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ANATOMICAL AND MORPHOLOGICAL FEATURES OF THE MENINGEAL SYNDROME DEVELOPMENT IN CEREBRAL ANEURYSM RUPTURE

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Introduction. The prevalence of cerebral aneurysms (CAs) worldwide is approximately 3% of the population. CA rupture accounts for 85% of all subarachnoid haemorrhage cases. One of the clinical manifestations of aneurysmal subarachnoid haemorrhage (aSAH) is neck stiffness caused by an inflammatory response to blood in the subarachnoid space. In fully conscious patients with aSAH and with no focal neurological deficit, meningeal signs may be the only diagnostic indicator.

Objective is to assess the anatomical and morphological features of meningeal syndrome development in CA rupture.

Materials and methods. The study included 480 medical records of the acute aSAH. There were two groups of patients: Group 1 – patients without meningeal signs, and Group 2 – patients with meningeal signs. Statistical analysis was performed using the χ^2-test and binomial logistic regression.

Results. Patients with ruptured CA located in the middle cerebral artery (MCA) territory have a threefold higher likelihood of exhibiting meningeal signs compared to those with CA located in the internal carotid artery (ICA) territory (OR=3.29; CI=1.313-8.26; p=0.011). In both groups, the most common locations of ruptured CAs were in the anterior communicating artery territory (34.0% and 40.0%, respectively) and the posterior communicating artery territory (26.3% and 15.9%, respectively). In both groups, the size of ruptured CA between 5 and 9 mm was most frequently observed. An increase in the size of the ruptured CA was associated with a 9.6% decrease in the likelihood of developing meningeal signs (OR=0.904; CI=0.853-0.959; p<0.001).

Conclusions. The presence of CA in the MCA territory significantly increases the likelihood of meningeal signs in the acute period of CA rupture compared to CA located in the ICA territory. An increase in the size of the ruptured CA significantly reduces the likelihood of meningeal signs in the acute period of CA rupture.

Key words: aneurysmal subarachnoid haemorrhage, meningeal signs, cerebral aneurysm.

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АНАТОМО-МОРФОЛОГІЧНІ ОСОБЛИВОСТІ РОЗВИТКУ МЕНІНГЕАЛЬНОГО СИНДРОМУ ПРИ РОЗРИВІ МОЗКОВИХ АНЕВРИЗМ

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Поширеність мозкових аневризм (МА) у світі становить близько 3% населення. Розрив МА становить 85% усіх випадків субарахноїдального крововиливу. У пацієнтів з аневризматичним субарахноїдальним крововиливом у ясній свідомості та без вогнищевого неврологічного дефіциту менінгеальні знаки можуть бути єдиною діагностичною ознакою. Мета цього дослідження – оцінити анатомо-морфологічні особливості розвитку менінгеального синдрому у разі розриву МА. Зі збільшенням розмірів МА, що розірвалась, зменшується ймовірність розвитку менінгеальних знаків. У разі локалізації МА, що розірвались, у басейні середньої мозкової артерії вища ймовірність наявності менінгеальних знаків у пацієнтів під час надходження порівняно з пацієнтами, в яких розірвались МА у басейні внутрішньої сонної артерії. Виявлено взаємозв'язок між менінгеальним синдром та анатомо-морфологічними характеристиками МА, що розірвались.

Ключові слова: аневризматичний субарахноїдальний крововилив, менінгеальні знаки, мозкова аневризма.

Introduction. The global prevalence of cerebral aneurysms (CAs) is approximately 3.2% of the population. The annual risk of CA rupture ranges from 2% to 10% [1]. CA rupture accounts for 85% of all cases of subarachnoid haemorrhage (SAH) [2]. It is worth noting that most CAs never rupture [1].

At the same time, several studies have identified risk factors for CA rupture. The most significant among these include arterial hypertension, age, Japanese and Finnish ethnicity, size, location, and morphological characteristics of the ruptured CA [3].

The symptoms of aneurysmal subarachnoid haemorrhage (aSAH) are most commonly described by patients as a "thunderclap" headache. Other clinical manifestations of aSAH include nausea, vomiting, meningeal signs, photophobia, seizures, focal neurological deficit, and impaired consciousness [4]. The pathophysiological mechanisms underlying the appearance of meningeal

signs in patients with aSAH involve the development of local inflammation of the meninges in response to blood in the subarachnoid space [5]. It should be noted that the majority of patients with aSAH present with normal state of consciousness, or their level of consciousness may alter. In such cases, meningeal signs may serve as an isolated objective diagnostic feature during neurological examination [6].

The size and location of the ruptured CA are among the factors influencing the course of aSAH [7]. A review of the literature revealed that the UCAS study stratified CAs by size based on rupture rates: small CAs up to 5 mm, medium-sized CAs between 5 mm and 10 mm, large CAs between 10 mm and 25 mm, and giant CAs larger than 25 mm [8]. It is known that approximately 90% of ruptured CAs were smaller than 10 mm [9]. Furthermore, a significant proportion of ruptured CAs smaller than 10 mm were located in the anterior communicating artery (AComA) territory, while those smaller than 5 mm were predominantly located in the AComA and posterior communicating artery (PCoA) territories [10; 11].

We found that the connection between meningeal syndrome and ruptured CAs remains insufficiently studied.

Objective is to assess the anatomical and morphological features of meningeal syndrome development in CA rupture.

Materials and methods. A single-centre retrospective cross-sectional study was conducted. This study included 480 patients' medical records in the acute phase of aSAH. The inclusion criteria were as follows: 1) SAH caused by CA rupture; 2) confirmation of CA presence via CT angiography; 3) age of 18 years or older. Exclusion criteria included: 1) incomplete medical records (missing data on meningeal syndrome); 2) absence of confirmed CA on CT angiography, traumatic SAH, or other causes of intracranial haemorrhage (arteriovenous malformations, coagulopathies, etc.). Patients were divided into two groups based on the presence of meningeal signs upon admission. Group 1 included patients without meningeal signs – 53 (11.0%) patients, among them 28 (52.8%) women and 25 (47.2%) men. Group 2 included patients with meningeal signs – 427 (89.0%) patients, among them 233 (54.6%) women and 194 (45.4%) men (Figures 1 and 2). The number of women prevailed in both groups. However, no statistically significant relationship between sex and meningeal signs was identified (χ^2=0.0573; df=1; p=0.811).

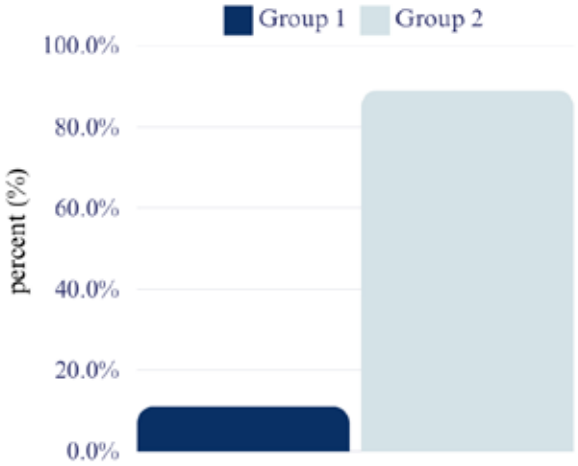

Fig. 1. Distribution by the presence or absence of meningeal signs

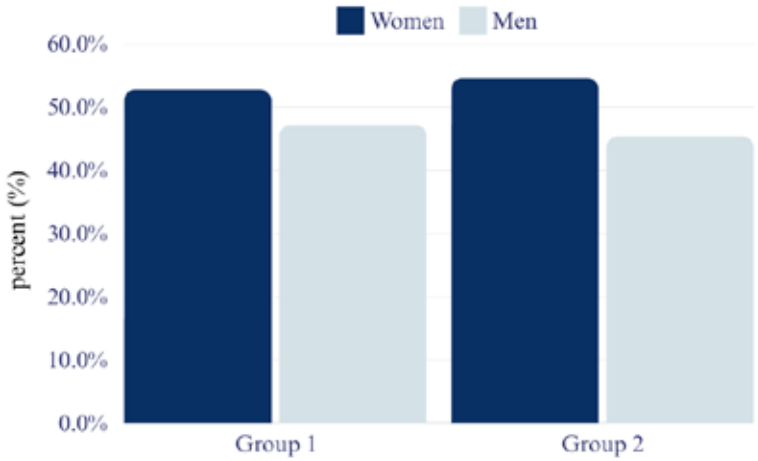

Fig. 2. Distribution by sex

In this study, the characteristics of the meningeal syndrome were assessed depending on the maximum dome size and location of the CA (in cases of multiple CAs, the location and size of the ruptured CA were considered). The extent of the haemorrhage was evaluated based on CT data.

The representativeness of findings for certain categories and the generalisability of results may be limited by the sample size and the single-centre study design. Consequently, when analysing the size of the ruptured CA, data were unavailable for 11 patients in Group 1 and 78 patients in Group 2.

Statistical analysis was performed using the χ^2 test and binomial logistic regression. Calculations were conducted using Jamovi software, version 2.3.28.0. Results with $p < 0.05$ were considered statistically significant.

The study was conducted in compliance with the principles of the Ethical Code of the World Medical Association (Declaration of Helsinki). Ethical approval for the study was obtained via Protocol No. 7 of the Ethics Committee of Odesa National Medical University, dated 30 September 2019.

Results and discussion. The analysis of haemorrhage distribution revealed that isolated SAH was the most common in both groups: in Group 1 – 29 (54.7%) patients and in Group 2 – 174 (40.7%) patients. The second most frequent type of haemorrhage in Group 1 was SAH with a parenchymal haemorrhage – 9 (17.0%) patients. In contrast, in Group 2, the next most common types of haemorrhage were SAH with a ventricular haemorrhage – 126 (29.5%) patients, and SAH with both ventricular and parenchymal haemorrhages – 60 (14.1%) patients (Figure 3).

Statistical analysis did not identify a significant association between the type of haemorrhage and meningeal signs (χ^2=4.85; df=3; p=0.183).

By the location of the ruptured CA, patients in Group 1 were distributed as follows: CAs located in the anterior cerebral artery (ACA) territory – 25 (47.2%) patients, CAs located in the internal carotid artery (ICA) territory – 18 (34.0%) patients, CAs located in the middle cerebral artery (MCA) territory – 7 (13.2%) patients, CAs located in the basilar artery (BA) territory – 2 (3.7%) patients, and CAs located in the vertebral artery (VA) territory – 1 (1.9%) patient. In Group 2, the distribution was as follows: CAs located in the ACA territory – 200 (46.8%) patients, CAs located in the MCA territory – 105 (24.6%) patients, CAs located in the ICA territory – 82 (19.2%) patients, CAs located in the BA territory – 24 (5.7%) patients, and CAs located in the VA territory – 16 (3.7%) patients. Thus, in Group 1, ruptured CAs were most frequently located in the ACA and ICA territories, whereas in Group 2, they were most commonly located in the ACA and MCA territories (Figure 4). There was no statistically significant association between meningeal signs and the location of the ruptured CA (χ^2=8.31; df=4; p=0.081). Despite this, using binomial logistic regression to compare different locations of ruptured CAs, it was found that patients with a ruptured CA in the MCA territory had three times higher odds of presenting with meningeal signs compared to those with a ruptured CA in the ICA territory (OR=3.29; CI=1.313–8.26; p=0.011) (Figure 5).

A more detailed analysis of the characteristics of ruptured CA locations revealed that in both Group 1 and Group 2, ruptured CAs were predominantly located in the AComA (34.0% and 40.0%, respectively) and PCoA (26.3% and 15.9%, respectively) territories, which aligns with previous studies (Figures 6 and 7).

The analysis of the size of ruptured CAs in Group 1 revealed the following: a size of up to 5 mm was identified in 6 (14.3%) patients, 5–9 mm in 20 (47.6%) patients, 10–25 mm in 15 (35.7%) patients, and larger than 25 mm in 1 (2.4%) patient. In Group 2, the distribution of ruptured CA sizes was as follows: a size of up to 5 mm in 84 (24.1%) patients, 5–9 mm in 200 (57.3%) patients, 10–25 mm in 64 (18.3%) patients, and larger than 25 mm in 1 (0.3%) patient. In both groups, the most frequent size of ruptured CAs was between 5 and 9 mm, which aligns with previous studies (Figure 8). An increase in the size of the ruptured CA was associated with a 9.6% lower chance of developing meningeal signs, which is a statistically significant result (OR=0.904; CI=0.853–0.959; p<0.001).

Conclusions. The presence of a CA in the MCA territory significantly increases the likelihood of meningeal signs during the acute phase of CA rupture compared to the ICA territory (OR=3.29; CI=1.313–8.26; p=0.011). An increase in the size of the ruptured CA significantly reduces the likelihood of meningeal signs during the

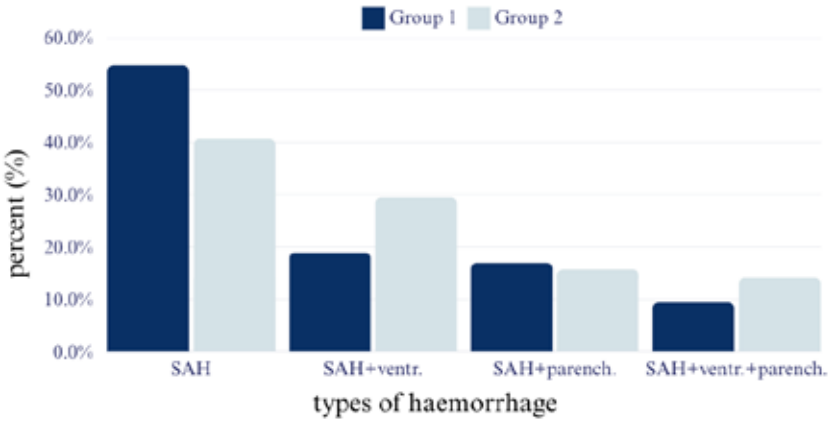

Fig. 3. Distribution of haemorrhage extent between groups

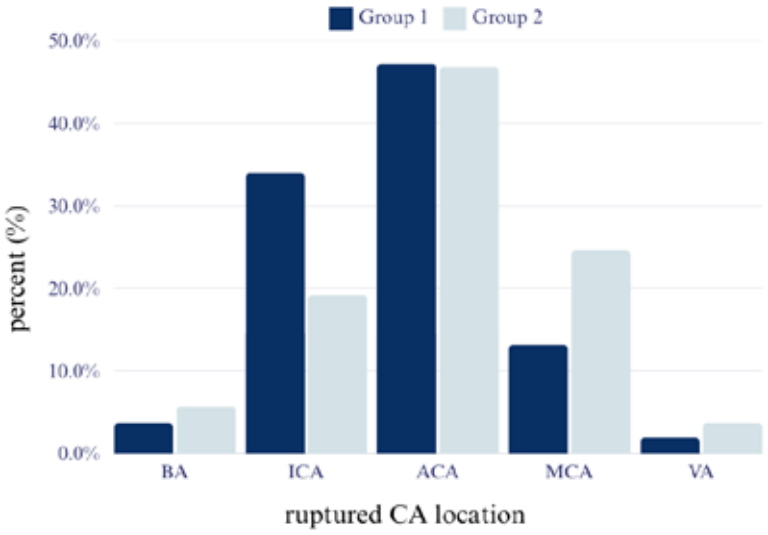

Fig. 4. Distribution of ruptured CAs locations between groups

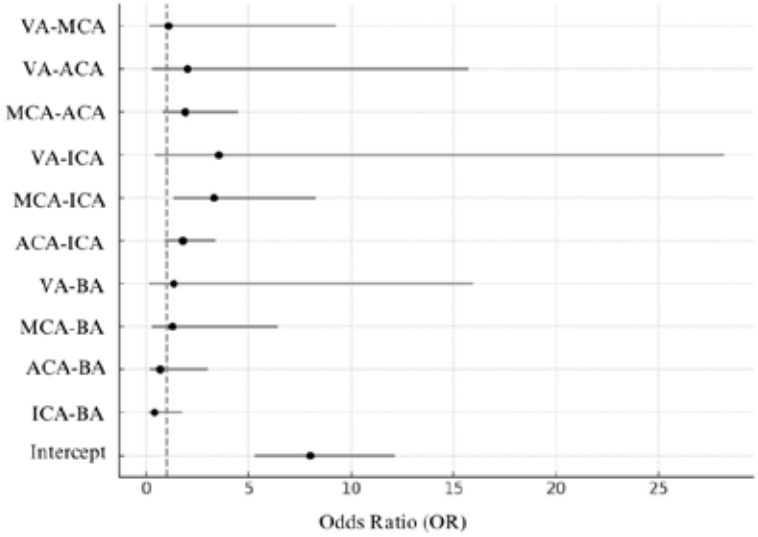

Figure 5. Results of binomial logistic regression

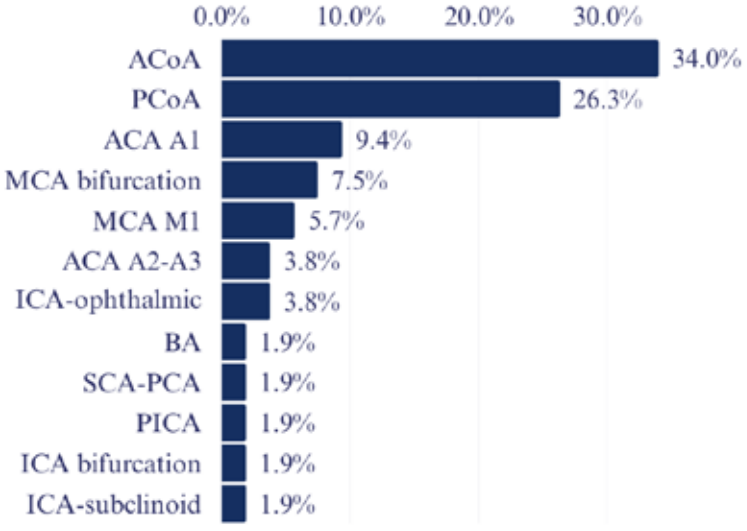

Figure 6. Distribution of ruptured CAs locations in Group 1

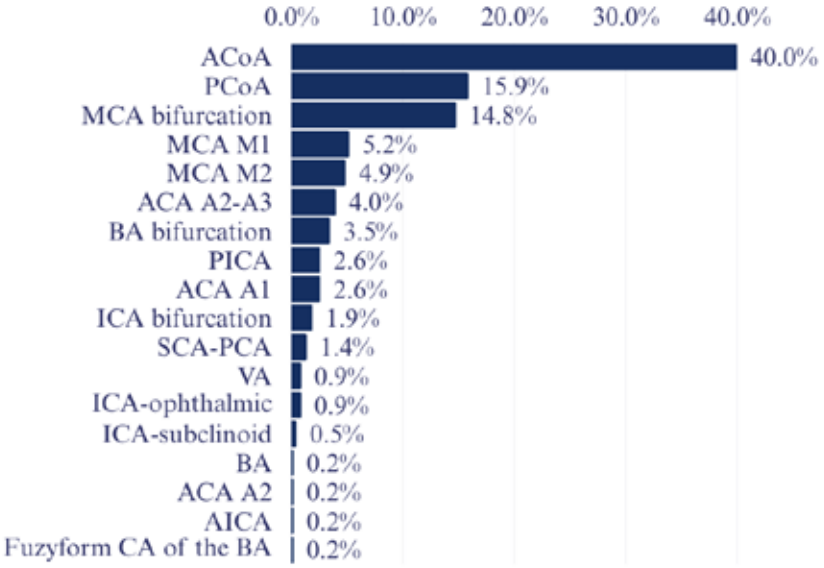

Fig. 7. Distribution of ruptured CAs locations in Group 2

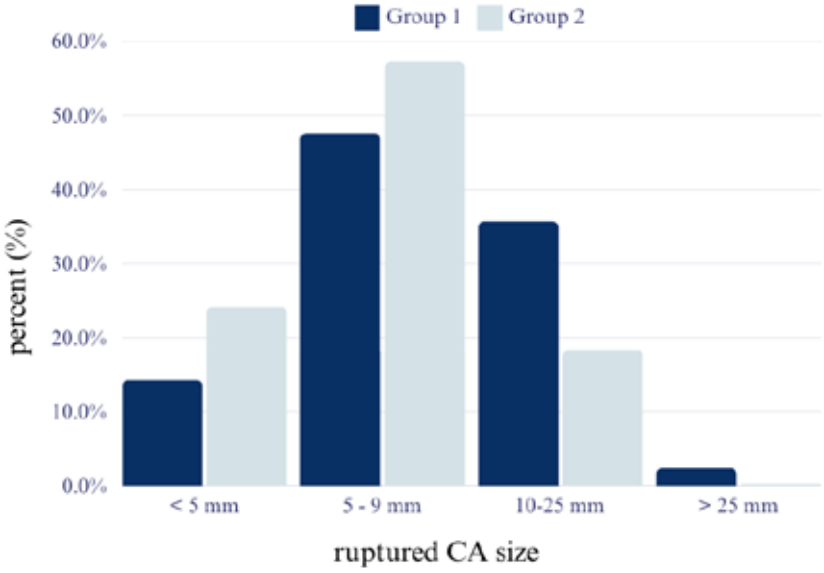

Fig. 8. Distribution of ruptured CAs sizes between groups

acute phase of CA rupture (OR=0.904; CI=0.853–0.959; p<0.001). Thus, understanding the relationship between CA location, size and clinical manifestations such as meningeal signs can assist clinicians in optimization of the diagnosis and management of patients in the acute phase of aSAH. Further multifactorial studies involving additional healthcare institutions will help deepen the understanding of this issue.

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