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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.

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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 ინგლისურენოვან 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. ექსპერიმენტული 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, შემაჯამებელი 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. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის 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 უცხოური 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 ხელმძღვანელის 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 შეჯერება 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.

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MEDICO-LEGAL APPLICATIONS OF FRACTURE HEMATOMA: REVIEW

Gonashvili Meri[1], Kilasonia Besarion[1], Chikhladze Ramaz[2], Merabishvili Gela[1], Beriashvili Rusudan[1].

[1]*Department of Forensic Medicine of Tbilisi State Medical University, Georgia.*

[2]*Department of Anatomic Pathology of Tbilisi State Medical University, Georgia.*

Abstract.

Aim of Study: This review aimed to elucidate the critical role of fracture hematoma in forensic medicine, with a specific focus on its utility in differentiating antemortem from postmortem fractures. The study seeks to provide a comprehensive synthesis of current knowledge on the subject, highlighting the biological and medico-legal implications of fracture hematoma analysis in forensic investigations.

Material and Methods: A systematic review of literature was conducted, encompassing various scientific databases including PubMed, Scopus, and Web of Science, focusing on studies published from 2000 to 2024. The search employed keywords such as "fracture hematoma," "antemortem fractures," „perimortem fractures" and "postmortem fractures," among others, to explore relevant data. Selected studies were scrutinized based on their relevance, the presence of substantial data on fracture hematoma, and their contribution to forensic analysis.

Results: The review underscores the significance of fracture hematoma as an indicator of antemortem injuries, revealing that active blood circulation at the time of injury facilitates hematoma formation. Detailed analyses within the selected studies illustrate the interplay of cellular and molecular dynamics within fracture hematomas, emphasizing the roles of cytokines, particularly IL-6, and cellular constituents in the healing process.

Conclusions: Fracture hematoma analysis emerges as a vital forensic tool in establishing the vitality of bone fractures, enhancing the accuracy of forensic assessments. However, the review also acknowledges the challenges posed by individual healing variability and postmortem changes, suggesting a need for further research to refine the interpretative frameworks used in forensic hematoma analysis.

Key words. Fracture hematoma, inflammation, antemortem fractures, postmortem fractures, forensic medicine, cytokines, bone healing, fracture forensic analysis.

Introduction.

The significance of differentiating antemortem from post-mortem fractures is paramount in forensic medical and anthropological studies, especially when analyzing bone system trauma for determining the age of antemortem fractures. This differentiation is crucial for forensic experts to provide scientifically grounded answers to investigative bodies, aiding in the determination of whether physical violence was a factor in a victim's death. Such insights are instrumental in analyzing causes of violent death [1].

Fracture hematoma, the localized collection of blood that forms around a bone fracture soon after the injury, plays a significant role in this differentiation process. The presence of a fracture hematoma is indicative of an antemortem injury, as it suggests that the fracture occurred while the circulatory system was still active, allowing blood to accumulate in the area of the break. In contrast, the absence of such a hematoma could suggest a post-mortem fracture, where no blood flow would be present to create a hematoma [1].

This distinction becomes particularly relevant in cases involving rib fractures, where it is essential to determine whether the injury resulted from resuscitation efforts or from intentional, non-accidental harm, such as physical violence against children. In forensic anthropology, differentiating antemortem from post-mortem fractures is also crucial when examining exhumed human remains. Taphonomic processes can alter bone condition post-mortem, presenting challenges in identifying intravital reactions in what is termed the "dry form" of bone, where organic structures are not preserved. Thus, the analysis of fracture hematoma contributes significantly to the forensic assessment, offering insights into the timing and circumstances of injuries, and aiding in the investigation of violent deaths [2].

This review acknowledges potential limitations, including publication bias and the variability in study designs and methodologies, which might affect the generalizability of the findings.

Methods.

Literature Search Strategy:

To compile a comprehensive review, a systematic search was conducted across various scientific databases, including PubMed, Scopus, and Web of Science. Keywords such as "fracture hematoma," "antemortem fractures," "postmortem fractures," "forensic anthropology," and "bone trauma" were used in various combinations to ensure a thorough search. The search was limited to studies published in English from 2000 to 2024 to capture the most recent and relevant findings.

Inclusion and Exclusion Criteria:

Studies were selected based on their relevance to the topic, focusing on those that provided significant insights into the differentiation of fractures and the specific role of fracture hematoma in forensic analysis. Exclusion criteria included studies that did not directly address fracture differentiation in a forensic context or lacked substantial data on fracture hematoma. Reviews, case reports, and original research articles were included, while non-peer-reviewed articles and abstracts were excluded.

Data Extraction and Analysis:

Relevant data extracted from the selected articles included study design, sample size, methods of fracture analysis, findings related to fracture hematoma, and implications for forensic practice. This information was categorized and tabulated to facilitate a comparative analysis, identifying trends, consensus, and gaps in the current knowledge.

Synthesis of Findings:

The extracted data were synthesized to highlight the key findings related to fracture hematoma's role in differentiating antemortem from postmortem fractures. The synthesis also aimed to draw correlations between study findings, theoretical implications, and practical applications in forensic investigations.

Results and Discussion.

Bone Blood Supply:

The vascular system within bones is indispensable for their growth, repair, and the maintenance of homeostasis. The disruption of blood supply due to a fracture triggers a series of pathological events leading to ischemia and subsequent necrosis of bone tissue. Understanding the dynamics of bone blood supply, particularly during the fracture healing process, is crucial for developing therapeutic strategies and enhancing recovery outcomes.

Bones receive blood through two primary flow mechanisms: centripetal and centrifugal. The centripetal flow is tasked with delivering essential nutrients and oxygen to the bone cells, supporting their metabolic functions. The centrifugal flow, conversely, is crucial for the elimination of metabolic waste from these cells. The differentiation between these flows highlights the sophisticated vascular architecture within bones, crucial for maintaining cellular health and facilitating repair processes [3,4].

Changing Blood Supply During Fracture:

Fractures compromise the integrity of this vascular network, leading to diminished blood supply and potential tissue death. Experimental insights, such as those from Johnson et al. (2004), have shown that injuries to the main vascular channels prompt compensatory mechanisms that enhance periosteal blood flow and stimulate localized centripetal circulation, underpinning the bone's intrinsic healing capabilities [5].

The bone's vasculature is composed of specialized endothelial cells lining H-type and L-type blood vessels, each serving distinct roles in bone biology. H-type vessels, associated with osteoprogenitor cell nourishment, are integral to the repair and regeneration processes post-injury. L-type vessels, predominantly located in the diaphyseal regions, facilitate metabolic waste removal and are less involved in direct osteogenic activities [6].

The interplay between vascular and neural elements is pivotal during bone repair, especially in the acute phase post-fracture. Neurotrophic factors like NGF (Nerve Growth Factor) and their high-affinity receptors (TrkA) are abundantly expressed in periosteal tissues, modulating vascular responses and osteogenic processes. The upregulation of NGF post-fracture underscores its role in coordinating vascular and bone cell responses to injury, essential for effective healing [7].

The intricate network of blood vessels in bones not only sustains cellular functions under physiological conditions but also plays a critical role during the healing process of fractures. Understanding the nuances of bone blood supply, particularly the specialized roles of different vascular components and their interaction with neural signals, can provide deeper insights into fracture healing mechanisms and potentially inform therapeutic approaches.

Characteristics of Acute Fracture Hematoma:

The hematoma formation phase is pivotal in the bone fracture healing continuum. Following fracture onset, there is an immediate induction of bleeding, leading to hematoma development, which is more than a mere aggregation of blood components. This hematoma exhibits a multifaceted structural organization crucial for healing processes. It serves as a foundational anchoring matrix at the fracture margins, facilitating the migration of critical cellular entities such as inflammatory cells, mesenchymal stem cells (MSCs), and osteoblasts, which are instrumental in the reparative cascade [8,9].

In the context of fracture healing, the hematoma not only provides a structural scaffold but also engages in biochemical signalling, essential for recruiting and directing the cellular constituents pivotal to tissue regeneration. Inflammatory cells, upon reaching the hematoma site, release cytokines and growth factors that mediate the initial inflammatory phase, subsequently attracting MSCs (Mesenchymal Stem Cells). These stem cells, under the influence of the hematoma's microenvironment, differentiate into osteoblasts and chondrocytes, propelling the bone healing process forward [10,11]. Osteoblasts, derived from MSCs within the hematoma, commence the bone remodelling phase by synthesizing new bone matrix and facilitating mineral deposition. The phase of hematoma formation plays a crucial role in the healing process of bone fractures. Immediately after the development of a fracture, bleeding and hematoma formation occurs. It is not only a pile of blood elements, but it is characterized by a complex structural composition. One function of the hematoma is to create a temporary anchoring system around the fracture edges, where various cells involved in the healing process, such as inflammatory cells, mesenchymal stem cells, and osteoblasts, will migrate [8].

In their seminal 1993 study, Grundnes and Reikeras explored the critical role of hematoma in rat fracture healing, revealing that hematoma's composition varies significantly across different healing stages. Initially, in the acute phase, the hematoma displays a lack of organization and differentiation. However, this structure starts to organize partially by the second- and fourth-days post-injury. The research underscores the osteogenic potential inherent in fracture hematomas, highlighting that hematoma removal can severely disrupt and complicate bone regeneration [12]. Schmidt-Bleek et al. delved into the cellular makeup of acute fracture hematoma during the inflammatory healing phase, contrasting it with soft tissue hematomas. They observed a lower granulocyte and higher T-helper cell presence in fracture hematomas, suggesting a more orchestrated inflammatory response, which may influence healing outcomes. Their findings prompt further investigation into the signalling molecules within hematoma that contribute to this process [13]. A 2017 study by Wang et al. examined the impact of pore sizes and thrombin concentrations in fibrin-filled hematomas using a rat model, emphasizing the dynamic nature of early fracture hematoma composition [14]. This early hematoma, forming minutes post-fracture, comprises various cellular and molecular

components like fibrin, platelets, erythrocytes, and leukocytes, all influenced by factors including fibrin polymerization and growth factor activity. These elements, along with cytokines and growth factors from surrounding tissues, are pivotal in bone healing, cell migration, proliferation, and differentiation [15]. Walters et al. highlighted the unique environment of fracture hematoma, characterized by specific conditions such as low oxygen levels, high acidity, and elevated calcium content, enriched with cytokines like IL-1β, IL-6, TNF, BMPs, TGF, PDGF, and VEGF. These components synergistically influence the bone healing process, underlining the complexity and critical nature of the hematoma environment in fracture repair [15,16].

Moreover, additional literature aligns with these observations, suggesting that the early fracture hematoma comprises a complex blend of blood, bone marrow, and other tissue components, forming a unique milieu that significantly influences bone repair. The hematoma's cellular content, predominantly leukocytes, evolves over time, reflecting the transient nature of cells like neutrophils. The role of cytokines and growth factors, particularly from immune cells during the inflammatory phase, is crucial for angiogenesis and bone regeneration, further supporting the intricate interplay of biological factors in bone healing [17,18].

Aging of Fracture Hematoma:

Research of Schmidt-Bleek et al. (2014) is a comparative analysis of the cellular composition of fractured bone hematoma and muscle soft tissue hematoma with different ages (4 h; 12 h; 24 h and 48 h) on a sheep model. Hematomas formed during bone and muscle injuries have a different cellular composition. In particular, the expression of T helper cells and anti-inflammatory cytokines is strongly expressed in bone hematoma, which was not detected in the case of muscle hematoma [19].

Also, a sharp increase in bone angiogenic factors was observed in contrast to soft bone hematoma. According to the authors, such a different cellular composition is due to the different cell sources invading the hematoma, which determine the cytokine expression profile, and through them, the regenerative healing of bone or the formation of scar tissue during muscle damage is carried out.

The study tracked the cellular changes over time in the hematoma:

• At 4 hours post-injury, the hematoma is rich in platelets, neutrophils, monocytes, lymphocytes, and mesenchymal stem cells within a fibrin matrix, crucial for chemotactic signalling and the recruitment of peripheral cells.

• By 12 hours, there is a notable reduction in nucleated cells, although the study does not specify the composition further.

• At 24 hours, there is a marked increase in anti-inflammatory cytokines, particularly IL-10 and TGF-β, alongside hypoxia-induced factors like HIF1a and pro-angiogenic proteins, indicating a shift towards healing and angiogenesis.

• By 48 hours, fibroblasts appear, suggesting the initiation of tissue remodelling and further angiogenesis marked by increased HIF1a and VEGF expression.

Despite the rather extensive analysis of hematoma composition, the mentioned work does not reflect the exact composition of the hematoma and the proportional indicators of the distribution of components in it [13].

Composition of Fracture Hematoma:

The detailed analysis by Shiu et al. delves into the intricate composition of fracture hematoma, elucidating its role as a complex amalgam of cellular and structural components essential for the healing process. This complexity is highlighted through the identification and functional characterization of various hematoma constituents:

• **Platelets:** Originating from megakaryocytes in the bone marrow, platelets are pivotal in thrombus formation at the injury site. Upon activation, they secrete a multitude of growth factors, cytokines, and enzymes, fostering the healing process and tissue regeneration.

• **Leukocytes:** The dynamic presence of leukocytes within the fracture hematoma plays a vital role in coagulation and immune response initiation. Notably, distinct macrophage populations, classified as inflammatory (M1 and M2) and resident (osteomacrophages/osteomacs), are identified within the hematoma, each contributing differently to the healing phases.

• **Cytokines:** The interplay between the immune system and bone, termed "osteoimmunology," is crucial for healing. Specific cytokines such as interleukin-1 (IL-1) and interleukin-6 (IL-6) are instrumental during the initial inflammatory phase, modulating various aspects of bone repair and regeneration.

• **Erythrocytes:** While typically known for their role in oxygen transport, erythrocytes within the hematoma are under investigation for their potential impact on the healing process, indicating a multifaceted role beyond oxygen delivery.

• **Fibrin Network:** This structural component provides the essential scaffold for the hematoma, facilitating cellular migration and localization, which are critical for the subsequent healing stages.

• **Growth Factors:** Various growth factors, including fibroblast growth factor (FGF), epidermal growth factor (EGF), and vascular endothelial growth factor (VEGF), are present within the hematoma, each playing significant roles in cellular proliferation, differentiation, and angiogenesis.

• **Hypoxia:** The localized hypoxic conditions induced by HIF within the fracture hematoma are pivotal in modulating the release of angiogenic factors like VEGF, thereby influencing vascularization and tissue repair processes.

Shiu et al. (2018) assert that understanding the multifaceted nature of fracture hematoma is imperative for comprehending its role in bone healing. The study underscores the necessity for further research to elucidate the specific contributions of each hematoma component to the overall process of bone repair and regeneration [19].

Hematoma and Periosteum:

Understanding the interaction between hematoma and periosteum is critical in the early stages of fracture healing, especially given the periosteum's significant role in chondrogenesis within the fracture hematoma. In a pivotal experimental study, researchers divided rats into three distinct groups to elucidate the contributions of the periosteum and hematoma to fracture healing: 1) rats with untreated fractures, 2) rats with removed bone marrow, and 3) rats with the periosteum removed. The study aimed to unravel the specific roles of the

periosteum and the hematoma in the context of fracture healing and tissue regeneration. Findings revealed that, by the third day post-fracture, cell proliferation within the periosteum was notably subdued in the group with removed bone marrow compared to the untreated fracture group. Similarly, a reduction in chondrogenesis was observed in the rats with the periosteum removed. These outcomes suggest that while the periosteum is pivotal during the initial chondrogenesis phase, the hematoma plays a more subdued yet supportive role in periosteal cell proliferation during bone healing. Despite these insights, the study did not pinpoint the exact mechanisms facilitating the interplay between the periosteum and bone marrow [20].

Role of Cytokines in Fracture Healing:

IL-6 serves as a critical cytokine in the early stages of fracture healing, demonstrating a multifaceted role in this intricate process. Research by Kaiser et al. (2018) revealed that blocking IL-6 trans-signalling can significantly improve fracture healing in mice, suggesting the cytokine's dual influence on healing dynamics. Further investigation by Tohma et al. into the IL-6/Reg pathway highlighted its significance in periosteal osteogenesis, emphasizing the periosteum's vital role in bone regeneration. Johnson et al. pointed out the necessity of IL-6 regulation within wound healing processes, cautioning that its mismanagement could result in fibrosis or hindered healing. Complementarily, Wallace et al. found that the absence of IL-6 diminished osteoclastogenesis and modified bone marrow density in early healing stages, illustrating IL-6's dual potential to both support and impede fracture repair [21-24].

Hoff et al. conducted a comprehensive study on the evolving composition of fracture hematomas, emphasizing the variety and dynamics of immune cell types and cytokine concentrations in acute human bone fractures. They documented a notable presence of various immune cells, including granulocytes, monocytes/macrophages, hematopoietic stem cells, T helper cells, and cytotoxic T cells, in early-stage fracture hematomas. Significantly, they also observed heightened levels of inflammatory cytokines such as IL-6 and IL-8. This research aligns with findings from Hauser et al. and Kolar et al., who both found increased levels of IL-6 in the early stages of fracture hematomas, reinforcing the role of IL-6 as a critical inflammatory biomarker in the context of bone healing [25,26,27].

The pivotal role of the cytokine IL-6 in the early stages of fracture healing is well-established, with numerous studies illustrating its pronounced expression in fracture hematomas within the first 48 hours post-injury. This expression profile of IL-6 not only underscores its significance in the inflammatory phase of healing but also highlights its potential as a biomarker for distinguishing between acute and post-mortem fractures.

Immunohistochemical techniques have simplified the detection of macrophages, revealing their crucial involvement in early fracture healing phases. Research by (McCauley et al., and Hoff demonstrated the activation of both M1 and M2 macrophage types during these initial stages. The presence of M1 macrophages correlates strongly with IL-6 levels, while M2 macrophages are predominantly associated with the later ossification phase, as noted by Schlundt (2018), who underscored macrophages' vital role in endochondral ossification. Furthermore, Hoff highlighted the adaptability of immune cells, including macrophages, to the hypoxic conditions prevalent within fracture hematomas. This body of research collectively emphasizes the integral role of macrophages and cytokines throughout the different phases of bone healing, from inflammation to ossification [28,29].

Role of Fracture Hematoma in Differentiating of Antemortem and Postmortem Fractures:

Antemortem fractures are identified by distinct biological responses, notably the formation of fracture hematoma and the subsequent inflammation, which are integral to the body's vital reaction to the injury. The presence of a fracture hematoma, initiates a cascade of healing processes, including inflammation. This inflammatory response, characterized by the infiltration of immune cells and the release of cytokines, plays a pivotal role in orchestrating tissue repair and cellular activities essential for bone healing. These features contrast with postmortem fractures, where such biological markers are absent due to the cessation of blood circulation and cellular functions following death, resulting in fractures that appear cleaner and devoid of any healing or hematoma evidence. Perimortem fractures are difficult to interpret because they occur near the time of death and may have antemortem fracture characteristics, such as partial symptoms of hematoma or inflammation, but lack the entire spectrum of biological healing responses. Recognizing these nuances is crucial for forensic doctors in determining the timing and vitality of fractures, significantly impacting the reconstruction of events at or near the time of death. Thus, understanding the role and presence of fracture hematoma and inflammation is instrumental in the forensic analysis of bone fractures, with advanced techniques like histological analysis and biomechanical modelling being vital for the accurate assessment and categorization of fracture timings, enhancing the reliability of conclusions drawn in forensic trauma analysis [1,2].

Conclusion.

In conclusion, the review elucidates the vital role of hematoma in the context of fracture healing and its emerging significance in forensic medicine, particularly in distinguishing between antemortem and postmortem fractures. The detailed characterization of hematoma composition, cellular activity, and cytokine profiles, particularly the presence and levels of IL-6, provides crucial insights into the timing and biological processes of fracture healing.

From a medico-legal perspective, the understanding of hematoma can be instrumental in differentiating antemortem fractures, which show active biological responses, from postmortem fractures that lack such responses. The presence of an organized hematoma, cellular elements indicative of a healing response, and specific cytokine profiles can serve as strong indicators of antemortem injuries. This knowledge is particularly useful in forensic investigations to ascertain the timing of injuries relative to death, which can be critical in cases of suspected foul play or in the investigation of accidents.

However, there are limitations to the practical application of this knowledge in medico-legal differentiation. The variability in individual healing responses, influenced by factors such as age, health status, and the presence of underlying conditions, can affect hematoma characteristics. Additionally, environmental

factors influencing the preservation or degradation of biological tissues postmortem can impact the detectability and analysis of hematomas. Furthermore, while the presence of certain cellular and molecular markers in a hematoma can suggest an antemortem fracture, the absence of these markers is not definitive proof of a postmortem injury. Decomposition processes, for example, can alter or degrade hematoma components, potentially confounding forensic analysis.

Future advancements in forensic methodologies should aim to refine the interpretation of hematoma characteristics in the context of fracture timing. More research is needed to establish standardized criteria for interpreting hematoma features in forensic cases, and to develop more sophisticated tools for analyzing and quantifying the biological markers within a hematoma.

In summary, while the study of hematoma offers valuable applications in forensic science for differentiating antemortem from postmortem fractures, the field must navigate the inherent biological variability and potential confounding factors to enhance the accuracy and reliability of these medico-legal assessments.

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აბსტარქტი
კვლევის მიზანი: კვლევის მიზანს წარმოადგენდა მოტეხილობის ჰემატომის როლის გამოვლენა სიცოცხლისდროინდელ და სიკვდილისშემდგომ მოტეხილობების დიფერენციაციის პროცესში. აღნიშნული კვლევის მეშვეობით მოხდა ამ საკითხზე არსებული ცოდნის თავმოყრა და ინტეგრაცია, რამაც გამოკვეთა ჰემატომის როლი, ძვლის ტრავმის სასამართლო სამედიცინო ანალიზის პროცესში მოტეხილობის სიცოცხლისდროინდელობის დადგენის თვალსაზრისით. მასალა და მეთოდები: ლიტერატურის მოძიება ჩატარდა სხვადასხვა სამეცნიერო მონაცემთა ბაზებში - მათ შორის PubMed-ში, Scopus-სა და Web of Science-ში. ძიების პროცესი ფოკუსირებული იყო 2000 წლიდან 2024 წლამდე გამოქვეყნებულ კვლევებზე. მონაცემების შესასწავლად გამოიყენებულ იქნა შემდეგი საკვანძო სიტყვები: „მოტეხილობის ჰემატომა", „სიცოცხლისდროინდელი მოტეხილობები", „პერიმორტული მოტეხილობები“ და "პოსტმორტული მოტეხილობები" და სხვ. და სტატიები შეირჩა მოტეხილობის ჰემატომის სასამართლო სამედიცინო ასპექტების გამოყენების თვალსაზრისით.
შედეგები: სტატია ხაზს უსვამს მოტეხილობის ჰემატომის მნიშვნელობას ძვლის მოტეხილობის სიცოცხლისდროინდელობის დადგენისას და მიუთითებს ჰემატომის, როგორც სიცოცხლისდროინდელი მოტეხილობის ინდიკატორის როლზე, რადაგანაც ძვლის დაზიანებისას სისხლის აქტიური მიმოქცევა განაპირობებს ჰემატომის წარმოქმნას. შერჩეული კვლევების დეტალური ანალიზი ასახავს მოტეხილობის ჰემატომაში უჯრედული და მოლეკულური დინამიკის ურთიერთკავშირს, ხაზს უსვამს ციტოკინების, განსაკუთრებით კი IL-6-ისა და უჯრედული კომპონენტების როლს შეხორცების პროცესში. დასკვნა: მოტეხილობის ჰემატომა წარმოადგენს მნიშვნელოვან ინსტრუმენტს ძვლის დაზიანების სიცოცხლისდროინდელობის დადგენისას. თუმცა, კვლევით გამოიკვეთა გამოწვევები, რაც ართულებს მოტეხილობის სიცოცხლისდროინდელობის დადგენის პროცესს. აღნიშნულ შეზღუდვებს მიეკუთვნება ძვლის შეხორცების ვარიაციები და ტაფონომიური პროცესების ზეგავლენა, რაც მიუთითებს შემდგომი კვლევის საჭიროებაზე ძვლის მოტეხილობს სიცოცხლისდროინდელობის სამეცნიერო ინტერპრეტაციული ჩარჩოების შემუშავებასთან დაკავშირებით და მოტეხილობის ჰემატომას ცენტარული როლის გათვალისწინებით.
საკვანძო სიტყვები: მოტეხილობის ჰემატომა, ანთება, სიცოცხლისდროინდელი მოტეხილობები, სიკვდილისშემდგომი მოტეხილობები, სასამართლო მედიცინა, ციტოკინები, ძვლის შეხორცება, ტრავმის ანალიზი.

Абстракт

Цель исследования: Целью данного обзора было прояснить критическую роль гематомы при переломе в судебной медицине, уделив особое внимание ее полезности для дифференциации предсмертных переломов от посмертных. Целью исследования является всесторонний синтез современных знаний по данному вопросу, подчеркивающий биологические и медико-правовые последствия анализа гематомы при переломе в судебно-медицинских исследованиях.

Материал и методы: Был проведен систематический обзор литературы, охватывающий различные научные базы данных, включая PubMed, Scopus и Web of Science, с акцентом на исследования, опубликованные в период с 2000 до 2024 года. В поиске использовались такие ключевые слова, как "гематома при переломе", " переломы при жизни", „перимортальные переломы” и "посмертные переломы", среди прочих, для изучения соответствующих данных. Отобранные исследования были тщательно проанализированы на основе их актуальности, наличия существенных данных о гематомах при переломах и их вклада в судебно-медицинский анализ.

Результаты: Обзор подчеркивает важность гематомы при переломе как показателя предсмертных травм, показывая, что активное кровообращение во время травмы способствует образованию гематомы. Подробные анализы в рамках выбранных исследований иллюстрируют взаимодействие клеточной и молекулярной динамики в гематомах при переломах, подчеркивая роль цитокинов, в частности IL-6, и клеточных компонентов в процессе заживления.

Выводы: Анализ гематомы при переломе становится жизненно важным судебно-медицинским инструментом для установления переломов костей при жизни, повышая точность судебно-медицинских оценок. Однако в обзоре также признаются проблемы, связанные с индивидуальной вариабельностью заживления и посмертными изменениями, что указывает на необходимость дальнейших исследований для уточнения интерпретационных рамок, используемых при судебно-медицинском анализе гематом.

Ключевые слова: Гематома перелома, воспаление, Предсмертные переломы, посмертные переломы, судебная медицина, цитокины, Заживление костей, судебно-медицинский анализ переломов.