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FORENSIC MEDICAL AND PATHOGENETIC ASPECTS OF FORMATION AND AGE DETERMINATION OF SUBDURAL HEMATOMAS IN TRAUMATIC BRAIN INJURY

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Abstract. The relevance of this study is determined by the high incidence of subdural hematomas among fatal outcomes of traumatic brain injury and the persistent challenges in their forensic medical interpretation. Despite advances in neuroimaging and neurosurgery, there are still no absolutely reliable criteria for determining the age of intracranial hematomas. This article analyzes current concepts of subdural hematoma pathogenesis from the perspective of trauma biomechanics, mechanical properties of pial veins, the role of dynamic loading, and premorbid factors. Special attention is paid to forensic evaluation of injury mechanisms, including impact and whiplash injuries, as well as the diagnostic potential of biochemical and biophysical methods (methemoglobin concentration, serum glucose levels) for estimating the timing of hemorrhage formation. The necessity of a comprehensive interdisciplinary approach to improve the accuracy of forensic conclusions is emphasized.

Keywords: traumatic brain injury, subdural hematoma, pathogenesis, forensic medicine, hematoma age determination, methemoglobin, trauma biomechanics

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СУДЕБНО-МЕДИЦИНСКИЕ И ПАТОГЕНЕТИЧЕСКИЕ АСПЕКТЫ ФОРМИРОВАНИЯ И ДАВНОСТИ СУБДУРАЛЬНЫХ ГЕМАТОМ ПРИ ЧЕРЕПНО-МОЗГОВОЙ ТРАВМЕ

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Аннотация. Актуальность исследования обусловлена высокой частотой субдуральных гематом в структуре летальных исходов черепно-мозговой травмы и сложностью их судебно-медицинской интерпретации. Несмотря на значительный прогресс в нейровизуализации и нейрохирургии, до настоящего времени отсутствуют абсолютно достоверные критерии определения давности формирования внутричерепных гематом. В статье рассматриваются современные представления о патогенезе субдуральных гематом с позиций механики травмы, биомеханических свойств пиаальных вен, роли динамических нагрузок и преморбидных факторов. Особое внимание уделено судебно-медицинской оценке механизмов травмы, включая ударные и хлыстовые воздействия, а также возможностям биохимических и биофизических методов (определение метгемоглобина, глюкозы сыворотки крови) в установлении давности кровоизлияний. Подчёркивается необходимость комплексного междисциплинарного подхода для повышения точности экспертных заключений.

Ключевые слова: черепно-мозговая травма, субдуральная гематома, патогенез, судебная медицина, давность гематомы, метгемоглобин, биомеханика травмы.

BOSH MIYA JAROHATLARIDA SUBDURAL GEMATOMALARNING SHAKLLANISHI VA DAVRINI ANIQLASHNING SUD-TIBBIY VA PATOGENETIK JIHATLARI

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Annotatsiya. Mazkur tadqiqotning dolzarbligi bosh miya jarohatlarida subdural gematomalarning yuqori uchrash chastotasi va ularning sud-tibbiy baholashdagi murakkabligi bilan belgilanadi. Neyrojarrohlik va neyrodiagnostika sohasidagi yutuqlarga qaramay, hozirgi kungacha intrakranial gematomalarning shakllanish davrini aniq aniqlash mezonlari mavjud emas. Maqolada subdural gematomalar patogenezi travma biomexanikasi, pial venalarning mexanik xususiyatlari, dinamik yuklamalar va premorbid omillar nuqtai nazaridan tahlil qilinadi. Shuningdek, zarba va "qamchi" mexanizmlarining sud-tibbiy bahosi hamda gematoma yoshini aniqlashda biokimyoviy va biofizik usullarning (metgemoglobin miqdori, qon zardobi glyukozasi) imkoniyatlari koʻrib chiqiladi. Sud-tibbiy ekspertiza aniqligini oshirish uchun kompleks yondashuv zarurligi asoslanadi.

Kalit soʻzlar: bosh miya jarohati, subdural gematoma, patogenez, sud-tibbiyot, gematoma davri, metgemoglobin, travma biomexanikasi

Relevance. Intracranial (including subdural) hematomas are the most common cause of adverse outcomes in neurotrauma [1,15]. The frequency of intracranial hematomas, according to L.B. Likhterman and L.Kh. Khitrin, in the structure of fatal traumatic brain injury varies from 15 to 53%. According to D. Crooks, in autopsy studies of closed head injury, subdural hematomas are detected somewhat more often - in 26 - 63% [2,6,21]. One of the most important problems of forensic medicine at present remains the determination of the time of formation of intracranial hemorrhages occurring both in traumatic brain injury and in cerebrovascular diseases [4,8]. The following types of intracranial hematomas are distinguished: epidural, subdural, subarachnoid and intracerebral. The mechanism of their occurrence is different and has been studied in sufficient depth both in acute cerebral circulatory failure and in traumatic brain injury. [6,11,13] The pathogenesis of traumatic intracranial hematomas is complex and does not relate to fully studied issues of traumatic brain injury. The literature covering the pathogenetic mechanisms of subdural hematoma formation cannot be considered extensive; the data presented in it are an opinion and, therefore, require certain correction from the point of view of forensic medical expert evaluation [18,20]. In the pathogenesis of subdural hematoma, trauma is a key link, but in some cases it can be a provoking factor, and in others - a direct cause of hemorrhage [4]. During autopsy, intracranial hematomas as a consequence of traumatic brain injury are detected in 15-35% of cases, of which subdural hematomas – in 22.8-35.8% [5]. The relative frequency of occurrence of subdural hematomas in the general structure of forensic and pathological autopsies is 4% [6; 7]. Acute subdural hematoma, as a rule, occurs in combination with high parameters of head acceleration during injury. With such injuries, fractures of the skull bones, primarily the base, are characteristic. I.M. Irger explains the frequent formation of acute subdural hematomas on the side opposite to the site of application of the traumatic factor by the displacement of both hemispheres in the direction of action of the traumatic agent. At the same time, according to L.B. Likhterman and L.Kh. According to Khitrin, subdural hematomas, unlike epidural hematomas, occur with approximately the same frequency both on the side of the force application and on the opposite side [3,7,22]. The development of subdural hematomas is possible even in the absence of direct application of a traumatic object to the head and may be associated with the whiplash mechanism of injury - a sharp change in the velocity vector of head movement (according to our data, about 5%) [12,18]. In some cases, both mechanisms (impact and whiplash) may be simultaneously involved in the formation of subdural hematomas, which L.Kh. Khitrin explains the possibility of their bilateral location [6].Subdural hematomas may be caused by ruptures of cortical arteries and veins, sinuses of the dura mater, but their most common cause is damage to the pial veins (veins tributary to the sinuses of the dura mater) [7,12], the strength properties of which and the peculiarities of fixation in the subdural space (along with some other factors) predetermine the possibility of rupture of the vascular wall at different levels of head acceleration at the time of injury. Pial perforating veins have sufficient strength (elastic) properties [6,18,22]. Their resistance to various degrees of stretching significantly depends on the speed with which the tension of the vascular wall occurs. It was found in the experiment that the average stretch at which a vein ruptures decreases by almost one order of magnitude if the development time of centripetal contact and non-contact loads is in the range from

0.1 to 3.3 ms [15,21]. Under static loads, damage may not occur even when the vascular wall is stretched more than 2-fold. Under dynamic loads, the resistance of the pial veins to rupture is significantly reduced; vascular damage may occur when the vascular wall is stretched slightly more than one-fifth [14,22]. The strength properties of the pial veins and their tolerance to the effects of physical agents cannot be considered in isolation from a number of other (premorbid) factors [1,4]. Most authors include acute and chronic infectious processes in the brain, vascular lesions, alcoholism, etc. among such factors. Moreover, D.T. Kuimov and A.S. Shmaryan believe that for certain types of subdural hematomas, the mechanical factor should be considered last among the other (above-mentioned) factors. In this regard, M.I. Avdeev calls for a very cautious expert evaluation of such cases (in the absence of skull fractures, contusions, etc.) and clarification of the role of trauma in the genesis of subdural hematoma by excluding the influence of other factors. The presented data do not reveal all aspects of the problem at hand, but indicate the need for further targeted comprehensive research into the strength properties of the brain vessels and its membranes, taking into account the mechanical parameters of the external load and the physical processes developing in response to trauma in the brain and paracerebral structures [13,17]. This type of research will make it possible to resolve the issue of the role of trauma in the formation of subdural hematoma (especially in cases where head trauma was not accompanied by skull fractures, brain contusions and other traumatic substrates) among a number of other endogenous and exogenous factors [18,21,22]. Also, along with the pathogenesis of intracranial hematoma formation, it is important to determine the duration of the hematoma formation. For this purpose, a number of researchers conducted an analysis of traumatic intracranial hematomas using biochemical and biophysical methods [7,9].Attempts have been made to establish the age of chronic subdural hematoma using histological examination of samples removed during surgery [10]. Selective sensitivity of biochemical research methods at certain stages of the post-traumatic period, the possibility of using them to diagnose the formation of traumatic intracranial hemorrhages and differential diagnosis from non-traumatic intracranial hemorrhages in acute cerebrovascular accident [15] have been identified and proven. A mathematical model for determining the time of injury based on serum glucose levels in traumatic intracranial hemorrhages, and a regression graph for determining the age of intracranial hemorrhage after injury based on serum glucose levels have been developed. The use of biochemical research methods, in the author's opinion, is most appropriate for determining the age of intracranial hemorrhage. In this case, the amount of methemoglobin in hematomas can serve as an indicator of the age of hematoma formation. To accurately assess the presence of methemoglobin, methemoglobin levels in the blood from the sinuses of the meninges can be used as a control test [14,19]. In the presence of large hematomas, it is advisable to examine both the central and peripheral parts. Methemoglobin levels at the periphery of the hematoma are typically several times higher than in the center, which is associated with the dynamics of hematoma formation. A comprehensive assessment of these results allows for a more accurate assessment of the time since hematoma formation [16].In the presence of large hematomas, it is advisable to examine both the central and peripheral portions. Methemoglobin levels at the periphery of a hematoma are typically several times higher than in the center, which is related to the dynamics of hematoma formation. A comprehensive assessment of these results allows for a more accurate assessment of the age of the hematoma [16].In the presence of large hematomas, it is advisable to examine both the central and peripheral portions. Methemoglobin levels at the periphery of a hematoma are typically several times higher than in the center, which is related to the dynamics of hematoma formation. A comprehensive assessment of these results allows for a more accurate assessment of the age of the hematoma [16].

Conclusion. In modern forensic medicine, there are no absolutely reliable and accurate criteria for determining the age of intracranial hematomas, which determines the relevance of these studies. Furthermore, studying the pathogenesis of this type of traumatic brain injury will allow us to determine its role in the formation of a subdural hematoma (especially when the head injury is not accompanied by skull fractures, brain contusions, or other traumatic elements) among a number of other endogenous and exogenous factors.

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