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Review Article

Recommended Algorithms for Surgical Treatment of Non-Traumatic Intracerebral Haematoma

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Abstract

The review includes the classification of non-traumatic cerebral haematomas (NTCH) by localization. For each specific localization of NTCH there are recommended optimal methods of their surgical treatment, which have suggestive nature. In all localization of NTCH and intraventricular haemorrhage the principle of minimal invasive neurosurgery dominates. The frequency of decompressive operations is increasing. In cases of destruction of internal capsule and brainstem structures the improvement of functional outcome is gained by early application of antioxidants.

Keywords: *Non-Traumatic Cerebral Haematomas (NTCH); Intraventricular Haemorrhage; Minimal Invasive Neurosurgery*

Introduction

The share of non-traumatic intracerebral hematomas (NTIH) accounts for 10 - 30% of all strokes. They are characterized by a high mortality rate, which reaches 50% during the first 24 hours. Only 20% of patients have a good functional outcome within 6 months [1,2]. To improve the results of treatment of this complex clinical pathology, the American Stroke and Heart Association has published 4 guidelines [3-6], which formulate general principles of management of patients with NTIH based on evidence-based medicine.

In 2005, the results of an international randomized study were published on early surgical (group 1) and conservative (group 2) treatment of patients with NTIH. The study included 1,033 patients from 27 countries and 83 vascular neurosurgery centers. A large number of clinical factors were statistically processed: age, score on the Glasgow coma scale (GCS) before surgery, detailed neurological symptoms upon admission, volume of NTIH, etc. The frequency of a favorable outcome in the group 1 was 26%, in the group 2 - 24%, mortality - 36 and 37%, respectively. According to the results of statistical analysis, the superiority of early surgical treatment over conservative treatment has not been established [7]. Given this authoritative study of surgical techniques for NTIH evacuation, the findings can be largely advisory.

The purpose of the literature review is to highlight the most optimal surgical techniques and their combinations for NTIH of a certain localization.

Classification of non-traumatic intracerebral hematomas by localization [5,6,8-10]:

1. Lobar (superficial), located in the white matter of one of the lobes.
2. Lateral, covering the subcortical nuclei (more often the shell), lateral to the inner capsule.
3. Mixed, covering the subcortical nuclei lateral to the inner capsule, the capsule itself and the thalamus.
4. Medial, located in the thalamus.
5. Brain stem (most often covering the Pons Varoli).
6. Cerebellar.
7. Intraventricular.

Lobar (superficial) non-traumatic intracerebral hematomas

This localization includes NTIHs, which are located in the white matter of the hemispheres and can capture the cerebral cortex. In most cases, the volume of lobar NTIHs ranges from 30 to 70 cm^3 (on average, 47 - 48 cm^3). NTIHs of lobar localization do not directly damage the internal capsule, which favorably affects the functional outcome of the disease [3,9,11-14].

In elderly patients, amyloid angiopathy is relatively often the etiological source of lobar NTIH. At a younger age (< 55 years) in non-smoking patients without arterial hypertension and coagulopathy, the following should be excluded: arteriovenous malformations (AVMs), tumors, moya-moya disease, thrombosis of cerebral fistulas and rupture of dural fistulas. For this purpose, a complex of neuroradiological research is used: magnetic resonance imaging (MRI), angiography (AG), computer (CT)-AG and digital AG [6,15-20].

Indications for surgical treatment of lobar NTIHs have been studied by many researchers. In their opinion, the boundary volume for this localization of hemorrhages is 30 cm^3 or more. This value may be less if the level of consciousness is below 9 points on the GCS and/or there is a significant dislocation syndrome. With a volume of lobar NTIH of more than 50 cm^3, the results of surgical treatment are much better than those when using the conservative method [3-5,9,13,14,21,22].

Three variants of the operating technique can be used: a) craniotomy with encephalotomy and microsurgical evacuation of NTIH at a minimum distance from the cerebral cortex to the hemorrhage, taking functionally significant areas into account; b) frameless neuronavigational puncture of NTIH with local fibrinolysis and subsequent aspiration; c) stereotactically-oriented endoscopic evacuation of NTIH [4,5,6,8,14,21-23].

It should be borne in mind that the frameless-navigation puncture of NTIH with local fibrinolysis involves a process of several cycles (every one lasting for 6-8-12 hours, depending on the drug), the introduction of a fibrinolytic into the cavity of the NTIH for 24-48 hours, which somewhat limits the use of the method in comatose patients with significant dislocation syndrome [6,12,24].

When choosing an operating technique, it should be borne in mind that open-access microsurgical evacuation has the following advantages: a complete view of the operating field, rapid evacuation of NTIH, elimination of dislocation and intracranial hypertension. However, the method is more traumatic in comparison with neuronavigation fibrinolysis and endoscopic evacuation of lobar NTIHs [6,14,21,25].

Most often, direct access is used for microsurgical evacuation of lobar NTIH, the technique of which includes the following main stages: CT-adapted localization or neuronavigation of craniotomy coordinates; craniotomy with a craniotome or crown cutter (about 35 mm in diameter); cruciform opening of the dura mater; puncture of NTIH with cannula and aspiration of liquid contents; formation of an surgical passage with a diameter of about 15 mm around the cannula; evacuation of the remaining NTIH; hemostasis (bipolar coagulation, wadding with hydrogen peroxide); thrombin-control solution, lining with surgical, etc.; drainage (related to observation) and completion of the operation. The use of intraoperative sonography improves the quality of the operation. In cases where the lobar NTIH is localized in functionally significant areas, MRI tractography may be useful [14,21,26,27].

In case of lobar localization of NTIH in the area of the Sylvian fissure after exclusion of the aneurysm, the hemorrhage can be successfully removed using pterional craniotomy and trans-Sylvian or paratrans-Sylvian access [14,28].

Comatose patients with significant dislocation syndrome and brainstem insertion were provided with a complex of unloading surgical techniques (see Unloading operations).

Postoperative mortality during microsurgical evacuation of lobar NTIH is 18 - 29% and depends on a number of clinical factors: the level of consciousness before surgery, the volume of NTIH, the degree of dislocation syndrome, the presence of blood breakthrough into the ventricular system, etc. A favorable functional outcome is observed in about 50% of operated patients [5,12-14,21,26].

Thus, effective surgical treatment of lobar NTIHs is achieved using direct microsurgical evacuation, neuro-navigation puncture with local fibrinolysis, and endoscopic evacuation of hemorrhage. The use of modern technical capabilities for microsurgical evacuation makes it possible to approach the principles of minimally invasive neurosurgery.

Lateral non-traumatic intracerebral hematomas

The lateral localization of LMWH includes putaminal-pallidal, putaminal-capsular, lenticulo-capsular, paralenticular and striocapsular hemorrhages. Lateral NTIHs belong to deep hemorrhages. Most often, the volume of lateral NTIH is from 20 to 60 cm^3 (on average, more than 40 cm^3). The extent of the spread of the NTIH zone to the inner capsule predetermines the functional outcome of the disease, regardless of the volume of hemorrhage [9,12-14,29].

The volume of lateral NTIHs over 30 cm^3 should be considered an indication for surgical treatment. These indications are enhanced by: a significant breakthrough of blood into the ventricular system (see Intraventricular hemorrhages), depression of the consciousness level and a significant dislocation syndrome [3,9,12-14,21,30].

In the case of lateral NTIH, the distance from the surface of the cerebral cortex to the adjacent sections of hemorrhage significantly exceeds 1 cm. In this regard, direct microsurgical evacuation of hemorrhage is technically feasible, but it leads to additional trauma to functionally significant brain structures, which enhances perihemorrhagic edema and the degree of dislocation syndrome, even with the operation performed qualitatively. In this regard, the indicators of postoperative mortality increase almost 2 times compared to stereotactic evacuation (mechanical destruction of blood clots by the Archimedean spiral), neuronavigation puncture of NTIH with local fibrinolysis and stereotactically oriented endoscopic evacuation of NTIH of lateral localization [3,6,9,13,14,21,25,30].

In a number of observations, especially in clinically decompensated patients, after evacuation of hemorrhage by any of the above methods, it is not possible to reduce the dislocation syndrome to the required extent. In such a situation, it is possible to successfully apply an extensive decompressive craniectomy with preservation of the bone graft until the symptoms of cerebral edema are reduced, followed by reimplantation (see Unloading operations) [6,31,32].

Postoperative mortality with direct neurosurgical access to lateral NTIH is more than 50%. At the same time, when using minimally invasive techniques (stereotactic evacuation, neuronavigation puncture with local fibrinolysis and neuroendoscopic evacuation), the lethality is much lower - 22 - 24% [9,13,30].

Thus, the use of direct microsurgical access to lateral NTIH is not recommended due to the high postoperative mortality. Preference should be given to the minimally invasive technique, which, if necessary, can be supplemented with decompressive craniectomy (see Unloading operations).

Mixed non-traumatic intracerebral hematomas

Mixed localization includes putaminal-capsular-thalamic, lenticulo-capsular-thalamic and thalamic-capsular-lenticular hemorrhages. Mixed NTIHs belong to deep hemorrhages. In the majority of observations, the volume of mixed NTIHs is 35 to 70 cm^3 (on average, about 45 cm^3). Mixed NTIHs directly destroy the structure of the inner capsule, which worsens the results of the functional outcome of the disease [9,12-14].

Surgical treatment of mixed NTIHs is indicated for volumes exceeding 30 cm^3. An exception may be observations with a smaller volume of hemorrhage with depression of consciousness below 9 points on the GCS and significant dislocation syndrome, as well as with a significant blood breakthrough into the ventricular system [9,12,13].

In case of mixed localization, the surgical passage during direct microsurgical evacuation (by analogy with lateral NTIHs) also significantly exceeds 1 cm, therefore, it causes additional trauma to functionally significant brain structures and significantly increases postoperative mortality. Therefore, in case of mixed localization, minimally invasive techniques are used: stereotactic evacuation of NTIH, neuronavigation puncture of NTIH and local fibrinolysis, neuroendoscopic evacuation of NTIH, if necessary, supplemented with an extensive decompressive craniotomy with preservation of the bone graft for reimplantation [9,12,13,24,30,32].

Destruction of the structures of the inner capsule in cases of mixed NTIH has a negative effect on the results of treatment, however, early addition of a wide range of antioxidant agents to therapy increases the degree of functional outcome [33-35].

Postoperative mortality in cases of mixed NTIH is about 25% with minimally invasive techniques and over 50% with open microsurgical evacuation of hemorrhages [9,12-14,30].

Thus, mixed NTIHs destroy the structures of the inner capsule, which reduces the probability of a favorable functional outcome. In the surgery of NTIH of this localization, preference is given to the minimally invasive technique, which, if necessary, can be supplemented with decompressive craniotomy. The early addition of antioxidants to complex therapy increases the degree of functional outcome.

Medial non-traumatic intracerebral hematomas

Medial NTIHs mainly cover the thalamus with extension to adjacent structures (more often to the capsule, as well as to the brain stem) and are characterized by a breakthrough of blood into the ventricular system. The volume of medial NTIHs varies from 1 to 40 cm^3 (on average, 13 - 14 cm^3). In case of thalamic-capsular-stem NTIH the volume is 28 - 40 cm^3 [9,12-14,30,34,35].

The neurological picture of NTIH is characterized by impaired consciousness (from 15 to 3 points on the GCS), impaired sensitivity (including paresthesias) and reduced motor skills, neuro-ophthalmic symptoms and signs (impaired response to light, dilated pupils, nystagmus, Parino syndrome, etc.), impaired cognitive functions, autonomic disorders and thalamic pain syndrome [12,35-38].

The indications for surgical treatment of NTIH of the thalamus are currently not completely defined, but the authors proposed successful volumes of hemorrhages and the corresponding optimal type of their treatment, as well as the prognosis. Thus, the volume of the NTIH of the thalamus 20 cm^3 is a conditionally critical value for a favorable or unfavorable outcome. Conservative therapy is indicated for patients with NTIH volume less than 10 cm^3. With a volume of 10 - 20 cm^3 in combination with depression of consciousness to obtundation and expressed neurological symptoms, surgical treatment is possible. If the volume of NTIH exceeds 20 cm^3, then surgical treatment is performed for saving the patient's life [6,12-14,34,39,40].

The arsenal of methods for surgical treatment of NTIH of the thalamus includes: external ventricular drainage (EVD) as an independent operation, puncture aspiration of NTIH with subsequent fibrinolysis, stereotactic evacuation of NTIH (using mechanical destruction of blood clots with an Archimedean spiral), endoscopic evacuation of NTIH and combination of EVD with puncture aspiration and local fibrinolysis. Direct microsurgical evacuation is not recommended [6,9,10,12-14,30,34,39,41].

This pathology is accompanied by a quite high unadjusted mortality rate, which, according to various authors, is 30-70%. Mortality is especially high in the case of NTIH of the thalamus with extension to the stem structures [9,12-14,30,34].

Thus, medial NTIHs are a severe clinical form of intracerebral hemorrhage with high mortality rate. Methods of minimally invasive neurosurgery in combination with EVD prevail.

Brain stem non-traumatic intracerebral hematomas

The most common localization of the NTIH of the stem is the pons, much less often - the mesencephalon and myelencephalon. Two clinical variants of the course of this disease are revealed: stroke-like and pseudotumorous. Most commonly, the volume of the stem NTIH is 1 - 5 cm^3 [42-45].

Before the operation, it is recommended to conduct a thorough neuroradiological diagnosis (CT, MRI, digital vertebral angiography) to detect or exclude vascular anomalies (cavernous angioma, telangiectasia, AVM, etc). This is of particular clinical importance in young patients without arterial hypertension [44-49].

Indications for direct microsurgical evacuation are determined after evaluating the first results of conservative treatment (including antioxidants) and EVD, which in some patients causes a significant clinical improvement [6,14,34,42,46,48,49].

The authors presented the borderline values of the volumes (3 - 5 ml) of the NTIH of the stem, the exceedance of which may serve as an argument in favor of microsurgical evacuation of hemorrhage [44,45,48].

The localization of the NTIH of the pons part of the stem determines the choice of the operative access. When it is localized in the dorsolateral part of the pons, the preference is given to the retrosigmoid (paramedian) approach. With this approach, the lateral surface of the pons is visualized, which has a yellow color due to imbibition by hemosiderin, as well as local edema. In case of a median or bilateral location of the NTIH of the pons, a median approach is used, during which the bottom of the IV ventricle is revised. A zone of discoloration in the area of the upper triangle is determined, as well as a cupular eminence. In individual observations, infratemporal approach is used. With all approaches, the liquid part of the NTIH is removed first, then the cavity walls are revised [42,44,46,47,50].

Theoretically, stereotactic aspiration of hemorrhage, which has been successfully performed in individual cases, is the ideal method for removing NTIH from the stem of hypertensive genesis. In this case, the trajectory of a puncture cannula with a diameter of 1.5 mm passed through the structures of the mesencephalon and the pons [43]. To perform this technique, one should have extensive experience in stereotactic neurosurgery, yet the probability of complications remains high enough.

In acute and hyperacute clinical course, when a comatose condition quickly sets in, the overall and postoperative mortality of the NTIH of the stem is high (65%). The results in the hypertensive genesis of the NTIH of the stem are worse. In the subacute and chronic course of the disease, the results are much better - postoperative mortality is on average about 15% [14,45,46].

The following are considered unfavorable prognostic criteria for the NTIH of the stem: comatose condition, localization of the NTIH over the entire diameter of the stem, including the mesencephalon and thalamus, the transverse diameter of the hemorrhage more than 20 mm or 25% of the cross section of the pons, fixed position of the eyeballs, lack of response to light and corneal reflexes, breakthrough of blood into the ventricular system, acute obstructive hydrocephaly syndrome, arterial hypertension, tachycardia, absence of spontaneous breathing, decerebrate rigidity [14].

Thus, NTIH of the stem is a severe clinical pathology with high mortality. The treatment process begins with conservative therapy, including antioxidants. If necessary, EVD is performed. In parallel, a neuroradiological examination is performed - to identify or exclude vascular defects. The decision on microsurgical evacuation of hemorrhage is made taking into account prognostic criteria. In case of vascular defects and NTIH of the stem, the condition is, as a rule, compensated, therefore, the operation is recommended to be performed in the subacute and chronic stage of the disease.

Cerebellar non-traumatic intracerebral hematomas

According to JR Little., *et al*. [40], patients with large cerebellar NTIH (more than 3 cm), acute occlusive hydrocephaly (AOH) should be operated, while conservative treatment is indicated for other patients with small hemorrhages (up to 3 cm) and no hydrocephaly syndrome. According to E Donauer., *et al*. conservative treatment is indicated for patients of the group one (a small volume of cerebellar NTIH without AHO and compression of the brain stem), external ventricular drainage with monitoring of intracranial pressure (ICP) - for patients in the group two (more than 7 points on the GCS, with AHO, but without compression of the brain stem), external ventricular drainage with ICP monitoring - for patients in the group three (large cerebellar NTIH, compression of the brainstem), the second stage - open evacuation of the cerebellar NTIH. If intracranial damage is supplemented by risk factors (diabetes mellitus, cirrhosis of the liver, etc.), then only external ventricular drainage is performed with ICP monitoring, in patients of the group four (AVM with hemorrhage) - open evacuation of cerebellar NTIH on a scheduled basis.

External drainage of the cerebral ventricles as an independent operation is indicated for patients with a relatively small volume of cerebellar NTIH, manifested by blood breakthrough into the IV ventricle and AHO syndrome [14]. In some patients, after external ventricular drainage without evacuation of hemorrhage, on the basis of the ICP gradient between the supra- and intratentorial space, cerebellar-tentorial dislocation is possible, followed by herniation, therefore, the intervention cannot be independent when the brain stem is compressed and the level of consciousness is significantly reduced. In such patients, external drainage of the cerebral ventricles is used in combination with the evacuation of the cerebellar NTIH [14]. To reduce the ICP gradient, a slight excretion of cerebrospinal fluid is recommended before opening the posterior cranial fossa (PCF). The combination of external ventricular drainage with intraventricular fibrinolysis reduces mortality and improves functional outcome. A higher efficiency of urokinase in comparison with plasminogen has been established [33].

The main complication of external ventricular drainage is bacterial meningitis. The main conditions for the prevention of this complication: exclusion of liquorrhea from the surgical wound, permanent circularity of the drainage system, a long subcutaneous passage [14].

In general, mortality after external drainage of the cerebral ventricles as an independent operation in cerebellar NTIH is low [14].

Of all types of surgical treatment of cerebellar NTIH, the most commonly used are craniectomy of the PCF and open evacuation of hemorrhage [14].

Indications for microsurgical (open) evacuation of cerebellar NTIH are: a) by clinical type - hyperacute and acute course of the disease; b) a decrease in the level of consciousness to 13 points or less (according to the GCS); c) the volume of the hematoma is 14 cm^3 or more, or its diameter is more than 3 cm; d) transverse and/or axial dislocation of the brain stem [14,35,45]. Many researchers suggest combining microsurgical evacuation of the cerebellar NTIH with external drainage of the cerebral ventricles, especially when AHO syndrome accompanies the breakthrough of blood into the ventricular system (BBVS) [14,44,48].

For microsurgical evacuation of the cerebellar NTIH, suboccipital-paramedian and suboccipital-median approaches are used. The latter approach for additional unloading can be combined with resection of the arch of the 1st cervical vertebra, when the cerebellum herniation into the dura at foramen magnum is observed. Most authors prefer craniectomy of the PCF, which also provides unloading, but there are also advocates of craniotomy. Three positions of the patient on the operating table are used to create approaches to the cerebellar NTIH: lying on the side, sitting with the forward flexion of head, and lying on the stomach with ventral neck flexion [14,24, 50].

The main provisions of the technique of removing the cerebellar NTIH have not changed since the time of A. Torkildsen (1937): opening the dura mater using the generally accepted technique; puncture of hemorrhage and aspiration of contents (target verification); corticotomy and creation of a surgical passage around the cannula to the adjacent sections of the cerebellar NTIH; evacuation of hemorrhage. In modern conditions, the operation is facilitated: the use of microsurgical techniques, fixation of the head using a Mayfield device, the use of local hemostatic agents - SurgicelA®, thrombin or fibrinogen solution, etc., the possibility of duroplasty (durotech), etc. [14].

Postoperative mortality after microsurgical evacuation of the cerebellar NTIH is from 18 to 64%, on average - 25% [14,45]. This indicator directly depends on the degree of clinical decompensation of the patient's condition before surgery, as well as on the presence of risk factors (diabetes mellitus, arterial hypertension, blood diseases, liver dysfunctions, etc.) [49].

Operations using stereotactic technique are indicated for patients who are awake with subcompensated clinical course [34].

The results of stereotactic evacuation of cerebellar NTIH in patients (9 - 11 points according to GCS) are presented in the works of A Etou., *et al*. [34]. The transcerebral approach path was applied using Riechert-Mundinger apparatus. The hemorrhage was aspirated, then a silicone catheter was implanted into the hemorrhage and fibrinolysis was performed using urokinase. One patient died of thromboembolia of the pulmonary artery.

V Smrcka., *et al*. [35] presented an experience of stereotactic evacuation of cerebellar NTIH in 6 patients (more than 10 GCS points) using a transtentorial approach trajectory using the Riechert-Mundinger apparatus. Hemorrhage was removed by vacuum under constant ICP monitoring. In all cases, a decrease in the volume of hemorrhage was accompanied by a significant decrease in ICP.

The stereotactic technique for aspiration of cerebellar NTIH is described in J Kim., *et al* [43]. The Leksell apparatus used a suboccipital-lateral approach and a transcerebellar trajectory. The position of the patient is lying on his back with a head turn by 30 - 40° in the opposite direction. Cerebellar NTIH aspiration was combined with local fibrinolysis and urokinase use. In 6 of 19 patients, stereotactic technique was supplemented with external drainage of the cerebral ventricles. A stereotactically oriented endoscopic technique is also used to remove the cerebellar NTIH or endoscopic hemorrhage evacuation using frameless neuronavigation [14].

Many studies emphasize the minimal invasiveness of the method and the rather wide possibilities of its use: aspiration of the cerebellar NTIH, implantation of a silicone catheter followed by local fibrinolysis [45].

This low-traumatic method of surgical treatment of cerebellar NTIH is indicated for elderly patients with a subacute clinical course of the disease, a relatively compensated state, without pronounced compression of the brain stem and a low level of consciousness [14,24]. The authors draw attention to the speed (30 - 40 minutes) of the operation under combined (local and intravenous) anesthesia [12].

The operation provides for the installation of a catheter in the cerebellar NTIH cavity, the use of frameless neuronavigation and the stereotactic apparatus of E.I. Kandel. A small incision of the skin and subcutaneous tissue is performed, the occipital bone is skeletonized, a burr hole is created, the dura mater of the brain is dissected, the hemorrhage is punctured and the liquid fraction is aspirated, the catheter is exteriorized through the counter incision and fixed, 50,000 - 100,000 IU of prourokinase is injected and the lysed part is aspirated through every 6 h. CT control is performed every 12 - 24 hours [14]. The frameless navigation system can be replaced by stereotactic ultrasound scanning and a mechanical navigator for puncture of the cerebellar NTIH [12].

Postoperative mortality in local fibrinolysis of cerebellar NTIH is 14 to 17% [12,14].

NTIH of the cerebellum is an acute, clinically severe disease characterized by high mortality rate. The urgency and method of treatment determines the type of clinical course of the disease and the CT scan (MRI). In the case of a hyperacute course of the disease, the maximum possible amount of treatment is used: artificial ventilation of the lungs, osmodiuretics, hemostatics, protease inhibitors, external drainage of the ventricles of the brain, microsurgical evacuation of hemorrhage, etc.

In the acute course of the disease, preference is given to direct microsurgical evacuation with/without EVD. The subacute type of cerebellar NTIH allows the use of minimally invasive techniques: aspiration and local fibrinolysis, stereotactic aspiration technique and enodoscopic evacuation of hemorrhage. The chronic form of the clinical course corresponds to the minimal invasive technique or conservative treatment [14].

Intraventricular hemorrhages

Intraventricular hemorrhages (IVH) are divided into primary and secondary. Primary IVHs include those that are localized only within the ventricular system. This form is rare and accounts for no more than 3% of all IVHs. With NTIH, secondary IVHs are formed, in which hemorrhage is formed by breaking through the wall of the hemorrhage cavity. This subdivision plays an important role in the selection of the optimal treatment.

IVHs are classified: a) by localization: lateral ventricles, III ventricle, IV ventricle and their combination; b) by the amount of blood: up to 5 ml, 5 - 10 ml, more than 15 ml; c) according to the aggregate state of blood (in Hounsfield units (H) according to CT data): up to 40 H units - blood admixture, 40 - 60 H units - blood clots, more than 60 H units - blood clots; d) by the presence of concomitant occlusive hydrocephaly: IVH of the first degree - an increase in ventricles up to 30%, second degree - 30 - 60%, third degree - more than 60% [13].

The IVH intensity is assessed according to the Graeb scale (1982), according to which the filling of the lateral ventricle by 50% corresponds to 1 point, by 67% - to 2 points, and complete filling with clots – by 3 points [33]. Filling with clots of the III and IV ventricles without dilatation corresponds to 1 point, and with dilatation - 2 points. The total number of points is summed up. According to this scale, the total hemotamponade of the ventricular system corresponds to 10 points. There are three degrees of filling: 1st degree - 1 - 2 points, 2nd degree - 3 - 6 points, 3rd degree - 7 - 10 points.

Three main variants of blood flow into the ventricular system have been established: a) perforation of the terminal plate of the III ventricle with ruptures of the aneurysm of the anterior parts of arterial circle; b) retrograde flow of blood through the foramina of Magendie and Luschka, c) breakthrough of blood into the ventricular system from NTIH, especially those of thalamic localization [24].

For local intraventricular fibrinolysis (IVF) of blood clots in NTIH and IVH mainly fibrinolytic drugs are used that do not significantly affect systemic blood coagulation. One of the main enzymes, which directly breaks down fibrin strands in the plasma in the process of IVF, is represented by an inactive form, plasminogen, and is activated in three ways: internal, external, and alternative [24].

Indications for conducting IVF of IVH are: a) IVH intensity corresponding to 8 - 10 points on the Graeb scale (1982) or grade 3, b) occlusive hydrocephaly, c) the level of consciousness according to GCS is 8 points or less, and on the Hunt-Hess scale - IV-V degree [24].

IVF, as a rule, is performed in combination with EVD, fibrinolytics (streptokinase, urokinase, prourokinase, tissue plasminogen activator, etc.) are administered intraventricularly through the drainage system. In terms up to 3 days of IVH, a tissue plasminogen activator is more effective; on days 5 - 8, urokinase is preferred for faster resorption [44]. The latter is used in a dose of 5,000 to 50,000 units 2 times per 24h. Specify the optimal daily dose of tissue plasminogen activator (from 1 to 4 mg 2 times per 24h). The approximate dosage of tissue plasminogen activator is carried out according to the maximum diameter of a NTIH (1 mm per 1 cm) [96].

Drainage for EVD through a transducer is connected to a device that records ICP. Usually, unilateral EVD is used through the anterior horn of the non-dominant cerebral hemisphere, less often (with occlusion of the interventricular openings and the III ventricle), bilateral EVD is used [6,13].

In case of aneurysmal IVH, EVD with IVF is performed only after preventive embolization of the aneurysm, which excludes the occurrence of repeated subarachnoid hemorrhage (SAH) and significantly reduces mortality.

In another variant, which was more often used in the initial period of the development of the IVF method, but still relevant, fibrinolytics were administered intrathecally [6,12,13,24]. In isolated cases of IVH, intrathecal administration of fibrinolytics was combined with lumbar drainage. The effectiveness of intrathecal fibrinolysis in non-traumatic IVH was assessed based on the analysis of the dynamics of the volume of intraventricular clots during fibrinolysis, the rate of sanitation of each ventricle (lateral, III and IV) during fibrinolysis, the dynamics of hemorrhage in the basal cisterns, the volume of concomitant IH, elimination of the occlusive hydrocephaly, rate of regress of impairment of consciousness and focal neurological symptoms [24].

An alternative to local IVF in IVH is endoscopic IVF evacuation in combination with EVD. The functional outcome of the endoscopic method according to the modified Rankin scale is comparable to that of the local IVF of IFH.

Mortality rate in IVH with the use of IVF ranges from 0 to 45%, on average - 20 - 30%. When using only EVD without a combination with IVF, mortality, according to randomized trials, increased by at least 2 - 3 times. A good functional outcome according to the Glasgow Outcome Scale with a combination of IVF and EVD was observed in 11-89% of cases, on average - in 50% [50].

In a study of IVF in IVH, which included 100 patients in whom an NTIH with a volume of less than 30 s was detected, repeated IVH was observed in 12% of patients after IVF, in 5% in the placebo group. According to other authors, the frequency of repeated IVH after IVF was 10 - 20%. A high risk of this complication was noted in patients with AVMs, arterial aneurysms and impaired coagulation processes. With intrathecal administration of fibrinolytics in a small series of observations, repeated IVHs were not found [6,13,24]. In a randomized study, it was found that local IVF with the use of tissue plasminogen activator significantly increased the incidence of EVD-associated ventriculitis. According to the literature, the incidence of EVD-associated ventriculitis in IVF averaged 20 - 30%.

In some patients, after IVH and local IVF, a fibrinolytic process was observed in the subarachnoid space and basal cisterns, which caused impaired reabsorption of cerebrospinal fluid and open (connecting) hydrocephaly. Such patients are shown permanent CSF shunting, usually into the abdominal cavity (ventriculoperitoneostomy). According to the summary results of a large number of studies, the need for bypass surgery ranged from 0 to 38%, on average - 15 - 25% in patients who underwent IVF due to IVH.

Currently, international, multicenter, randomized, scientific, multistage research projects are being developed to study NTIH: MISTIE (in particular, Minimally Invasive Surgery plus rt-PA for Intracerebral Hemorrhage Evacuation - MISTIE Decreases Perihematomal Edema); CLEAR IVH Trial (in particular, Resolution of Intraventricular Hemorrhage Varies by Ventricular Region and Dose of Intraventricular Thrombolytic: the Clot Lysis: Evaluating Accelerated Resolution of IVH - CLEAR IVH), STICH (in particular, Early Surgery versus Initial Conservative Treatment in Supratentorial Intracerebral Haematomas in the International Surgical Trial in Intracerebral Haemorrhage - STICH: a randomized trial [7]).

IVH is a complication of NTIH and many other vascular diseases. This complication worsens the prognosis in NTIH. For planning the IVF, IVH is assessed by localization, the amount of blood, its aggregate state, the presence of occlusive hydrocephaly, the intensity of IVH according to the Graeb scale. As a fibrinolytic, urokinase and tissue plasminogen activator are most often used, which are administered intraventricularly through the drainage. In aneurysmal IVH, the IVF is performed after aneurysm embolization. Postoperative mortality in IVH of NTIH genesis averages 20 - 30%. With the combined use of IVF with EFD, the lethality decreases by 2 - 3 times compared to that with EVD without IHF. Complications of the method (repeated hemorrhages, EVD-associated ventriculitis, the need for bypass surgery, etc.) do not significantly affect the treatment outcome. The method of local IVF in combination with EVD can be successfully recommended for the treatment of IVH in patients with NTIH.

Unloading operations

In some cases, decompressive craniectomy is indicated in comatose patients with NTIH, the effectiveness of which is confirmed by the first randomized trials and meta-analysis. The indications for surgery are: clinic of the brain stem herniation, the level of consciousness is less than 8 points on the GCS; a large (over 60 cm^3) volume of NTIH with significant dislocation syndrome on CT, increased ICP (over 20 mm Hg) and intraoperative edema. Decompressive craniotomy can be performed as an adjunct to the evacuation of NTIH or be performed independently. The use of this operation reduces lethality and increases the degree of functional outcome, but does not affect postoperative (repeated) hemorrhages and the formation of hydrocephaly. In all cases, ICP registration is recommended. The effectiveness of decompressive craniectomy is increased by its combination with EVD [6,31,32].

The scope of these operations is expanding. They are successfully used in severe traumatic brain injury, extensive medial cerebral artery infarction, etc., when there is an acute, pronounced dislocation syndrome.

Conclusion

NTIH are a severe clinical form of acute cerebrovascular accident with high mortality and disability. In their development, NTIHs multifactorially damage important structures of the brain. Surgical treatment presupposes a certain additional trauma to the brain with the aim of evacuating NTIH and eliminating the syndrome of dislocation of intracranial hypertension, however, surgery temporarily increases perihemorrhagic reactions and edema. Using modern technical possibilities (neuronavigation, ultrasound, tractography, etc.) with lobar NTIH, when the surgical passage is about 1 cm, the additional trauma is insignificant, which cannot be said about lateral hemorrhages, in which the length of the surgical passage is much greater and, accordingly, additional trauma and perihemorrhagic reactions increase. Therefore, in deep NTIH, the preference is given to minimally invasive techniques (stereotactic evacuation, neuronavigation puncture with local fibrinolysis, and neuroendoscopic evacuation). If necessary, these operations can always be supplemented with an extensive decompression craniectomy. Intraventricular hemorrhage is successfully treated with EVD and local fibrinolysis. Indications for surgical treatment of brain stem NTIHs are determined in a balanced manner, since microsurgical approach is technically difficult and associated with additional trauma. Surgical treatment of cerebellar NTIH is mostly developed. Depending on the clinical situation, it includes: EVD, microsurgical evacuation, stereotactic evacuation and puncture with local fibrinolysis. An increase in the degree of functional outcome is achieved by the early addition of antioxidants to therapy.

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