately but after some time, within the first day. Death could occur either at the scene of injury or during transportation to or at the hospital.

The work was carried out in accordance with the «Instructions on the Forensic Medical Examination» (Order of the Ministry of Health of Ukraine No. 6 dated 01/17/1995), complying with the requirements and norms, the standard provision on ethics of the Ministry of Health of Ukraine No. 690 dated 09/23/2009, and the «Procedure for the Removal of Biological Objects from the Dead, whose Bodies are Subject to Forensic Examination and Pathoanatomical Examination for Scientific Purposes» (2018). Approval was obtained from the Ethics Committee of the State Institution "Luhansk State Medical University," Rivne, Ukraine (project no 2, date: 02/24/2023).

Method of data collection:

We used the modern method of infrared thermometry to assess the extent of damage to the right and left kidneys. Infrared thermometry was employed to measure the temperatures of injured and healthy tissues in the liver, spleen, pancreas, and kidneys to determine the damage's severity and timing. The study utilized thermal ITMO tracer models Th 9100 pmvi-wl, a contactless, high-sensitivity infrared camera from Japan. Infrared radiation emitted by the objects was detected and converted into electrical signals, then transformed from an analog temperature signal into a digital format displayed as a colored thermogram. In our study, we monitored the temperature of the right and left kidneys at 1, 2, 10, 12, 14, 16, 18, 20, and 24 hours after injury. Internal organ temperatures in healthy individuals typically remain stable, depending on heat production, metabolic activity, and chemical reactions. The temperature within the abdominal cavity stays relatively constant, averaging around 37.0 ± 1°C, while the ambient temperature in the morgue during the research was 18°C.

Statistical Analysis:

Statistical data analysis was conducted using Microsoft Excel XP and StatSoft Statistica 10.0 software. Descriptive statistics included the arithmetic mean (M), standard error of the mean (m), median (Me), lower (LQ) and upper (UQ) quartiles, as well as the 95% confidence interval (95% CI).

Before selecting statistical tests to evaluate the significance of differences, data distribution was assessed with the Kolmogorov–Smirnov test. The homogeneity of variances was examined using Fisher’s F-test.

When a normal distribution was not observed, the Mann–Whitney U-test was used as a non-parametric alternative to Student’s t-test for comparing independent samples. The calculation was performed using the following formula:

$$U = (n_1 \times n_2) + \frac{n_x \times (n_x + 1)}{2} - T_x$$

where: n_1 and n_2 – the sizes of the compared samples; T_x – the larger of the rank sums; n_x – the number of observations in the group with the higher rank sum.

The null hypothesis of no statistically significant differences was rejected at $p < 0.05$.

The required sample size was calculated using the following formula:

$$n = \frac{t^2 S_X^2}{\Delta^2}$$

where: n — required sample size; t — standard deviation corresponding to the desired confidence level; S — sample variance; Δ — margin of the confidence interval.

The obtained thermometric values (organ temperatures) were additionally analyzed by calculating the variance (D), standard deviation (σ), and coefficient of variation (V).

The study compared temperature indicators of injured and intact tissues of the right and left kidneys, taking into account the sex of the deceased, the postmortem interval, and the ambient temperature. Depending on the distribution characteristics, either parametric or non-parametric tests were applied for each comparison.

Based on temperature changes in the tissues of parenchymal organs (kidneys, liver, spleen, pancreas), multiple linear regression models were developed to estimate the time of death. The models incorporated skin temperature, subcutaneous fat thickness, and the temperatures of each studied organ. Separate models were created for conditions of positive and negative ambient temperatures.

The adequacy of the models was evaluated using the coefficient of determination (R^2 ranging from 0.78 to 0.86) and the t-tests of the regression coefficients.

To ensure analytical transparency, Table 1 provides a list of the statistical tests applied to the main study variables.

During biometric analysis, calculations were performed using the PSAT system with the relevant licensing applications. The registration of research materials, depending on their features,

Table 1. Statistical tests applied to the study variables.

Compared variables	Tissue type (temperature)	Statistical test	Significance (p-value)
Temperature of injured and intact kidney tissues (within the same kidney)	Injured / intact	Mann–Whitney U test	p < 0.0001
Temperature of right and left kidney in females and males	Intact tissue	Mann–Whitney U test	p = 0.001–0.049
Kidney temperature under different ambient temperature conditions	Injured and intact	Mann–Whitney U test	p < 0.0001
Assessment of variance within groups	—	Fisher's F-test	p > 0.05
Assessment of distribution normality	—	Kolmogorov–Smirnov test	p < 0.05
Regression model construction for time of death	Injured/intact organ tissues	Multiple linear regression	p < 0.05 for each β

Table 2. Dynamics of changes in the average values of the temperature of the right kidney depending on sex and ambient temperature, M±m (95% CI).

Terms of research after autopsy	Negative temperature		Difference level	Positive temperature		Difference level
	Male, n=76	Female, n =32		Male, n=80	Female, n =68	
5 minutes	18,31±0,27 (17,77 – 18,84)	17,31±0,42 (16,44 – 18,17)	0,10	17,83±0,20 (17,44 – 18,21)	15,93±0,15 (15,63 – 16,22)	<0,0001
1 hour	17,87±0,28 (17,31 – 18,44)	16,94±0,43 (16,06 – 17,82)	0,21	17,43±0,20 (17,02 – 17,83)	15,41±0,15 (15,10 – 15,71)	<0,0001
2 hours	17,73±0,28 (17,17 – 18,29)	16,69±0,44 (15,79 – 17,59)	0,08	17,19±0,20 (16,79 – 17,58)	15,29±0,16 (14,98 – 15,60)	<0,0001
4 hours	17,49±0,28 (16,92 – 18,05)	16,43±0,45 (15,51 – 17,35)	0,09	16,94±0,20 (16,54 – 17,33)	15,08±0,16 (14,76 – 15,39)	<0,0001
6 hours	17,29±0,29 (16,72 – 17,86)	16,21±0,45 (15,28 – 17,13)	0,056	16,73±0,20 (16,33 – 17,13)	14,90±0,16 (14,58 – 15,21)	<0,0001
10 hours	17,02±0,29 (16,45 – 17,59)	15,95±0,45 (15,02 – 16,88)	0,046	16,45±0,20 (16,06 – 16,85)	14,71±0,16 (14,40 – 15,03)	<0,0001
14 hours	16,94±0,30 (16,34 – 17,53)	15,84±0,48 (14,86 – 16,81)	0,06	16,24±0,20 (15,84 – 16,63)	14,59±0,17 (14,25 – 14,92)	<0,0001
16 hours	16,69±0,30 (16,09 – 17,30)	15,63±0,46 (14,68 – 16,57)	0,17	16,11±0,20 (15,70 – 16,51)	14,47±0,16 (14,15 – 14,79)	<0,0001
18 hours	16,60±0,29 (16,02 – 17,17)	15,51±0,46 (14,57 – 16,45)	0,027	15,95±0,20 (15,55 – 16,35)	14,38±0,16 (14,06 – 14,70)	<0,0001
20 hours	16,47±0,29 (15,90 – 17,03)	15,42±0,45 (14,49 – 16,34)	0,049	15,85±0,20 (15,46 – 16,25)	14,30±0,16 (13,98 – 14,62)	<0,0001
24 hours	16,37±0,29 (15,80 – 16,93)	15,32±0,45 (14,39 – 16,24)	0,049	15,75±0,20 (15,36 – 16,15)	14,20±0,16 (13,88 – 14,52)	<0,0001

was entered into the corresponding protocols. Microphotography of the study objects was carried out both on the photographic equipment "Mikrat-300" with the camera "Zenith E" and using modern digital technologies (camera "Canon", computer). Standard photographs were used for microphotographs.

Results.

As a result of a study, when performing renal thermometry, it is important to consider the above-mentioned features. These include the fact that the kidneys' location, with a prominent network of blood vessels, creates the possibility of significant hemorrhages and tissue damage if injured. Additionally, the right kidney is more protected than the left, and in women, the kidneys are situated lower than in men. Using infrared thermometry, it was first determined that temperature readings in the injured and uninjured right and left kidney tissues, as well as the surrounding skin, gradually decrease over time after injury. Moreover, higher temperature readings are observed directly in the injured area compared to the non-injured kidney tissues, with an average difference of 2-3 °C, as shown in Figures 1-6.

After analyzing the temperature indicators of the right and left kidneys, including the injury area, surrounding uninjured tissues, and the skin covers, it was found that there is a statistically significant progressive decrease in the temperature of both kidneys in men and women. This variation depends on ambient temperature at the time of death, the thickness of subcutaneous tissue, and the time elapsed before examining the injured and uninjured organs after autopsy.

The dynamics of changes in temperature indicators of the right and left kidneys depending on sex and ambient temperature at the time of death are shown in Tables 2 and 3.

A statistically significant dynamic decrease in temperature indicators in both injured and intact right and left kidneys tissues in individuals who died from injuries was established. It was used as one of the criteria for determining the time of the injury onset. At the same time, in the area of injury during the entire period after the autopsy of the deceased (24 hours of study), higher quantitative temperature indicators were observed compared to uninjured kidney tissues, on average by 2-3°C (±0.28). Take into account the feature that the right kidney is more protected than the left and less vulnerable when the body is compressed, is not accompanied by displacement when exposed to traumatic objects, its temperature indicators during examination decrease more gradually compared to the left

Table 3. *Dynamics of changes in the average values of the temperature of the left kidney depending on sex and ambient temperature, M±m (95% CI).*

Terms of research after autopsy	Negative temperature		Difference level	Positive temperature		Difference level
	Male, n=76	Female, n=32		Male, n =80	Female, n=68	
5 minutes	18,30±0,25 (17,80 – 18,80)	17,11±0,46 (16,17 – 18,06)	0,001	17,90±0,18 (17,53 – 18,26)	15,74±0,14 (15,47 – 16,01)	<0,0001
1 hour	17,89±0,26 (17,37 – 18,42)	16,75±0,47 (15,79 – 17,71)	0,002	17,35±0,19 (16,97 – 17,72)	15,37±0,14 (15,09 – 15,65)	<0,0001
2 hours	17,73±0,26 (17,20 – 18,25)	16,49±0,48 (15,52 – 17,47)	0,001	17,09±0,19 (16,71 – 17,46)	15,20±0,14 (14,91 – 15,48)	<0,0001
4 hours	17,49±0,27 (16,96 – 18,02)	16,22±0,49 (15,23 – 17,21)	0,002	16,80±0,19 (16,43 – 17,17)	14,96±0,14 (14,68 – 15,25)	<0,0001
6 hours	17,28±0,27 (16,75 – 17,81)	16,00±0,49 (15,00 – 17,00)	0,002	16,61±0,19 (16,23 – 16,98)	14,79±0,14 (14,51 – 15,08)	<0,0001
10 hours	17,01±0,27 (16,47 – 17,54)	15,75±0,49 (14,75 – 16,75)	0,004	16,34±0,18 (15,97 – 16,70)	14,62±0,14 (14,33 – 14,91)	<0,0001
14 hours	16,85±0,27 (16,32 – 17,38)	15,54±0,49 (14,55 – 16,54)	0,002	16,16±0,19 (15,79 – 16,54)	14,49±0,15 (14,19 – 14,78)	<0,0001
16 hours	16,70±0,28 (16,15 – 17,25)	15,44±0,50 (14,42 – 16,46)	0,002	15,97±0,19 (15,59 – 16,35)	14,36±0,15 (14,06 – 14,65)	<0,0001
18 hours	16,59±0,27 (16,05 – 17,13)	15,31±0,49 (14,30 – 16,32)	0,003	15,83±0,19 (15,46 – 16,20)	14,28±0,15 (13,98 – 14,58)	<0,0001
20 hours	16,47±0,27 (15,93 – 17,00)	15,23±0,49 (14,23 – 16,22)	0,003	15,73±0,19 (15,36 – 16,10)	14,20±0,15 (13,91 – 14,49)	<0,0001
24 hours	16,37±0,27 (15,83 – 16,90)	15,12±0,49 (14,13 – 16,12)	0,001	15,62±0,19 (15,25 – 15,99)	14,10±0,15 (13,81 – 14,39)	<0,0001

Table 4. *Regression model for estimating the time of death based on the temperature parameters of parenchymal organs.*

Variable	Notation	β Coefficient (low t°C)	p-value (low t°C)	β Coefficient (high t°C)	p-value (high t°C)
Subcutaneous fat thickness	X_1	+18.3	<0.001	+24.5	<0.001
Skin temperature	X_2	–6.9	<0.001	–844.3	<0.001
Liver temperature	X_3	–631.3	<0.001	+760.7	<0.001
Spleen temperature	X_4	+281.2	<0.001	+277.9	<0.001
Pancreas temperature	X_5	–173.3	0.014	–14.7	0.019
Right kidney temperature	X_6	–40.9	0.007	+633.2	<0.001
Left kidney temperature	X_7	+268.8	<0.001	–917.6	<0.001

Notes: The model includes only statistically significant predictors (p < 0.05). Left columns represent the model for low ambient temperature; right columns – for high ambient temperature. Y denotes postmortem interval (minutes) from the moment of injury. Positive β values indicate a direct association with time, negative values indicate an inverse relationship.

kidney and are lower, on average, by 1.5-2°C (±0.14) - shown in Figure. The identified statistically significant difference in the temperature indicators of the right and left kidneys depending on the time of injury and the time of death allowed to develop mathematical models for the most accurate determination of the time of death, taking into account external and internal factors, such as ambient temperature, thickness of the subcutaneous tissue and the time of the study after autopsy. Such a factor as sex does not significantly affect the temperature indicators of the right and left kidneys.

As a result of further statistical processing of the temperature indicators of the right and left kidneys, it was found that for a more accurate determination of the time of death, the temperature indicators of the right and left kidneys alone are not enough. It is necessary to take into account the temperature indicators of other parenchymal organs of the abdominal cavity and retroperitoneal space (liver, spleen, kidneys), as a result of which a regression model was obtained for determining the time of death of individuals who died as a result of mechanical injury at different temperatures. In the case of negative temperatures:

$$\mathbf{Y=7291.5+X_1x18.3-X_2x6.9-X_3x631.3+X_4x281.2-X_5x173.3-X_6x40.9+X_7x268.8}$$

where Y – time of death, X_1 – thickness of subcutaneous tissue; X_2 – temperature of external covers; X_3 – liver temperature; X_4 – spleen temperature; X_5 – pancreas temperature; X_6 – temperature of the right kidney; X_7 – temperature of the left kidney.

The regression model for determining the time of death according to the temperature indicators of parenchymal organs of the abdominal cavity and retroperitoneal space (liver, pancreas, spleen, kidneys) of individuals who died as a result of mechanical injury in the case of positive temperatures is as follows:

$$\mathbf{Y= 6324.7+X_1x24.5-X_2x844.3+X_3x760.7+X_4x277.9-X_5x14.7+X_6x633.2-X_7x917.6}$$

where Y – time of death, X_1 – thickness of subcutaneous tissue; X_2 – temperature of external covers; X_3 – liver temperature; X_4– spleen temperature; X_5 – pancreas temperature; X_6 – temperature of the right kidney; X_7 – temperature of the left kidney.

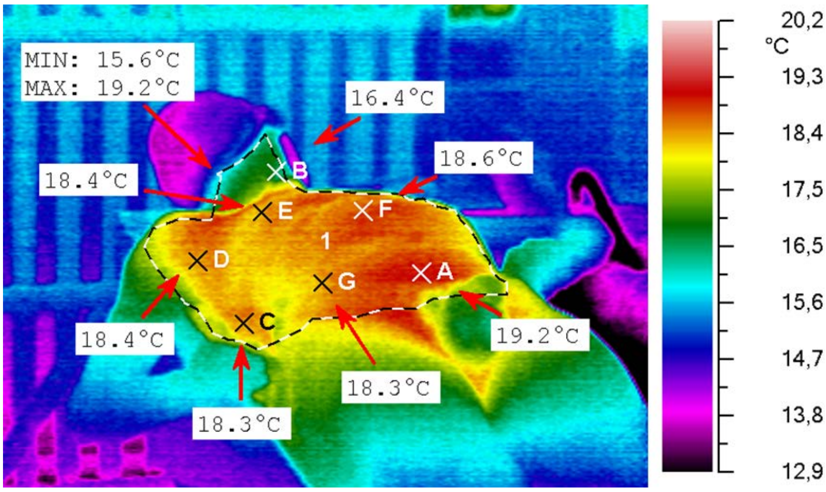

Figure 1. *Temperature indicators of the skin covers of 38-year-old women who died from a mechanical injury.* ***Notes:*** *A,C – anterior surface of the abdominal wall in the in the lower region; B – front surface of the neck; D – anterior surface of the chest on the right; F - anterior surface of the chest on the left; E - anterior surface of the chest; G - anterior abdominal wall abdominal wall.*

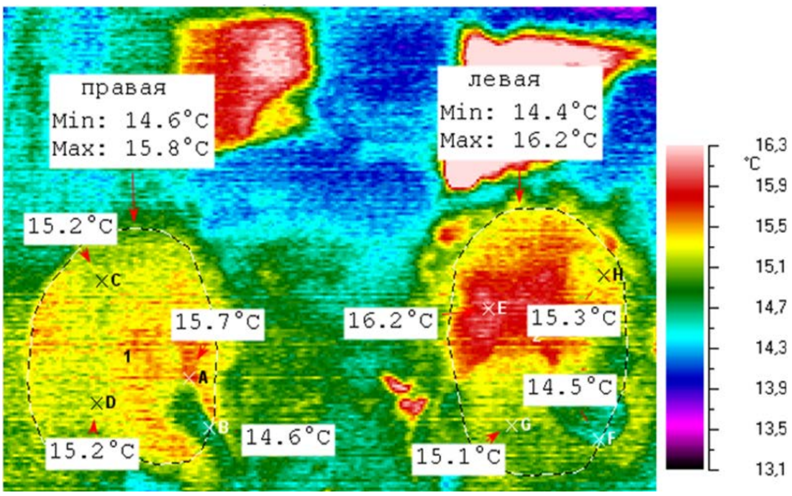

Figure 2. *Temperature indicators of kidneys tissues 1 hour after autopsy. Notes: E – left kidney area of injury; A,B,C,D,H – area of uninjured tissues of the right and left kidneys.*

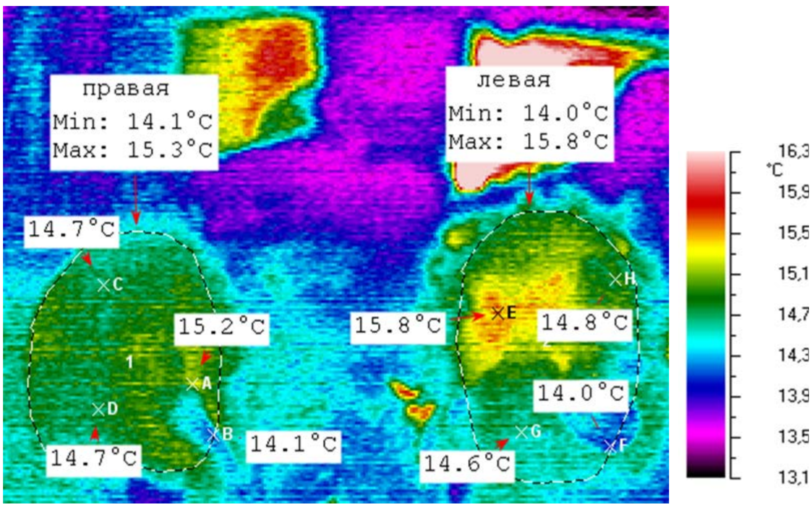

Figure 3. *Temperature indicators of kidneys tissues 6 hours after autopsy. Notes: E – left kidney area of injury; A,B,C,D,H – area of uninjured tissues of the right and left kidneys.*

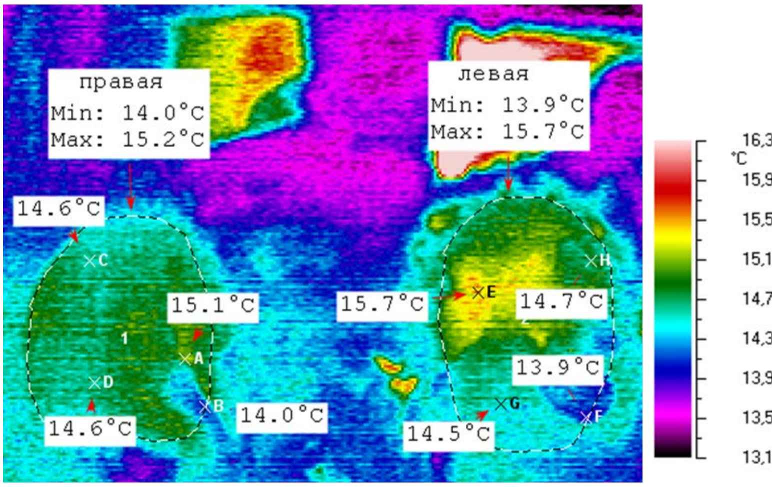

Figure 4. *Temperature indicators of kidneys tissues 12 hours after autopsy. Notes: E – left kidney area of injury; A,B,C,D,H – area of uninjured tissues of the right and left kidneys.*

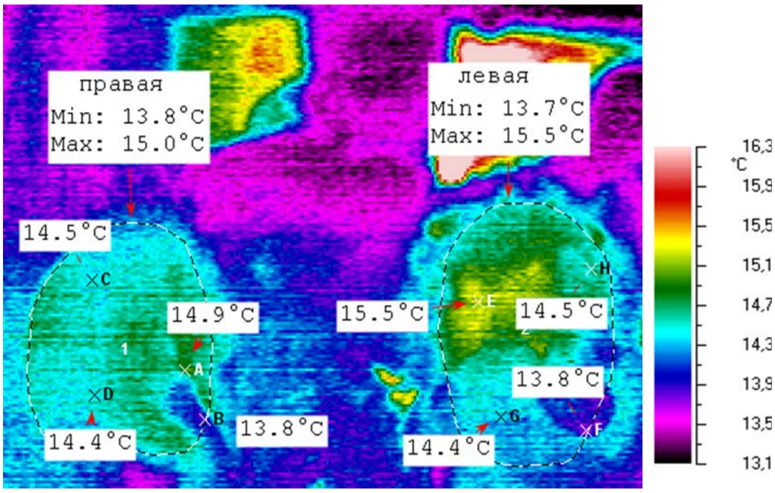

Figure 5. *Temperature indicators of kidneys tissues 18 hours after autopsy. Notes: E – left kidney area of injury; A,B,C,D,H – area of uninjured tissues of the right and left kidneys.*

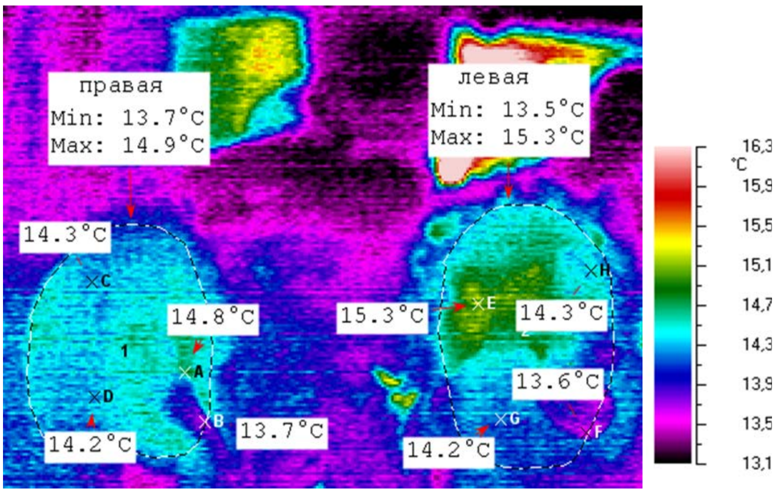

Figure 6. *Temperature indicators of kidneys tissues 24 hours after autopsy. Notes: E – left kidney area of injury; A,B,C,D,H – area of uninjured tissues of the right and left kidneys.*

Regression model for estimating the time of death:

Based on the data obtained, a multifactorial regression model was built to estimate the time of death in individuals who died due to mechanical trauma. The model includes temperature indicators of parenchymal organs in the abdominal and retroperitoneal cavities. The dependent variable (Y) is the estimated time since death (in minutes). The independent variables are the temperatures of the liver, spleen, pancreas, right and left kidneys, skin temperature, and the thickness of subcutaneous adipose tissue. Separate regression models were developed for different ambient temperature ranges (positive and negative temperatures). All predictors in the model were statistically significant ($p < 0.05$), indicating their substantial contribution to explaining the variability of Y. The regression coefficients (β) represent the estimated change in the postmortem interval (in minutes) for a one-unit change in each variable. For instance, an increase in liver temperature by 1 °C under high ambient temperature conditions correlates with a prolongation of the postmortem interval by about 760.7 minutes. Negative β values, such as for "skin temperature" or "left kidney," suggest an inverse relationship – meaning higher temperatures in these areas are associated with a shorter time since death (Table 4).

The resulting equations enable an approximate estimation of the time of death, significantly improving the accuracy and objectivity of forensic examinations, particularly under variable environmental conditions and differing degrees of organ damage.

This Table 4 shows that all variables have a statistically significant impact on the model (all $p < 0.05$), confirming their predictive value. The coefficient of determination ($R^2 = 0.86$) indicates a high level of explanation for the variability of the dependent variable—the time of death. Therefore, the developed model can serve as a reliable tool in forensic practice for estimating the post-traumatic death interval under different environmental temperature conditions.

Discussion.

Injuries to the parenchymal organs of the abdominal cavity, especially the kidneys, make up 6% to 18% of all trauma cases in this area, as confirmed by numerous clinical and anatomical studies [10-12]. However, despite extensive empirical experience, accurately determining the time of injury and the moment of death remains difficult in both clinical and forensic practices. In our study, we examined – for the first time – the temperature changes in injured and uninjured kidney tissue using infrared thermometry. We found that in individuals who died from mechanical trauma, there was a consistent decrease in tissue temperature, with the temperature difference between injured and healthy kidney areas averaging from 1.5–3 °C to 4–5 °C. This aligns with the mechanisms of postmortem tissue cooling but also points to localized thermodynamic changes related to vascular damage and altered microcirculation. It is important to consider several external factors that can influence the rate of postmortem cooling: ambient temperature, humidity, presence of clothing, thickness of subcutaneous fat, duration of the agonal period, and others [13]. The study showed a statistically significant trend toward decreasing temperature values in both injured and uninjured kidney tissues in individuals who died from mechanical trauma. The data obtained may serve as a validated criterion for retrospective assessment of the time of injury [14,15].

Our analysis confirmed the importance of these variables – especially, the thickness of subcutaneous fat (SCF), which showed a statistically significant effect in the regression models we built. In contrast, the sex of the deceased did not have a notable impact on kidney temperature indicators, consistent with previous research findings [16,17]. For the first time in this study, we proposed multifactorial regression models that estimate the approximate time of death based on temperature indicators of the abdominal and retroperitoneal organs. The study revealed statistically significant differences in the temperatures of parenchymal tissues from individuals who died due to mechanical trauma, particularly in the kidneys, depending on tissue type (injured vs. intact), ambient temperature, and time since injury. These findings provided the foundation for developing models that accurately determine the time of death ($R^2 = 0.86$). Each predictor — including organ temperature, skin temperature, and SCF thickness — was statistically significant, supporting a multifactorial approach. Using infrared thermometry improves the objectivity of forensic assessments, especially in complex cases where other reliable postmortem interval markers are lacking. Most traditional methods for estimating the postmortem interval rely on measuring temperatures of the rectum, liver, or skin. However, these methods have limitations, especially in cases of localized trauma or altered heat retention, which can distort thermal dynamics [18]. For example, Henssge and Madea (2004) found that liver thermometry provides an accuracy of ±1.5 hours only within the first ~16 hours after death, with accuracy decreasing afterward [19]. Similarly, Maile AE et al. (2017) confirmed that liver temperature is more stable than rectal or brain temperature but only during a short postmortem window – roughly up to 18 hours [20]. Our approach, however, is based on a multi-organ thermal assessment, including the liver, spleen, pancreas, kidneys, and skin. This integrated method offers a more precise and stable estimation of the postmortem interval, even during extended periods after death, which is especially useful in cases involving abdominal trauma. It is now well understood that algor mortis is a complex, multifactorial process influenced by environmental factors like temperature and humidity, as well as body mass, clothing, metabolic state, and other variables. As Eden, Das, and Thomas (2025) emphasized, the lack of a universal correction formula for these variables limits the reliability of time-of-death estimations based solely on single-region or surface temperature measurements [21]. These insights support the use of multi-organ thermometric analysis, as in our study, which improves the accuracy of postmortem interval estimates by assessing parenchymal and surface temperatures while considering environmental and individual factors. Our model offers a personalized approach through the simultaneous evaluation of multiple organ and tissue temperatures, resulting in greater accuracy and resilience to environmental differences. Additionally, it is known that highly vascularized organs, like the spleen or kidneys, retain heat longer than muscles or skin – an aspect incorporated into our model. Overall, the results demonstrate the potential of this model as a practical tool.

Clinical and Forensic Significance.

The presented model has potential usability not only in forensic medical practice but also in situations involving mass casualties, military conflicts, or delayed transportation of bodies. When standard thermometry is not practical or produces unreliable results, measuring multiple organ temperatures can serve as a strong marker for reconstructing the sequence of events and estimating both the time of trauma and death.

Conclusion.

1. In individuals who died due to mechanical trauma, the temperature of injured renal tissue consistently remained higher than in intact areas—by an average of 2–3 °C—which may serve as an indicator of the time of injury.
2. The regression model based on temperature parameters of parenchymal organs (liver, spleen, pancreas, kidneys), skin temperature, and subcutaneous fat thickness enables highly accurate estimation of the time of death ($R^2 = 0.86$).
3. The developed multifactorial regression model, which incorporates thermal data from both injured and intact parenchymal organs, is effective and can be used in forensic practice for more accurate determination of the postmortem interval.

Ethics.

Ethics Committee Approval: This study was approved by «Instructions on the Forensic Medical Examination» (Order of the Ministry of Health of Ukraine No. 6 dated 01/17/1995), in accordance with the requirements and norms, standard provision on ethics of the Ministry of Health of Ukraine No. 690 dated 09/23/2009, «Procedure for the Removal of Biological Objects from the Dead, whose Bodies are Subject to Forensic Examination and Pathoanatomical Examination for Scientific Purposes» (2018). Ethics Committee of the State Institution "Luhansk State Medical University", Rivne, Ukraine (project no 1, date: 24.02.2023).

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Author Contributions:

Conceptualization, Babkina Olena and Korobko Ihor; methodology, Babkina Olena, Korobko Ihor; software, Danylchenko S.; validation, Zozuliak Vadym and Korobko Ihor; formal analysis, Valerii Kucher; investigation, Babkina Olena, Korobko Ihor; resources, Zozuliak Vadym, Valerii Kucher; data curation, Valerii Kucher, and Zozuliak Vadym; writing-original draft preparation, Babkina Olena, Korobko Ihor; writing-review and editing, Babkina Olena, Korobko Ihor; visualization, Babkina Olena and Danylchenko S.; supervision, Korobko Ihor; project administration, Babkina Olena, Korobko Ihor. All authors contributed equally to the present work. All authors contributed to the critical revision of the article for valuable intellectual content. All the authors have read and agreed with the final version of the article.

Conflict of Interest.

No conflict of interest was declared by the authors.

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ORCID.

Olena Babkina ORCID: 0000-0001-8120-6526
Svitlana Danylchenko ORCID: 0000-0001-5312-0231
Ihor Korobko ORCID: 0000-0002-1292-9971
Vadym Zozuliak ORCID: 0009-0006-2973-1546
Valerii Kucher ORCID: 0009-0004-8463-4904

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