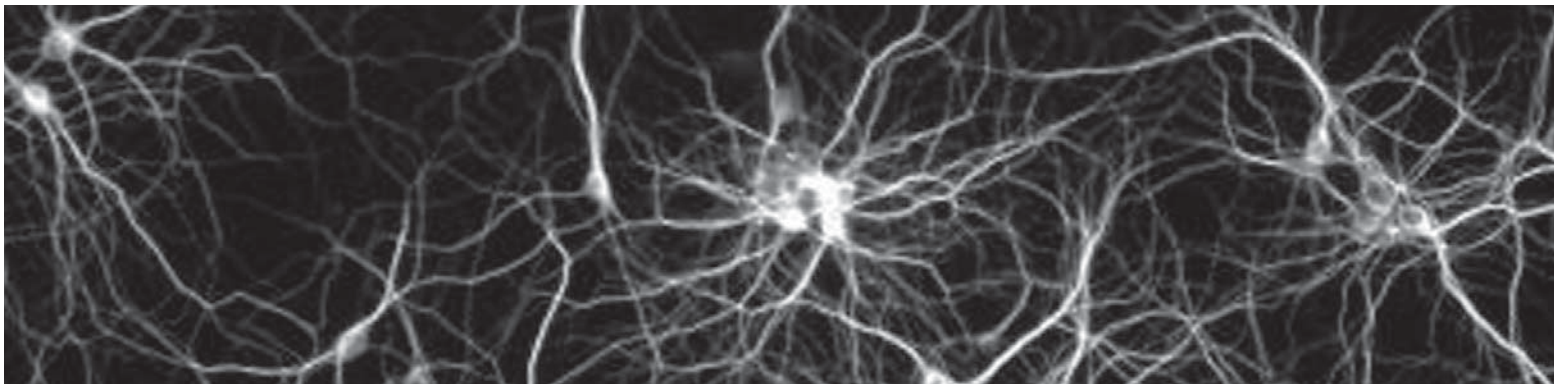

Basic algorithm for management of patients with aneurysmal subarachnoid hemorrhage

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ABSTRACT - Aneurysmal subarachnoid hemorrhage (aSAH) is one of the most urgent clinical conditions among neurologic diseases. If untreated, the disease has high mortality and morbidity, and the outcome depends mostly on optimal diagnostic and treatment procedure. Currently, no national guidelines for the management of aSAH have been published or accepted in Croatia. Therefore, treating procedures depend on individual estimation, knowledge and experience, as well as on technical facilities available at different medical institutions. On the other hand, by accepting a uniform approach in the management of aSAH, according to the specific conditions in Croatian medical institutions, reaching optimal outcome for each patient will be accomplished. The aim of this algorithm is to define the basic characteristics of the disease, its epidemiologic data as well as its clinical picture, and to present appropriate diagnostic algorithm in accordance with specific facilities of different medical institutions. Furthermore, this algorithm will consider optimal management of a patient with verified aSAH in prehospital and hospital conditions, and finally in a Comprehensive Stroke Center. In addition, it will focus on the endovascular management of ruptured aneurysms and on the complications of subarachnoid hemorrhage. This algorithm is based on the already published international guidelines for aSAH management as well as on own experience in treating ruptured aneurysms and subarachnoid hemorrhage at the Referral Center for Intensive Neurology of the Croatian Ministry of Health during a five-year period (2007-2012, altogether 515 patients). The level of evidence of these guidelines is, according to the classification, Level A, grade I to Level C, grade IIb.

Key words: acute subarachnoid hemorrhage, ruptured aneurysm, comprehensive stroke center, endovascular treatment

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INTRODUCTION

Aneurysmal subarachnoid hemorrhage (aSAH) is one of the most urgent clinical conditions among neurologic diseases. It is an acute cerebrovascular event with direct consequences on brain tissue and numerous medical complications (1). Complex multiorgan pathophysiology of aSAH includes injury of the cardiovascular, respiratory and renal systems, which leads to various clinical manifestations and worsens the outcome. Therefore, aSAH medical care does not include only neurointerventional program, but also implies a multidisciplinary approach (2).

Analysis of aneurysm genesis is not the issue of this algorithm; however, considering the risk of hemorrhage and possible prevention of hemorrhage, as well as timely diagnosis and treatment of aSAH, the following should be emphasized:

a) aSAH occurs more often in persons with some genetic predisposition (history of previous SAH or aneurysms, or SAH in family history) or in some special syndromes like Ehlers-Danlos syndrome type IV or autosomal dominant polycystic kidney disease (1);

b) the condition occurs more often in women, persons with low body mass index (BMI), smokers, patients with hypertension, and those with increased consumption of alcohol and cocaine (1);

c) proven aneurysm of more than 5 mm in diameter has a higher risk of rupture, especially if associated with some of the above mentioned risk factors (1); and

d) aneurysms of anterior circulation rupture more often in patients younger than 55 years, and aneurysms of posterior circulation rupture more often in men (1).

The condition complexity demands multidisciplinary approach not only during diagnostic procedure, but especially considering therapeutic approaches when equal engagement of neurocritical care specialists (neurologists, neuroanesthesiologists, vascular neurosurgeons and interventional neuroradiologists) is required.

Fast and precise diagnostic workup and urgent treatment of the aneurysm, followed by timely prevention and management of the complications are critical points of care in patients with aSAH (2).

As it is still impossible to organize the best management at all levels of medical care, optimal approach to aSAH patients, according to the international guidelines, includes the following:

1. high quality network of prehospital and hospital emergency care of patients with aSAH;
2. well organized urgent transportation of patients with aSAH to high-volume centers; and
3. further treatment in high-volume centers which should be reachable within maximum of 6-8 hours from every part of the country.

According to definition, a "high-volume" center for aSAH should be a hospital with more than 60 treated aSAH patients *per* year (2). Recent data on the outcome of treatment in such centers report mortality reduced by about 20% and morbidity by about 30% compared with hospitals that treat less than 20 aSAH patients *per* year (2). Such results justify the costs of primary care in primary medical centers and transportation of the patient to a high-volume center. Transportation of the patient who has been appropriately cared for is considered less risky for outcome than to continue treating such a patient in a center without the possibility of multidisciplinary approach.

EPIDEMIOLOGY

The incidence of aSAH varies among different regions of the world, probably due to different genetic factors (1,2). On the other hand, the influence of the environment and life habits should be less important. According to the World Health Organization, differences in the annual incidence of aSAH vary by more than ten times in different parts of the world (1). In China, for example, the annual incidence is 2/100 000 inhabitants, while in Finland or Japan the incidence is 22.5/100 000. The average incidence in Europe is 10-12 patients *per* 100 000 inhabitants. Women have a 1.24-fold higher incidence recorded for men of the same age (1).

In spite of the modern diagnosis and treatment, aSAH is still an illness with a high mortality. In the first 5 months, it is up to 40% (1,3). Approximately 10%-15% of patients die before reaching the hospital. In hospitalized patients, mortality in the first week is up to 25% and nearly one-third of patients (and according to some statistical data, even up to 50%) have a permanent neurologic deficit of different grade. The mortality and morbidity rates do not depend on population differences in the incidence (1,3).

Epidemiological data for Croatia are not known completely. According to available data, in the last 5 years, the incidence of aSAH in Croatia is about 10 patients *per* 100 000 inhabitants, which means

that in Croatia we have about 450 patients *per* year. According to statistical data on prehospital mortality, 400 patients *per* year reach hospitals in Croatia. In our Referral Center for Intensive Neurology, also including Department of Neurosurgery, we treat 140-150 patients *per* year, which makes more than one-third of all Croatian patients with aSAH.

According to our data, 30-day mortality is 27% and morbidity 41%. In the group of patients with permanent neurologic disability, 68% of patients have minor neurologic deficit, 24% have mild neurologic deficit, and 8% have severe neurologic deficit and are entirely dependent. In the last 5 years, having introduced the multidisciplinary treatment approach, we have reduced mortality of our aSAH patients from 39% to 27% and morbidity from 47% to 41%.

This significant reduction of mortality is the result of the following:

1. lower number of re-ruptured aneurysms, which is due to systemic endovascular approach (having the possibility of treating patients even in poor condition in the acute phase of the illness);
2. shortening the time window from diagnosis of aSAH, diagnosis of aneurysm and treating the aneurysm. We treat most of the aneurysms within 12 hours of patient admission; one-third of the patients are treated within 24 hours, and just 15% of patients are treated after 24 hours of admission; and
3. modern neurocritical intensive care unit managing patients according to recent guidelines.

Decrease in morbidity is the result of neurocritical care treatment using multimodal neuromonitoring approach in the unit.

COMPREHENSIVE STROKE CENTERS

Comprehensive stroke centers (CSC) are highly specialized multidisciplinary hospital units having neurointensive care beds and equipment, as well as all facilities and organization of intensive care units (2,3).

CSC provides care for patients with severe strokes, patients with complications of any type of stroke that require further intervention, patients with intracerebral hemorrhage (of vascular origin), and patients requiring specific methods of treatment (endovascular treatment, neurosurgical care). Experts working in CSC are neurovascular (sub)specialists forming stroke team. Stroke team usually includes intensive neurologists, neuroanesthesiologists, interventional neuroradiologists, and vascular neurosurgeons. All members of the stroke team must be accessible 24 hours/7days, and if needed consultation of other specialists (like neuroinfectologist, cardiologist, ENT specialist, vascular surgeon or neuropathologist) must be ensured.

Furthermore, in CSC all neuroimaging (computerized tomography (CT), magnetic resonance (MR), digital subtraction angiography (DSA)) must be available 24 hours/7days. CSC must also fulfill the high-volume hospital criteria for all types of stroke (1,2,4).

In Referral Center for Intensive Neurology of the Croatian Ministry of Health, a CSC fulfilling the above-mentioned criteria has been formed. It is, for now, the only CSC in Croatia, which also fulfils the high-volume center criteria and has multidisciplinary approach for stroke patients. For now, this is the only center in Croatia with such references. Other university hospitals in Croatia are able to take care of patients with aSAH up to the level of adequate and complete diagnostic procedures (CT, CT angiography, DSA, MR, MR angiography), but cannot provide complete therapeutic approach (lacking endovascular methods, adequate (in technical and organizational terms) neurocritical care units) and do not have characteristics of a high-volume center.

These data are important considering our national diagnostic and therapeutic guidelines, and have to be considered while making decision about transporting patients for further diagnostic and especially therapeutic methods.

RECOMMENDATIONS

Basic facts

1. Aneurysmal subarachnoid hemorrhage is medical emergency that requires multidisciplinary (intensive neurologists, neuroanesthesiologists, interventional neuroradiologists and vascular neurosurgeons) approach during diagnostic procedure and especially during therapeutic procedure (1-3).
2. Special attention during diagnostic procedure should be paid to patients with a clinical picture of aSAH and additional risk factors for this illness (like personal or family medical history of

aSAH, patients with genetic risk factors, women, hypertensive patients, alcohol or cocaine abusers, patients with low BMI, patients with verified intracranial aneurysm) (1).

3. Primary care of a patient with aSAH should be organized, according to guidelines, in every medical center that is, after relevant diagnostic procedure, able to establish the diagnosis of SAH.

4. Final care of a patient with aSAH should be organized in a specialized high-volume (with more than 60 SAH patients *per* year) center, which has the possibility of multidisciplinary approach for 24 hours/7days (2-4).

5. The outcome of patients treated in CSC justifies the risks as well as the cost of transportation to CSC (2,4).

6. In spite of the established approach in the diagnosis and treatment of aSAH, mortality and morbidity are still high (mortality in hospitalized patients is up to 25% during the first 30 days and morbidity is up to 50% during 6-month follow up) (1-3).

7. Such a high mortality rate is due to re-rupture of the aneurysm as the first cause. The highest risk of re-rupture is during the first 24 hours after first rupture; aSAH is therefore an emergency requiring urgent diagnostic evaluation and urgent treatment (closing of the aneurysm) within the first 24 hours of illness, if possible (1,2).

8. High morbidity rate is the result of various neurologic and/or organic complications. The management of patients in Neurological Intensive Care Units and by multimodal neuromonitoring significantly reduces the mortality and morbidity (1,2).

Diagnostic algorithm in aSAH

1. More than 10% of aSAHs are misdiagnosed on initial exams. Every patient with sudden intensive headache must raise suspicion of SAH, especially if, beside headache, the patient had a sudden loss of consciousness, even without any other symptom, or focal neurologic deficit (1).

2. Every patient who has probable SAH must be referred to a medical facility with the possibility of appropriate diagnostic workup. Urgent diagnostic workup includes brain CT, and if CT is inconclusive, analysis of cerebrospinal fluid obtained by lumbar puncture (1).

3. Proven SAH requires urgent (within 24-hour time window, if possible) examination of intracranial blood vessels with one of the appropriate methods (CT angiography or DSA). If at least one of these methods is not available, the patient has to be transported to a hospital where diagnostic procedure can be completed and where appropriate treatment can be provided. Transportation has to be as urgent as possible, but after stabilization of the patient.

4. In perimesencephalic SAH, CT angiography can be sufficient for definitive diagnosis. However, even then, follow up angiography in delayed (between day 14 and day 28 after SAH) phase of the illness is recommended (at least repeated CT angiography, yet DSA is preferred) (1,2).

5. In diffuse SAH and/or SAH with initial loss of consciousness, even after a negative finding of CTA or DSA, a follow up angiographic (DSA) examination in delayed phase of the illness is recommended (1).

Primary management of the patient diagnosed with aSAH

1. Clinical assessment of a patient with aSAH is crucial for determination of further management. For clinical assessment, implementation of international scales is recommended. Such assessment enables precise presentation of clinical status of the patient, helps making decisions on therapy approach and can even help in final outcome prognosis. Considering the complexity of the illness, the best assessment is achieved by using a combination of three traditional scales: Hunt-Hess (HH) scale, Fisher's scale and Glasgow Coma Scale (GCS). Initial medical documentation of the patient must, beside other data, also include the above mentioned clinical assessment by using all three scales (5).

2. In patients with aSAH, clinical status should be assessed continuously, and obligatorily if changes in neurologic status are noticed, or after medicamentous therapy with influence on neurologic status. It should be presented in Hunt-Hess scale and GCS. The most recent available grade of Fisher's scale should be documented as well. These data are very often crucial for further management decisions for the patient (1,3,5).

3. If further diagnostic procedure (CTA or DSA) can (within 24 hours) be performed in the first-contact hospital, it is reasonable to do it. If it is

not possible, the patient should be transported to the hospital where it can be done. However, it is reasonable to transport the patient to the facility where both diagnostic and therapeutic measures can be done, in order to avoid additional transportation (3,6).

4. Therapeutic measurements of aSAH consist of excluding the aneurysm from the circulation by one of the possible methods (neurosurgical or endovascular treatment) during acute phase (up to 72 hours of the initial bleeding) of the illness. The patient should undergo necessary examinations before therapeutic procedure, and should be managed in the neurointensive care unit after the procedure. Postoperative care should be especially focused on the early detection of complications (1,2,6).

5. Patients who are estimated as first group according to the severity of their clinical state (HH I and II, Fisher 1, 2, 3 and GCS 11-15), are hemodynamically stable, require only analgesics and proper venous access during primary care. These patients are candidates for urgent (within the first 24 hours) treatment (neurosurgical or endovascular approach) in a hospital where it can be organized. If optimal treatment is not possible in the hospital of primary care, such a patient should be transported to the appropriate facility as soon as possible. During this time, continuous clinical assessment according to the guidelines, is obligatory (1-3,5).

6. Patients who are estimated as second group according to the severity of their clinical state (HH III, Fisher 2, 3 and GCS 8-10) are often hemodynamically unstable and require more extensive primary care. They are also candidates for urgent treatment, but in this group endovascular treatment is preferred. Extensive anesthesiologic care implies airway management (including intubation with rapid sedation induction if needed) as well as hemodynamic stabilization and antiedematous therapy (in patients with signs of raised intracranial pressure). In this group, continuous clinical assessment according to the guidelines is crucial. Unnecessary sedation should be avoided, as well as hyperventilation (pCO_2 should be about 30-35 mm Hg). Adequate analgesic measures are obligatory. These patients should be treated within the first 24 hours. If optimal treatment is not possible in the hospital of primary care, such a patient should be transported to the appropriate facility as soon as possible (1-3,5).

7. Patients who are estimated as third group according to the severity of their illness (HH IV and V, Fisher 2, 3, 4 and GCS 3-7) are clinically unstable patients and further therapeutic decisions are made individually. Patients in this group should be hemodynamically stabilized, which includes intubation and analgosedation. In this group, further clinical deterioration is highly probable. Most of them have signs of raised intracranial pressure and need antiedematous treatment. They must be managed in intensive care units, with the possibilities of continuous multimodal neuromonitoring and in hospitals that have continuous neurosurgical service. Also, in these patients continuous clinical assessment is often impossible due to therapeutic measures, and the first clinical assessment is critical for further therapeutic decisions (1-3,5).

8. Hemodynamically stable patients in the third group can also, in some cases, be candidates for urgent treatment if there was no deterioration in their clinical status within the first 8 hours. If so, these patients should only be treated endovascularly, which is important while choosing the hospital, if transportation from the initial facility is necessary.

9. Hemodynamically unstable patients, patients who have deteriorated within the first few hours after bleeding, or patients who are initially in group III without achieving stabilization, are not candidates for immediate treatment. They should be treated in the delayed phase of the illness. Until then, medical care should be provided in the nearest appropriate intensive care unit.

10. In patients who are candidates for urgent treatment, but for some reasons treatment is not possible within the first 24 hours, measures for preventing re-rupture are indicated. Such specific measures include analgesic therapy, mild analgosedation according to clinical indication, control of hemodynamic parameters, especially blood pressure (BP) (systolic BP should not be over 160 mm Hg to diminish the risk of re rupture, but still not too low to maintain cerebral perfusion; values should be about 150/90 +/- 10 mm Hg), and antifibrinolytic therapy (1,2).

Therapeutic approach in the hospital of ultimate management

1. Hospital of ultimate management should be able to:

a. offer at least one of the possible methods of treating aneurysms. Treatment should be available continuously (24h/7d);

b. offer continuous availability of diagnostic methods which are essential for treatment and appropriate follow up procedures;

c. offer appropriate intensive care unit, with optimal equipment and experts in neurovascular field, and with at least minimal level of essential multimodal neuromonitoring; and

d. offer multidisciplinary approach for individual assessment of optimal method for each patient with aSAH (1-3).

2. In hospitals where both methods of treatment are available, endovascular treatment can have some advantages compared with neurosurgical method (1). Endovascular method is also the first choice treatment in patients with worse clinical status, patients with aneurysms that are morphologically not acceptable for neurosurgery, and for aneurysms that are located in posterior circulation (1).

3. Neurosurgical treatment is preferred in patients with large intracerebral hematomas (>50 mL), patients with middle cerebral artery aneurysm, or patients with aneurysms that are morphologically not acceptable for endovascular approach (1).

4. Treatment options should be assessed by multidisciplinary stroke team in high-volume centers. In hospitals without stroke team, assessment should be made by a neurologist and neurosurgeon according to the guidelines. For patients in which, due to some specific clinical conditions, actual guidelines are not applicable, transportation to the hospital with multidisciplinary stroke team, or to the CSC is advisable (4).

5. No matter which therapeutic approach is chosen, after treating the aneurysm, follow up diagnostic procedure should be performed by one of the angiographic methods in order to estimate the efficacy of the treatment. If aneurysmal growth, recanalization or some residual flow is observed, it is necessary to repeat the treatment and to exclude the aneurysm from the circulation entirely (1).

6. In the hospital where patients with aSAH are definitely managed (CSC), patients should be treated in intensive care units (ICU), preferably in neurointensive care units (NICU). In such units, an adequate level of neurointensive care is established with experts in neurocritical care field, which are organized by continuous principle (24 hours/7 days/year) and which have minimal necessary level of multimodal continuous neuromonitoring (2,4,7).

Special features of monitoring of patients before and after endovascular treatment of intracranial ruptured aneurysm

1. Diagnostic algorithm for these groups of patients is not significantly different from the usual diagnostic workup of patients with aSAH. In patients in whom initial treatment refers to the posterior circulation aneurysms or patients who due to the previously mentioned reasons are primary candidates for endovascular treatment, the preferred noninvasive diagnostics is MSCT angiography, since DSA has to be done anyway in the first phase of endovascular procedure.

2. Special workup of the patients before endovascular approach includes the usual laboratory tests (complete hematology, biochemistry, blood type, including PT, APTT, fibrinogen), x-ray of the heart and lungs, 12-lead ECG, and preoperative examination by neuroanesthesiologist. Before the procedure, the patient must be hemodynamically stable, with corrected metabolic and electrolyte parameters, if necessary analgosedated with correctly managed airway (6,8).

3. The most common form of complication of endovascular approach is thrombosis of the treated vessel and consecutive ischemic damage to the brain parenchyma. The prevention and treatment of thrombotic complications are therefore antithrombotics (9).

4. Monitoring of clinical status in patients who, before surgery, were in the first group: waking up after anesthesia should occur no later than within 60 minutes of the operation, after which further sedation/mechanical ventilation is usually not necessary. Measures of adequate analgesia with hemodynamic monitoring, especially blood pressure monitoring should be applied (continuous noninvasive or manual measurement every 15 minutes in the first 2 hours, then every half an hour in the next 4 hours, then every hour for the next 12 hours, then every 2 hours up to 24 hours. Invasive blood pressure measurement is indicated only for patients with highly unstable and variable pressures. Blood pressure should be maintained within the values of 140-160/80-95 mm Hg). Clinical neurological assessment

should be performed every hour for the first 6 hours after surgery, then every 6 hours until 48 hours after the procedure. If clinical follow up reveals neurologic deterioration within the first 24 hours, urgent neuroradiological diagnostic workup should be done.

5. Monitoring of clinical status in patients who, before surgery, were in the second group: waking up after anesthesia should occur no later than within 60 minutes after the procedure, however, the need of prolonged intubation and mechanical ventilation is individually assessed. Excessive sedation should be avoided because of the impossibility of appropriate monitoring of neurologic status, which is the basic parameter to estimate the possible complications or worsening of the patient's condition. Analgesia is allowed and required. Other hemodynamic monitoring and neurological follow up workup is carried out as in the first group.

6. Monitoring of clinical status in patients who, before surgery, were in the third group: analgosedation is continued, as well as continuous hemodynamic monitoring for a minimum of 48 hours, after which cessation of sedation should be assessed individually. No later than 24 hours after the procedure, and in case of noticed oscillations in hemodynamic parameters despite controlled conditions, neuroradiological diagnostic workup should be implemented.

7. Monitoring of complete laboratory tests is carried out after 24 hours of the operation. Monitoring of electrolytes and essential metabolic parameters is performed 4-6 hours after the procedure, or if there is any suspicion of the development of complications (prolonged awakening, changes in neurologic status, changes in heart rate, oxygen saturation, respiration, or vegetative instability) immediately, and then according to clinical indication. APTT should be controlled immediately after the procedure and then for 4-6 hours, and if necessary, repeated according to clinical indication.

8. Neurological assessment is performed normally 24-48 hours after surgery in patients with no signs of complications. It is recommended to do MSCT of the brain, which gives enough information about the intracranial status in these patients. Earlier CT (within the first 24 hours) is generally not indicated, due to the high probability of contrast artifacts occurrence.

9. If procedural complications occur within the first 24 hours after the procedure regardless of whether they are verified by clinical examination, hemodynamic monitoring (extreme fluctuations in blood pressure, respiratory failure or arrest, electrocardiographic disorders, vegetative dysfunction), or specific neurological monitoring (TCD, EEG, ICP), urgent MRI, MRA should be performed. Sometimes it may be necessary to perform control DSA and additional endovascular or neurosurgical intervention as well. In patients with a high risk of thrombotic incidents, or already observed thrombotic complications during the procedure, DSA should be performed after the first 24 hours. If necessary, additional endovascular treatment should follow. In patients with prolonged awakening (more than 2 hours after the procedure despite adequate hydration and perfusion), even if there are no other listed signs of deterioration, and if the cause of this condition cannot be connected with the applied therapy or significant disturbance of laboratory parameters, urgent follow up workup is indicated. Preferably, it should be MRI.

Further follow up of patients with aSAH and workup of aSAH complications

1. Patients with acute subarachnoid hemorrhage regardless of the severity of their illness and their current clinical status must finally be managed in the ICU, where the minimum of multimodal neuromonitoring is enabled (2,7).

2. Hemodynamic monitoring and basic laboratory parameters should be performed even during primary management of the patient. In the hospital where patients are ultimately managed, patients with aSAH must be put on invasive monitoring by clinical indication, not routinely. Central venous catheter inserted solely for the purpose of routine measurement of central venous pressure, routine measurement of intracranial pressure, pulmonary artery catheters or invasive measurement of blood pressure are not justified in this group of patients. Therapeutic measures in primary care settings include adequate rehydration (it is recommended to maintain euvolemia, preferably with isotonic crystalloid solutions, and to measure input/output of fluids), control and correction of laboratory parameters, control and correction of blood pressure, nimodipine (Nimotop) at a dose of 60 mg every 4 hours, or 5-10 mL/h/24h IV (2,7).

a) The extent and frequency of continuous monitoring in the first two weeks of disease depend on the clinical stage of the disease:

A) Patients classified in group I (HH I and II):

a) continuous neurologic monitoring (monitoring of neurologic status)
b) traditional measures of continuous hemodynamic monitoring
c) TCD monitoring of vasospasm (daily from the third to the twelfth day, and by clinical indication)
d) CT of the brain – not later than 24 hours after the procedure, later according to indication or at least once in 7 days
e) laboratory diagnosis – at patient admission, all routine laboratory parameters, further monitoring requires basic laboratory parameters (bedside device) on daily basis during the first 14 days, or follow up of abnormal laboratory values according to indication
f) MRI/DSA according to indication
g) continuous EEG according to indication, or if epileptic seizures are observed at any stage of the disease, for at least 48 hours after the seizure

B) Patients classified in group II (HH III or higher stage of Fisher scale)

a) continuous neurologic monitoring (monitoring of neurologic status)
b) traditional measures of continuous hemodynamic monitoring
c) TCD monitoring of vasospasm (daily until the condition stabilizes)
d) CT of the brain – not later than 24 hours after the procedure, later according to indication, at least once every 72 hours during the first 10 days of illness
e) laboratory diagnosis tic – at patient admission, all routine laboratory parameters, further monitoring requires basic laboratory parameters (bedside device) on daily basis during the first 14 days, or follow up of abnormal laboratory values according to indication
f) invasive methods of continuous monitoring according to indication
g) continuous EEG monitoring during the first ten days of illness
h) MRI/DSA according to indication

C) Patients classified in group III (HH IV, V HH)

a) continuous neurologic monitoring (monitoring of neurologic status) – in this group of patients less reliable
b) traditional measures of continuous hemodynamic monitoring
c) TCD monitoring of vasospasm (daily until the condition stabilizes)
d) CT of the brain – not later than 24 hours after the procedure, later according to indication, at least once every 72 hours during the first 10 days of illness
e) laboratory diagnosis – at patient admission, all routine laboratory parameters, further monitoring requires basic laboratory parameters (bedside device) on daily basis during the first 14 days, or follow up of abnormal laboratory values according to indication
f) continuous EEG monitoring during the first ten days of illness or until patient stabilizes
g) invasive methods of multimodal neuromonitoring
h) measuring brain metabolic parameters according to indication
i) MRI/DSA according to indication

3. The most important complications of aSAH are re-rupture of the aneurysm, vasospasm, hydrocephalus, electrolyte disbalance, epileptic seizures, and cardiopulmonary complications (2).

4. Re-rupture occurs more frequently in patients with severe neurologic deficits, initial loss of consciousness, "sentinel" headache, larger aneurysms, and higher or unstable blood pressure (systolic blood pressure higher than 160 mm Hg). The most effective prevention of re-rupture is early treatment of the aneurysm. If the treatment is, for some reason, delayed, it is necessary to provide emergency care for patients in ideal hemodynamic conditions and using continuous monitoring. Application of antifibrinolytic therapy (aminocaproic acid) during a maximum of 72 hours is recommended in the group of patients with a high risk of re-rupture. It is very important to maintain hemodynamic stability and stabilization of blood pressure from the recommended upper limit of up to 160/90 mm Hg. Also, during this period prevention of deep venous thrombosis is recommended, but solely by mechanical methods, or using elastic stockings (2-4).

5. Vasospasm usually develops on the third day after initial bleeding and is mostly pronounced between day 7 and day 10 after aSAH. Later it gradually regresses, and usually completely disappears after day 21 of the disease. The most se-

rious consequence of vasospasm is the development of delayed neurologic deficits due to ischemic lesions of the brain. Diagnosis of vasospasm is based on the assessment of the clinical picture, permanent monitoring of cerebral perfusion parameters (measurement of intracranial pressure or monitoring of vasospasm by transcranial ultrasound), and on neuroimaging methods (MSCT perfusion, MSCT angiography, DSA).

Treatment of vasospasm includes:

a) nimodipine

b) triple-H treatment

c) intra-arterial medical vasodilatation

d) balloon-angioplasty

e) statins (1,2).

6. Acute hydrocephalus develops in 15%-85% of patients with aSAH, and approximately half of these patients require continuous drainage. It is significantly more common in patients with intraventricular hemorrhage or rupture of the aneurysm of the posterior circulation. In both groups, more intensive monitoring of intracranial pressure or the volume of ventricles by neuroimaging methods is necessary. If hydrocephalus develops, external ventricular drainage should be a treatment option (1,2).

7. The most common form of electrolyte imbalance in acute aSAH is impairment of serum sodium concentration. When it drops to values lower than 135 mmol/L, correction or substitution therapy should be applied.
   Hypomagnesemia is also common in aSAH. Magnesium substitution therapy should be given, however, hypermagnesemia is not justified. In hypothalamic dysfunction, the administration of minerals or corticosteroids is required (1,2,7).

8. Epileptic seizures occur in approximately one-quarter of patients with SAH. Preventive use of antiepileptic therapy is not indicated. Patients who are at a higher risk of developing epilepsy are patients with middle cerebral artery aneurysm, intracerebral hematoma, re-rupture, patients after surgically treated aneurysms, patients with a greater amount of blood in the subarachnoid space, patients who developed ischemia, patients with poor initial neurologic status and with a history of hypertension. In all patients with aSAH and especially in patients who are at an increased risk, continuous EEG monitoring for at least first 72 hours from the onset of aSAH is required (1,2,7).

9. About 35% of patients present with elevated troponin levels and cardiac arrhythmias. Pulmonary edema is the cause of death in about 12% of patients with aSAH, while pulmonary complications in general (usually cardiogenic or neurogenic edema or acute respiratory distress syndrome) are found in nearly 20% of patients. Because of this, continuous monitoring is essential, while treatment of these complications does not differ from common treatment of such illnesses.

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